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Estimation of costs of (behavioural) emission mitigation measures and instruments including estimation of utility loss

Teilbericht zum F&E-Vorhaben „Strategien zur Verminderung der Feinstaubbelastung - PAREST"

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Summary

In this study costs for (behavioural, non-technical) emission mitigation measures and instruments are estimated including utility loss. The measures and instruments have been identified and analysed in the PAREST project, which investigates possible mitigation options to reduce particulate matter concentrations in Germany and explores impacts of mitigation options on concentrations of PM, ozone and NO_2 concentrations in Europe. The costs of those options are used to examine which mitigation options are favourable.

This report focuses on the estimation of the costs of (behavioural, non-technical) emission mitigation measures and instruments, including one mitigation option from the agricultural sector, one for aerosol sprays and several from the transport sector.

Cost components are factor costs and utility loss. The latter is included to give an as comprehensive picture as possible of the total costs of the option. Utility loss can be loss of time, loss of convenience / comfort, loss of status, or the reluctance to adopt a required change in workflows or (production) processes.

Means for deriving costs for utility are e.g. to determine the loss in welfare by estimating the dead weight loss due to a measure or a policy; to use price elasticity for a good; for time loss to employ a value to an hour lost in travel compared to the situation without the measures; for comfort loss to use the hedonic pricing approach.

Costs are annualised and discounted to the base year 2000 to make them comparable.

Uncertainties are high as all costs are based on highly uncertain assumptions. This means that also the results are highly uncertain and only aim to show a direction and order of magnitude what the real costs could be.

Costs for the mitigation options in general range from the order of magnitude of -10^8 to the order of magnitude of 10^{10}. For the option “speed limit of 120 km/h on motorways” sensitivity analyses show that, based on different assumptions, costs range from the order of -10^7 to 10^9. This example reflects well how uncertain the assumptions are.

Zusammenfassung

In dieser Studie werden Kosten für (nicht-technische und ggf. auf das Verhalten einwirkende) Emissionsminderungsmaßnahmen und politische Instrumente inklusive Nutzenverlust abgeschätzt. Die Maßnahmen und Instrumente wurden im Projekt PAREST ermittelt und analysiert. Das Projekt untersucht mögliche Minderungsoptionen, um Feinstaubkonzentrationen in Deutschland zu reduzieren, und untersucht deren Auswirkungen auf die Konzentrationen von Feinstaub, Ozon und NO_2 in Europa. Die Kosten dieser Optionen werden herangezogen, um zu bewerten, ob die Maßnahmen günstig (im Sinne von Kosten gegenüber Nutzen) sind.

Dieser Bericht beschäftigt sich mit der Abschätzung der Kosten von (nicht-technischen und ggf. auf das Verhalten einwirkenden) Emissionsminderungsmaßnahmen und politischen Instrumenten, u.a. werden eine Minderungsoption aus der Landwirtschaft, eine Option für Aerosolsprays und mehrere Optionen aus dem Transportsektor betrachtet.

Kostenbestandteile sind Faktorkosten und Nutzenverlust. Letzterer wird betrachtet, um ein möglichst vollständiges Bild der Gesamtkosten der Option zu erhalten. Nutzenverlust kann sich in Zeitverlust manifestieren, in Komfortverlust, Verlust des aktuellen Status oder dem Unwillen Arbeits- und Produktionsprozesse umzustellen.

Der Nutzenverlust kann abgeschätzt werden, indem der Wohlfahrtsverlust bestimmt wird, der sich aus einer Maßnahme oder einem Instrument ergibt, indem die Preiselastizität für ein Gut angewendet wird, indem für Zeitverlust der Wert einer verlorenen Stunde im Verkehr abgeschätzt wird (verglichen mit der Situation ohne die Maßnahme) und indem für Komfortverslust die Methode Hedonische Preisbildung („Hedonic pricing“) angewendet wird.

Die Kosten werden auf ein Jahr umgerechnet / diskontiert und von der Inflation bereinigt (Basisjahr 2000).

Die Unsicherheiten sind für alle Kosten sehr hoch und basieren auf sehr unsicheren Annahmen. Das bedeutet, dass auch die Ergebnisse sehr unsicher sind und nur mögliche Größenordnungen der Kosten aufzeigen können.

Die Kosten für die Minderungsoptionen insgesamt haben Größenordnungen von -10^8 bis 10^{10}. Für die Option „Geschwindigkeitsbegrenzung von 120 km/h auf Autobahnen“ zeigen Sensitivitätsanalysen, dass die Kosten, basierend auf unterschiedlichen Annahmen, in der Größenordnung von -10^7 bis 10^9 liegen könnten. Dieses Beispiel zeigt, wie unsicher die Annahmen sind.

1) Introduction

The aim of this report is to give coarse estimates of costs of (behavioural) emission mitigation measures and instruments including estimation of utility loss. The outcome is used in the PAREST project which conducts a (socio-)economic assessment of policy instruments and mitigation measures to reduce (primary and secondary) particulate matter concentrations.

1.1) Context

For air pollution management and control the development of (cost-efficient) air pollution reduction strategies is of central relevance. Science can help policy makers with identifying policy instruments and emission abatement, reduction and mitigation measures.

Policy instruments are "used by the government to make producers and consumers change their behaviour" [Sternhufvud et al., 2006] in order to pursue the environmental objectives of states. *Abatement, reduction and mitigation measures* are often used synonymously. A slight distinction can be made by suggesting that abatement measures reduce the emission at the source; reduction measures would be the same but might include additionally changes in the energy or transport system; mitigation measures focus on the scoped environmental or health target (decreased damage) no matter where the measure applies and how the mechanisms work.

Furthermore, sometimes it is useful to make a distinction between *technical* and *non-technical* or *behavioural* measures. A clear distinction is not possible (and also depending on the scope of the considered issue, see chapter 2), but generally, technical measure influence the emission factor while non-technical or behavioural measures influence the activity leading to the emission.

Air pollution control and management can base the decisions to be taken on the results from *different types of assessments*, each of which set a slightly different framework and context. The use of the different frameworks is dependent on the question that is asked. Focusing e.g. on health effects, Integrated Environmental Health Impact Assessment [Briggs, 2008] is one of the frameworks that can be employed. It provides a comprehensive information basis on health effects due to emissions characterised in certain future scenarios including one or more mitigation measure(s).

Based on considerations regarding costs and benefits of policy instruments and mitigation measures *cost-benefit-analyses* and *cost-effectiveness-analyses* can be conducted (see chapter 3) to investigate if instruments or measures are worthwhile.

From the economic viewpoint, a distinction can be made between *ecological economics* (EE) and *environmental and resource economics* (ERE) [van den Bergh, 2000]. The consideration and examination of policy instruments and mitigation measures, employing cost-benefit-analyses or cost-effectiveness-analyses tend to be more related to ERE.

In PAREST a (socio-)economic assessment of policy instruments and mitigation measures to reduce particulate matter and its precursor substances is conducted. Costs of the measures are estimated; and the impacts of the modelled measures on the concentrations of particulate matter, ozone and nitrogen dioxide are considered. **This report** focuses on the costs of (behavioural) emission mitigation measures and instruments including estimation of utility loss.

Implications and consequences of policy instruments and mitigation measures affect different levels and parts of the whole system. Interpretation of measures can vary: depending on if the viewpoint of an individual is taken or the viewpoint of the society or the government.

Especially for assessing the costs of an instrument or a measure it is important to explicitly make clear which viewpoint is taken. Costs for the instruments and measures 5 are listed in chapter 5 according to different viewpoints or economic agent (citizen, sovereign institutions). Even if costs cancel out from a macroeconomic viewpoint (which is taken in this report) it is important to consider individual costs to understand the steering effect of instruments / measures. A tax e.g. is not considered as costs because they are transfers (see chapter 2.2.1) but it constitutes costs for the citizen who acts consequently.

1.2) Importance of including utility loss into measure costs

For many measures, mainly technical measures, factor costs (see chapter 2.2.1) are the main cost component. Those costs can be derived quite straightforward. However, some measures are not implemented although they seem to have “negative” costs. For some of those measures the investment costs are just too high compared to the “negative” costs to be a strong enough incentive.

Other measures may involve a utility loss which cannot be labelled with a market price. Utility loss can be time loss, loss of convenience / comfort, loss of status, or the reluctance to adopt a required change in workflows or (production) processes.

2) Properties of mitigation measures and instruments

Measures and instruments do not have a useful meaning if they are not set in a context. A measure or an instrument acts in a system and is dependent on the scope inside which it is defined. System boundaries might include the location in which the measure or instrument takes place (e.g. Europe, Germany, Berlin), the time horizon in which it is implemented (e.g. 2010, 2015, 2050) and the sector (e.g. transport: Diesel passenger cars).

The system boundaries also define which effects of the measure or instrument are taken into account and which not (e.g. shifting to other transport modes or not). In- and exclusion should be based on the relevance of the effects. Sometimes however, aspects cannot be taken into account due to lacking data or due to high complexity of the system. For the importance of defining the scope of an assessment see [Briggs, 2008].

Especially for valuation purposes the scope defining a measure or instrument is important: Different assumptions need to be made and different effects need to be taken into account, depending on whether the measure is set on a national, local or European level (e.g. time loss or damage costs). If measures or instruments in several countries are assessed transfers between the countries need to be considered.

The context in which the measure or instrument is applied influences further properties of the measure / instrument, e.g. costs, benefits and mitigation potential.

An instrument can involve several measures, and a measure can consist of several parts. The implementation of “speed limits on certain streets” e.g. includes changing the law, setting up road signs, having an administration to control the speed limit, and maybe starting campaigns to promote the speed limit among the society.

2.1) Time scale and horizon

The time frame of a study (an assessment) is based on its scope and the specified boundaries. The scope and boundaries depend amongst others on the purpose of the strategy (e.g. if only the reduction potential of mitigation measures is considered a short time frame suffices; if long-term effects of the reduction of e.g. greenhouse gases are considered a longer time frame is needed).

