Behavioural Climate Change Mitigation Options

Domain Report Transport

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Author(s):
Arno Schroten (CE Delft)

Fraunhofer ISI

LEI WAGENINGEN UR

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CE Delft's solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

Preface

This is the final report on *Behavioural Climate Change Mitigation Options in the Transport Domain*. It is part of the study 'Behavioural Climate Change Mitigation Options and Their Appropriate Inclusion in Quantitative Longer Term Policy Scenarios for the European Commission, DG Climate Action. The aim of the study is threefold:

1. To assess and demonstrate the GHG emission reduction potential of changes in behaviour and consumption patterns.
2. To analyse policy options for the further development of community policies and measures inducing changes in behaviour and consumption patterns. And
3. To identify the linkages with other technical and economic variables in such a way that it can be used in modelling and scenario development.

The study has focused on three domains: transport, food and housing.

This report is part of five reports which together constitute the final report of the contract 070307/2010/576075/SER/A4. The other reports are:

1. The Main Final Report.
2. The Food Domain Final Report.
3. The Housing Domain Final Report.
4. A Technical Report on the appropriate inclusion of results of the analysis in model-based quantitative scenarios.

The study has been conducted by a consortium led by CE Delft comprising of Fraunhofer ISI and LEI.

Jasper Faber

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Summary

Transport is responsible for around a quarter of EU greenhouse gas emissions (AEA et al., 2010). More than two-thirds of these transport-related greenhouse gas (GHG) emissions are emitted by road transport. In contrast to many other sectors the GHG emissions of transport are predicted to continue to increase. AEA et al. (2010) shows figures showing 25% higher GHG emission levels in 2050 than in 2010. A large share of these emissions are covered by the non-ETS targets.

In the Transport White Paper (COM(2011) 144 final) the European Commission presents their transport strategy for the period up to 2050. One of the key goals in the White Paper is a reduction of transport GHG emissions by 60% in 2050. Changing people's transport behaviour could contribute to this objective.

Many behavioural changes in transport can be identified that could contribute to the decarbonisation of transport. Based on a review of the literature we identified four important ones (in terms of abatement potential, policy relevance and lack of quantitative knowledge):
- buying and using an electric car or a plug-in hybrid;
- buying and using a smaller car;
- applying a fuel-efficient driving style; and
- making use of ICT to decrease business travel: teleworking and applying virtual meetings.

For these four behavioural changes we carried out detailed assessments to estimate their abatement potential, identify the main barriers inhibiting their implementation and identify policy instruments that could be used to overcome the main barriers. Finally, for two behavioural changes (buying a smaller car and teleworking) an assessment of the effectiveness of selected policy packages is carried out.

GHG abatement potential
The maximum realistic mitigation potential[1] of four car based behavioural change options are presented in Table 1. Buying and using electric cars has the highest mitigation potential (particularly on the long-term), mainly because of the large maximum technical potential and the lack of non-behavioural constraints on the longer term. However, it should be mentioned that the mitigation potential of this behavioural change is probably an overestimation, since the impact of large-scale shift to electric vehicles on the power supply sector (a possible shift to electricity generated by fossil fuels) is not taken into account. The mitigation potential for the use of plug-in hybrids is smaller than for electric vehicles because they use fossil fuel. Buying and using smaller cars and applying a fuel-efficient driving style have a smaller maximum realistic mitigation potential, amongst others because they lower the cost of driving significantly and therefore have a rebound effect. The potential of applying a fuel-efficient driving style is projected to decrease over time due to the deployment of advanced vehicle technologies, which automate eco-driving techniques.

[1] The maximum realistic mitigation potential is defined as the reduction in GHG emissions achieved when the option is adopted by the largest number of actors possible, taking into account realistic and structural constraints, indirect effects and rebound effects.

Table 1 **Maximum realistic CO_2 mitigation potential of car based behavioural change options**

Behavioural change	2020	2030	2050
Buying and using an electric car: per pkm	19-34%	64-72%	82-90%
Buying and using an electric car: absolute CO_2 mitigation potential (Mton)	96-174	330-371	420-462
Buying and using an plug-in hybrid: per pkm	11-22%	39-56%	49-69%
Buying and using an plug-in hybrid: absolute CO_2 mitigation potential (Mton)	56-113	198-286	251-354
Buying and using a smaller car: per pkm	17-20%	18-21%	18-21%
Buying and using a smaller car: absolute CO_2 mitigation potential (Mton)	80-96	74-88	71-84
Fuel-efficient driving style: per pkm	10%	7%	2%
Fuel-efficient driving style: absolute CO_2 mitigation potential (Mton)	47	32	10

Table 2 shows the maximum realistic CO_2 mitigation potential of teleworking and virtual meetings (in terms of relative reductions in CO_2 emissions of all passenger transport). It should be noted that the uncertainty in these estimations are quite large, especially since not all rebound effects could be quantified. Moreover, in case the rebound effects were quantified, the uncertainty in these quantifications are rather large.

Table 2 **Maximum realistic CO_2 mitigation potential of teleworking and virtual meetings**

Behavioural change	2020	2030	2050
Teleworking: relative reduction in CO_2 emissions of total passenger transport	5-6%	6-7%	6-8%
Teleworking: absolute CO_2 mitigation potential (Mton)	35-45	38-47	40-49
Virtual meetings: relative reduction in CO_2 emissions of total passenger transport	6%	6%	9%
Virtual meetings: absolute CO_2 mitigation potential (Mton)	39	35	55

Overview of barriers

Based on an extensive literature review, the following barriers were identified as most important ones for the various behavioural changes:

- *Buying and using an electric or plug-in hybrid car:* the main barriers are at both the individual and societal level. At the individual level consumers rather have negative attitude to electric and plug-in hybrid cars are a main barrier. Electric cars are perceived as less attractive than conventional cars on many dimensions: performances (e.g. range), reliability, costs, image, etc. Additionally, electric and plug-in hybrid vehicles may challenge mobility related habits of people, forcing people to change their lifestyles. At the societal level structural barriers (the poor availability of charging infrastructure and the limited number of electric and hybrid vehicle models) and economic barriers (high purchase costs) are the main barriers for an uptake of electric and plug-in hybrid vehicles.
- *Buying and using smaller cars:* the main barriers are psychological ones (people prefer larger cars over smaller ones, since large cars are more practical and safer and have preferable symbolic advantages; small cars challenge mobility related habits of people), indicating that consumers are often able to buy a smaller car, but that they are not always willing to do so.

- *Applying a fuel-efficient driving style*: most of the main barriers to applying a fuel-efficient driving style are individual ones (habitual character of driving style, preference for aggressive driving style, lack of knowledge on eco-driving), indicating that people perceive that they should be able to apply a more fuel-efficient driving style, but (that some of them) are not willing to do that or don't know how to do that.
- *Teleworking*: the main barriers for teleworking are social/psychological and institutional ones. The social/psychological barriers refer to people's perceptions of the drawbacks of teleworking: social isolation, tendency for overworking, adverse impacts on career, etc. The institutional barriers are related to the resistance of organisations and direct managers to allow their employees to work at home (due to concerns on the productivity of employees, security issues, adverse impacts on teambuilding, etc.).
- *Applying virtual meetings*: the main barriers exist at both the individual as societal level. At the individual level, people's perception that virtual meetings are a poor substitute for physical meetings is a main barrier (especially for meetings meant to exchange non-tangible values like trust or interest). At the societal level, the main barrier refers to organisations/ managers resistance to allow their employees to apply virtual meetings.

Overview of policies

Based on desk study a for every behavioural change option a broad overview of policy instruments is identified, that could be used to overcome the main barriers. The following policy categories are distinguished: regulative instruments, economic instruments, communication, direct governmental expenditures and procedural instruments. The (cost) effectiveness of all identified policy instruments are discussed, particularly in qualitative terms.

Policy packages

Based on the analysis of barriers and policy instruments we also composed (in close agreement with the Commission) policy packages for further research for two mobility related behavioural changes: buying and using smaller cars and teleworking.

Buying and using smaller cars

An effective policy package to stimulate the purchase and use of smaller cars could consist of the following five policies:
- a CO_2 differentiated purchase tax;
- a CO_2 differentiated company car tax;
- a (CO_2 differentiated) increase of fuel taxes;
- spatial policies favourable to smaller cars, like parking charges differentiated to the size of the car and restricted access to city centres for large cars;
- a supportive communication strategy, consisting of CO_2/energy labels and the provision of data via an independent website.

This policy package provides strong (financial and regulative) incentives for consumers to change their car purchase and use behaviour. In this way the main psychological barriers to buying smaller cars (see above) could be addressed.

A rough estimation of the effectiveness (in terms of CO_2 reductions) of the entire policy package[2] is presented in Table 3. Both the CO_2 impacts of the individual policy instruments as the CO_2 impact of the entire policy package is presented. We were not able to quantify the CO_2 impact of spatial policies favourable to small cars.

Table 3 Rough estimation of the relative CO_2 reductions of passenger cars of both individual instruments and policy packages for stimulating the purchase and use of smaller cars

Policy (package)	CO_2 reduction due to smaller cars	Total CO_2 reduction
CO_2 differentiated purchase tax	3-4%	6-10%
CO_2 differentiated company car tax	2-3%	4-7%
10% fuel tax increase	0.5%	3-4%
20% fuel tax increase	1%	6-8%
Spatial policies favourable to small cars	?	?
Supportive communication strategy	Not significant	Not significant
Policy package 1 (incl. fuel tax increase of 10%)	At least 6-8%	At least 13-21%
Policy package 2 (incl. fuel tax increase of 20%)	At least 6-9%	At least 16-25%

Note: Due to possible interaction effects, the CO_2 impacts of individual policy instruments do not necessarily add up to the CO_2 impacts of the various policy packages.

Implementation of the proposed policy package result in at least 6-8% (or 6–9% in case a fuel tax increase of 20 instead of 10% is introduced) lower CO_2 emissions of passenger cars due to the purchase and use of smaller cars. By implementing a supportive communication strategy the actual CO_2 reduction will shift to the upper bound of the presented bandwidth.

Many of the policy instruments applied in this policy package do have broader CO_2 impacts than only affecting the purchase and use of smaller impacts (e.g. a fuel tax provides also incentives to reduce the demand for transport). If these broader impacts are also taken into account, the reduction potential increase by a factor 2.5 (see the third column of Table 3).

Teleworking

The policy package to stimulate teleworking consists of six policies:

- an increase of fuel taxes;
- development of a regulatory framework concerning employment conditions of teleworkers;
- support provision of (broadband) IT infrastructure and equipment;
- EU communication campaign;
- voluntary agreements with private organisations;
- stimulating teleworking at governmental institutions.

2 Two policy packages are distinguished, differing in the fuel tax increase assumed: 10 and 20% respectively.

The policies in this package address both the psychological barriers related to employees' doubts on some aspects of teleworking, like social isolation and adverse impacts on one's career (e.g. by providing a set of clear employment conditions for teleworkers) and the institutional barriers related to the lack of support of managers/organisations (by arranging voluntary agreements and providing information on the advantages of teleworking for organisations).

