IMPACT ASSESSMENT OF CO_2 EMISSION LIMITS OF CARS IN GERMANY AND THE EU

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ABSTRACT

In its 4th Assessment Report the Intergovernmental Panel on Climate Change (IPCC) concludes that the risk of climate change with temperature increases of 4-5°C until 2100 has grown substantially and recommends strong actions to curb greenhouse gas emissions (GHG) until 2020 [IPCC 2007]. In the EU the transport sector is the major sector that showed growth of GHGs in the last years. One of the most promising measures to bring down the GHG emissions of transport is to define emission limits for new vehicles [Markewitz/Matthes 2008, ISI et al. 2008]. These emission limits should not be static but have to follow a reduction path such that car manufacturers could anticipate the requirements for future cars as they are facing significant lead times in the development of new engines and cars.

This paper presents and analyses different assessments of the introduction of binding CO2 emission limits of cars. The assessments cover both the estimation of CO2 savings as well as the transport and economic impacts. The focus of analysis will be on transport and economic impacts. Studies for Germany and for the EU level will be taken into account. The analysis applies both partial models and the integrated assessment model ASTRA. Based on the partial models it can be estimated that the full user cost of car users (i.e. the fixed cost of car purchase plus variable cost) are reduced by the CO2 limits [ISI et al. 2008]. In other words, well-designed climate policy will decrease total user cost of car users.

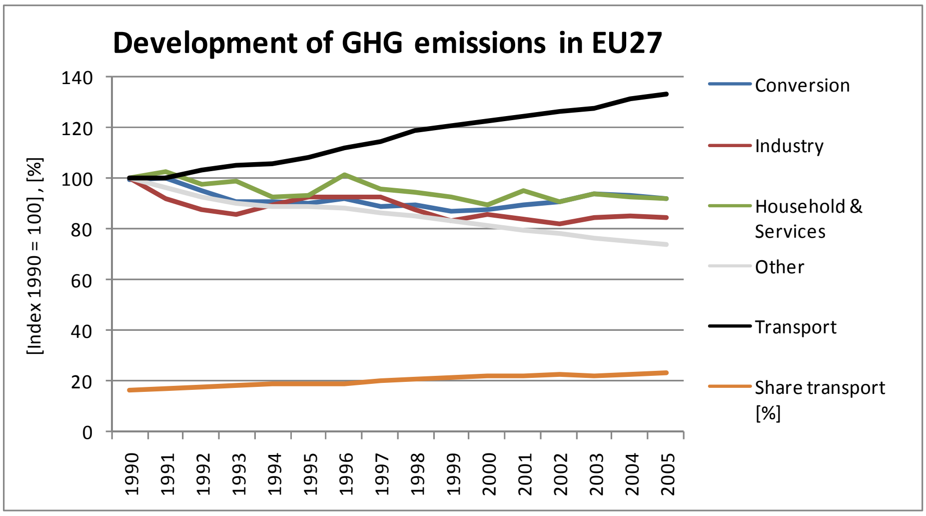
This is in line with the findings obtained by the ASTRA model for Germany and Europe that over a short period car transport is reduced compared with a reference case with no CO2 limits, but over the medium to long-term the rebound effect of reduced variable cost increases the modal-share of car transport [Markewitz/Matthes 2008, Schade et al. 2008].

Looking at the macro-economic consequences it is found that in Germany a transport policy package including the CO2 limits can increase employment by about 200.000 persons in 2020 [Schade et al. 2009] and that economic growth in Europe as well can be stimulated in the medium term by the CO2 emission limits [Schade et al. 2008].

Keywords: CO2 limits cars, climate policy, transport policy, abatement cost, abatement benefit, impact assessment, 2030, Germany, Europe.

INTRODUCTION

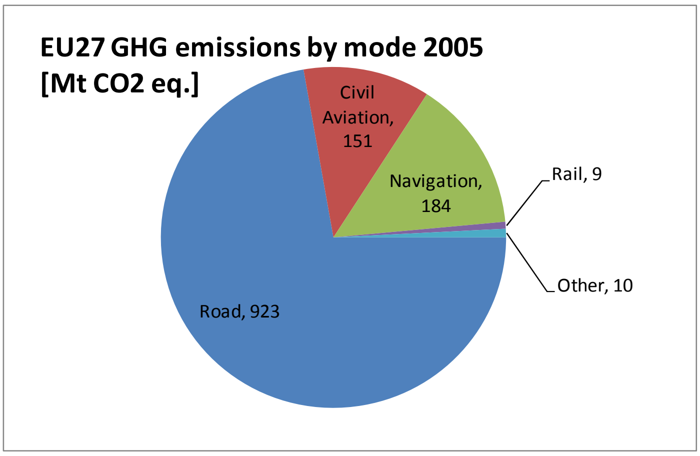
The transport sector in Europe contributed more than 23% of EU-27 GHG emissions in 2005 (1277 Mt CO2 eq.). Due to the high share of fossil fuel use, the share of CO2 emissions is even higher, amounting to more than 27% of EU-27 CO2 emissions in 2005 (1247 Mt CO2). As Figure 1 reveals, the transport sector is the only major sector in the EU-27 in which GHG emissions have risen compared with 1990. The same holds for the CO2 emissions of transport [European Commission 2007a]. Despite this growth trend, the European Commission has agreed on a target of a -10% reduction of GHG emissions by 2020 compared with the year 2005 for the non-ETS sectors, which includes transport [European Commission 2008].



Source: European Commission, 2007a

Figure 1: Development of GHG emissions of transport compared with other sectors in EU-27 (1990 to 2005)

The split of GHG emissions across the major modes of transport is presented in Figure 2. With more than 70%, roads generate by far the largest quantity of GHG emissions. Navigation and Civil Aviation, both including international bunkers, generated about 14% and 12% in 2005, respectively.



Source: European Commission, 2007a

Figure 2: EU-27 GHG emissions of transport by major mode in 2005

The EU has developed its position on climate change and climate policy through a number of communications, which all emphasize the target to stabilize temperature increase at 2-degree Celsius compared with pre-industrial levels [European Commission 2007b, European Commission 2009a]. For 2020 this would imply that the EU reduces its GHG emissions by -20% by 2020 compared with 1990, if the rest of the world does not agree on reductions. However, if a joint global agreement similar to the Kyoto Protocol is achieved for the post-Kyoto period after 2012, the EU would accept a reduction target of as much as -30% by 2020. At the global level, the EU formulated the target of a reduction of -50% GHG emissions by 2050 compared with 1990, which according to the Intergovernmental Panel on Climate Change (IPCC) means a reduction of -80 to -95% by the industrialised countries by 2050 [IPCC 2007]. In other words: in 2050 the EU must emit less than 20% of the greenhouse gases emitted today. Comparing this conclusion with the 23% share of transport on today's EU GHG emissions it becomes obvious that transport also has to reduce its emissions drastically – despite the projected transport demand growth.