For technical mitigation measures temporal boundaries depend on their life time.

In PAREST we focus on the reduction of particulate matter concentrations. Emissions of primary particles (PM10 and PM2.5) and secondary aerosol precursors are assumed as emissions occurring in a certain year (2010, 2015 and 2020). The reduction in emissions due to instruments or measures takes place in the respective year. Damages (e.g. health impacts and impacts on crops, ecosystems and materials) might occur later, but are not object of this study (they would need to be discounted, see chapter 3.1). Concentration changes are taken into account; they are modelled within the year of the emissions. So looking at the three years 2010, 2015 and 2020 is sufficient.

Instruments and measures are characterised among others by their time of implementation. They are considered to be effective either from 2010 onwards, from 2015 onwards or from 2020 onwards. A business as usual scenario (BAU), in which all instruments and measures are included that are implemented already, is the basis for comparison to a scenario including a new instrument or measure. Implementing the instrument or measure in 2010 implies that its effect is also existent in 2015 and 2020 (see figure 1). In other studies starting from a later point in time, of course this measure would be included in a BAU scenario.

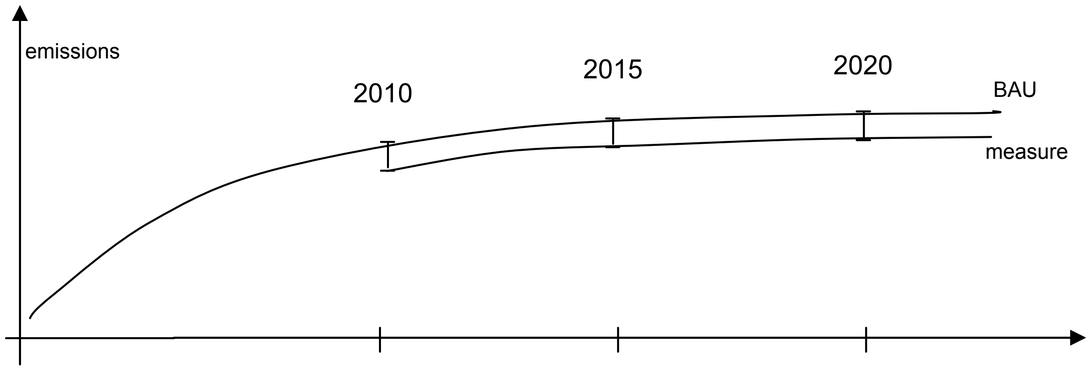

Fig 1: Impact of a mitigation measure on the emissions: comparison of two scenarios

Other properties of the measures and instruments are allocated to the time of the reduced emissions. That means that the costs are allocated to the year of the emission reduction.

To make costs of measures comparable they are annualised, given the life time of the respective measure (see chapter 3.1). Costs that are occurring each year repeatedly are added. Benefits in form of reduced health impacts are not included in PAREST as the focus is on a cost-effectiveness analysis, so there is no need to make benefits comparable.

A special situation emerges when considering **utility losses**: One could imagine that newly lost utility is more painful than if one has already got accustomed to the situation. To account for this effect average values (money per unit utility loss) are used. These average values include persons that feel a high loss and persons that feel a low loss due to familiarisation. Values for utility loss are sparse and do not exist, as it is difficult to find a metric for the utility loss. In case of time loss in the transport sector values do exist (e.g. [Bickel et al., 2005a]). They are often derived applying the contingent valuation method, see e.g. [Mitchell et al., 1989], meaning that an informed and representative subgroup of the population is asked to state their preferences regarding the object of interest.

2.2) Costs of measures and instruments

As costs are a property of instruments and measures the definition and scope of the measure also influence its costs (see e.g. chapter2.1). As a measure can consist of several parts of costs all parts need to be taken into account (see the example of a ‘speed limit’ explained above).

For the costs of each part of the instrument or measure assumptions need to be made (e.g. regarding its life time). Further assumptions need to be made to merge the costs of all parts of a measure or instrument (e.g. merge costs of parts that have a different life time). These assumptions are the most relevant source of uncertainties (see chapter 4).

Implementing an instrument or a measure might serve several purposes one of which may be emission mitigation. If several purposes are pursued only those costs that can be allocated to the objective of reducing the emissions must be taken into account. However, in PAREST we do not consider instruments or measures that serve several purposes (although of course they may have side-impacts, e.g. some measures may influence green house gas emissions). Thus, we consider all costs emerging for an instrument or measure.

Costs can be characterised according to different criteria:

- Of which type are the costs? Which components can be quantified?
  - Is there a utility loss and how does it manifest itself?
- Who pays? Is it a sovereign institution, the citizen, the user of a service, the company?
- Where are the system boundaries? What is the scope? Which costs are considered, which effects, which changes in systems? What is excluded? (see chapter 2)
- Which time horizon is considered? (see chapter2.1)

Filling these coarse criteria for each measure or instrument helps to achieve an overview over the relevance of the different cost components (see chapter 2.2.1).

2.2.1) Cost components

Costs of measures and instruments coarsely consist of the following components: factor costs, taxes and fees, and costs of utility loss.

Factor costs

Factor costs comprise capital costs (acquisition costs) for an object (e.g. Diesel particle filter, road signs, purchase of a new bus) and running / operating costs (and savings), other material costs, labour costs, service costs etc. Costs are given adjusted for taxes as taxes are not taken into account (see below).

Factor costs can be derived straightforward from market prices.

Taxes and fees

Taxes and fees constitute a transfer from the citizen to the sovereign institutions / state / society. Thus, in a (socio-)economic approach they are not taken into account (when analysing from the perspective of total society and not a specific individual). However, it is important to recognise their steering effect on individuals to understand the mechanism of the measure / instrument.

Utility loss

Utility loss cannot be measured directly. It does not have only one definition. It can consist of comfort/status loss, of time loss etc. or it can be dead weight loss etc.

In contrast to technical measures, for behavioural measures, especially those that lead to utility losses, costs cannot be calculated straightforward. As no markets and thus no prices exist for utility losses, a metric needs to be found to express it. Furthermore, coarse assumptions need to be made that often are not obvious or unambiguous (e.g. how many people use public transport instead of cars, how many take the bike or walk).

In this report several types of utility loss are distinguished: a) *time loss*, b) *comfort loss*, and c) *dead weight loss*. For a time loss (e.g. time lost due to travelling more slowly due to a speed limit) the hours of time lost (i.e. the additional time used for transport compared to the reference situation without the measure) are estimated.

The method applied for estimating the *value of an hour lost in travel* is the contingent valuation study method [Mitchell et al., 1989]. “Contingent valuation is a survey method in which respondents are asked to state their preferences in hypothetical or contingent markets, allowing analysts to estimate demands for goods or services that are not traded in markets. In general, the survey draws on a sample of individuals who are asked to imagine that there is a market where they can buy the good or service evaluated. Individuals state their individual willingness to pay for a change in the provision of the good or service, or their minimum compensation (willingness to accept) if the change is not carried out” [Bickel et al., 2005a]. The willingness to pay of the individuals is dependent on their income, age and educational background as well as on the prices of other goods.

Comfort loss occurs in this report as the possible loss to use another type of deo application than spray containing a large amount of VOCs (volatile organic compounds), and the loss to not eat as much meat as one would like to. In the case of the deo sprays the hedonic pricing method is applied [Rosen, 1974]. The “analysis refers to the estimation of implicit prices for individual attributes of a market commodity when an environmental good or service can be viewed as attributes of a market commodity, such as properties or wages“ [Bickel et al, 2005a]. As an example, rents for similar houses can be compared one of which is exposed to noise and the other is not. The difference is attributed to the noise and provides a “price” for the avoided noise.

Dead weight loss (or excess burden) occurs when an equilibrium for a good or service is not Pareto optimal. It can include monopoly pricing, externalities, taxes or subsidies [e.g. Case et al., 1999]. Dead weight loss related to the concept of consumer and producer surplus can be estimated by estimating the changes in the total surplus (see e.g. [Harberger, 1971], [Hines, 1999]). In this report the concept of dead weight loss is applied to the internalisation of costs in air traffic (kerosene tax and emission trading).

In the case of reduced animal protein consumption the utility loss is estimated using the *price elasticity* of meat, which, for a given amount of consumption, the desired reduction in consumption and the meat price, can be used to calculate the price necessary to “force” people to eat less meat.

2.2.2) Who pays?

As already explained in the introduction to this chapter and in chapter 1.1 costs can be allocated to different economic agents. Costs for citizens, like taxes, can have a steering effect for behaviour but might not be considered in a macroeconomic approach. Depending also on the context and question it is important to be aware of what economic agents are taken into account and how their costs are interpreted.

2.3) Benefits of measures and instruments

Benefits of an instrument or a measure can include different aspects. Most often in the context of pollution control and environmental and health impact assessments, benefits are defined as avoided (health) impacts due to a reduction in emissions by the implementation of a measure or instrument. Methods to value these benefits are reviewed in several literature sources, e.g. [Cropper, 2000], [Bickel et al., 2005b], [UBA, 2007]. Other aspects might be positive health effects due to physical activity, e.g. while biking or walking. However, benefits other than changes in concentration of particulate matter, ozone and NO_2 are not considered in PAREST (although side-effects on e.g. green house gases are indicated).

3) Comparison of mitigation measures

For ranking of mitigation measures and policy instruments it is necessary to compare them to each other. Cost-benefit-analyses and cost-effectiveness-analyses can be applied for this purpose (e.g. [Bickel et al., 2005b], [Mishan at al., 2007], [Robinson, 1993]; for cost-benefit-analyses in decision making see e.g. [Hahn et al., 1996], [Eckstein, 1958]).

Cost-effectiveness-analyses compare costs of alternative measures or instruments with their ability to reach certain aims (usefulness, benefit). Benefits are given in physical units, e.g. concentration change. Therefore, cost-effectiveness-analyses are helpful when measures or instruments with a similar aim are compared – as it is the case in PAREST.