The main barriers with respect to teleworking are addressed by an EU communication campaign and voluntary agreements with private organisations. The other policies should be considered as supportive measures. Therefore the effectiveness of the total policy package could be mainly based on the impacts of these two instruments. We estimate that this policy package results in about 6-12% less commuting travel and hence 1% less CO_2 emissions of total passenger transport. However, it should be mentioned that these figures are very rough estimates; since the empirical evidence on the effectiveness of policy instruments with respect to teleworking is very scarce, it was not possible to come up with a more reliable estimation. Therefore, the figures with respect to the effectiveness of policies stimulating teleworking should be considered carefully.

1 Introduction

1.1 Background to the project

The EU's greenhouse gas (GHG) emission reduction policies and the goal to keep the global temperature increase below 2°C commits the EU to reduce emissions by at least 20% below 1990 levels by 2020, and by 80-95% by 2050. The Transport White Paper (COM(2011) 144 final) sets out how the transport system can reduce its emissions by 60% in the same period.

The current models for quantitative assessments of climate policies are implicitly or explicitly focused on technical mitigation measures and on behavioural changes induced by market based instruments. From these models, it is clear that there is a considerable potential to reduce emissions, both in the ETS and in the non-ETS sectors. However, they also show that reaching ambitious targets in some non-ETS sector by conventional means may become quite costly.

An emerging body of literature shows that changes in consumption patterns can achieve considerable reductions in emissions at relatively low costs. This body of literature focuses on the emission reduction potential of behavioural changes, associated costs, and barriers to these changes and policy instruments to overcome these barriers. Many of these studies are case studies or qualitative assessments, and hence the results are not yet translated into scenarios or policy assessment models.

The Low Carbon Economy Roadmap and the Transport White Paper both also acknowledge that behavioural changes may be needed to reach the emissions targets or that the targets may be reached at lower costs of behavioural change would occur (see also the accompanying impact assessments SEC(2011) 288 final and SEC(2011) 358 final).

Because of the importance of behavioural changes, this study assesses their impacts on GHG emissions. It also analyses which barriers exist to behavioural changes, whether policies can help overcoming these barriers and if so, to which extent.

1.2 Objective of this report

This report presents the results on the assessments made on behavioural changes in the transport domain. The main behavioural changes (in terms of mitigation potential) are identified and for a selection of these options an analysis of GHG mitigation potential, barriers and policies is carried out.

With respect to the scope of the report, it should be mentioned that behavioural mitigation measures with regard to air travel are not included, since aviation will be included in the European ETS system in 2012. Additionally, mitigation measures associated to freight transport are not taken into account, since the relation between consumer choices and climate impacts of freight transport is indirect and will be covered by the discussion of behavioural mitigation measures in other domains, e.g. food and drink.

1.3 Outline of the report

In Chapter 2 we provide a broad overview of behavioural changes in the transport sector. Based on a broad assessment of mitigation potentials of these behavioural changes, we select four of them for further investigation in the remainder of the study. In Chapter 3 a detailed assessment of the abatement potential of the four selected behavioural changes is presented. Additionally, cost and co-benefits are discussed. The main barriers inhibiting the selected behavioural changes are discussed, as well as relevant consumer segments and policy instruments. Additionally, a broad overview of policy instruments that could be implemented to address the barriers is given. Finally, in Chapter 5 we discuss the effectiveness and implementation costs of policy packages for some of the behavioural changes in the transport sector.

2 Overview of behavioural change options

2.1 Introduction

Based on a review of the literature (factsheets of the literature studied can be found in Annex A), we identified a broad range of behavioural changes in transport that could contribute to climate change mitigation. In Section 2.2 we provide an overview of the identified behavioural changes. A brief assessment of these behavioural changes in terms of their mitigation potential is provided in Section 2.3. Finally, some of these behavioural changes are selected for further investigation in the following chapters in Section 2.4.

2.2 Mobility overview of behavioural changes

Four general classes of behavioural mitigation options in transport can be distinguished:

- *Using more fuel-efficient cars*; people could reduce the climate impact of their mobility behaviour by using more fuel-efficient cars. E.g. they could choose for a smaller car or an electric car. As mentioned in Chapter 1 we will not study purchase behaviour which do not significantly affect the way the product could be used. Therefore, measures like buying a more fuel-efficient car (e.g. due to a more efficient engine) from the same size or buying cars running on alternative fuels (e.g. biofuels, natural gas) are not taken into account.
- *Making use of the car in a more efficient way*; by using passenger cars in a more efficient way GHG emission reductions of road transport could be realised. Efficiency measures that could be applied are: applying a more fuel-efficient driving style, car pooling, sharing cars, etc.
- *Using more sustainable modes;* a shift to travel modes with relatively low GHG emissions per passenger kilometres (e.g. walking, cycling, public transport) could contribute to decarbonisation of transport. Other behavioural measures would be to participate in car-sharing projects or make use of collective transport programs organised by employers for commuting trips.
- *Reducing travel distance;* people could reduce the number of kilometres they travel in lots of ways: working at home, living near to the job, less holidays (to far-away countries), combining various trips, etc.

In the literature review, measures from all four classes are identified (see Table 4). However, not all possible behavioural measures are assessed in the literature. Especially behavioural mitigation measures related to less transport demand are poorly studied: no studies on living near to the job, less holidays, combining various trips, etc. are found. The literature reviewed did also not cover the option to drive more slowly.

Studies differ significantly in the way the mitigation potential of behavioural measures is estimated. Some studies estimate the maximum technical mitigation potential, while others present more ‘realistic’ potentials. Other differences between studies are related to the time horizon applied, the geographical scope of the study (global, EU-27, individual countries) and whether indirect and rebound effects are taken into account or not. All these differences in the estimation approach should be taken into account when evaluating the various behavioural measures.

Table 4 **Behavioural mobility measures**

Behavioural measure
Buying smaller cars
Buying electric or plug-in hybrids
Applying a fuel-efficient driving style
Increasing the occupancy rate of the car (incl. car pooling)
Sharing a car
Extending the life-time of the car
Travel by train instead of by car
Travel by local public transport instead of by car
Travel by bicycle instead of by car
Travel by foot instead of by car
Teleworking
Apply visual meetings
Make (more) use of e-commerce

2.3 Reported mitigation potential of identified behavioural changes

In this section the mitigation potentials of the identified behavioural changes in transport as reported by the studies reviewed are discussed. It should be mentioned that we only present mitigation potentials as presented by the studies reviewed and that we don't aim to come up with a best estimate of the mitigation potential for the various behavioural changes. The main aim of this broad assessment of mitigation potential of the identified behavioural measures was to provide input for the selection of the most promising behavioural changes, for which more detailed assessments will be carried out in the following chapters of this study.

Not all studies reviewed present the mitigation potential of the various behavioural measures in the same units. However, for a balanced evaluation of the measures, comparable mitigation potentials would be useful. Therefore, we expressed in this section all reported mitigation potentials in the same unit (relative reduction in total transport CO_2 emissions) by using the following assumptions from TREMOVE (with the exception of the last assumption which is based on AEA et al., 2010):
- 62% of total transport CO_2 emissions are emitted by passenger cars;
- 1,5% of total transport CO_2 emissions are emitted by passenger trains;
- 9% of total transport CO_2 emissions are emitted by aviation;
- 66% of total transport CO_2 emissions are emitted by road passenger transport;
- 88% of total transport CO_2 emissions are emitted by road transport;
- 76% of total transport CO_2 emissions are emitted by passenger transport;
- 20% of total passenger car kilometres are related to commuting traffic;
- 25% of total CO_2 emissions in the EU in 2020 are due to transport.

Buying and using smaller cars

By buying smaller cars consumers can reduce the CO_2 emissions related to their travel behaviour. In addition to the change in purchase behaviour, this measure also results in changes of use behaviour. Due to the limited (luggage) space these cars are less suitable for some kind of trips or transport demands (e.g. transporting big purchases home, holiday trips, etc.). People have to find other solutions for these kind of trips, e.g. renting a big car, use home delivery services, etc.

AEA et al. (2010) and CE (2008b) estimate a realistic CO_2 abatement potential of 6 to 12% for buying smaller cars. Bouwman and Mol (2000) estimate the CO_2 abatement potential of the case that consumers buy on average passenger cars of 850 kilogram; this potential ranges from 9% in 2000 to 14% in 2050. It should be mentioned that possible indirect and rebound effects of this behavioural measure are not presented by the various studies.

Buying an electric car or an plug-in hybrid

By buying an electric car instead of a fossil fuel car, consumers could reduce the CO_2 emissions of their passenger car travel. This change in purchase behaviour also has some implications with regard to the use behaviour of the car. Due to their limited range electric cars are less suitable for long-distance trips (especially in case loading infrastructure is scarce and slow). For these trips people have to find other mobility options, e.g. renting a car or taking the train. Because the range depends on the other power needs of the car (heating, air-conditioning, lighting, radio, etc.), users may need to make trade-offs between comfort and range. Moreover, people may need to change their parking behaviour, e.g. park in the vicinity of a power supply rather than close to their home or work.

The estimated maximum CO_2 abatement potential of buying an electric car is up to 62% on the long run, depending on the way the electricity is produced (AEA et al., 2010; King, 2007). The maximum CO_2 abatement potential of buying a plug-in hybrid is estimated at 25 to 40% (AEA et al., 2010). By estimating the CO_2 abatement potentials most studies have taken the indirect emissions related to fuel production into account. Potential rebound effects are not considered.

Applying a fuel-efficient driving style

The maximum CO_2 abatement potential of applying a fuel-efficient driving style is estimated at 6 to 9%, which could be realised in the short term (AEA et al., 2010; CE, 2008b; King, 2007; TNO et al., 2006). Since passenger cars will probably become more fuel-efficient in the future (e.g. due to CO_2 limits for new passenger cars), this reduction potential will be (much) smaller on the long run. Indirect CO_2 reductions (fuel production) are taken into account, but possible rebound effects are not.

Increasing the occupancy rate of the car (incl. car pooling)

Bouwman and Mol (2000) estimate the maximum CO_2 abatement potential of doubling the average vehicle occupancy at 31%. However, it should be mentioned that the CO_2 emissions related to detours, needed for travel partners to meet each other, are not taken into account. Therefore this estimation should be regarded as an overestimation of the maximum potential of this behavioural measure. UBA (2010) estimate a realistic potential of car pooling in the long run at 2%. Rebound effects are not taken into account by both estimates.

Sharing the car

Sloman (2003) estimate a realistic CO_2 abatement potential of participating in car clubs in the UK at ca. 1% in the long run. Indirect and rebound effects are not taken into account.

Extending the life-time of the car

Bouman and Mol (2000) estimate the CO_2 abatement potential of an increase in the average vehicle life-time from 12.5 to 15 years at ca. 1%.