This paper is structure into five sections following this introduction. The first section will briefly present the ASTRA model, which is used for many of the impact assessments presented in the following sections. The second section will show the impact of the CO2 limits of cars for Germany with respect to the economics of the user cost and the savings of CO2. The third section will explain the macro-economic impact of the CO2 limits on Germany and on the EU, respectively. In the fourth section my results will briefly be compared with similar studies. The final section will present some policy conclusions.

The results presented in the second and third section have been prepared in studies where I have been responsible for the transport and economic impact assessment of transport policies that have been developed for climate impact mitigation [Markewitz/Matthes 2008, ISI et al. 2008, Schade et al. 2008, Schade et al. 2009]. This is the first attempt to put these studies into a joint picture to provide a comprehensive impact assessment of the CO2 limits of cars, though I have to admit that this has to remain on a strategic level of information in such a short paper.

RATIONALE OF ASTRA MODEL

ASTRA (Assessment of Transport Strategies) is developed since the 4th European Research Framework Programme. The model is applied for the integrated assessment of policy strategies. It is implemented as a system dynamics model. The ASTRA model has been developed and applied in a number of European research and consultancy projects for more than 10 years now by three institutions: Fraunhofer ISI, IWW and TRT. Applications included analysis of transport policy (e.g. TIPMAC, TRIAS), climate policy (e.g. ADAM project) or renewables policy (e.g. Employ-RES project). A comprehensive description of the model can be found in Schade (2005) with extensions in Krail (2009). The ASTRA model consists of nine modules that are all implemented within one Vensim© system dynamics software file. An overview of the nine modules and their main interfaces is presented in Figure 3.

The Population module (POP) provides the population development for the 29 European countries with one-year age cohorts. The model depends on fertility rates, death rates and immigration of the EU27+2 countries. Based on the age structure, given by the one-year age cohorts, important information is provided for other modules, like the number of persons of working age or the number of persons in age classes who are permitted to acquire a driving licence. POP is calibrated to EUROSTAT and UN population predictions.

Key features:
- Integrated models
- System Dynamics (Vensim)
- 27 EU countries (+ NO, CH)
- 76 zones
- 25 economic sectors
- >230.000 OD flows (P, F)
- 8 modes (P+F)
- 800 MB of output data
- Time horizon up to 2050

Abbreviations for 9 Modules:

POP = Population Module
MAC = Macroeconomics Module
REM = Regional Economics Module
FOT = Foreign Trade Module
TRA = Transport Module
VFT = Vehicle Fleet Module
ENV = Environment Module
WEM = Welfare Measurement Module
INF = Infrastructure Module

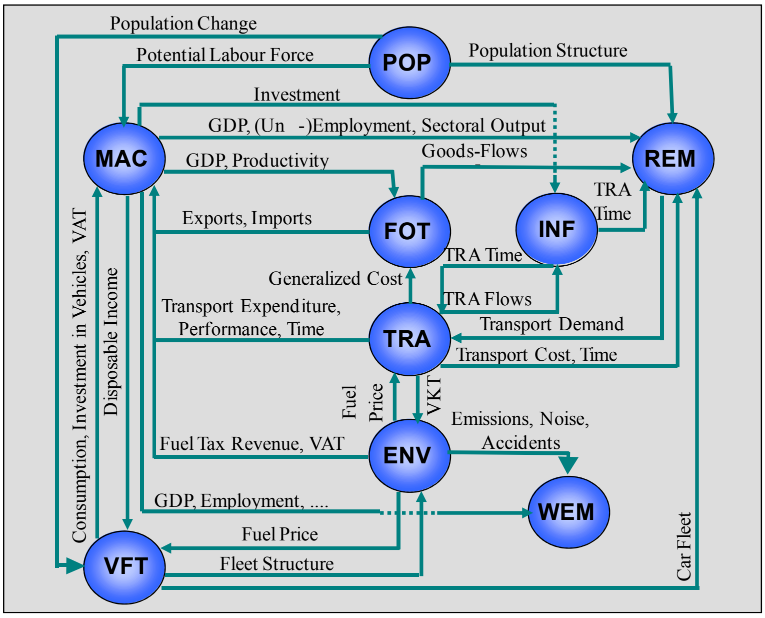


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Figure 3: Overview on the structure of the ASTRA model

The MAC provides the national economic framework, which imbeds the other modules. The MAC could not be categorised explicitly into one economic category of models for instance a neo-classical model. Instead it incorporates neo-classical elements like production functions. Keynesian elements are considered like the dependency of investments on consumption, which are extended by some further influences on investments like exports or government debt. Further elements of endogenous growth theory are incorporated like the implementation of endogenous technical progress (e.g. depending on sectoral investment) as one important driver for the overall economic development.

Six major elements constitute the functionality of the macroeconomics module. The first is the sectoral interchange model that reflects the economic interactions between 25 economic sectors of the national economies. Demand-supply interactions are considered by the second and third element. The second element, the demand side model depicts the four major components of final demand: consumption, investments, exports-imports and the government consumption. The supply side model reflects influences of three production factors: capital stock, labour and natural resources as well as the influence of technological progress that is modelled as total factor productivity. Endogenised total factor productivity depends on investments, freight transport times and labour productivity changes. The fourth element of MAC is constituted by the employment model that is based on value-added as output from input-output table calculations and labour productivity. Employment is differentiated into full-time equivalent employment and total employment to be able to reflect the growing importance of part-time employment. In combination with the population module unemployment was estimated. The fifth element of MAC describes government behaviour. As far as possible government revenues and expenditures are differentiated into categories that can be modelled endogenously by ASTRA and one category covering other revenues or other expenditures. Categories that are endogenised comprise VAT and fuel tax revenues, direct taxes, import taxes, social contributions and revenues of transport charges on the revenue side as well as unemployment payments, transfers to retired and children, transport investments, interest payments for government debt and government consumption on the expenditure side.