Cost-benefit-analyses consider costs and benefits of a measure or instrument over a relevant time period. To compare costs and benefits, the benefits need to be translated into monetary values (e.g. [UBA, 2007]). Cost-benefit-analyses achieve a positive appraisal if at a certain point in time the discounted difference between the benefits and the costs is positive. Different metrics can serve as decision criteria, e.g. net present value (difference between discounted costs and discounted benefits) or benefit-cost-ratio of discounted benefits and discounted costs [Bickel et al., 2005b].

3.1) Discounting / depreciating

Costs for measures and instruments can occur at different points in time. To make them comparable they need to be *annualised* given the life time of the respective measure. In a (socio-)economic assessment capital costs are generally assigned to the year of purchase (in contrast to a pure financial assessment of a project). However, to be able to compare the costs of different measures to each other the acquisition costs are annualised by applying equation 1 For Germany a discount rate of 3 % is used [Bickel et al., 2005b],

$$A_t = C_0\left(\left(r(1+r)^n\right) \Big/ (1+r)^n - 1 \right) + OC_t , \qquad \text{(Equation 1)}$$

where A_t = annualised costs for time period t (usually 1 year),

C_0 = total investment expenditure of the measure, t=0,

OC_t = operating and maintenance costs in period t,

r = discount rate per period,

n = the estimated lifetime of the equipment / measure (in years)

When future benefits of a measure or instrument are taken into account in a cost-benefit-analysis, measured in monetary values, the benefits need to be *discounted* to the year of the emissions to obtain their net present value. Thus, discounting is a method to compare costs and benefits with different time frames by relating them to one point in time. See equation 2 for discounting a future value to its present value.

$$p = f\,(1+r)^{-n} \qquad \text{(Equation 2)}$$

where p = present value of the future value fv,

f = future value,

r   = discount rate per period,

n   = period (in years)

Adjustment to a base year: Costs need to be referenced to a base year to adjust for inflation (i.e. monetary values are expressed in constant money values of a base year). In this report all costs are referenced to the year 2000 ($Euro_{2000}$).

4) Uncertainties

All the given costs are based on highly uncertain assumptions. This means that also the results are highly uncertain and only aim to show a direction and order of magnitude of the real costs. Clearly, more research needs to be undertaken in this field. The uncertainties are mainly of systematic origin, not of measurement or statistical origin. Uncertainties mainly consist of a) missing information and data and b) therefore of the uncertainty of the assumptions made to account for the missing information. A quantitative statement about uncertainties is not possible.

5) Economic costs of certain mitigation measures and policy instruments

Based on the principles described in chapters 1)-4), costs for certain mitigation measures and policy instruments have been estimated. From all measures and instruments described in [Theloke et al., 2010] those measures were selected that are not purely technical measures, i.e. that they have cost components other than (only) factor costs. An overview over the methods, main assumptions and costs is found in table 1. Detailed descriptions for each measure/instrument can be found in the section following this table.

Table 1: Very coarse estimates of the economic costs of certain mitigation measures and policy instruments in $EUR_{2000.}$ (Note that the uncertainties are very high!)

Measure	Method	Assumptions	2010	2015	2020
Scenario: Reduced animal protein consumption	• Reduced consumption of meat • Use meat elasticity to calculate the price needed to “force” people to eat less meat as desired	• Only reduced meat consumption is considered, no animal protein products other than meat • Possible reduced meat consumption: 26.8 kg/cap/y • Elasticity for meat prices for West Europe: -1.191 • Costs of 1 kg meat: 11 EUR_{2009}	$\leq 2.47 * 10^8$	$\leq 1.4 * 10^9$	$\leq 2.7 * 10^9$
Reduction of NMVOC emissions from aerosol spray applications	• Utility loss due to a change in applications for deo sprays is not quantifiable • Increase in product costs due to the necessity of other containers		-	$7.6 * 10^6$	$7.6 * 10^6$
Speed limit of 120 km/h on motorways	• Time loss for people going by car • Time gain due to less traffic jams not quantitatively considered • Saved fuel • Street facilities • Information campaigns	• 70 % of the motorway have no speed limit to date • 20 % of the passenger car traffic are business, 80 % are leisure traffic • Value of time: 20 EUR_{2002} / h business travel, leisure traffic: 3.80 EUR_{2002} / h	$-1.3 * 10^7$ Sensitivity analyses show positive costs (see below)	$-5.9 * 10^7$ Sensitivity analyses show positive costs (see below)	-10^7 Sensitivity analyses show positive costs (see below)

Measure	Method	Assumptions	2010	2015	2020
Speed limit of 80 km/h on federal state roads	• Time loss for people going by car • Saved fuel • Information campaigns	• 100 % of the rural roads are affected • 20 % of the passenger car traffic are business, 80 % are leisure traffic • Value of time: 20 EUR_{2002} / h business travel, leisure traffic: 3.80 EUR_{2002} / h	$4*10^9$	$4*10^9$	$4.4*10^9$
Adjustment of diesel fuel tax to petrol fuel tax	• Saved fuel • Utility loss for people not buying new cars is not quantifiable (see measure description below)	• In 2010 46% of new cars are Diesel cars instead of 50%	$-1.81*10^8$ (Utility loss of those not buying any car is not quantifiable)	$-2.23*10^8$ (Utility loss of those not buying any car is not quantifiable)	$-2.44*10^8$ (Utility loss of those not buying any car is not quantifiable)
Environmental zone (hypothetical maximum scenario)	• Market value loss for cars that have to be sold earlier than without the measure • Road signs • Administration	• Only cars with a green badge are allowed to enter Berlin, Munich and the Ruhr area in 2015 • Vehicle kilometres of banned cars are replaced proportionally by vehicle kilometres of allowed cars • Costs are allocated to 2015; for investment costs an average life time of 5 years is assumed • Market value loss of a car is assumed to be 2000 EUR • Impacts of the scrappage scheme are not considered.	-	$3 *10^8$ (from these: $4.9 *10^5$ for administration and road facilities)	.
Speed limit on urban roads	• Time loss due to reduced speed	• Half of the urban vehicle kilometres are affected. • 50 % of the traffic are business, 50 % are leisure traffic • Value of time: 20 EUR_{2002} / h business travel, leisure traffic: 3.80 EUR_{2002} / h	$3.03 *10^{10}$	$3.05 *10^{10}$	$3.03 *10^{10}$
Shift of travel in passenger cars to bike usage	• Utility loss including time loss and gains due to saved fuel • Information campaigns, road facilities	• 4 % of urban vehicle kilometres by passenger cars are affected	-	$5.2*10^7$	$5.15*10^7$

Measure	Method	Assumptions	2010	2015	2020
Ecodriving			$-8.6 * 10^7$	$-9 * 10^7$	$-9.3 * 10^7$
Internalisation of costs in air traffic			$2.5 * 10^7$	$2.7 * 10^7$	$2.8 * 10^7$
Emission related landing charges for air traffic			Not quantifiable	Not quantifiable	Not quantifiable

Measure Scenario: Reduced animal protein consumption			
System boundaries This hypothetical scenario assumes that only as much (animal) protein / meat is consumed as human beings need. This leads to reduced meat consumption compared to the current situation. The comfort loss that arises due to the reduction in meat consumption is considered. The reduction in consumption of other animal protein products (other than meat) is not considered due to lacking data. Neither are economic consequences considered originating from a reorganisation of the structure of the agricultural sector and from a reorganisation of production processes because no estimation is possible.			
	Who pays?	**Of which kind are the costs?**	**Of which kind is the utility loss?**
a	Citizens	Utility loss	Comfort loss
b	Companies	Reduction in meat consumptions leads to reorganisation of the production processes	

Time horizon

It is assumed that this measure is implemented gradually from 2010 to 2020.

Approach

From the reduced protein consumption in animal products the fraction of reduced meat consumption is derived (other animal protein products are neglected due to lacking data).

To gain insight into the utility loss the following question needs to be answered: What would be the price increase necessary to reduce the meat consumption by the amount desired?

Assumptions and detailed method

The average protein requirement of a German female is about 50 g/d, of a German male about 60 g/d. The recommended amount of *animal* protein is about 30 g/d [Dämmgen et al., 2008]. Dämmgen furthermore states that woman consume 42 g/d animal protein and men 55.6 g/d animal protein. Assuming a mean of 48.8 g/d/cap of animal protein this results in a possible reduction of 18.8 g/d/cap in *animal* protein.

Food balance sheets of the UN [Faostat] assume an average consumption of animal protein (total protein in animal products including meat, milk, eggs etc.) of 59.5 g/d/cap for a German citizen in 2003. The amount of meat protein consumption is 27.7 g/d/cap according to Faostat. This leads to a percentage of 47 % of meat protein vs. (total) animal protein consumption.

The amount of possible reduced protein consumption in meat is the percentage of meat protein vs. animal protein consumption (47%, calculated from Faostat) times the possible reduction in animal protein (18.8 g/d/cap, calculated from Dämmgen): 8.8 g/d/cap.

The percentage of possible reduction of protein consumption in meat is calculated dividing the possible reduction in protein consumption in meat by the total consumption: 8.8 g/d/cap / 27.7 g/d/cap → ca. 32 %.

The total amount of meat consumption is 84.7 kg/cap/y (Faostat). The possible reduction in meat consumption is thus the total amount times the percentage of possible reduction in meat consumption: 84.7 * 32 % → ca. 26.8 kg/cap/y.

There are emotional reasons for meat consumption. The higher the meat consumption the higher are the emotional relations [Barrena et al, 2009].

The question now is: What would be the price increase necessary to reduce the meat consumption by the amount desired?