Travel by train instead of by car

The CO_2 abatement potential of a modal shift from the car to the train is estimated at 1 to 9% on the long-term (AEA et al., 2010; ETC/ACC, 2008; UBA, 2010). The lower bound of this bandwidth is based on estimates of a realistic potential, while the upper bound is based on a theoretical potential. However, the maximum potential could even be larger, since a model shift to the train for short-distance trips and in high densely populated areas is not assessed (see factsheet M6). Potential rebound effects are not taken into account.

Travel by local public transport instead of by car

A realistic CO_2 abatement potential of a modal shift from the car to local public transport is estimated at ca. 0.6% at the short run to 1.4% in the long run (Sloman, 2003; UBA, 2010). In Sloman (2003) a distinction is made between a shift to the bus and to the tram/light rail. However, the realistic potential of the latter option was estimated to be negligible, especially due to a lack of available infrastructure. Both possible indirect CO_2 effects and rebound effects are not taken into account.

Travel by bicycle instead of by car

A realistic CO_2 abatement potential of 1-2% in the short run and up to 3% in the long run is estimated by various studies for a modal shift from the car to cycling (Nuyts and Van Hout, 2007; Sloman, 2003; UBA, 2010). Possible indirect CO_2 effects and/or rebound effects are not discussed by the various studies.

Travel by foot instead of by car

Sloman (2003) estimate the maximum CO_2 abatement potential of a modal shift from the car to walking at 3%. A more realistic estimate on the short term is ca. 2% CO_2 reduction. Indirect CO_2 effects and rebound effects are not taken into account.

Teleworking

A realistic CO_2 abatement potential of teleworking on the short to medium term is estimated at 0 to 2% (AVV, 2003; Sloman, 2003; The Climate Group, 2008). For the longer run (2030) Ecofys (2008) estimate the abatement potential associated to the scenario that 30% of the commuters adopt telecommuting at 4%. However, the latter estimate is probably an underestimation of the maximum mitigation potential of teleworking. It should be mentioned that some of the studies (Ecofys, 2008; Sloman, 2003) do not take all direct CO_2 effects of teleworking into account (changes in energy use at home and in office buildings).

Apply visual meetings

A realistic medium to long-term CO_2 abatement potential of applying visual meetings is estimated at ca. 1% (Ecofys, 2008; The Climate Group, 2008). The maximum potential will probably be larger, among other things due to the fact that only replacements of business trips by aviation (and rail in The Climate

Group (2008)) by visual meetings are considered. Possible rebound effects are not taken into account.

Make (more) use of e-commerce
The mitigation potentials estimated by the various studies are quite uncertain. Siikavirta (2003) estimate the maximum CO_2 mitigation potential of e-commerce in Finland at 2 to 9% (100% e-grocery shopping is assumed). Ecofys (2008), however, estimate the CO_2 abatement potential associated to a shift of 20% of daily household goods to e-commerce, even at 12%. Both studies only take the direct transport emissions into account. Indirect CO_2 effects and direct CO_2 effects related to overproduction, internet use, energy consumption by warehouses, etc. are not considered.

2.4 Selection of behavioural change options

We have applied a three step process for selecting behavioural changes:

Step 1: Remove behavioural changes with poor data availability and lack of conceivable policy instruments
Behavioural changes with a poor data availability do not allow for the calculation of GHG emission reduction potential and costs. Behavioural changes for which no policy instrument is conceivable are excluded because they cannot contribute to the study objective to 'analyse policy options for the further development of community policies and measures inducing changes in behaviour and consumption patterns'.

Step 2: Rank behavioural changes according to their mitigation potentials
In this second step the remaining behavioural changes are ranked based on their mitigation potential. The ranking process is complicated by the fact that for some behavioural changes the literature reviewed presented maximum potentials, while for other changes just 'realistic' potentials are given. In addition, the time horizon of the mitigation potential estimates differs between studies (and hence behavioural changes). Therefore, the ranking of the various behavioural changes was performed by expert judgement based on the results of the literature review.

Step 3: Select options that have a high policy relevance and/or are (usually) not covered by existing models
This step eliminates behavioural changes that have a relatively large GHG abatement potential but are already included in models, and changes that have a relatively large abatement potential but that are studied elsewhere or have little policy relevance for other reasons.

The selection process has resulted in the selection of four behavioural changes in the transport domain:
1. Buying an electric car or a plug-in hybrid.
2. Buying a smaller car.
3. Applying a fuel-efficient driving style. And
4. Teleworking and virtual meetings.

The GHG impacts, costs, and barriers of these behavioural changes are studied in more detail in the next chapters.

3 Abatement potential and costs

3.1 Selected behavioural changes

In this chapter we will discuss the maximum CO_2 reduction potential[3], end-user costs and co-benefits of the behavioural changes in the field of transport. The following changes are selected for this assessment:

- buying and using an electric car or plug-in hybrid (Section 3.2);
- buying and using a smaller car (Section 3.3);
- applying a fuel-efficient driving style (Section 3.4);
- making use of ICT to decrease business travel: teleworking and applying virtual meetings (Section 3.5).

For the first three changes, the maximum reduction potential is expressed as a relative change in the (Tank-To-Wheel) CO_2 emissions per passenger kilometre of a passenger car in the Business-As-Usual (BAU) scenario (which is based on the PRIMES-GAINS reference scenario 2010, as e.g. described in European Commission, 2011d)[4]. With regard to teleworking and applying virtual meetings, the maximum reduction potential is expressed as a relative change in the direct CO_2 emissions of passenger transport in the BAU scenario. In addition, for all behavioural changes the CO_2 reduction potential will also be presented in absolute values (Mton).

3.2 Buying and using an electric car or plug-in hybrid

In this section we discuss the abatement potential, costs and co-benefits of the purchase and use of an electric or plug-in hybrid passenger car[5]. With electric cars we refer to full electric cars, i.e. cars having an electric engine and batteries for energy storage, but no internal combustion engine (ICE). Plug-in hybrid cars have both an ICE and an electric engine, with a battery that can be charged on the grid. So-called electric cars with a range extender, i.e. cars with an electric engine and an ICE that can be used to charge the battery[6] and so extend the vehicle's range, are not taken into account in this study.

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3 Since CO_2 accounts for the main part of the GHG emissions of passenger transport (e.g. for road transport about 98%) we limited our assessment in this chapter to CO_2 emissions.

4 Note that this doesn't mean that changes in Well-To-Tank CO_2 emissions are not taken into account. These emissions are, as well as the changes in TTW CO_2 emissions, taken into account. What it does mean is that the overall CO_2 emissions are compared to TTW CO_2 emissions of (conventional) passenger cars in the PRIMES-GAINS reference scenario. In this way the estimated reduction potential is in line with the way passenger car emissions are often expressed in quantitative transport models.

5 In this section we only discuss the purchase of electric or plug-in hybrid passenger cars (M1 vehicle category). The purchase and use of electric or plug-in hybrid vans (or trucks) will not be discussed.

6 The battery can also be charged on the grid.

3.2.1 Abatement potential

Theoretical maximum emission reduction potential

The theoretical maximum emission reduction potential of buying and using electric and plug-in hybrid cars is estimated by comparing the Well-to-Tank emissions of electric/plug-in hybrid cars and conventional cars. The Well-to-Tank emissions of electric/plug-in hybrid cars depend, among other things, on the electricity use (per kilometre) assumed for these cars and the fuel mix used for the power production.

Since electric and plug-in hybrid cars are innovative products and lots of developments are still expected with regard to battery technologies, the electricity use of these cars is quite uncertain. Therefore we will make use of a bandwidth for this variable (see Table 5), based on the range for electricity use by electric vehicles presented by CE et al. (2011). In this study the electricity use figures are based on a thorough review of available evidence on electric and plug-in hybrid vehicles.

Table 5 Electricity use of electric and plug-in hybrid cars

	2020	2030	2050[1]
Electricity use of electric cars (kWh/100 km)	26.2-27.6	23.6-26.2	19.2-23.7
Electricity use of plug-in hybrid cars (kWh/100 km)	15.7-16.5	16.5-15.7[2]	13.5-14.2
Share of electricity use in total energy use of plug-in hybrid cars	60%	60-70%	60-70%

Source: CE et al., 2011; adapted by CE Delft.

1 In CE et al. (2011) only electricity consumption figures for the period 2010-2030 are presented. The electricity consumption figures for 2050 are estimated based on the assumption of 2.5-5% efficiency improvements in every five years. The same assumption was used by CE et al. (2011) to estimate the electricity figures for 2020 and 2030.

2 The fact that the lower bound value is higher than the upper bound value can be explained by the share of electricity use in total energy use assumed. For the lower bound this share is 60%, while it's 70% for the upper bound.

The fuel mix used for power production is based on the PRIMES-GAINS EU-27 reference scenario 2010 as e.g. described in European Commission (2011e).[7] The associated CO_2 intensity of electricity is presented in Table 6. The significant decrease in CO_2 intensity of electricity is due to an increasing share of renewable sources in the fuel mix (in line with the Renewables directive and tightening caps of the EU ETS).

Table 6 CO_2 intensity of electricity

	2020	2030	2050
CO_2 intensity (t CO_2 per MWh)	0.23	0.18	0.07

Source: PRIMES-GAINS reference scenario 2010

7 A larger share of renewable resources in the fuel mix of power production than assumed in the PRIMES-GAINS reference scenario would increase the abatement potential of buying an electric or plug-in hybrid car. Theoretically, an abatement potential of 100% is possible if only renewable fuels are used for power production. However, this requires rather far-reaching policy instruments in the power supply sector, which will be out of the scope of this study.

In this study, the impact a large-scale shift to electric vehicles on the power supply sector is not taken into account. From CE (2010) and CE et al. (2011) it becomes clear that the additional electricity demand generated by electric and/or plug-in hybrid cars will not automatically be met by renewable energy sources; the electricity may also come from conventional plants. Therefore, the CO_2 intensity of the marginal kWh of electricity use (electricity produced for electric vehicles) may be higher than the CO_2 intensity of the average kWh of electricity. Estimating the future CO_2 intensity of marginal electricity use is out of the scope of this study, and hence we are not able to take this impact on the power supply sector into account. Therefore we will base our calculation on the average figures presented by the PRIMES-GAINS reference scenario, which may result in an overestimation of the abatement potential of buying and using an electric or plug-in hybrid car.

Based on the data presented above and data on the CO_2 emissions per passenger kilometre for conventional cars from the PRIMES-GAINS reference scenario, we estimated the theoretical maximum abatement potential of buying and using electric or plug-in hybrid cars (see Table 7).