Sixth and final of the elements constituting the MAC are the micro-macro bridges. These link micro- and meso-level models, for instance the transport module or the vehicle fleet module to components of the macroeconomics module. That means, that expenditures for bus transport or rail transport of one origin-destination pair (OD) become part of final demand of the economic sector for inland transport within the sectoral interchange model. The macroeconomics module provides several important outputs to other modules. The most important one is, for sure, Gross Domestic Product (GDP). This is for instance required to calculate sectoral trade flows between the European countries. Other examples are employment and unemployment representing two influencing factors for passenger transport generation. Sectoral production value is driving national freight transport generation. Disposable income exerting a major influence on car purchase affecting finally the vehicle fleet module and even passenger transport emissions.

The rationale and structure of the transport model in ASTRA, which is made up of four of the nine ASTRA modules, is described in the following paragraphs. The transport models consider both passenger and freight transport covering a spatial representation consists of 76 zones in Europe, which indicates the strategic nature of the transport model. Both passenger and freight transport estimate transport demand (i.e. transport performances) using a modified 4-stage transport model with a strongly simplified assignment stage, in which the major function applied are discrete choice functions, i.e. logit functions [Ortuzar/Willumsen 2004].

The ASTRA model focuses on intra-European transport, i.e. those transport activities within European countries (EU-27 plus Norway and Switzerland) and across them. This is particularly relevant for the navigation and aviation modes. Here, intercontinental transport is excluded, i.e. transport leaving the EU to other continents or entering the EU from other continents. Pipeline transport is excluded as well from the analysis. The transport models distinguishes five modes for passenger transport: Slow modes (i.e. non-motorised transport by foot and by bike), car transport, bus transport, rail transport including trams and metros for short distances and air transport (domestic and intra-EU-27+2). For freight transport, three-plus-one modes are differentiated: Road mode differentiating heavy duty vehicles (HDV, larger than 3.5 t gross vehicle weight) and light duty vehicles (LDV, smaller than 3.5 t gross vehicle weight), Rail mode integrating inland waterways (IWW) in those countries where they play a role and allowing a separation of rail and IWW for selected indicators and ship mode, which means the short sea shipping occurring within and between the European countries.

The model most relevant to assess the impacts of the CO2 limits of cars is the car fleet model consisting of a stock model, a purchase model and a choice model for the selection of newly purchased cars. The car fleet model constitutes one of the most policy-sensitive model elements in ASTRA as it reacts to policies that support new technologies (e.g. subsidies or 'feebates', a novel combination of fees and rebates), to taxation policies (i.e. car and fuels) and to fuel price changes including changes of CO_2 taxes/certificates and energy tax

changes. Other socio-economic drivers also affect the development of the car fleet, especially income, population and the existing level of car-ownership (see Figure 4).
The car fleet model starts with the purchase model, which determines changes in the absolute level of the car fleet. Depending on changes in income, population and fuel prices, the level of the car fleet is estimated for the next time period. Together with information on the scrappage of cars which mainly depends on the age structure of the fleet, the number of newly purchased cars is then calculated. Purchase of cars via the second-hand market from other countries is neglected, which is a simplification that played a role for the new Member States before they joined the EU.
In the second step, the newly purchased cars are transmitted to the choice model, which determines the types of cars that are purchased. Car types include: Gasoline cars: three types differentiated by cubic capacity (<1.4l, 1.4-2.0l, >2.0l); Diesel cars: two types differentiated by cubic capacity (<2.0l, >2.0l); Compressed natural gas (CNG) cars; Liquefied petroleum gas (LPG) cars; Bioethanol cars, i.e. cars that can run on 85% bioethanol (E85) and more (incl. flex fuel); Hybrid cars, meaning advanced hybrid cars depending on timing, i.e. plug-in hybrids with the ability to run for a significant distance on electricity; Battery electric cars, i.e. smaller cars running in battery-only mode; Hydrogen fuel cell vehicles (hydrogen internal combustion engine is not considered a reasonable option).
The choice of new car depends on fuel prices (incl. taxes), car prices, taxation of car technologies, efficiency of cars, filling station network and, in the case of new technologies, on subsidies or feebates (combined fee and rebate system). In the case of electric vehicles, preferences are also altered by adapting the choice parameters in the model equations. Emission standards are also considered in the car fleet model. The point of time when a new car is purchased determines to which emission standard it belongs and which emission factors have to be applied to model its emissions. ASTRA distinguishes nine emission standards (2 pre-euro standards, euro1 to euro 7 standard). For example, if a car is purchased in 2005, it is assumed that it complies with the euro 3 standard. The third element is the stock model of the existing fleet. This model provides the number of cars and the age distribution in the fleet.

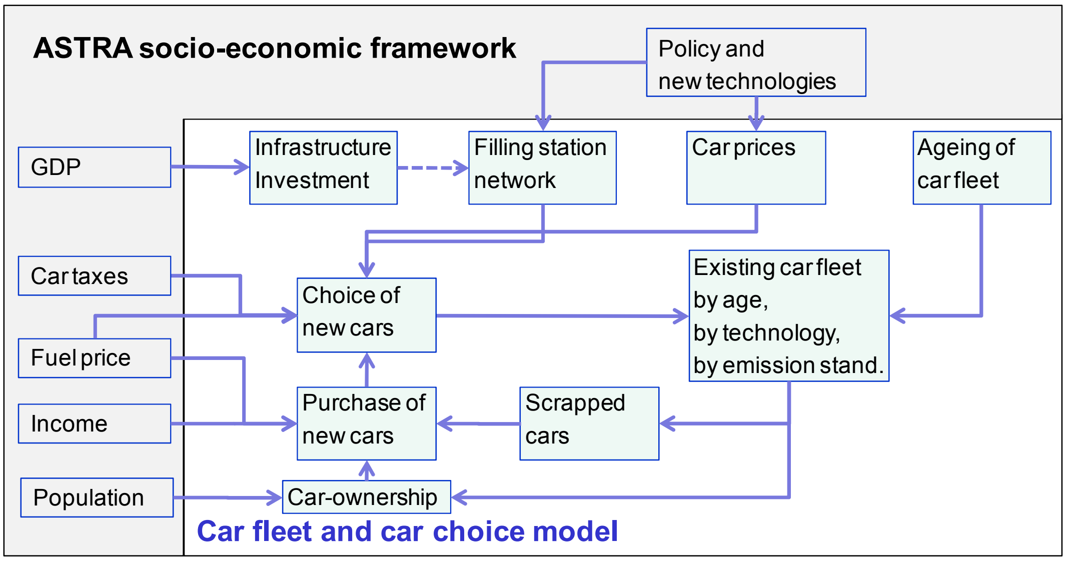

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Figure 4: ASTRA car fleet and car choice model

Based on the transport demand models, the vehicle fleet model and the emission factors taken from the Swiss/German handbook on emission factors [HBEFA 2004] the ASTRA model enables to calculate transport emissions occurring over the whole life-cycle but excludes those arising from vehicle scrapping. That means the emission calculations consider the emissions from the driving activity including cold start emissions, upstream emissions of fuel production and upstream emissions of vehicle production.