This question can be answered by making use of the price elasticity of meat, which, for a given

amount of consumption, the desired reduction in consumption and the meat price, can be used to calculate the price necessary to “force” people to eat less meat. $\eta_{Q,P} = \frac{\frac{(Q_2 - Q_1)}{Q_1}}{\frac{(P_2 - P_1)}{P_1}}$, where P_1 (Q_1) is the old price (demand), P_2 (Q_2) is the new price (demand) The elasticity is assumed to be -1,191 [Gallet, 2010]. The old demand is the current amount of meat consumed: 84.7 kg/cap/y. The new demand is the old demand minus the possible reduction (26.8 kg/cap/y): 57.9 kg/cap/y. The old price for meat is assumed with 11 EUR_{2009} per kg [Bundesanstalt für Agrarwirtschaft]. Based on these values a new price of 13.9 EUR_{2009} is applicable. The difference is 2.9 EUR_{2009} per kg meat. Finally, the costs are obtained by estimating the welfare loss based on the change in demand and in price: ((26.8 kg/cap/y * 82 Mio. cap) * 2.9 EUR_{2009}/kg) / 2 ≈ 3.2 E+9 EUR_{2009}/y. It is assumed that this measure is implemented gradually from 2010 to 2020. This means that 2010 1/11 of the total reductions (and costs) would appear (2.9 E+8 EUR_{2009} = 2.47 E+8 EUR_{2000}), 2015 6/11 (1.7 E+9 EUR_{2009} = 1.4 E+9 EUR_{2000}), and 2020 11/11 (3.2 E+9 EUR_{2009} = 2.7 E+9 EUR_{2000}). These costs are to be seen as upper boundary. If a decrease of meat consumptions could be achieved by campaigns for this decrease no utility loss would exist, and just the costs for the campaigns would show up (lower boundary).
Costs **2010:** a) 2.47 E+8 EUR_{2000} b) not considered **2015:** a) 1.4 E+9 EUR_{2000} b) not considered **2020:** a) 2.7 E+9 EUR_{2000} b) not considered

Measure Reduction of NMVOC Emissions from aerosol spray applications			
System boundaries It is investigated if other forms of application of deo sprays, hair sprays and manufacturing sprays lead to a utility loss (comfort loss) due to other physical properties of the product. An increase in production costs due to the usage of other material for containers of the products is considered. Economic consequences due to a reorganisation of production processes are not considered. They come under RTD (research and technological development) activities. (see [Theloke, 2005])			
	Who pays?	**Of which kind are the costs?**	**Of which kind is the utility loss?**
a	Citizens	Utility loss → not quantifiable	Comfort loss
b	Companies	Additional production costs	
c	Companies	Another system for application leads to reorganisation of the production processes	

Time horizon

2015

Approach

a) It was investigated if other forms of application lead to a utility loss.

b) Product prices rise due to a change in the containing system.

Assumptions and detailed method

a) It was investigated if other forms of application lead to a utility loss.

i) Hair sprays: A solvent content of 90% instead of 98% is suggested. This leads to no disadvantages during the usage of the product.

ii) Deo sprays: Different systems of application, which contain different amounts of VOCs, might lead to different comfort levels for the user, e.g. one person likes sprays more than roll-on sticks, pump sprays or other types of application. If the user is now forced to use another type which he/she dislikes a utility loss occurs. The question is, how much cheaper the roll-on stick needs to be so that the utility loss and the price difference equal out and the user buys the roll-on stick rather than the spray although he/she likes it less. In other words, the difference in the price would reflect the utility loss to the users.

At the moment there is no major difference in prices of different applications. However, what would be the reduction in prices necessary to get the citizens using only roll-on sticks? This question cannot be answered without conducting surveys; so we cannot quantify the utility loss.

b) Additional production costs arise due to a change in the containing system. Costs are estimated to be around 500 EUR_{2000}/t avoided NMVOC [Theloke, 2005]. Per year 15,284 t NMVOC from aerosol sprays could be avoided leading to yearly costs of 7.6 E+6 EUR.

Costs

2010

a) -

b) -

total

2015

a) -

b) $7.6*10^6$ EUR_{2000}

total

$7.6*10^6$ EUR_{2000}

2020

a) -

b) $7.6*10^6$ EUR_{2000}

total

$7.6*10^6$ EUR_{2000}

Measure
Speed limit of 120 km/h on motorways

System boundaries

Due to the speed limit the citizens might endure a time loss. Only passenger cars are taken into account as there already is a speed limit for heavy duty vehicles. In contrast to the time loss, there might be less traffic jams, and thus these effects might compensate each other – depending on the assumptions.

Cost savings due to saved fuel are considered.

Shifting of transport to other modes is not considered as it is assumed that the comfort loss to use e.g. a train instead of the car is higher than the time loss due to the speed limit.

The loss of comfort (enjoyment due to driving a fast car) for the citizens due to the speed limit is not considered. However, some people tend to enjoy the stress free traffic flow in countries with speed limits.

Costs for additional road signs and street infrastructure facilities are considered to be negligible. Costs for the administration are considered to be negligible.

	Who pays?	Of which kind are the costs?	Of which kind is the utility loss?
a	Citizens	Time loss	Time loss
b	Citizens	Saved fuel	-
c	Sovereign Institutions	Road signs, street facilities → negligible	-
d	Sovereign Institutions	Information campaigns	-
e	Sovereign Institutions	Administration → negligible	-
f	Citizens	Utility loss or gain → not quantifiable	Comfort loss

Time horizon

a) Costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year.

b) Negative costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year.

c) It is assumed that no costs occur for street facilities or road signs as the speed limit is set by law.

d) In analogy to the measure “Shift of travel in passenger cars to bike usage“ costs for information campaigns are assumed to exist.

Approach

Due to a speed limit people cannot travel as fast as they would have liked to. This is especially the case for passenger cars, not for lorries as those are driving below 120 km/h anyway. This means that it takes longer to get from A to B than before. The time loss can be valued resulting in the costs for the time loss.

Assumptions and detailed method

a) To derive the time loss due to a reduced speed one needs to know the current speed (best is a frequency distribution), the new speed (also as a frequency distribution) and the number of kilometres driven on motorways. The number of kilometres driven on German motorways is 1.88E+11 km in

2010, 2.04E+11 km in 2015 and 2.18E+11 km in 2020 for passenger cars (source: Tremod 4.17). We assume that lorries are not influenced by the speed limit. Furthermore, we assume that 30 % of the motorways are already equipped with speed limits (BAST: personal communication with UBA) and thus the remaining **70 %** of the vehicle kilometres are affected by the speed limit.

Regarding the speed of the cars, there are different sources: [Gohlisch et al, 1999] cite a study by Kellermann from 1992 which states that the mean speed of passenger cars on motorways is 120.4 km/h in 1992. 85% of the drivers of passenger cars drive below 148.2 km/h. There is a trend in this data source with increasing speed from 112.3 km/h in 1982 to 120.4 km/h in 1992. It is to be assumed that in the present and future the speed is higher than the one given for 1992. In addition, a better description of a frequency distribution would be of more help.

Another source is the information given in a press release of the Bavarian Interior ministry http://www.stmi.bayern.de/presse/archiv/2003/287.php . On a piece of motorways without speed limit the following percentage of speeds were measured in 2003 for passenger cars: 12.93 % drive less than 100 km/h, 47.59 % are going with a speed of 101 – 130 km/h, 24.45 % are going with a speed of 130 – 150 km/h and 15.02 % are going even faster than 150 km/h.

A third source of information is [Maier, 2004] (see Fig 1). In this source, also information regarding a speed limit of 120 km/h can be found (see below).

Now, the time needed for **70%** of the number of kilometres driven on German motorways (VKM-PC = vehicle kilometres driven in a passenger car) without the measure can be calculated: (VKM-PC km/h) / (“130” km/h). The time needed with the implemented measure can be calculated likewise: (VKM-PC km/h) / (“120” km/h). (“130” means the speed distribution driven in the status quo, “120” means the speed distribution driven when the speed limit is implemented.) The difference results in ((VKM-PC km/h) / (“120” km/h)) - ((VKM-PC km/h) / (“130” km/h)) = VKM-PC (1/”120” - 1/”130”) h (equation 1). For the cumulative probability distributions [Maier, 2004] was taken.

Using Monte Carlo analysis to solve equation 1 a mean of 60.73 E+6 h is estimated for the hours lost in 2010 (median 71.27 E+6), 65.9 E+6 h in 2015 (median 77.3 E+6 h), and 70.4 E+6 h for 2020 (median 82.7 E+6 h) (Fig 2, 3 and 4). The mean is the actual arithmetic mean. The median is the most middle value. Comparing mean and media gives information about the variance. For further calculations the mean is taken.

The cumulative probability for the hours lost are given below (Figures 2, 3 and 4).

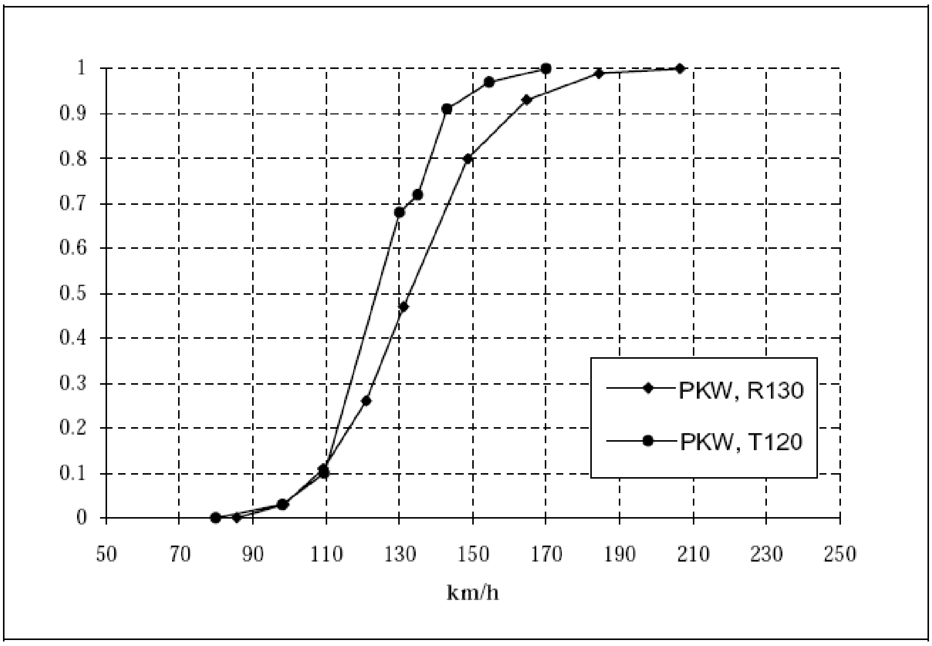

Fig 1 Wunschgeschwindigkeitsverteilungen für PKW auf zweistreifigen Autobahnen [Maier, 2004]