Table 7 **CO_2 emissions per pkm and theoretical maximum abatement potential**

	2020	2030	2050
WTW CO_2 emissions per passenger kilometre (g/pkm)			
CO_2 emissions conventional car	104	86	74
CO_2 emissions electric car	35-37	24-27	8-10
CO_2 emissions plug-in hybrid car	56-57	39-45	25-31
Theoretical maximum abatement potential (as % of WTW CO_2 emissions per pkm)			
Buying and using electric cars	65-66%	69-72%	86-89%
Buying and using plug-in hybrid cars	39-40%	43-50%	53-62%

Note: The CO_2 emissions per passenger kilometre for conventional cars are from the PRIMES-GAINS reference scenario 2010 and hence do not include future policies which are not yet set definitely. The PRIMES-GAINS reference scenario only provides TTW emission figures. WTT CO_2 emissions are added by CE Delft.

Non-behavioural constraints to the implementation of the change

Using an electric or plug-in hybrid car may constrain people in the way they can use their car. Especially the restricted range of an electric car makes it less suitable for long-distance trips than conventional cars. CE et al. (2011) assumes that the range of an electric car is in 2020 about 150-250 kilometres, while the range for a conventional car is on average 600 kilometres. The range of a plug-in hybrid car is expected to be 500–550 kilometres. In the period 2020-2050 the range of electric cars is expected to increase, but will probably be smaller than for conventional cars. It will be clear that this restricted range of electric cars will constrain people in the use of their car. However, this constrain will be a behavioral one: people are able to adapt their mobility patterns (e.g. take some more time for long-distance trips, finding destinations closer to home) to overcome this barrier. Also the fact that people have to replace their current car sooner by an electric or plug-in hybrid car is assumed to be a behavioural barrier.

Next to these technical constraints there may also be some structural constraints, like the limited availability of charging infrastructure (including the limited capacity of the electricity infrastructure) or constraints to the production capacity of electric vehicle manufacturers. Especially, on the short term (2020) this may be barriers to realise the full potential of this behavioural change. These barriers could maybe partly be overcome by stringent government policies, but it seems likely that these barriers (at least partly) exists in 2020. Therefore, we assume based on CE et al. (2010) that due to these barriers about 30–50% of all passenger cars in 2020 could be electric ones. On the longer term (2030 and 2050) these barriers are not relevant.

Indirect effects

An indirect effect that should be considered is the change in CO_2 emissions related to vehicle production. This effect is researched in Ricardo et al. (on-going). Based on a literature review it was estimated that the GHG emissions related to vehicle production are 60-80% higher for electric cars compared to diesel/petrol cars[8]. The figures found for plug-in hybrids show a much wider range: 18 to 56%; these figures heavily depends on the type and size of the batteries applied.

The CO_2 emissions associated to vehicle production are ca. 18, 22 and 25% of the exhaust CO_2 emissions per pkm in 2020, 2030 and 2050 respectively. Therefore, in terms of exhaust CO_2 emissions this indirect effect is for electric cars equal to an increase of 11-14% in 2020, 13-18% in 2030 and 15-20% in 2050. With respect to plug-in hybrid cars these percentages are equal to 3-10%, 4-12%, 5-14%.

Rebound effects

There is not much evidence on the rebound effects of buying and using an electric car or plug-in hybrid (especially since actual user data is hardly available). On the one hand, the energy costs of using the car will decrease, which will provide an incentive to drive more kilometres. However, the life-time of the battery is dependent on the number of kilometres driven; due to the high costs of the battery this provides an incentive to drive less kilometres (CE et al. 2011). Moreover, due to the high investment costs of electric cars it is sometimes argued that completely new mobility concepts will come up with the introduction of electric vehicles, e.g. car clubs (people sharing electric vehicles) instead of an individual car for every family (Peters et al., 2010). Also these kinds of developments may affect the impact on use behaviour of electric car drivers.

Due to all these uncertainties it is not possible to provide reliable estimates of the rebound effect of buying and using an electric car or plug-in hybrid.

Maximum realistic mitigation potential

The maximum realistic mitigation potential of buying and using electric or plug-in hybrid cars is based on the results presented above (see Table 8). For 2020, a CO_2 reduction (in terms of TTW CO_2 emissions) of 19-34% per passenger kilometre could be realised by buying and using an electric car and 11-22% by buying and using a plug-in hybrid car. For 2030 and 2050 significantly higher mitigation potentials are found, which is due to the lack of structural constraints, lower CO_2 emissions related to electricity production and higher energy efficiency of the electric vehicles. It should be noticed that these reduction potentials are probably an overestimation of the real maximum realistic mitigation potentials, since the impact of a large-scale shift to electric vehicles on the power supply sector is not taken into account.

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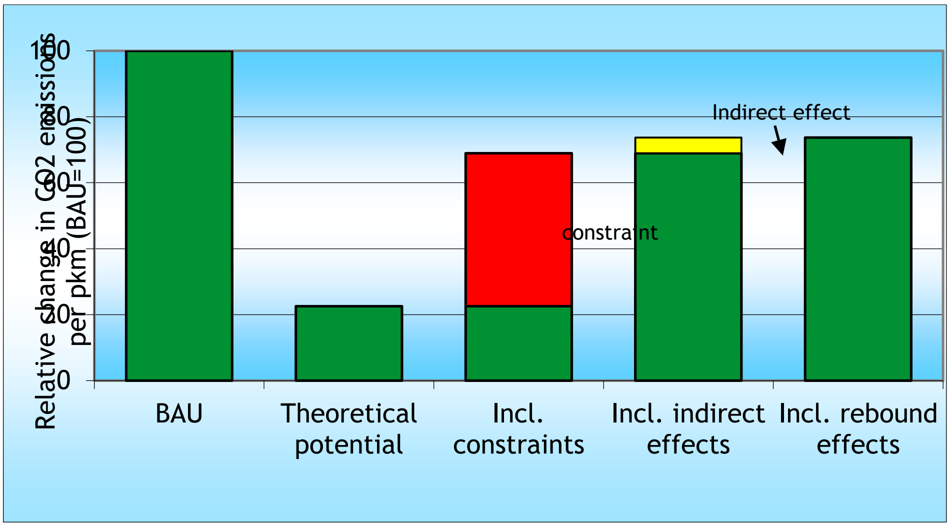
8 These figures are related to current vehicles. According to Ricardo et al. (on-going) it is not clear whether the GHG emissions related to the production of vehicles will change in the future. Therefore, we use current emission figures as a best guess for future emissions in this study.

Table 8 **Maximum realistic CO_2 mitigation potential of buying and using an electric or plug-in hybrid car**

Behavioural change	2020	2030	2050
Buying and using electric cars			
Relative reduction in CO_2 emissions per pkm	19-34%	64-72%	82-90%
Absolute CO_2 mitigation potential (Mton)	96-174	330-371	420-462
Buying and using plug-in hybrid cars			
Relative reduction in CO_2 emissions per pkm	11-22%	39-56%	49-69%
Absolute CO_2 mitigation potential (Mton)	56-113	198-286	251-354

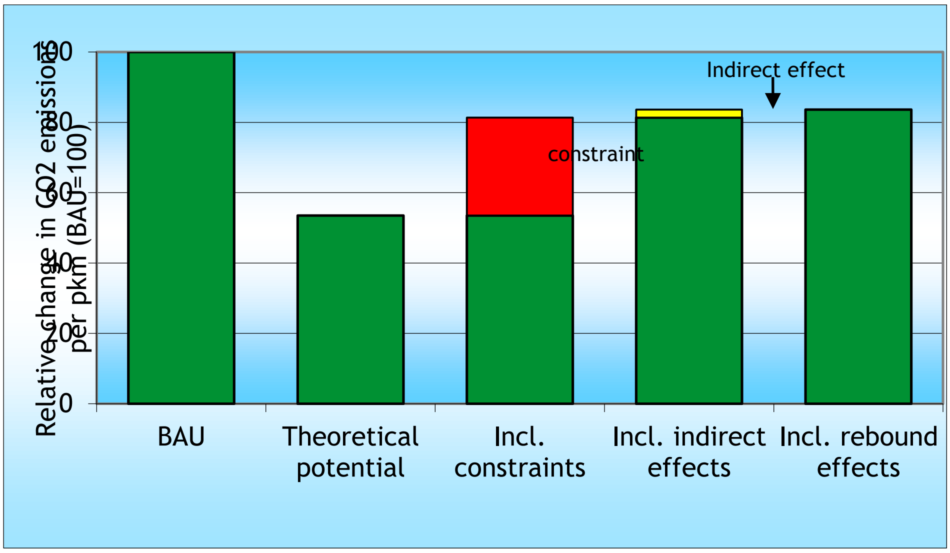
The composition of the maximum realistic CO_2 reduction potential of buying and using electric cars for 2020 is shown in Figure 1. In this figure we used the central values for the bandwidth of the reduction potential as presented in Table 8. The main part of the maximum reduction potential could be allocated to the WTW CO_2 effects of buying and using electric cars. This effect results in 77% lower CO_2 emissions. Due to structural constraints (limited availability of charging infrastructure, incl. limited capacity of the electricity infrastructure, and constraints to the production capacity of electric vehicle manufacturers) only 40% of this potential is realised, i.e. 31%. Finally, since the CO_2 emissions related to the production of electric vehicles are higher than the emissions related to the production of conventional vehicles the reduction potential declines by ca. 5 to 26%.

Figure 1 **Composition of the maximum realistic mitigation potential of buying and using electric cars in 2020**



The composition of the maximum realistic CO_2 reduction potential of buying and using plug-in hybrid cars is shown in Figure 2. Again, we used the central values from the bandwidth for the reduction potential to make this figure.
As for buying and using electric cars also the maximum realistic reduction potential of buying and using a plug-in hybrid car is mainly determined by the WTW CO_2 effects. This effect accounts for 47% lower CO_2 emissions. Again, only 40% of this potential is realised in 2020, i.e. 19%. Finally, due to indirect effects (additional emissions related to vehicle production) the reduction potential is reduced by another 2 to 16%.

Figure 2 **Composition of the maximum realistic mitigation potential of buying and using plug-in cars in 2020**



3.2.2 End-user costs

The end-user costs of electric and plug-in hybrid cars are quite uncertain, especially in the long run. Among other things, this is the result of uncertainties in learning and scale effects. Not only the size of the end-user costs is uncertain, also the structure. It is often assumed that purchase costs will be higher for electric and plug-in hybrid cars than for conventional ones, while the energy costs per kilometre will be lower. However, alternative business models are also considered to bring the cost structure more in line with the current situation: if the battery pack is leased rather than bought by the car owner, for example, the initial purchase price of the vehicle (excl. battery packs) could be much lower. The battery cost could then be recovered by paying a fee per kWh or per kilometre.

Based on a thorough study of the literature, interviews with experts and analyses of costs of existing electric vehicles, CE et al. (2011) provide some scenarios for the costs of electric and plug-in hybrid cars. The estimates presented in these scenarios should be considered as rough estimations of the actual future costs. All cost estimates are excluding taxes[9].