MICRO-ECONOMIC ANALYSIS OF CO_2 LIMITS OF CARS IN GERMANY

During the mid 1990ies the European Commission had developed a voluntary agreement with the car manufacturers represented by the Association des Constructeurs Européens d'Automobiles (ACEA), Japan Automobile Manufacturers Association (JAMA) and Korea Automobile Manufacturers Association (KAMA). The voluntary agreement foresaw that until 2008 the average CO_2 emissions per driven km of the newly purchased cars of that year would be 140 gCO_2/km.

Since after close to ten years of that voluntary agreement it became obvious that the CO_2 emission target would be missed, the European Commission developed a proposal for binding CO_2 emission limits of cars [European Commission 2007c]. The proposal kept the target of 140 g CO_2/km in 2008/2009 and introduced a new binding target of 120 gCO_2/km by 2012 for the average of all new cars sold in Europe in 2012. This target included additional measures like biofuels and the efficiency improvements of auxiliary equipment such that the target to be achieved by improvements on the powertrain and by increased energy efficiency of engines would be 130 gCO_2/km.[1]

In 2007 the German government agreed on a strategic energy and climate policy programme, the so-called Meseberger IEKP, consisting of 29 measures (some of them policy bundles themselves) covering all relevant sectors including the transport sector [Bundesregierung 2007]. Setting CO_2 emission limits for cars was one of the most important measures of the Meseberger IEKP, in particular for the transport sector. The Meseberger IEKP adopted the original proposal of the European Commission of a target of 130 gCO_2/km until 2012 [European Commission 2007c]. Since the average of the German fleet roughly emits 10 gCO_2/km more than the European average the target for the German average new cars fleet was set to 140 gCO_2/km.

Based on this decision we estimated the cost and emission impacts of the CO_2 emission limits of new cars in Germany. The estimations were largely based on the European study from TNO et al. (2006), which was an important contribution to the impact assessment of the CO_2 limits, in particular as the numbers of the study concerning CO_2 savings potentials and cost impacts have been agreed with ACEA.

For the assessment of the measures it was assumed that a binding target is defined by an EU directive, which allowed different CO_2 emission targets for different size classes of cars

[1] This target has been finally specified in the EU Regulation 443/2009, but instead of setting the limit of 130 gCO2/km for the year 2012 it was shifted three years later after strong stakeholder involvement such that the target has to be achieved only by 2015 [European Commission 2009b].

i.e. larger cars were allowed to emit more than 140 gCO_2/km, which than had to be compensated by smaller cars that have to emit less than the 140 gCO_2/km. This structure was also applied in TNO et al (2006), which defined six car classes with three classes for gasoline and diesel each, that are differentiated by three different cubic capacity classes (<1.4 l cubic capacity (cc), 1.4 to 2.0 l cc, > 2.0 l cc).

Expected impacts of the CO_2 limits on user cost

In terms of impacts on user cost two major directions have to analysed:

1. Cost increase of purchase cost of new cars as these have to be equipped with additional efficiency technologies or energy saving measures.
2. Changes of user cost due to savings of fuel consumption. This impact strongly depends on the oil price trends in the future.

It was not assumed that due to the CO_2 emission limit the structure of vehicle purchases in Germany would change. Thus the vehicle purchase trends of the German TREMOD model until 2020 could be used for the assessment [IFEU 2005]. A further important parameter to estimate the benefits of fuel savings is the average life time of vehicles, which was assumed to be 9 years for the smallest vehicle class and 11 years for the largest class. This was assumed to be constant, though in recent years it could be observed that these average life times are increasing.

Estimation of impacts of the CO_2 limits on car prices and fuel savings

Estimating the impact of CO_2 limits on the car users we strictly follow the approach of TNO et al. (2006) since these study results follow from a close stakeholder process with ACEA. Starting from a reference case of each car and from single measures for which cost and CO_2 savings have been quantified bundles of measures for the different car categories have been identified that in the sum of all car categories would lead to meeting the targets of 140 gCO_2/km in 2008/2009 and of 130 gCO_2/km in 2012 in Europe for the new fleet. The emission development for the six car categories is presented in Table 1. In this study no further improvements of new cars after 2012 have been assumed. But one should consider that even then the fleet average CO_2 emissions would still continue to improve as until 2020 still older and less efficient cars will be replaced by new and more efficient cars complying to the regulation.

Table 1: Development of CO_2 emissions of the six car categories starting from reference cars in 2002

[g CO_2/km]		**2002**	**2008**	**2012**	**2020**
Gasoline	Small car	149	120	112	112
	Medium car	184	148	138	138
	Large car	238	185	172	172
Diesel	Small car	123	115	107	107
	Medium car	153	141	131	131
	Large car	201	178	165	165

Source: ISI et al. (2008) based on TNO et al. (2006)

The calculation of the additional cost to develop and implement the efficiency measures in the new cars compared with the reference cars of 2002 is based on the bundles of measures again. For each single measure additional cost are estimated and aggregated across all measures of a bundle of a car category. Further it was considered a reduction factor on the CO_2 reductions of the measures to avoid double counting. The curves to estimate additional cost for different levels of CO_2 reductions are presented in Table 2 and are build again on TNO et al. (2006).

Table 2: estimation of additional cost dependent on the size of CO_2 reductions

Coefficients of additional cost C (CO_2-reduction = x):				$C = a x^3 + b x^2 + c x$		
	Gasoline			Diesel		
	Small car	Medium car	Large car	Small car	Medium car	Large car
a	0.007	0.0055	0.0025	0.012	0.011	0.006
b	-0.1	-0.11	-0.027	0.9	0.4	0.2
c	22	18	14	12	11	8

Source: ISI et al. (2008) based on TNO et al. (2006)

Since the estimations had to be performed keeping the user cost perspective a transfer from the production cost to user cost had to be made, again following TNO et al. (2006) we use a factor of 1.44. Since the TNO et al. calculations only explained CO_2 reductions and cost reductions until 2012, we had to consider the effect of learning-by-doing through the increased production and increased sales of the new technologies. Thus we implemented a learning curve that started in 2012 and allowed projections of cost reductions until 2020. The cost savings had been for the different car categories in the order of -10% to -35%. This led to the calculation of additional user cost per car until 2020 as shown in Table 3.