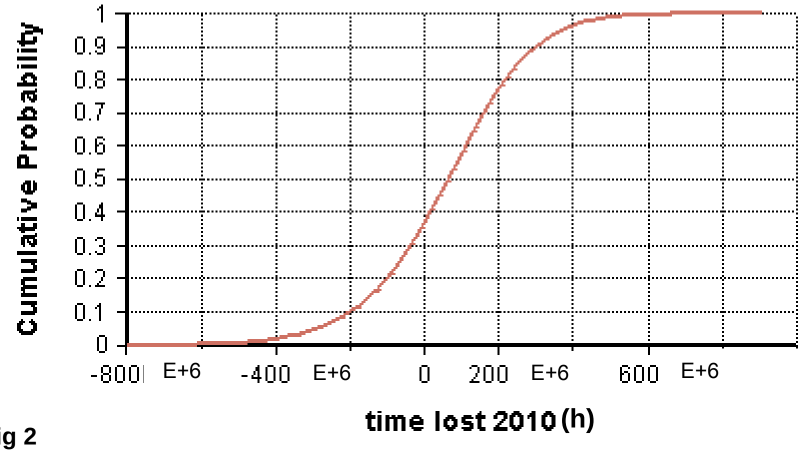

Fig 2

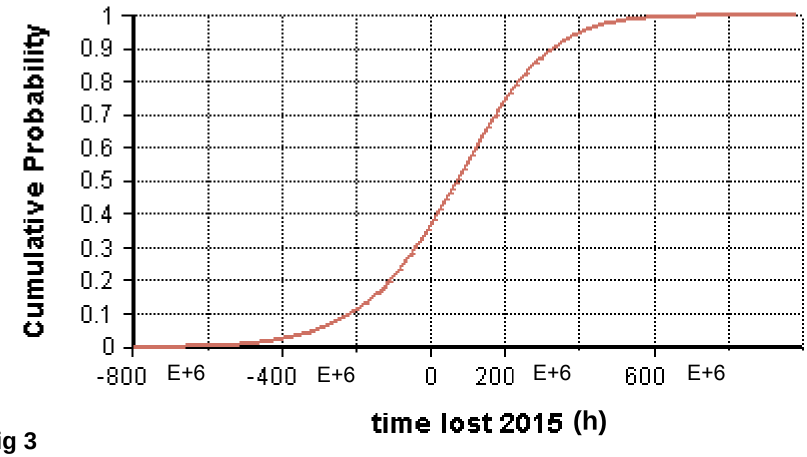

Fig 3

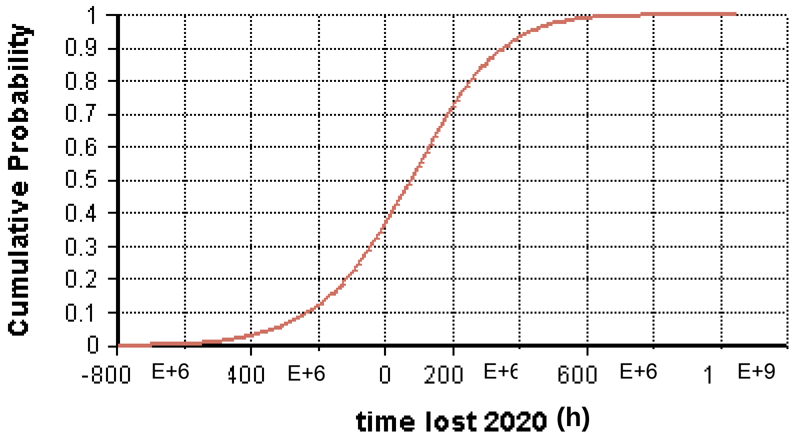

Fig 4

[Bickel et al. 2005a] give an estimate for the value of travel time saved (for reasoning why time has a value see e.g. [Mackie et al., 2001], for different approaches see e.g. [Mackie et al., 2003], [Harrison, 1974], [Hensher, 1977] and [Bickel et al., 2005a]). For business travel they assume 20 EUR_{2002} / h. For leisure travel they assume a factor of 0.19 leading to 3.8 EUR_{2002} / h. Assuming a composition of 80 % leisure travel vs. 20 % business travel ([Hautzinger et al., 2002]) the mean value of travel time saved would be 7.04 EUR_{2002} / h. Another source for value of time is [Flötteröd et al., 2008]. They assume 12 EUR / h but do not state which year the EUR are given in.

Multiplying the time lost with the value of time gives the costs of the time loss:
2010: approx. 430 E+6 EUR_{2002} (approx. **410 E+6 EUR_{2000}**)
2015: approx. 460 E+6 EUR_{2002} (approx. **450 E+6 EUR_{2000}**);
2020: approx. 500 E+6 EUR_{2002} (approx. **480 E+6 EUR_{2000}**).

This corresponds to about **0.3 ct_{2000} per km** driven with reduced speed.

Sensitivity analyses:

__i)__ An __alternative distribution__ for the speed during the speed limit of 120 km/h is assumed. It seems to fit better (fewer people are going so fast), but it is inconsistent as it is based on a different source [Kühlwein, 2004] and it is based on the measurement of a single piece of motorway (Fig 5).

Using Monte Carlo analysis to solve equation 1 a mean of 242.8 E+6 h is estimated for the hours lost in 2010 (median 222.8 E+6), 263.6 E+6 h in 2015 (median 241.6 E+6 h) and 281.6 E+6 h in 2020 (median 258.4 E+6 h) (Fig 6, 7 and 8). The mean is the actual arithmetic mean. The median is the most middle value. Comparing mean and media gives information about the variance. For further calculations the mean is taken.

The cumulative probability for the hours lost are given below (Fig 6, 7 and 8).

Multiplying the time lost with the value of time gives the costs of the time loss:
2010: approx. 1.7 E+9 EUR_{2002} (approx. __1.65 E +9 EUR_{2000}__)
2015: approx. 1.85 E+9 EUR_{2002} (approx. __1.79 E+9 EUR_{2000}__);
2020: approx. 1.98 E+9 EUR_{2002} (approx. __1.92 E+9 EUR_{2000}__).

This corresponds to about __1.2 ct_{2000} per km__ driven with reduced speed.