The additional purchase costs (excl. taxes) of electric vehicles in 2020 are estimated at 11,000 to 17,000 € for small cars and 20,000 to 28,000 € for large cars. For 2030 the additional purchase costs are estimated at 3,000 to 15,000 € for small cars and 7,000 to 24,000 € for large cars. No estimates are provided for 2050. The energy cost savings are ca. 19-23% in 2020 and 10-19% in 2030. Maintenance costs of electric vehicles are assumed to be ca. 55% lower compared to conventional cars, while insurance costs, on the other hand, are assumed to be 50-55% higher for electric cars. Finally, vehicle and energy taxes of electric cars will differ from the taxes for conventional cars; however, since tax levels differ widely between countries it is not possible to present some general figures here.

9 Currently, taxes on electricity are in general lower than taxes on fossil fuels for transport. A large switch from conventional cars to electric/plug-in hybrid ones results therefore in significant tax revenues losses for the national governments. In the long run it may therefore be expected that vehicle and fuel taxes will we adjusted to guarantee budget neutrality for the national governments.

For plug-in hybrids, CE et al. (2011) estimates additional purchase costs of 7,000 to 11,000 € for small cars and 7,000 to 13,000 € for large cars, both in 2020. For 2030, 0 to 10,000 € additional purchase costs are estimated for small cars, and 6,000[10] to 13,000 € for large cars. The energy cost savings are ca. 14-16% in 2020 and 9-15% in 2030. Maintenance costs are assumed to be equal for plug-in hybrids and conventional cars, while insurance costs are estimated ca. 55% higher for plug-in hybrids. Finally, vehicle and energy taxes of plug-in hybrid cars may differ from the taxes for conventional cars. Since tax levels differ widely between countries it is not possible to present some general figures on these differences in taxes.

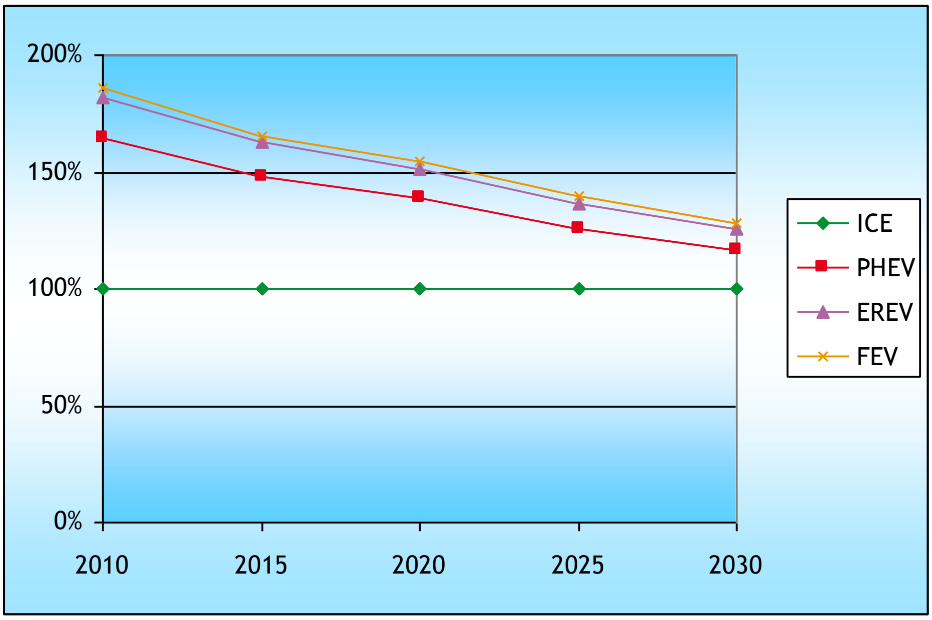
Finally, CE et al. (2011) provide also some comparisons of the TCO (total cost ownership) of various vehicle types. In Figure 3 and Figure 4 the TCO for small and large cars are compared for various types of electric/hybrid cars and conventional cars (ICE). As can be seen in these figures, the currently relative high TCO of electric/hybrid vehicles are assumed to reduce over time. In the small vehicles, the relative cost difference is the highest, in particular due to the high purchase cost and the relatively low annual mileage (a higher purchase price can be recovered due to the lower cost per kilometre).
The results also show that with the assumptions used by CE et al. (2011), the TCO for any of the electric/hybrid car will not be comparable to conventional cars before 2030. In the medium and large segment the TCO of especially plug-in hybrids become quite similar to that of conventional cars in 2025-2030, but the lines do not cross.

However, these TCO figures are based on averages of quite large vehicle categories (for example, medium sized petrol cars). In this case, comparable costs will mean in reality that the electric/hybrid vehicles will be cheaper than conventional cars for half of the vehicle owners in that category, and more expensive for the other half.

The TCO figures presented in Figure 3 and Figure 4 depend heavily on some external variables, like energy prices and government policies. A large increase in fuel prices, for example, may improve the competiveness of electric and hybrid cars.

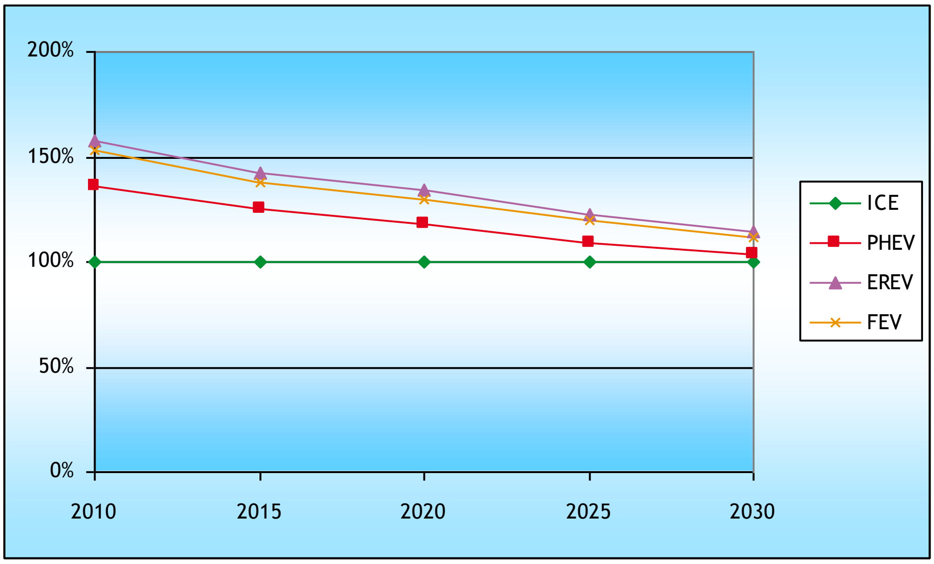
[10] The negative additional costs in 2030 are based on a scenario in which strict emission norms for passenger cars are in place, for which complex fuel saving technologies should be applied on conventional cars. As a consequence the purchase prices of conventional cars increase sharply and hence plug-in hybrids have lower purchase costs.

Figure 3 **TCO of small electric vehicles compared to the TCO of a comparable conventional car (ICE = 100%)**



NB. Including fuel and electricity taxes, excluding purchase or registration taxes and subsidies. ICE = conventional vehicle; PHEV = plug-in hybrids, EREV = electric vehicle with range extender (not considered in this study) and FEV = full electric vehicle.

Figure 4 **TCO of large electric vehicles compared to the TCO of a comparable conventional car (ICE = 100%)**



NB. Including fuel and electricity taxes, excluding purchase or registration taxes and subsidies. ICE = conventional vehicle; PHEV = plug-in hybrids, EREV = electric vehicle with range extender (not considered in this study) and FEV = full electric vehicle.

3.2.3 Co-benefits

Air pollution
Vehicles in electric driving mode do not have any tailpipe emissions of air pollutants, but may show additional upstream emissions due to the production and distribution of electricity. It may be expected that urban emissions would be significantly reduced (notice that plug-in hybrids will be most of the time in electric driving mode in urban areas), since grid electricity is mostly generated outside urban areas. This ‘relocation’ of air pollutant emissions may provide considerable health benefits, since it is assumed that rural emissions of $PM_{2,5}$ and CO cause only one fourth of the damage compared to urban emissions (EEA, 2009). In addition, more efficient emission control technologies could be applied on power plants than on cars.

Noise
Noise levels of electric vehicles are much lower than conventional vehicles in cases where engine sound is the main source of a vehicle (CE, 2011). This is typically the case at low speeds, so mainly in urban areas. A study on the noise impact of electric vehicles is performed by the US Department of Transportation, comparing Toyota Prius Hybrids operating in pure electric mode with conventional cars in a wide variety of conditions. The overall sound levels of the Prius were significantly lower at low speeds (< 10 km/h), slightly lower (ca. 2 dB(A)) at speeds of ca. 20 km/h and becoming almost equivalent at speeds over 30 km/h. The study also noted that the Prius emitted a higher pitch sound when decelerating, which was attributable to the regenerative braking related noise form the motor and power electronics.

Safety
There are concerns about potentially higher accident risks of electric vehicles due to the low noise levels of these vehicles. Electric and hybrid vehicles may not be audibly detectable by pedestrians (especially visually impaired) and cyclists. The problem can be especially acute at urban intersections with loud background noise.

In response to the ‘silent’ vehicle issue there were several recent studies performed to better understand the issue and a number of technical solutions were proposed. Based on these studies CE et al. (2011) identify the following three categories of technical solutions:
- infrastructure-based; examples include intersection rumble strips and audio warnings at intersections;
- communications-based; which include personal proximity warning transmitters, electronic travel aids;
- vehicle-based; which include artificial vehicle sounds when approaching intersections or moving at low speeds.

CE et al. (2011) conclude that there are an adequate number of low cost solutions to address the problem of silent vehicles and that regulatory bodies are expected to propose specific industry wide solutions to this issue in the near future.

3.3 Buying and using smaller cars

In this section we discuss the abatement potential, end-user costs and co-benefits of buying and using a smaller car. Small refers to the size of the car and not to the size of the engine[11].

3.3.1 Abatement potential

Theoretical maximum emission reduction potential

The theoretical maximum emission reduction potential of buying and using a smaller car is explicitly studied by Bouwman and Mol (2000). They estimated the CO_2 reduction potential if all cars would be replaced by small cars (850 kg) at 20% in 2015, 21% in 2030 and 22% in 2050. These reduction potentials do cover the direct emission reduction, but also indirect effects on fuel and vehicle production. Therefore, the reduction potential excluding the indirect effects will be a little bit lower.

Estimates of the CO_2 reduction potential of buying and using a smaller car by AEA et al. (2010) and CE (2008b) are in the range of 10 to 20%. However, the authors emphasise that this range reflects a realistic reduction potential, so the theoretical maximum emission reduction potential will be at least 20%. Finally, we conduct some own calculations based on the Dutch car ownership model DYNAMO (version 2.2). We compared the CO_2 emissions of an average car with the CO_2 emissions of a small car (< 950 kg)). Based on this analysis we found a CO_2 reduction potential for 2020 and 2030 of ca. 20%.

Based on the evidence above, we estimate the theoretical maximum CO_2 reduction potential of buying and using smaller cars on 20 to 25%.