Table 3: Total additional cost for the six car categories

[€ / car]		**2008**	**2010**	**2012**	**2015**	**2020**
Gasoline	Small car	936	1339	1606	1250	1054
	Medium car	984	1504	1873	1514	1299
	Large car	1341	1977	2413	2153	1889
Diesel	Small car	206	596	935	683	540
	Medium car	269	829	1316	948	744
	Large car	469	1183	1792	1273	991

Source: ISI et al. (2008)

Fuel savings have been estimated converting the CO_2 savings back into demand of different fuels and have then been multiplied with the fuel prices presented in Table 4. Obviously the prices increase only quite moderate. I.e. with higher prices the fuel cost savings would also be increasing i.e. the CO_2 car limits would even become more beneficial.

Table 4: Price assumptions of crude oil and fossil fuels (constant prices of 2000)

	2000	2005	2010	2015	2020	2025	2030
Ressource prices							
Crude oil fob (US-$/bbl)	28.4	48.3	50.0	48.5	47.0	53.5	60.0
Household prices (incl. VAT.[b])							
Heating oil (ct/l)	40.8	50.7	60.9	61.4	61.9	69.4	76.9
Natural gas (ct/kWh)	3.7	4.8	5.4	5.5	5.5	6.3	7.0
Gasoline (€/l)	0.99	1.14	1.27	1.28	1.29	1.36	1.43
Diesel (€/l)	0.80	1.02	1.11	1.12	1.14	1.21	1.27

Source: Markewitz/Matthes (2008)

Not considered in this micro-economic analysis have been the macro-economic impacts e.g. the increased investment of car manufacturers into R&D, which is complementary to the increased user cost of car purchase. Further, the impacts of the changed consumption pattern of households on other sectors had been neglected.

Estimation of total cost and benefits of CO_2 limits of cars in Germany

Based on the previously described impacts and framework conditions user cost and benefits of German car owners can be estimated as well as environmental impacts in particular impacts on energy demand and CO_2 emissions of car transport (see Table 5). Estimating the cost and benefits of the measure it is important to respect the time dimension as the cost and the benefits occur at different points of time i.e. the cost (car purchase) appear earlier than the benefits (fuel savings). For a proper comparison the cost have to be annuitized and both the costs and the benefits have to be discounted to the same year i.e. to the year 2008 in this analysis. Table 5 shows that the undiscounted cost increase is in the range between 2 and 3.6 billion € annually, in total 45 billion € between 2008 and 2020. The fuel cost savings will be in the range of 2.1 to 8.7 billion € annually, in total 79 billion €. These undiscounted values already drive the expectation that the benefits will be higher than the cost.
In physical terms we estimate the annual savings of energy to be between 66 and 275 PJ, in total from 2008 until 2020 2491 PJ, and the savings of CO_2 over the same period would be between 4.3 and 17.4 Mt CO_2 annualy, in total 159 Mt CO_2 over the whole period.

Table 5: Development of cost and savings (non-annuitized, undiscounted)

		Unit	2008	2010	2015	2020	2008-2020
Car purchase	Increased investment	billion €	2,0	3,5	3,6	3,0	45
Fuel	Fuel demand savings	PJ	66	111	227	275	2.491
	Fuel cost savings	billion €	2,1	3,6	7,2	8,7	79
CO_2	CO_2 savings	Mt	4,3	7,1	14,4	17,4	159

Source: own calculations, ISI et al (2008)

The most relevant number to be derived from these calculations is the abatement cost of the CO_2 emission limits of cars in Germany. To estimate the abatement cost first the definition was made that only the period 2008 to 2020 is considered. This is important because (1) fuel savings of cars purchased e.g. 2019 would only count for 2019 and 2020 though the savings occur also in the years after 2020, and (2) the investment cost are annuitized, but also only annuities until 2020 are counted. With such an approach the cost and the benefits are brought onto the same and consistent time scale. With such an approach instead of comparing the 79-45=34 billion € of Table 5 we estimate the net present value of CO_2 limits of cars in 2008 to be 16 billion € (see Table 6) i.e. German car users are better off with the measure than without it. Putting this into correlation with the total CO_2 savings over the period we obtain an abatement cost of 100 €$_{2000}$ per ton of CO_2. In fact it should not be named an abatement cost, but an abatement benefit as overall the cost constitutes a saving from the user perspective.

Table 6: Micro-economic assessment of impacts of CO_2 limits of cars in Germany – user perspective

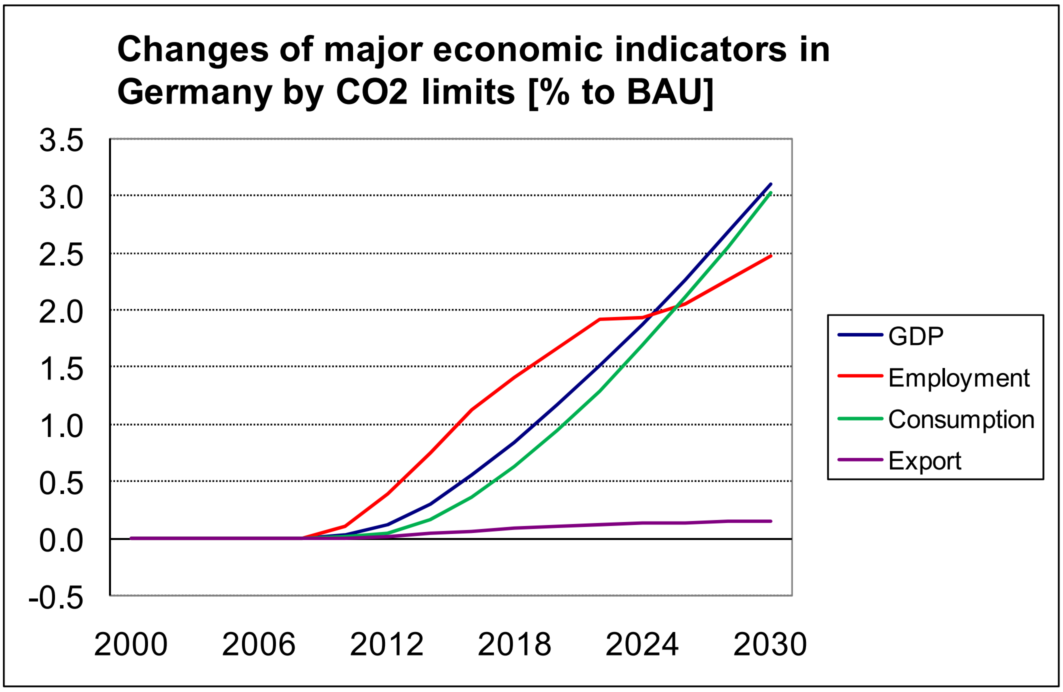
CO_2 savings of CO_2 limits of cars in Germany (2008-2020)	Mt CO_2	159
Net present value of CO_2 limits cars in Germany (2008-2020)	Billion €2000	16
Abatement cost of CO_2 limits of cars in Germany (2008-2020)	€2000/tCO_2	100

Source: own calculations, ISI et al (2008)

It should also be pointed out that in a full cost-benefit analysis or an integrated assessment we would additionally receive a benefit due to the avoided damage cost of the CO_2, which is not emitted due to the measure.