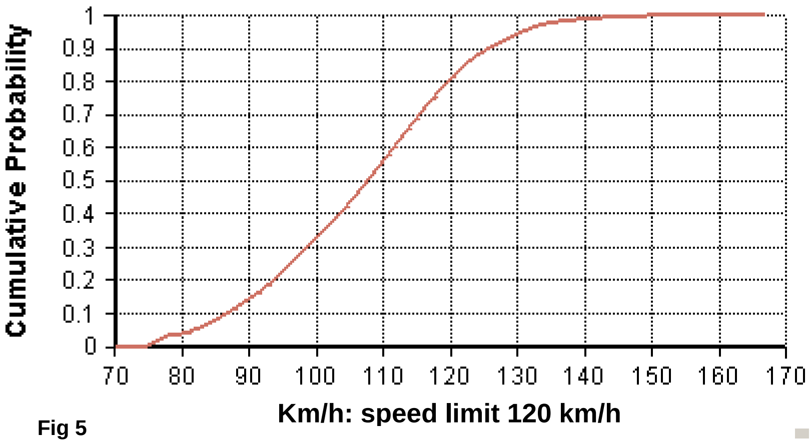

Fig 5

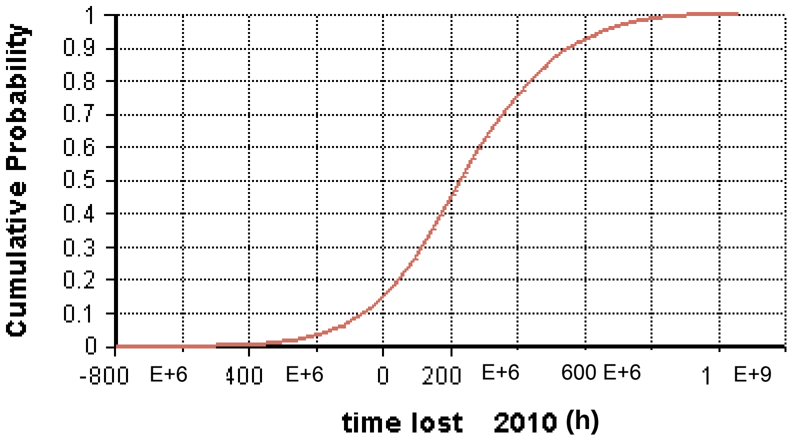

Fig 6

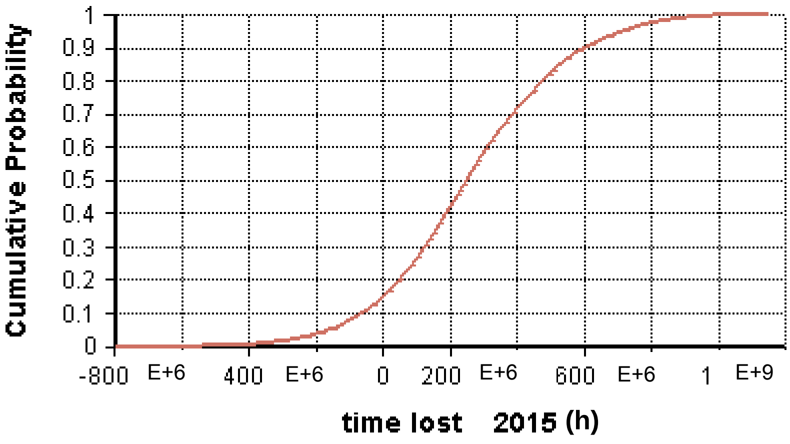

Fig 7

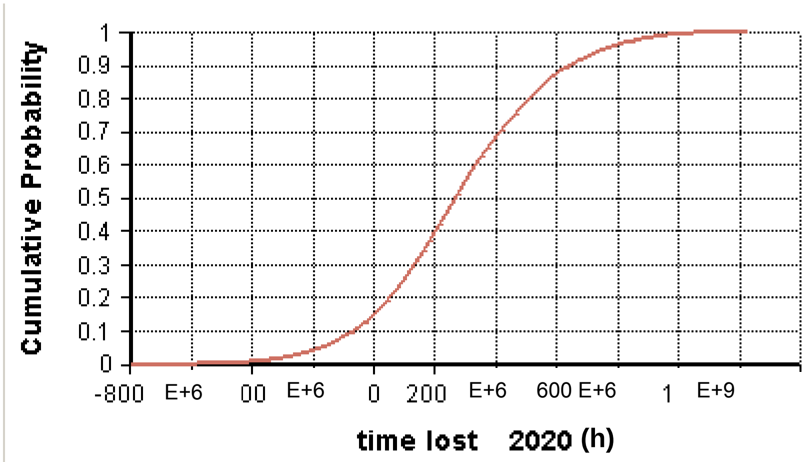

Fig 8

ii) *An* ***alternative composition of traffic*** *(50 % business, 50 % leisure) is assumed. This leads to costs of 11.90 EUR per hour. This leads to costs due to lost travel time of approx. 720 E+6 EUR_{2002} (700 E+6 EUR_{2000}) in 2010, 780 E+6 EUR_{2002} (760 E+6 EUR_{2000}) in 2015, and 840 E+6 EUR_{2002} (810 E+6 EUR_{2000}).*

Time gain (qualitatively):

In a study about speed limits on example road sections no effect on the capacity of the motorway was found, only an effect on the homogeneity of the traffic flow [Schick, 2003]. This homogeneity is resulting in less traffic accidents and time saved due to less traffic jams. Schick concludes that the total benefits of a speed limit on example road sections justify the speed limit. He gives values for a motorway with 3 lanes in each direction for the stabilising effect (Stabilisierungswirkung)using a dynamic speed limit equipment (not a static speed limit!): 1,000 EUR_{2003} per km, direction and year for an average daily traffic volume of 42.500 vehicles, and 50,000 EUR_{2003} per km, direction and year for an average daily traffic volume of 70.000 vehicles using a dynamic speed limit equipment (Streckenbeeinflussungsanlage).

b) The reduction in vehicle speed leads to fuel savings as less engine power is needed. UBA [2003] assume that by limiting maximum vehicle speed to 120 km/h on motorways, fuel consumption by passenger cars is 9% less. The average fuel consumption of passenger cars on motorways is 6.6 l/100 km [HBEFA, 2004], the price of fuel is 0.41 €/l excluding taxes (assuming an oil price of € 50/bbl

[Smokers et al., 2006]). For further details, refer to [Theloke et al., 2010].

d) For the mitigation measure „Shift of travel in passenger cars to bike usage“ (see below), it is assumed that € 600 million are needed for information campaigns [Schärer et al., 2008]. As a proxy for introducing a lower speed limit on motorways this figure is adopted here. For further details, refer to [Theloke et al., 2010].

Costs

2010

	Basic assumptions	Alternative speed distribution	Alternative composition of traffic
a)	$410*10^{6}$ EUR_{2000}	$1.65*10^{9}$ EUR_{2000}	$700*10^{6}$ EUR_{2000}
b) +d)	$-423*10^{6}$ EUR_{2000}		
c)	Assumed to be negligible		
e)	Assumed to be negligible		
total	**$-13*10^{6}$ EUR_{2000}**	$1.2*1^{9}$ EUR_{2000}	$277*10^{6}$ EUR_{2000}

2015

	Basic assumptions	Alternative speed distribution	Alternative composition of traffic
a)	$450*10^{6}$ EUR_{2000}	$1.79*10^{9}$ EUR_{2000}	$760*10^{6}$ EUR_{2000}
b) +d)	$-459*10^{6}$ EUR_{2000}		
c)	Assumed to be negligible		
e)	Assumed to be negligible		
total	**$-59*10^{6}$ EUR_{2000}**	$1.3*10^{9}$ EUR_{2000}	$301*10^{6}$ EUR_{2000}

2020

	Basic assumptions	Alternative speed distribution	Alternative composition of traffic
a)	$480*10^{6}$ EUR_{2000}	$1.92*10^{9}$ EUR_{2000}	$810*10^{6}$ EUR_{2000}
b) +d)	$-490*10^{6}$ EUR_{2000}		
c)	Assumed to be negligible		
e)	Assumed to be negligible		
total	**$-10*10^{6}$ EUR_{2000}**	$1.4*10^{9}$ EUR_{2000}	$320*10^{6}$ EUR_{2000}

Measure Speed limit of 80 km/h on federal state roads (Bundesstraßen)			
System boundaries Due to the speed limit the citizens will endure a time loss. Only passenger cars are taken into account, as heavy duty vehicles usually drive more slowly than 80 km/h. Cost savings due to saved fuel are considered as it is assumed that the comfort loss to use e.g. a train instead of the car is higher than the time loss due to the speed limit. Shifting of transport to other modes is not considered. Costs for additional street infrastructure and facilities are considered to be negligible. Costs for the administration are considered to be negligible.			
	Who pays?	**Of which kind are the costs?**	**Of which kind is the utility loss?**
a	Citizens	Time loss	Time loss
b	Citizens	Saved fuel	-
c	Sovereign Institutions	Road signs, street facilities → no data available	-
d	Sovereign Institutions	Information campaigns	-
e	Sovereign Institutions	Administration → negligible	-
Time horizon a) Costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year. b) Negative costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year. d) In analogy to the measure "Shift of travel in passenger cars to bike usage" costs for information campaigns are assumed to exist.			
Approach Due to a speed limit people cannot travel as fast as they would have liked to. Only passenger cars are taken into account as heavy duty vehicles usually drive more slowly than 80 km/h. This means that it takes longer to get from A to B than before. The time loss can be valued resulting in the costs for the time loss. No data on costs for replacing road signs are available [Theloke et al., 2010]. Costs of information campaigns are taken from the description of the measure "Shift of travel in passenger cars to bike usage" [Theloke et al., 2010].			
Assumptions and detailed method a) To derive the time loss due to a reduced speed one needs to know the current speed, the new speed and the number of kilometres driven on federal state roads. The number of kilometres driven on rural roads is 2.59 E+11 km for passenger cars in 2010, 2.7 E+11 km in 2015 and 2.8 E+11 in 2020 (source: Tremod 4.17). We assume that lorries are not influenced by the speed limits. As a mean speed for the status quo 100 km/h is assumed; and in the case of the speed limit 80 km/h (this is due to a lack of data in the literature. Probably not everyone is going with the maximum speed, but there are also always people who are faster). Now the time needed for the number of kilometres driven on rural roads (VKM-PC = vehicle			

kilometres driven in a passenger car) without the measure can be calculated: (VKM-PC km/h) / (100 km/h). The time needed with the implemented measure can be calculated likewise: (VKM-PC km/h) / (80 km/h). The difference results in ((VKM-PC km/h) / (80 km/h)) - ((VKM-PC km/h) / (100 km/h)) = VKM-PC (1/80 - 1/100) h = 650 E+6 h in 2010, 680 E+6 h in 2015, and 710 E+6 h in 2020. [Bickel et al. 2005a] give an estimate for the value of travel time saved (for reasoning why time has value see e.g. [Mackie et al., 2001], for different approaches see e.g. [Mackie et al., 2003], [Harrison, 1974], [Hensher, 1977] and [Bickel et al., 2005a]). For business travel they assume 20 EUR_{2002} / h. For leisure travel they assume a factor of 0.19 leading to 3.8 EUR_{2002} / h. Assuming a composition of 80 % leisure travel vs. 20 % business travel ([Hautzinger et al., 2002]) the mean value of travel time saved would be 7.04 EUR_{2002} / h. Another source for value of time is [Flötteröd et al., 2008]. They assume 12 EUR / h but do not state which year the EUR are given in. Multiplying the time lost with the value of time gives the costs of the time loss: 2010: approx. 4.6 E+9 $EUR_{200\#2}$ (approx. 4.4 E+9 EUR_{2000}) 2015: approx. 4.8 E+9 EUR_{2002} (approx. 4.6 E+9 EUR_{2000}). 2020: approx. 5 E+9 EUR_{2002} (approx. 4.8 E+9 EUR_{2000}). b) The reduction in vehicle speed leads to fuel savings as less engine power is needed. UBA [2003] assume that by limiting maximum vehicle speed to 80 km/h on federal state roads, fuel consumption by passenger cars is 8% less. The average fuel consumption of passenger cars on rural roads is 5 l/100 km [HBEFA, 2004], the price of fuel is 0.41 €/l excluding taxes (assuming an oil price of € 50/bbl [Smokers et al., 2006]). For further details, refer to [Theloke et al., 2010]. c) No data on costs for replacing road signs are available [Theloke et al., 2010]. d) For the mitigation measure „Shift of travel in passenger cars to bike usage“ (see below), it is assumed that € 600 million are needed for information campaigns [Schärer et al., 2008]. As a proxy for introducing a lower speed limit on rural roads, this figure is adopted here. For further details, refer to [Theloke et al., 2010].
Costs **2010** a) $4.4*10^9$ EUR_{2000} b) + d) $-385*10^6$ EUR_{2000} total: **$4*10^9$ EUR**$_{2000}$ **2015** a) $4.6e^9$ EUR_{2000} b) + d) $-406e^6$ EUR_{2000} **total: $4*10^9$ EUR_{2000}** **2020** a) 4.8 $*10^9$ EUR_{2000} b) + d) $-423*10^6$ EUR_{2000} **total: 4.4 $*10^9$ EUR_{2000}**