Non-behavioural constraints to the implementation of the change

Driving a small car restricts people in the possibilities of their car use. This is especially the case for large families, who will not be able to be transported at once by one small car. Therefore, household size may be a non-behavioural constraint to the implementation of this behavioural change. Statistics from Eurostat shows that the relative share of households consisting of more than four people is about 5% (Eurostat, 2011). Therefore, we will reduce the maximum technical potential by this percentage to take the non-behavioural constraint due to large families into account.

Another potential constraint to buy a smaller car is the amount or size of luggage people sometimes want to transport. However, we don't consider this constraint a non-behavioural one, since people can rent a big car for these occasions. Also other motivations of consumers not to buy a small car (e.g. they are less safe than larger ones) are considered to be behavioural constraints (see also Chapter 4).

Indirect effects

There are two potential indirect CO_2 effects of buying and using a smaller car:
- change in CO_2 emissions related to fuel production;
- change in CO_2 emissions related to vehicle production.

[11] Size of the car could be measured by various dimensions (mass, wheelbase, etc.). Since these dimensions are rather strongly correlated, we will not specify 'size' any further in this study.

The reduction in fuel consumption due to the shift to smaller cars results in less CO_2 emissions related to fuel production. The relative decrease in these emissions will be equal to the reduction in direct (exhaust) CO_2 emissions, viz. 20%. Since the CO_2 emissions related to fuel production are per kilometre about 18% of the size of the exhaust emissions, the reduction of these emissions will result in ca. 4% lower CO_2 emissions per passenger kilometre.

With regard to the change in CO_2 emissions related to vehicle production, Ricardo et al. (on-going) estimated that these emissions are about 15% lower for a small petrol car than for a medium-sized one. The vehicle production emissions for a small and medium-sized diesel car are comparable. Based on the fact that these emissions are about 15 (2020) to 25% (2050) of the size of the exhaust emissions and that the petrol/diesel mix of the European fleet is about 50/50 (according to the PRIMES Reference scenario), we estimated that the lower emissions of the production of smaller cars result in about 1 (2020) to 2% lower CO_2 emissions per passenger kilometre.

Rebound effects
Buying and using a smaller car leads to lower purchase costs and, since these cars are (ceteris paribus) more fuel-efficient than average cars, to lower fuel costs. These cost reductions may result in a rebound effect: additional CO_2 emissions since people will travel additional kilometres.

The impact of fuel costs (and fuel prices) on vehicle kilometres and fuel consumptions has been widely studied in the international literature. UKERC (2007) concludes, based on a literature review of 17 studies, that the rebound effect caused by lower fuel costs is equal to 10-30% of the direct effect. Based on PBL and CE (2010) a rebound effect of 30-40% can be estimated for the long run. In this study we will estimate the rebound effect due to lower fuel cost at 30% of the direct CO_2 effect of smaller cars.

The lower purchase prices of smaller cars may stimulate people to drive more kilometres with the car or to buy a second car (and hence drive even more kilometres). Although there are some studies who studied this effect (e.g. vehicle price elasticities with regard to fuel consumption), they are unable to reach firm conclusions of this matter. For that reason we will not quantify this rebound effect in this study.

Maximum realistic mitigation potential
Based on the results presented above the maximum realistic mitigation potential of buying and using smaller cars is estimated (see Table 9). For 2020 a CO_2 reduction of 17 to 20% per passenger kilometre (of a passenger car) could be realised by buying and using smaller cars. For 2030 and 2050 slightly larger (relative) reduction potentials are found, which is due to the larger impact the reduction in vehicle production emissions have on the total reduction potential[12]. In absolute terms the reduction potential declines over the years, which is the consequence of declining CO_2 emissions of passenger cars in the BAU scenario.

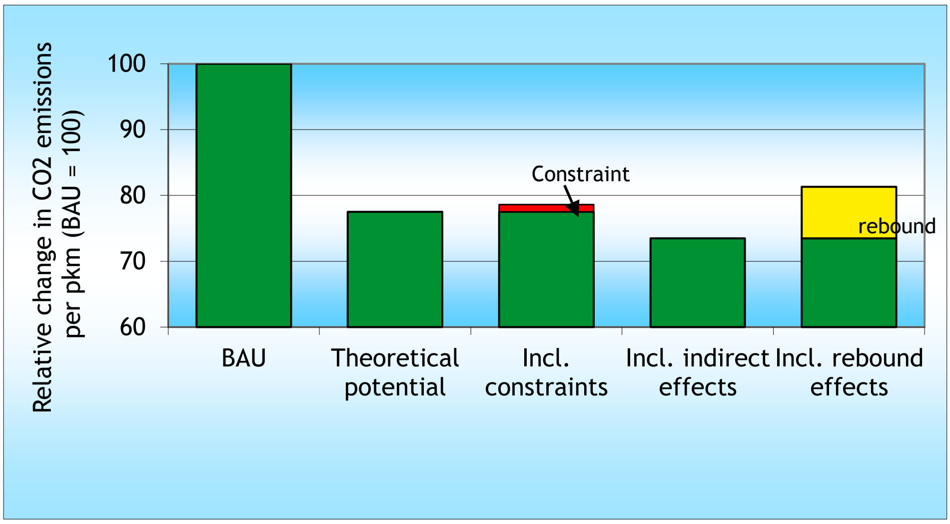
[12] Since exhaust CO_2 emissions reduce over time, the share of the CO_2 emissions related to vehicle production in total vehicle CO_2 emissions will become larger. Therefore, also the impact of the reduction in these emissions on the total reduction potential will increase.

Table 9 **Maximum realistic CO_2 mitigation potential of buying and using smaller cars**

Behavioural change	2020	2030	2050
Relative reduction in CO_2 emissions per pkm	17-20%	18-21%	18-21%
Absolute CO_2 mitigation potential (Mton)	80-96	74-88	71-84

In Figure 5 the composition of the maximum realistic CO_2 reduction potential of buying and using smaller cars is shown for 2020. In this figure we presented the central values for the bandwidth of the reduction potential. It becomes clear that the main part of the reduction potential could be allocated to the direct CO_2 effects of driving smaller cars. This effect results in 22% less CO_2 emissions. The reduction potential is corrected for the fact that some families are constrained by their size in buying a small car (ca. 1%). The indirect CO_2 effects (CO_2 emissions reduction related to fuel production and vehicle production) contribute 5% to the reduction potential. Finally, 9% of the reduction potential is undone by the fact that people will drive more kilometres since their car is more fuel-efficient (rebound effect).

Figure 5 **Composition of the maximum realistic mitigation potential of buying and using smaller cars in 2020**



3.3.2 End-user costs

Buying and using a smaller car provides consumers with some financial benefits:

- Lower purchase costs; based on the EU car prices report, CE et al. (2011) estimated the purchase costs of different sizes of passenger cars. Based on these figures we estimated that the purchase costs of a small passenger car is ca. 50% lower than for an average passenger car.
- Lower energy costs; as discussed above, the fuel consumption of a small car is estimated to be 20 to 30% lower than for an average car. Hence, also the energy costs of a small car will be 20 to 30% lower.
- Lower maintenance costs; based on CE et al. (2011) we estimate that the maintenance costs of a small car are ca. 60% lower than for an average car.
- Lower insurance costs; based on CE et al. (2011) we estimate that the insurance costs of a small car will be ca. 60% lower than for an average car.

– Lower vehicle and fuel taxes; since tax levels differ widely between countries, it is not possible to present some general figures on the change in taxes to be paid when shifting from a large to a small car.

3.3.3 Co-benefits

The mass and size of the car are essential drivers of the crashworthiness of the car (another important driver is how rigid the structure of the car is). Smaller cars have a larger occupancy risk while they are less aggressive, i.e. generates fewer casualties for non-occupants than smaller cars. For overall traffic safety especially differences in mass between vehicles are important. These mass differences determine which vehicle absorbs which part of the released energy. Generally speaking, the energy absorption is inversely proportional to the masses of the vehicles. Hence, by reducing the mass differences in the vehicle fleet the general traffic safety could be improved.
A large scale shift to smaller cars (due to consumers buying and using smaller cars) could be an important contribution to such a decrease in mass difference and hence an increase in traffic safety.

3.4 Applying a more fuel-efficient driving style

In this section we discuss the abatement potential, end-user costs and co-benefits of applying a more fuel-efficient driving style. A fuel-efficient driving style includes a number of techniques (AEA et al., 2010):
– ensuring that the engine is used at its most efficient, for instance by early gear changes and fewer hard braking and accelerating;
– applying rules to minimise redundant energy use, i.e. not using the air-conditioning if it is not needed, remove unused roof racks and weight, minimise idling;
– maintaining the tyre pressure at the specified level.

3.4.1 Abatement potential

Theoretical maximum emission reduction potential
In the literature a broad scope of estimations of the theoretical maximum reduction potential of applying a more fuel-efficient driving style can be found. Most of the estimations are in the range from 10 to 15% (AEA et al., 2010; CE, 2007; King, 2007; TNO et al., 2006). By applying ICT tools, like an Eco-driver Assistance or Eco-driver coaching[13], these potentials could be realised easier (TNO, 2009).
The reduction potentials above are defined for the vehicles of today. When the behavioural changes are applied in future years, the effect in absolute terms will become smaller, since future vehicles will become more energy-efficient already by fuel efficiency improvements (TNO, 2009). However, also in relative terms the impact of fuel-efficient driving may decline due to the incorporation of technologies which automate eco-driving techniques in new cars. Hence the reduction potential of this behavioural change will probably diminish in the longer term. The size of this reduction in the impacts of fuel-efficient driving are scarcely researched. UBA (2010) assumes that the maximum reduction potential is lowered by 20 in 2020 and 40% in 2030, due to the implementation of these techniques. In this study we will apply the same rates for 2020 and 2030. For 2050 we assume that the reduction potential is lowered by 80% (linear extrapolation of decline in potential for the period 2020-2030).

[13] These tools provide the driver information about the fuel consumption, energy-use efficiency, appropriate gear selection, route data, etc.

Based on a current theoretical maximum reduction potential of 15%, we find the following reduction potentials for 2020, 2030 and 2050: 12, 9 and 3%.

Non-behavioural constraints to the implementation of the change

A fuel-efficient driving style can be applied by all road users in (almost) all circumstances. In principle a differentiation of the estimated potential for different EU countries could be justified, as the driving style in Northern countries is known to be generally less dynamic/aggressive than in Southern European countries (TNO et al., 2006). The potential CO_2 reduction of applying a fuel-efficient driving style in Southern countries therefore may be higher. However, such a differentiation is not applied in any study estimating the reduction potential of this behavioural change. The theoretical maximum emission reduction potential estimated above should therefore be regarded as an European average. So no non-behavioural constraints need to be taken into account for this behavioural change.

Indirect effects

Since the amount of fuel used by passenger cars decrease, also the CO_2 emissions related to fuel production will be reduced by applying a fuel-efficient driving style. The relative reduction in these emissions will be proportional to the exhaust CO_2 emission reduction, viz. 12% in 2020, 9% in 2030 and 3% in 2050.