MACRO-ECONOMIC ANALYSIS OF CO_2 LIMITS OF CARS IN GERMANY AND THE EU

A first attempt to estimate the macro-economic effects of CO_2 limits of cars with the ASTRA model was made in the policy scenarios for climate change IV [Markewitz/Matthes 2008]. The approach to estimate the impact of the measure was simpler at that time, since the detailed studies to quantify the cost were not available mid 2006. The CO2 savings were compared with a reference scenario continuing the autonomous trend of efficiency gains of the period 1995 to 2005, such that the savings reached about 11 Mt CO2 in 2020 compared with the 17.4 Mt CO2 of Table 5 above, which were achieved following the TNO approach of using a reference vehicle of the year 2008.
Vehicle cost increase was assumed in the range of +3% to +10% and the fuel cost savings were in line with the CO2 savings. In this case, also no static composition of the vehicle fleet was assumed, but the endogenous fleet model of ASTRA allowed structural changes favouring smaller vehicles and more diesel vehicles. The macro-economic effects are presented in Figure 5. The policy was implemented in 2008 and after a time lag of about 4 years significant positive economic effects emerge due to the replacement of spending foreign money for fossil fuels by spending more money for efficient vehicles as well as by the additional investment to be made by the car manufacturers. Until 2020 GDP is about 1% higher than without the measure. Employment even increases slightly faster, while consumption is growing roughly at the same rate as GDP.



Source: own calculation, Markewitz/Matthes (2008)

Figure 5: Changes of macro-economic indicators due to CO2 limits of cars in Germany

Another important effect of the measure should also be mentioned. Though in the short to medium-term the CO2 limits of cars have a dampening effect on car transport demand, it can be observed in the long run that modal-share of car transport increases and is about 1% higher in 2030 than without the measure.

In 2008/2009 we undertook the next study to analyse the macro-economic effects of the German Meseberger IEKP, which included 5 transport related measures including the CO2 limits of cars as explained in the previous section. Since, the Meseberg IEKP seems to fail the -40% GHG reduction aspired by Germany until 2020 a number of further measures were defined to achieve this reduction. For the transport sector two further measures were defined, such that in total 7 transport related measures were considered in the study (see Table 7). The CO2 limits of cars was the most important one in terms of CO2 savings by the measure, as it was also supported by two flanking measures.

Table 7: Transport measures of the German Meseberger IEKP plus two additional measures

No in IEKIP	Measure
IEKP M16	CO2 limits of cars with the target of 130 gCO2/km in 2012.
IEKP M18	Adapting the annual circulation tax of cars such that it is based on CO2.
IEKP M19	Binding energy and CO2-efficiency labelling of cars.
IEKP M20	Adapting the heavy goods vehicle charge such that more incentives are set to purchase modern and fuel efficient trucks
IEKP M26	Support to R&D and market entry of electro mobility.
Add 1	Speed limit on motorways of 130 km/h.
Add 2	Regulation for binding use of ultra fluid engine oils.

Source: Schade et al (2009)

The economic impulses generated by this package of transport measures affect the fuel cost of households and business cars and the investments of car manufacturers and energy utilities. Car manufacturers have to invest into energy efficiency technologies and at some point also into electro mobility. On the other hand the car manufacturers will avoid some investment that they would have undertaken to develop more powerful and faster cars. In macroeconomic terms the net balance of additional investment into efficiency and avoided investment into "traditional" concepts is relevant.

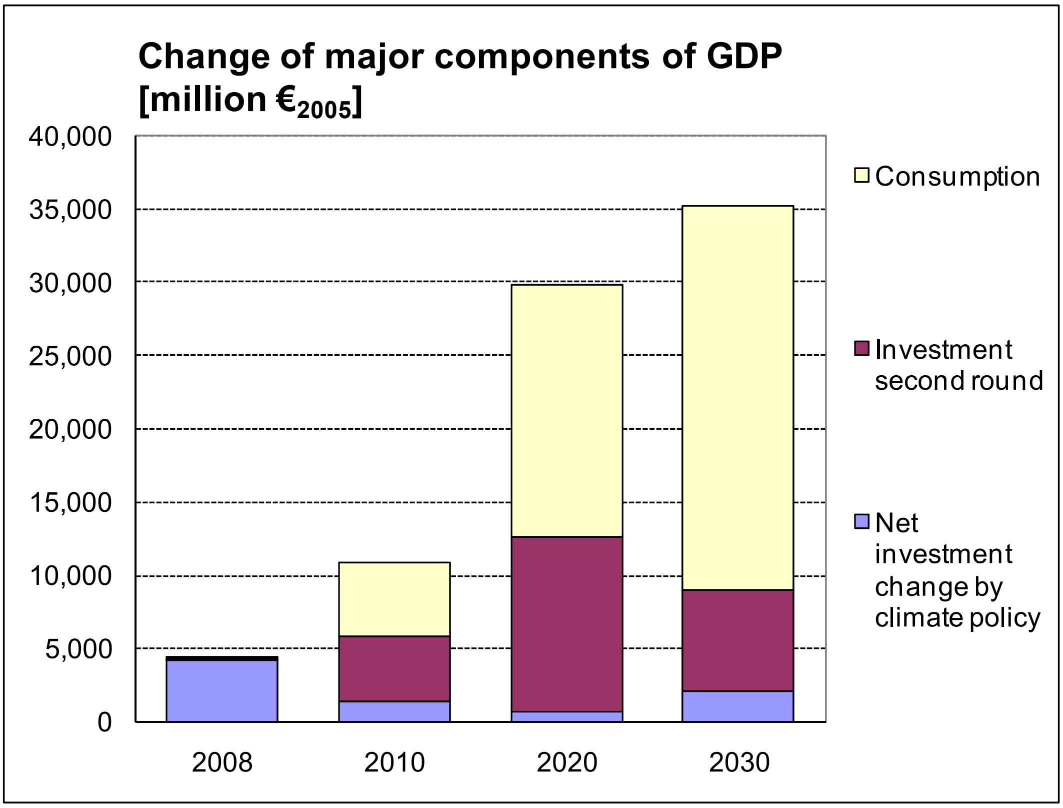
Table 8: Economic impulses of the transport measures of the Meseberger IEKP (see Table 7)