Measure Adjustment of diesel fuel tax to petrol fuel tax			
System boundaries Taxes are costs to the citizens but income to the state (or another Sovereign Institution). In a macroeconomic approach they cancel out. Furthermore, taxes are transfers, no service or good is acquired in return. Cost savings due to saved fuel are considered. It was examined if there is a market value loss of Diesel passenger cars (when people try to sell them to buy a new car) due to the higher tax. The main assumption underlying the measure is that in 2010 46% of new cars will be Diesel cars instead of 50% (partly, gasoline cars will be bought, partly, no car will be bought). Considerations showed that the assumed effect on new cars was small and that effects of other measures and developments are much higher on the market value of a Diesel car to be sold, namely the car scrappage scheme (Abwrackprämie) and the environmental zone. Thus, no utility losses or gains are allocated to this measure. Commercial transport is assumed to not increase more slowly than without the measure [Theloke et al., 2010]. The Diesel price will of course be higher due to higher taxes; but as taxes are transfers they are not considered. Thus, no costs for commercial transport are assumed.			
	Who pays?	**Of which kind are the costs?**	**Of which kind is the utility loss?**
a	Citizens	Saved fuel	-
b	Citizen	Market value loss → negligible	-
c	Citizens	Utility loss for people that buy neither a Diesel nor a gasoline car → not quantifiable	
Time horizon Negative costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year.			
Approach Costs savings due to saved fuel are considered.			
Assumptions and detailed method Increasing taxes lead to decreasing mileage which in turn leads to fuel savings. Theloke et al. [2007] and Jörß et al. [2007] assume that fuel consumption by diesel fuelled passenger cars is 3% less compared to the current situation. The average fuel consumption of diesel passenger cars is 5.3 l/100 km [HBEFA, 2004], the price of fuel is 0.41 €/l excluding taxes (assuming an oil price of € 50/bbl [Smokers et al., 2006]). For further details, refer to [Theloke et al., 2010].			
Costs 2010: $-181 \cdot 10^{6}$ EUR_{2000} 2020: $-223 \cdot 10^{6}$ EUR_{2000} 2030: $-244 \cdot 10^{6}$ EUR_{2000}			

Measure

Environmental zone (Umweltzone)

System boundaries

This hypothetical measure is to be interpreted as maximum scenario: in 2015 only cars with the green badge are allowed to enter Berlin, Munich and the Ruhr area.

An assumption made is that nobody switches to pubic transport but the vehicle kilometres of the banned cars are replaced by a proportional mix of allowed vehicles.

a) Diesel cars that are not allowed to go into the cities any more need to be sold earlier than their life time ends. However, as the cars are not as useful as before (because they are not allowed to go into the city) the market value is lower than it would be without the measure. This constitutes a loss for citizens that would not want to sell their cars at this point in time.

b) and e) The costs for badges are transfers from the citizens to the sovereign institutions (state) and thus do not occur as costs.

c) Costs for road signs need to be taken into account as investment costs.

d) Costs for administration in the beginning phase and the later phase are also taken into account.

The effects of the car scrappage scheme (Abwrackprämie) have not been taken into account for this measure.

	Who pays?	Of which kind are the costs?	Of which kind is the utility loss?
A	Citizen	Loss of market value of old cars	-
B	Citizen	Badges → are transfers and thus no costs	-
C	Sovereign Institutions	Road signs	-
D	Sovereign Institutions	Administration	-
E	Sovereign Institutions	Income due to badges → transfers and thus no income	-

Time horizon

c) Investment costs occur in the first year. They need to be annualised over the life time. In general it is assumed that the average life time of an environmental zone is about 5 years.

d) Administration costs are higher in the first year. Decreased costs will continue during the life time of the measure.

Approach

See "System boundaries"

Assumptions and detailed method

a) As described under "System boundaries" a market value loss occurs for people who do not want to sell their Diesel cars anyway.

To give an estimate for the market value loss occurring for the citizens, some assumptions need to be made:

For urban roads in 2015 about 13 E+9 vehicle kilometres are assumed (source: Tremod 4.17). As no information is available how many vehicle kilometres of those are driven in Berlin, Munich and the Ruhr area, the kilometres are estimated by breaking them down proportionally to the population living in the areas of interest (population Germany: ca. 81.88 E+6; Berlin: ca. 3.4 E+6; Munich: ca. 1.3 E+6; Ruhr area: ca. 5.2 E+6). Derived vehicle kilometres are for Berlin: ca. 5 E+8; Munich: ca. 2 E+8; Ruhr area: ca. 7.6 E+8.

To estimate the number of vehicles affected per area the vehicle kilometres need to be translated to vehicles by estimating the yearly average mileage of passenger cars (ca. 13,400 km/a [Hautzinger et al., 2005]) and from this the fraction of mileage on urban roads (ca. 25% → 3,350 km/a). Number of affected cars: Berlin: ca. 161,000, Munich: ca. 62,000, Ruhr area: ca. 246,000. The market loss of a car that did not get a badge is about 2,000 EUR_{2009} [Dudenhöffer, 2009]. The amount lost is thus for **Berlin**: ca. **3.2 E+8** EUR_{2009} (**2.7 E+8** EUR_{2000}), **Munich**: ca. **1.2 E+8** EUR_{2009} (**0.96 E+8** EUR_{2000}), and **Ruhr area**: ca. **4.9 E+8** EUR_{2009} (**4.2 E+8** EUR_{2000}).

However, not only the inhabitants of Berlin, Munich and the Ruhr area go into town, but also people living in the vicinity. It is assumed (based on population density around the cities) that an additional 50% (compared to Berlin's inhabitants) people will enter the city from the vicinity. So another 50 % of the costs for Berlin are added to the costs for Berlin's inhabitants: the total costs for **Berlin** are thus **4 E+8** EUR_{2000}. Likewise, for **Munich** 70% are added: **1.63 E+8** EUR_{2000}, and for **Ruhr area** 100% are added: **8.4 E+8** EUR_{2000}.

Assuming a life time of 5 years, yearly costs are for **Berlin**: **8.7 E+7** EUR_{2000}, for **Munich**: **3.6 E+7** EUR_{2000}, and for **Ruhr area**: **1.8 E+8** EUR_{2000}.

c) Investment costs for road signs etc. according to a study in Munich are 75,000 EUR [Foster et al., 2008]. Assuming an average life time of 5 years of the measure and a discounting rate of 3%, yearly costs of 16000 EUR_{2009} arise (approx.14,000 EUR_{2000}). It is assumed that the same costs apply for Berlin and the Ruhr area.

d) According to [Forster et al., 2008] costs for administration are 630,000 EUR_{2008} in the first year (divided by 5 to give annual costs: 126,000 EUR_{2008}; approx. 110,000 EUR_{2000}) while for future years two employees are kept, equalling 55,800 EUR_{2008}/year (approx. 49,000 EUR_{2000}). It is assumed that the same costs apply for Berlin and the Ruhr area.

Costs

2010

-

2015

a) **Berlin** and vicinity: **8.7 E+7** EUR_{2000}, **Munich** and vicinity: **3.6 E+7** EUR_{2000}, **Ruhr area** and vicinity: **1.8 E+8** EUR_{2000}

c) 4.2 E+4 EUR_{2000}

d) 4.8 E+5 EUR_{2000}

e) -

total: **3 * 10^8** EUR_{2000}

2020

-

Measure

Lower speed limit for urban roads

System boundaries

Time loss of the citizens due to a speed limit on urban roads is considered.

Costs for additional road signs and administration cannot be quantified as no data is available.

Costs for information campaigns are considered.

	Who pays?	**Of which kind are the costs?**	**Of which kind is the utility loss?**
a	Citizen	Utility loss	Time loss
b	City	Information campaigns	-
c	City	Administration, road signs → negligible	-

Time horizon

Costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year.

Approach

Due to a speed limit people cannot travel as fast as they would have liked to. This means that it takes longer to get from A to B than before. The time loss can be valued resulting in the costs for the time loss. All vehicle types are included. Information campaigns are assumed to be needed and thus costs are allocated to them.

It cannot be assessed whether and how the lower speed limit and traffic jams influence each other. So possible effects cannot be quantified.

Assumptions and detailed method

a) To derive the time loss due to a reduced speed one needs to know the current speed, the new speed and the number of kilometres driven on urban roads with a speed limit of 50 km/h. The number of kilometres driven on urban roads is 1.98 E+11 km for all kinds of vehicles in 2010, 1.99 E+11 km in 2015, and 1.98 E+11 km in 2020 (source: Tremod 4.17). In [Theloke et al., 2010] it is assumed that half of the kilometres driven on urban roads have a speed limit of 50 km/h. Thus, half of the kilometres driven on urban roads are affected.

As (max.) speed for the status quo 50 km/h are assumed; in the case of the speed limit a (max.) speed of 30 km/h is assumed due to a lack of data.

Now the time needed for the number of kilometres driven on urban roads (VKM = number of kilometres driven) without the measure can be calculated: (VKM km/h) / (50 km/h). The time needed with the implemented measure can be calculated likewise: (VKM km/h) / (30 km/h). The difference results in ((VKM km/h) / (30 km/h)) - ((VKM km/h) / (50 km/h)) = VKM (1/30 - 1/50) h = approx. 2.635 E+9 h in 2010, 2.65 E+9 h in 2015, and 2.636 E+9 h in 2020.

[Bickel et al. 2005a] give an estimate for the value of travel time saved (for reasoning why time has value see e.g. [Mackie et al., 2001], for different approaches see e.g. [Mackie et al., 2003], [Harrison, 1974], [Hensher, 1977] and [Bickel et al., 2005a]). For business travel they assume 20 EUR_{2002} / h. For leisure they assume a factor of 0.19 leading to 3.8 EUR_{2002} / h. Assuming a composition of 50 % leisure travel vs. 50 % business travel (including *all* vehicles) the mean value of travel time saved would be 11.9 EUR_{2002} / h. Another source for value of time is [Flötteröd et al., 2008]. They also assume 12 EUR / h but do not state which year the EUR are given in.