Rebound effects

The lower fuel cost due to the more fuel-efficient driving style may stimulate people to drive more vehicle kilometres, which will partly offset the CO_2 reductions achieved by applying the fuel-efficient driving style. As for the behavioural change 'buying and using a smaller car', the size of the rebound effect is estimated at 30% of the direct impact (see Section 3.3).

Maximum realistic mitigation potential

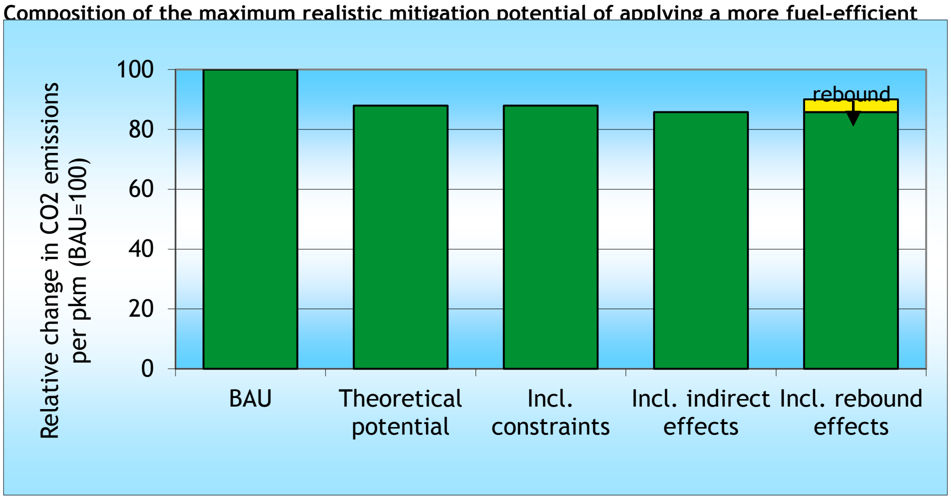
The estimates for the maximum realistic mitigation potential of applying a fuel-efficient driving style are shown in Table 10. As expected, the reduction potential declines over time, which is due to the deployment of advanced vehicle technologies, which automate eco-driving techniques.

Table 10 Maximum realistic CO_2 mitigation potential of applying a fuel-efficient driving style

	2020	2030	2050
Relative reduction in CO_2 emissions per pkm	10%	7%	2%
Absolute CO_2 mitigation potential (Mton)	47	32	10

The composition of the maximum realistic CO_2 reduction potential of applying a more fuel-efficient driving style in 2020 is shown in Figure 6. The main part of the reduction potential could be explained by the lower exhaust CO_2 emissions due to the adapted driving style; this effect results in 12% less CO_2 emissions per passenger kilometre (of a passenger car) in 2012. The indirect CO_2 effect (less CO_2 emissions due to fuel production) contributes another 2% to the reduction potential. Of this reduction potential of 14% per passenger kilometre, about 28.5% (4%) is undone by people driving more kilometres. So the final maximum CO_2 mitigation potential in 2020 is equal to 10%.

Figure 6 Composition of the maximum realistic mitigation potential of applying a more fuel-efficient



3.4.2 End-user costs

The costs of applying a fuel-efficient driving style consist of:

- The costs of an eco-driving course, which ranges from 50 to 100 € (excl. VAT) according to TNO et al. (2006).
- Purchase costs of ICT tools, like a gear shift indicator. The costs of the latter are estimated by TNO et al. (2006) at € 15.
- The avoided fuel costs due to the lower fuel consumption. If we assume that a passenger car drives on average 15,000 kilometres a year (based on Tremove), the average fuel consumption is 7.5 litre/100 kilometre (based on CE et al., 2011) and that the average fuel price is equal to € 1.50 per litre, than the avoided fuel cost per year is in 2020 (10% fuel reduction by applying a fuel-efficient driving style) about € 170.

Based on the figures above, it is clear that applying a fuel-efficient driving style is a cost-effective behavioural change for consumers.

3.4.3 Co-benefits

Although applying a fuel-efficient driving style may result in lower CO_2 emission, the emissions of air pollutants will not be reduced by this behavioural change (CE Delft, 2007). In fact, by applying the driving style instructions in an incorrect way the emission of air pollutants may even increase.

Due to its anticipative character a fuel-efficient driving style may result in an improvement of traffic safety (CE Delft, 2007).

3.5 Making use of ICT to decrease business travel: teleworking and applying virtual meetings

In this section we discuss the abatement potential, end-user costs and co-benefits of two ICT related behavioural changes: teleworking and applying virtual meetings.

Gareis (2003) distinguish three types of telework:
- home-based: working at home, using ICT to transfer work results;
- mobile: working away from main place of work, using online-connections during business trips or in the field;
- self-employed in SOHO's (small office, home office): home is the main place of work or the base for trips into the field.

In this study we will focus on the first and third type of telework; this means a shift from work location from the firm to home.

Virtual meetings can take several forms. These include audio or voice conferencing where three or more participants speak together via a common phone number. Web conferencing allows participants to follow a common presentation by all accessing the same website (often accompanied by an audio conference). Finally, videoconferencing allows participants to see as well as hear each other via a video link. In this study we will use a broad definition of virtual meetings, covering all the forms presented above.

3.5.1 Abatement potential

Theoretical maximum emission reduction potential

The theoretical maximum emission reduction potential of both teleworking and applying virtual meetings is determined by several factors. The most important ones are:
- the number of vehicle kilometres substituted by teleworking and/or visual meetings;
- less energy use (for heating, air-conditioning and lighting) at the office (only for teleworking);
- more energy use (for heating, air-conditioning and lighting) at home (only for teleworking);
- energy use of the ICT appliances used.

Substitution of mobility

The number of kilometres that potentially could be substituted by teleworking and videoconferencing is significant, as becomes clear from the figures in Table 11. The total number of passenger kilometres made for commuting trips is equal to 12-13% of all passenger kilometres of passenger transport[14] in the EU-27. The theoretical potential reduction of CO_2 emissions of passenger transport (in case total passenger kilometres of passenger transport is reduced by all commuting kilometres) is equal to 11 in 2020 and 9% in 2050. For videoconferencing the potential of CO_2 reduction due to a substitution of transport is even larger: 11% of all emissions of passenger transport in 2020 and 13% in 2050.

14 Including passenger kilometres made by road, rail and air transport.

Table 11 **Potential share of passenger kilometres and CO_2 emissions to be saved by applying teleworking and virtual meetings**

	2020	2030	2050
Commuting trips			
Relative share pkm commuting in total number of pkm of passenger transport	13%	12%	12%
Relative share CO_2 emissions due to commuting in total CO_2 emissions of passenger transport	11%	10%	9%
Business trips			
Relative share pkm business trips in total number of pkm of passenger transport	11%	12%	12%
Relative share CO_2 emissions due to business trips in total CO_2 emissions of passenger transport	11%	13%	13%

Source: PRIMES and TREMOVE; adapted by CE Delft.

Changes in energy use at the office and at home

In addition to impacting CO_2 emissions from transportation, teleworking also changes usage patterns from buildings, as teleworkers may increase energy use from their home while enabling their companies to use less energy in existing buildings or build/rent less building spaces. The empirical evidence on these effects is scarce, and therefore the results presented here are characterised by a relatively high level of uncertainty.

The overall impact of teleworking on the energy use at the office and at home depends heavily on the extent teleworking is applied in firms. If a significant number of people work from home for 3-4 days a week, firms could reduce their energy use significantly, especially by reducing their office space. However, if the take-up of teleworking is lower it would still be necessary to maintain office space for periodic home-workers and hence the energy reduction at the office would be significantly lower. For example, Bannister et al. (2007) estimate that the energy use at the office could be saved by maximum 5% if everybody works at home for 1 day a week, but by ca. 50% if everyone would work at home for 3-4 days a week.

Since we look at maximum GHG reduction potentials of teleworking, we consider high levels of teleworking in this study[15]. For that case, Goodman et al. (2004) report, based on a case study in the UK, that the total amount of energy used per person working at home is less than for office workers (50 to 80%). Expected economies of scale for energy consumption in office buildings do not occur due to energy-inefficient spaces and having energy systems (heating, lighting, air-conditioning) on all day. Additionally, energy savings can be realised in office buildings by reducing the office space. Also TIAX (2007) finds that at high levels of teleworking (4 or 5 days a week) results in a net decrease of energy used for heating and electricity (taking potential floor space reductions into account); they estimate that the net energy reduction at the home and at the office is about 30 to 40% of the energy reduction realised by less transportation. In this study we will use these figures to estimate the overall GHG reduction potential of teleworking.

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15 Notice that the net impact of teleworking on energy use at home and at the office will probably be negative in case of low levels (1-2 days a week) of teleworking. In this situation the extra energy use at home will outweigh the energy reduction at the office. For example, TIAX (2007) found that if everyone works at home 1-2 days a week the sum of energy use at home and at the office will increase by 45 to 55%. However, this increase in energy use is outweighed by the decrease in energy use for transportation: the net reduction of energy use (and CO_2 emissions) is about 6-14%. Also Bannister et al. (2007) and CE (2008a) find (small) net reductions in CO_2 emissions at low levels of teleworking.

Energy use of the ICT appliances used
Both teleworking and visual meeting requires ICT technologies, which consume energy and hence produces CO_2 emissions. According to Ecofys (2008) the energy use of ICT technologies for videoconferencing is negligible compared to the energy reduction due to a lower number of transport movements.
For teleworking, we assume that the direct energy use of ICT appliances is included in the changes in energy use at the office and at home, as discussed above. The indirect energy use of these technologies is assumed to be negligible.

Non-behavioural constraints to the implementation of the change
Clearly not everyone works in a job where teleworking is possible (all the time). In some jobs face-to-face contact with customers or colleagues is required and other jobs requires access to e.g. machines. The commission of the European communities estimate that about 50% of all employment in Europe is not bound to a geographical location (Ecofys, 2009), a statement which is confirmed by Sloman (2003). Since even in jobs which are not bound to a geographical location it sometimes is necessary to meet colleges or customers, we assumed that people in these jobs could work at home for 80% (based on Bannister et al., 2007). If we assume that people working in jobs suitable for teleworking have comparable commuting patterns (trip length) as people in other jobs, we find that the theoretical maximum reduction potential of teleworking, as calculated above, should be reduced by 60% due to non-behavioural constraints.

With regard to virtual conferencing Sloman et al. (2004) extensively reviewed the available literature. They found that about 40-50% of the business trips could be replaced by virtual meetings. Ministry of the Environment (2001) mention that on average ca. 60% of the business trips could be substituted by virtual meetings. However, it is not clear to whether or not behavioural constraints are taken into account in these estimates. Ecofys (2009) present some predictions of the potential of virtual meetings to replace business trips using several sets of assumptions. In the most favourable world context up to 40% of the business trips in 2020, 60% of the business trips in 2030, and 90% of the business trips in 2050 could be replaced by virtual meetings[16]. If we take into consideration that the estimations of Sloman et al. (2004) and Ministry of the Environment (2001) refer to the current potential, these estimations of potential are quite well in line. Therefore, we will use the estimations from Ecofys (2009) in this study.