		Unit	**2010**	**2020**	**2030**
Household & business cars	Fuel	% change against BAU	-14.0%	-24.2%	-25.8%
Industry	Trucks & fuel	% change against BAU	0.0%	0.1%	-0.4%
Investment	Additional	Million Euro	9,077	2,334	2,994
	Avoided	Million Euro	-7,691	-1,648	-824

Source: Schade et al (2009)

Figure 6 presents the macroeconomic impacts of the transport measures of the Meseberger IEKP including the CO2 limits of cars as the most important measure. We can observe the high additional investment impulse of the German car industry, which between 2008 and 2010 has to invest about 8 to 9 billion € additional annually to develop the more efficient and lighter cars to comply with the CO2 emission limits. Around 2010 it is assumed it will be possible to avoid significant investment into "traditional" technology development (i.e. more power and faster), such that the net of additional climate policy motivated investment and avoided investment decreases to below 2 billion € additional.

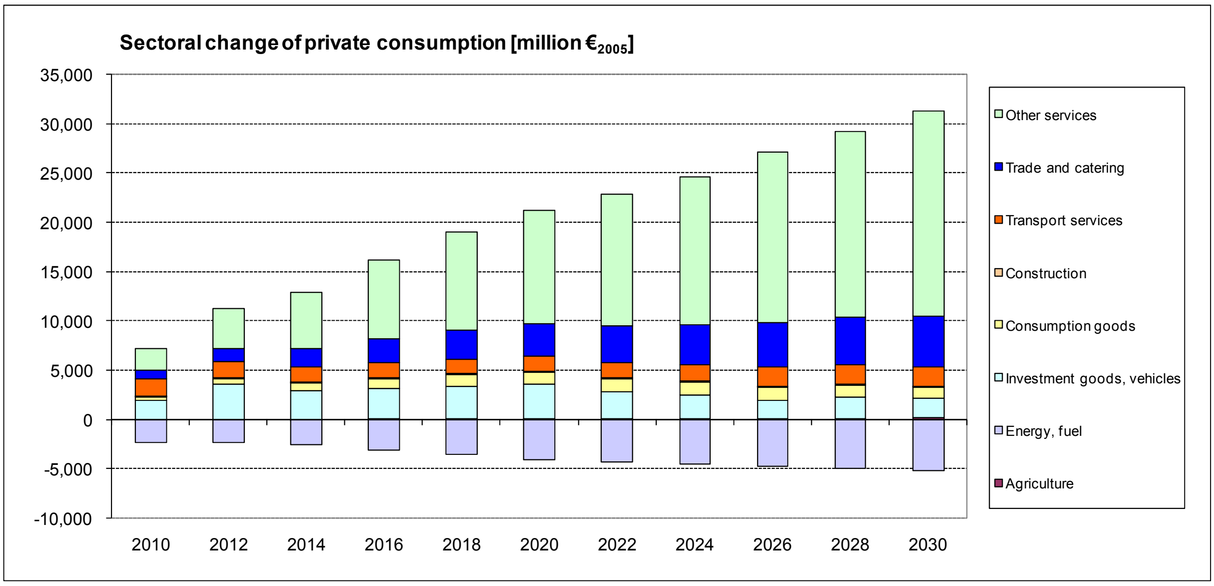
In 2010 we can already observe that the second round effects of the measures have become larger than the first round of the climate policy induced investment. About 40% each comes from increased consumption and induced investment due to the higher GDP than without the measures. In 2010 households decrease their fuel cost bill already by -14%, though part of this saving has to be spent for the more expensive efficient cars (see above sections). However, the net already constitutes a savings of the households. Further we observe reduced imports of fossil fuels that in 2010 are worth 5 billion € and in 2030 15 billion €. In 2020 we observe an increase of GDP in Germany of about 30 billion €, which is in the range of the undiscounted net user cost between increased investment and fuel cost saving that amount to 34 billion € and was presented for the micro-economic analysis above in Table 5.



Source: Schade et al. (2009)

Figure 6: Changes of macro-economic indicators due to Meseberger IEKP including CO2 limits of cars in Germany

Figure 7 presents the changes of consumption patterns due to the Meseberge IEKP and the CO2 limits of cars. These changes are composed out of direct effects of the measures (e.g. less expenditures on fuel and more on vehicles), out of the net effect of fuel and vehicle expenditures being positive such that more money can be spend for other consumption purposes than transport and out of the second round effects of the growing GDP and income (e.g. growth of demand for other services or of trade and catering). It should be noted that the reduction of demand for fuel in 2030 amounting to 5 billion € does not represent the full savings of households due to fuel savings. This is only the energy component additioally fuel tax and VAT on fuel is also saved by households, but these savings show-up in the government model of ASTRA as these do not constitute consumption expenditures but tax payments of households.



Source: Schade et al. (2009)

Figure 7: Changes of the consumption pattern due to Meseberger IEKP including CO2 limits of cars in Germany

BRIEF COMPARISON WITH OTHER STUDIES

At that time when we developed our IEKP-study on the single measures [ISI et al 2008] the German Industry Association (BDI) had contracted McKinsey to perform an analysis of the GHG reduction potentials in Germany in major sectors including transport. Instead of opposing climate policy and GHG reduction measures the study came to similar conclusions as ours, i.e. until 2020 large GHG reductions would be possible and a significant number of measures would even have negative abatement cost i.e. abatement benefits [McKinsey 2007]. For instance this holds for many of the efficiency measures that have to be implemented for cars to achieve the CO2 limits of cars. This confirms the findings of our micro-economic analysis and as well makes plausible our findings of positive impacts on the German macro-economy.

The discussion above had to be shortened such that it focussed in the end only on Germany. However, an earlier study in which the ASTRA model was linked with the POLES global energy model and the VACLAV transport network model showed that the CO2 limits of cars would be the best scenario in terms of fostering economic development on the level of the EU27 [Schade et al. 2008]. Concerning this study it should be pointed out that the scenarios (e.g. on biofuels and hydrogen policies) have been defined earlier than in the other studies presented in this paper, such that recent developments e.g. on the relatively cheap availability of efficiency technologies of vehicles or of electro mobility have not been considered.