Multiplying the time lost with the value of time gives the costs of the time loss:
2010: approx. $31.4 \cdot 10^9$ EUR_{2002} (approx. $30.3 \cdot 10^9$ EUR_{2000})
2015: approx. $31.5 \cdot 10^9$ EUR_{2002} (approx. $30.5 \cdot 10^9$ EUR_{2000})
2020: approx. $31.4 \cdot 10^9$ EUR_{2002} (approx. $30.3 \cdot 10^9$ EUR_{2000}).

b) For the mitigation measure „Shift of travel in passenger cars to bike usage“ (see below), it is assumed that € 600 million are needed for information campaigns [Schärer et al., 2008]. As a proxy for introducing a lower speed limit on urban roads, this figure is adopted here. For further details, refer to [Theloke et al., 2010].
Costs **2010** a) $30.3*10^9$ EUR_{2000} b) $3.5*10^7$ EUR_{2000} **total: $30.3*10^9$ EUR_{2000}** **2015** a) $30.5*10^9$ EUR_{2000} b) $3.5*10^7$ EUR_{2000} **total: $30.5*10^9$ EUR_{2000}** **2020** a) $30.3*10^9$ EUR_{2000} b) $3.4*10^7$ EUR_{2000} **total: $30.3*10^9$ EUR_{2000}**

Measure

Shift of travel in passenger cars to bike usage

System boundaries

Costs for the expansion of existing bicycle lanes to a seamless network and information campaigns are considered as minimum costs. Only these costs would appear if everybody switched to the bike voluntarily. No comfort or time loss would appear as utility loss due to the decision to switch voluntarily.

Costs for comfort and time loss, and for saved fuel, are taken into account as a total. These (utility) losses (and gains) occur for persons that do not use the bike voluntarily. Due to the upgrading of bicycle lanes streets are narrowed down which causes a further negative effect for the car drivers – who might switch to the bike then. These costs are considered as maximum costs.

No positive health effects (or other forms of utility gain) are taken into account as the project does not perform a cost-benefit analysis but a cost-effectiveness-analysis. However, to gain a comprehensive picture of the measure, health benefits should be taken into account as well!

	Who pays?	Of which kind are the costs?	Of which kind is the utility loss?
a	Sovereign Institutions	Information campaigns, road facilities	-
b1	Citizen	Utility loss	Time loss, loss of comfort, gain of comfort
b2	Citizen	Saved fuel	-

Time horizon

a) Costs for information campaigns are given for a 3-year period. The life time of the measures is assumed to be 20 years.

b) Costs are allocated to each year of the considered time frame as also the emission reduction is allocated to each year.

Approach

a) Investment costs for road signs, street facilities, and costs of information campaigns are taken from [Theloke et al., 2010]. They reflect the minimum costs assuming that people are motivated by these campaigns to switch to the bike voluntarily.

b) When people are forced to switch to the bike they endure a utility loss including time loss and comfort loss. They also save costs for fuel that is not needed. All these aspects are reflected in the price difference of a kilometre driven in a car vs. driven by bike. Multiplied with the kilometres switched, they give the utility loss for switching for those people who are forced to switch. This is considered as maximum costs.

Assumptions and detailed method

a) Creation of a seamless network of bicycle lanes: 6 E+8 EUR per year (2009-2011). Information campaigns: 2 E+8 EUR per year (2009-2011). Depreciated over 20 years with a discount rate of 3% the yearly average costs are 5.4 E+7 EUR_{2009} = 4.6 E+7 EUR_{2000}.

b) An assumption underlying the emission reduction calculations is that 10% of the car trips that are shorter than 5 km are shifted to bikes. According to [Theloke et al, 2010] this equals to a reduction of particulate matter emissions of 4%. Due to lacking data it is assumed that this mitigation potential can be transferred to a reduction of vehicle kilometres driven in cars (shifted to bikes) by also 4%. No change in the car fleet is assumed.

The total urban vehicle kilometres of passenger cars are 1.62 E+11 km in 2015, and 1.59 E+11 km in

2020 (source: Tremod 4.17). For a car average costs per km are assumed to be 45 ct_{2009} = 38.4 ct_{2000} [ADAC, 2009]. For a bike, average costs per km are assumed to be 42 ct_{2009} = 37.5 ct $_{2000}$([Dierig, 2007] assumes about 300 km per year as average yearly mileage for bikes, and 345 EUR_{2007} for a new bike (depreciated over 10 years this gives 75 EUR_{2007} per year); 50_{2007} EUR for annual costs are added) – giving a difference (= utility loss) of 0.9 ct_{2000} per km switched. The product of the difference (0.9 ct_{2000}) and the switched kilometres (2015: 6.48 E+9 km; 2020: 6.36 E+9 km) gives the costs of the utility loss: 5.8 E+7 EUR_{2000} for 2015 and 5.7 E+7 EUR_{2000} for 2020.
Costs **2010** a) - b) - **2015** a) $4.6*10^7$ EUR_{2000} (min) b) $5.8*10^7$ EUR_{2000} (max) **average $5.2*10^7$** EUR_{2000} **2020** a) $4.6*10^7$ EUR_{2000} (min) b) $5.7*10^7$ EUR_{2000} (max) **average $5.15*10^7$** EUR_{2000}

Measure

Ecodriving

System boundaries

	Who pays?	Of which kind are the costs?	Of which kind is the utility loss?
a	Citizen	Utility loss → negligible	Time loss
b	Sovereign Institutions	Investment costs & campaigns	-
c	Citizen	Fuel savings	-

Time horizon

a) -

b) Investment costs are depreciated to the life time of the measure.

c) Fuel savings are given annually.

Approach

a) It was examined, if ecodriving leads to a time loss. Several sources indicate that a time loss exists but is very small; thus, a utility loss due to time loss is considered to be negligible, and no utility loss costs or gains are allocated to this measure. Furthermore, if people drive more environmentally sound voluntarily (e.g. due to campaigns) no utility loss occurs for them.

b) Investment costs for e.g. information campaigns are considered.

c) Driving more efficiently also means that the drivers save fuel.

Assumptions and detailed method

a) It was examined if ecodriving leads to a time loss. Some sources indicate that a time loss exists but is very small, e.g. http://www.stralsund.de/hst01/ressourcen.nsf/docname/Ressourcen_1542457E1234F226C1257091002DB404/$File/EnergiesparendFahren.pdf and [Austrian Energy Agency, 2007]. Thus, a utility loss due to time loss is considered to be negligible. So no utility loss costs or gains are allocated to this measure. Furthermore, if people drive more environmentally sound voluntarily (e.g. due to campaigns) no utility loss occurs for them. It could be helpful to include a control panel for fuel consumption in the board computer so that people see the amount of fuel they are using and see an incentive to save fuel.

b) In the Netherlands, the national programme „Het nieuwe rijden" that advocated economic driving from 2000-2007 cost € 30 Million [SenterNovem, 2007]. Allocated to the 8.7 Mio vehicles in the Netherlands, investment costs were € 3.50 per vehicle. However, costs are saved due to fuel savings. For further details refer to [Theloke et al., 2010].

c) Driving more efficiently means also that the drivers save fuel. For further details refer to [Theloke et al., 2010].

Costs

2010

a) -

b)+c): $-86*10^6$ EUR_{2000}

total: $-86*10^6$ EUR_{2000}

2015

a) -

b)+c): $-90*10^6$ EUR_{2000}

total: $-90*10^6$ EUR_{2000}

2020

a) -

b)+c): $-93*10^6$ EUR_{2000}

total: $-93*10^6$ EUR_{2000}

Measure Internalisation of costs in air traffic (tax on kerosene and emission trading)			
System boundaries The welfare loss or dead weight loss due to a higher ticket price is considered in a macroeconomic approach.			
	Who pays?	**Of which kind are the costs?**	**Of which kind is the utility loss?**
a	Consumer and producer	Smaller consumer and producer surplus	Smaller consumer and producer surplus
Time horizon Given for the years 2010, 2015 and 2020 based on demand decrease.			
Approach The welfare loss due to a higher ticket price is considered in a macroeconomic approach. It is assumed that the consumer surplus and the producer surplus are both decreased due to the rise in the ticket price.			

Assumptions and detailed method

The welfare loss due to a higher ticket price is considered in a macroeconomic approach. It is assumed that the consumer surplus and the producer surplus are both decreased due to the rise in the ticket price.

Elasticity for business journeys is given as -0.1 to -0.9 (mean: -0.5) and for touristic journeys with -1.0 to -2.4 (mean: 1.7) in [Matthes et al., 2008]. The mean is -1.1. A decrease in demand is estimated with -30% in 2010, -31.6% in 2015 and -32.5% in 2020 [Matthes et al., 2008].

A surcharge on the ticket price is given for example between 15.83 EUR for short distance flights and 165.66 EUR for long distance flights (mean: 90.75 EUR). The mean of ticket prices (without low price segment) is 631 EUR [Matthes et al., 2008].

An average surcharge per ticket is 90,75 EUR/ticket. There were 2,143,700 starts and landings in 2006 [Statistisches Bundesamt, 2007]. The welfare loss is estimated as (ticket surcharge * change in demand) / 2.

For 2010 (based on demand of 2006) the welfare loss is 29,179,508 EUR_{2008} (25,374,675 EUR_{2000}), for 2015 it is 30,735,748 EUR_{2008} (26,727,991 EUR_{2000}) and for 2020 it is 31,611,134 EUR_{2008} (27489232 EUR_{2000}).

Costs

2010

a) 25.4 E+6 EUR_{2000}

2015

a) 26.7 E+6 EUR_{2000}

2020

a) 27.5 E+6 EUR_{2000}

Measure Emission related landing charges for air traffic
System boundaries An additional fee for landing for planes with high emissions leads to changes in the consumer and the producer surplus. Burdens on the producer are passed on to the consumers. No statements are possible regarding the share of the additional costs.

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