CONCLUSIONS

The conclusions that can be drawn on the impacts of the CO_2 emission limits of cars are quite surprising given the strong debate that has accompanied the process of agreeing on the targets and implementing the legislation.

In terms of impacts on users and user cost of car users we can expect a significant reduction of user cost as the increased investment required to purchase a new and more efficient car will be overcompensated by fuel savings. Depending on the size of the car the duration of the compensation period seems to be between 4 and 6 years, i.e. after this period the user has a net benefit of the measure. In total we obtain an **abatement benefit** (not abatement cost!) of 100 € per ton of CO_2 saved by the CO_2 limits of cars. This even holds with a rather low oil price compared with what we observe today and what we have to expect in the future. I.e. with the most probable higher oil prices the break-even period will even be shorter and the net benefits will be higher.

In terms of the car manufacturers and the automotive industry it also seems beneficial. Of course, they need to invest into additional R&D of the new technologies. However, they can also charge higher prices for the cars that are more efficient, such that they should increase value-added and employment due to the policy. A second effect on the car manufacturers is that the policy increases their certainty in which direction they should spend their R&D investment i.e. into the direction of improving energy efficiency and climate efficiency of their cars.

Finally, the macro-economy also benefits as investments are increased first to increase R&D in the automotive sector and second, when the cars are purchased. On the other hand, fuel savings will lead to decreased imports of fossil fuels, such that in macro-economic terms a positive impulse is stimulated, while a dampening impulse is reduced.

Thus our conclusion is that imposing the CO_2 limits of cars was one of the most beneficial policy measures that could be and have been taken in the area of transport and climate policy. It seems also very reasonable to continues this policy and strengthen the limits for 2020, which is already in the pipeline, and beyond 2020.

REFERENCES

Bundesregierung (2007). Eckpunkte für ein integriertes Energie- und Klimaprogramm. Strategic energy and climate programme of the German government, Meseberg. English version at: http://www.bmu.bund.de/files/pdfs/allgemein/application/pdf/klimapaket_aug2007_en.pdf.

European Commission (2007a). Energy and Transport in Figures 2007. Joint publication of EC DG TREN and EUROSTAT.

European Commission (2007b). Limiting Global Climate Change to 2 degrees Celsius The way ahead for 2020 and beyond. EC Communication COM(2007)2, http:// eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0002:FIN:EN:PDF.

European Commission (2007c). Results of the review of the Community Strategy to reduce CO2 emissions from passenger cars and light-commercial vehicles. COM(2007) 19 final, Brussels.

European Commission (2008). 20 20 by 2020 - Europe's climate change opportunity. EC communication COM(2008) 30, Brussels.

European Commission (2009a) Towards a comprehensive climate change agreement in Copenhagen. EC Communication COM(2009)39, http://eur-lex.europa.eu/ LexUriServ/LexUriServ.do?uri=COM:2009:0039:FIN:EN:PDF.

European Commission (2009b). Setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles. Regulation (EC) No 443/2009, Brussels.

HBEFA (2004). Handbook of Emission Factors for Road Traffic. Version 2.1. German Environmental Agency Berlin, Infras AG, Bern.

IFEU - Institut für Energie- und Umweltforschung (2005). Fortschreibung Daten- und Rechenmodell: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2030. Final report on behalf of the German Environmental Agency. Heidelberg.

IPCC – Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Synthesis Report. Pachauri, R.K. and Reisinger, A. (Eds.), IPCC Fourth Assessment Report (AR4), Geneva. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

ISI, FZJ, Öko-Institut, CEPE (2008). Wirtschaftlicher Nutzen des Klimaschutzes - Kostenbetrachtung ausgewählter Einzelmaßnahmen der Meseberger Beschlüsse zum Klimaschutz". Final Report of the IKEP-Mikro project on behalf of the German Environmental Agency (UBA), Karlsruhe, Germany.

Jochem E., Jäger C., Schade W. et al. (2008). Investitionen für ein klimafreundliches Deutschland". Final Report of the KlimInvest 2020 project on behalf of the German Ministry for Environment, Nature and Nuclear Safety, Karlsruhe, Berlin, Germany.

Krail M. (2009). System-Based Analysis of Income Distribution Impacts on Mobility Behaviour. Dissertation thesis at University of Karlsruhe (TH), Nomos, Baden-Baden.

Markewitz P., Matthes F. (eds.) (2008). Politikszenarien für den Klimaschutz IV – Szenarien bis 2030. Schriften des Forschungszentrums Jülich, ISBN 978-3-89336-518-0, Jülich. Also published by the German Environmental Agency, Climate Change Series 01/2008. Download at http://www.umweltdaten.de/publikationen/fpdf-l/3361.pdf.

McKinsey (2007). Kosten und Potenziale der Vermeidung von Treibhausgasemissionen in Deutschland. Study on behalf of the German Industry Association (BDI), Download: http://www.bdi.eu/download_content/Publikation_Kosten_und_Potenziale_der_Vermeidung_von_Treibhausgasemissionen_in_Deutschland.pdf.

Ortuzar JD, Willumsen LG (2004). Modelling Transport. 3rd edition, Wiley, Chichester.

Schade W (2005). Strategic Sustainability Analysis: Concept and application for the assessment of European Transport Policy. Nomos, Baden-Baden.

Schade W., Helfrich N., Wietschel M., Krail M., Scholz A., Kraft M., Fiorello D., Fermi F., Martino A., Schade B., Purwanto J., Wiesenthal T., Christidis P. (2008). Alternative Pathways for Transport, Technology and Energy to promote sustainability in the EU. Deliverable 4 of TRIAS (Sustainability Impact Assessment of Strategies Integrating

Transport, Technology and Energy Scenarios). Funded by European Commission 6th RTD Programme. Karlsruhe, Germany.

Schade W, Lüllmann A, Beckmann R, Köhler J (2009). IEKP-Makro - Gesamtwirtschaftliche Wirkungen von Energieeffizienzmaßnahmen in den Bereichen Gebäude, Unternehmen und Verkehr". Final Report of the IKEP-Makro project on behalf of the German Environmental Agency (UBA), Climate Change Series 08/2009, Karlsruhe. To be downloade at http://www.umweltdaten.de/publikationen/fpdf-l/3763.pdf.

TNO Science and Industry (2006). Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2-emissions from passenger cars. Study on behalf of the European Commission. Delft.