Indirect effects
Like for the other behavioural transport changes the reduction in energy use also result in less CO_2 emissions related to energy production. The relative decrease in these emissions is equal to the relative decrease in the emissions related to the direct energy use.

Ecofys (2008) mention that also vehicle ownership may be affected by teleworking. Individual teleworkers may decide that they do not need to own a private vehicle anymore. This would generate a positive indirect effect (in terms of increased GHG emission reductions) as teleworkers would further decrease their travel related emissions by walking, biking and using more public transportation also for recreational travel. Moreover, the decrease in the total stock of passenger cars would lead to a reduction in GHG emissions associated with vehicle production. However, in the literature no empirical

16 The assumed increase in the potential to replace business trips by virtual meetings is, among other things, the result of improvements of ICT facilities.

evidence on this indirect effect is found and hence this effect will not be quantified in this study.

Rebound effects

In the literature (AVV, 2004; Bannister et al., 2007; Ecofys, 2008; Ecofys, 2009; Sloman, 2003) several potential rebound effects of teleworking are mentioned:

- *Additional trips (and GHG emissions) by the employees that take advantage of the commuting time saved thanks to teleworking*. These trips might have been made as part of a linked trip if he had been driving to work. The empirical evidence on this rebound effect is limited, as mentioned by both Bannister et al. (2007) and Sloman (2003). In their calculations, TIAX (2007) assumes that ca. 20% of the reduced commuting kilometres is replaced by other car kilometres, while Sustel (2004) estimate this effect to be equal to 40%. In this study we will apply this bandwidth to estimate this rebound effect.
- *Additional car use by family members who take advantage of the fact the car is available*. However, based on a literature review Sloman (2003) conclude that the evidence about the impact of teleworking on other members of the household is thin, but points towards their car mileage remaining the same or perhaps even falling slightly, rather than increasing. This conclusion is confirmed by Bannister (2007).
- *Additional traffic (and GHG emissions) due to latent demand effects from people who decide to travel as congestion, thanks to teleworking, decreases*. No empirical evidence for this rebound effect was found.
- *In the longer run, it is argued that teleworking could encourage people to live further from their work*. The benefit of reduced travel time on teleworking days would be (partly) offset by increased travel on days when the employee travelled to work. However, empirical evidence on this rebound effect is not convincing (e.g. see Ettema, 2010). Moreover, Ory and Mokhtarian (2006) find that those who are teleworking and then move actually tend to relocate closer to their workplace. On the other hand, people who begin teleworking following a residential relocation tended to have moved much farther from their workplace. So, this study supports a positive view of telecommuting, that it is ameliorating the negative transportation impacts of moves that occur for other reasons.

Concluding, the empirical evidence on the rebound effects of teleworking is limited. From the literature only sound empirical evidence is found for the additional trips made by people at home-working days. Therefore, we will only take this rebound effect into account in this study.

As with teleworking, applying visual meetings also results in some potential rebound effects. Next to substitution teleconferencing may also lead to (Ecofys, 2009):

- Supplementation: virtual communication supplements physical travel. Companies will use the possibility to communicate more often without reducing the number of face-to-face contacts.
- Generation: virtual communication leads to more numerous and remote contacts and businesses, stimulating and generating more demand for travel. The extra travel can be created by the time savings due to teleconferencing or by the extension of networks, which are made possible by conferencing technologies.

Empirical evidence on the rebound effects of teleconferencing is hardly available. Therefore we were not able to quantify this effect.

Maximum realistic mitigation potential

Based on the results presented above the maximum realistic mitigation potential for teleworking and applying virtual meetings is estimated for the EU-27. As is presented in Table 12, the maximum realistic mitigation potential of teleworking is equal to ca. 5 to 8% of the total CO_2 emissions of passenger transport in the EU-27. The maximum realistic mitigation potential of virtual meetings equals 6 to 9%. It should be noted that the uncertainty in these estimations are quite large, especially since not all rebound effects could be quantified. Moreover, in case the rebound effects were quantified, the uncertainty in these quantifications are rather large.

Table 12 Relative reductions in CO_2 emissions of passenger transport in the EU-27 by applying teleworking

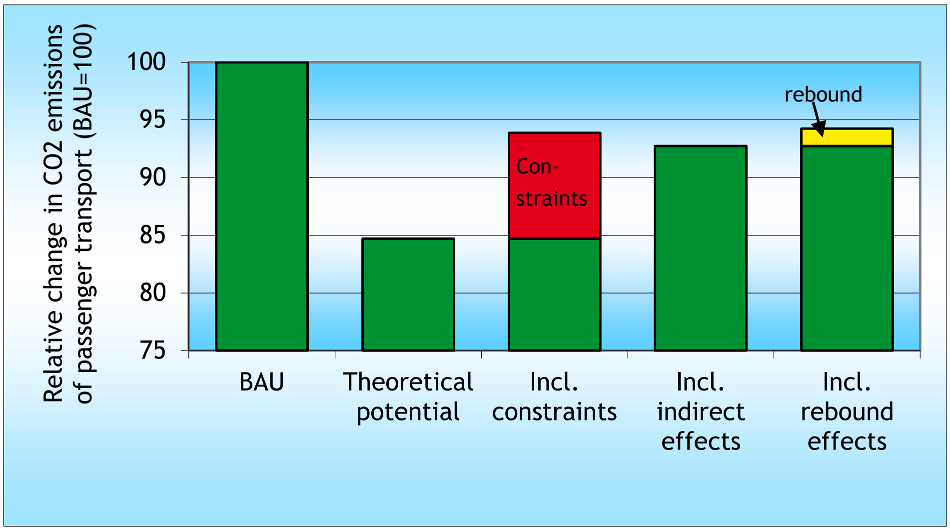
	2020	2030	2050
Relative reduction in CO_2 emissions of total passenger transport	5-6%	6-7%	6-8%
Absolute CO_2 mitigation potential (Mton)	35-45	38-47	40-49

Table 13 Relative reductions in CO_2 emissions of passenger transport in the EU-27 by applying virtual meeting

Mitigation potential	2020	2030	2050
Relative reduction in CO_2 emissions of total passenger transport	6%	6%	9%
Absolute CO_2 mitigation potential (Mton)	39	35	55

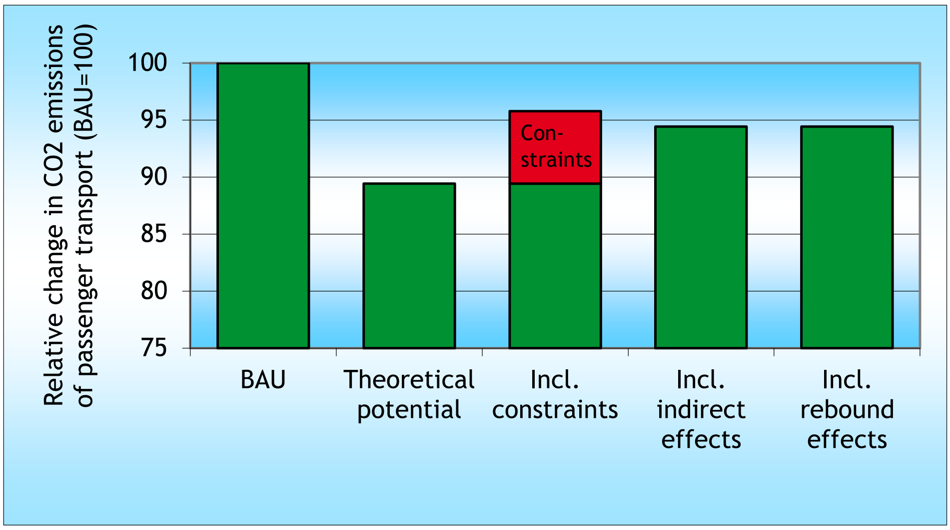
In Figure 7 the composition of the maximum realistic CO_2 reduction potential of teleworking is presented. The theoretical maximum potential is equal to 15% of the total CO_2 emissions of passenger transport. However, since not all people could telework and since we assumed that on average teleworkers could maximally telework for 80%, the theoretical maximum potential is reduced by 60%. The reduction potential is slightly extended by the indirect CO_2 effects (less CO_2 emissions due to lower fuel production), ca. 1%. Of the resulting reduction potential about 20% is undone by people using their car for other purposed instead of commuting. So the final maximum CO_2 mitigation potential in 2020 is estimated at 5 to 6%. Notice, that this potential is probably an overestimation, since we were not able to quantify all rebound effects.

Figure 7 Composition of the maximum realistic mitigation potential of teleworking in 2020



The composition of the maximum realistic CO_2 reduction potential of applying virtual meetings in 2020 is shown in Figure 8. The theoretical maximum reduction potential is estimated at ca. 11% of the CO_2 emissions of passenger transport in the EU. Of this theoretical reduction potential 60% could not be realised because for 2020 is was assumed that only 40% of the meetings could be replaced by virtual meetings. The indirect CO_2 effect (less CO_2 emissions due to fuel production) contributes ca. 1% to the reduction potential. Since no rebound effects are quantified, the resulting maximum realistic CO_2 reduction potential in 2020 is equal to 6%.

Figure 8 Composition of the maximum realistic mitigation potential of applying virtual meetings in 2020



3.5.2 End-user costs

Teleworking results in various changes in the end-user costs:

- *Lower mobility costs*; since teleworkers travel less kilometres than non-teleworkers, the travelling costs (both fuel and other variable costs) will decrease by 5 to 8%.
- *Changes in energy costs for heating, air-conditioning and electricity;* as we saw in Section 3.5.1, teleworking may result in less energy use for heating, air-conditioning and electricity. No empirical evidence on these costs was found in the literature.
- *Lower costs due to smaller offices;* on the long-term firms with a high level of teleworkers could reduce their office space and sublet some space to other firms or move to smaller (and cheaper) locations. In the literature no estimates for these potential cost savings were found.
- *Less parking places necessary at the office;* firms can realise cost savings by reducing the number of parking places at the office. No estimates for this potential financial benefit of teleworking were found in the literature.
- *Increased productivity of teleworkers;* several studies (Ecofys, 2009; Sustel, 2004) show that employees who work at home regularly become more productive. This is due to lower absenteeism, longer working hours which are not claimed, and a better environment at home to work concentrated. These benefits are not quantified in the literature.

Also applying virtual meetings result in various changes in the end-user costs:
- *Lower mobility costs;* since less kilometres are travelled, the travelling costs (both fuel and other variable costs) will decrease by 6 to 9%.
- *Investment costs in ICT*; to apply virtual meetings investments in ICT appliances may be needed. The costs depends heavily on the type of equipment used. No complete information on these costs are found in the literature.
- *Increased productivity of employees*; applying virtual meeting may increase the effectiveness of meetings, improving the productivity of employees. These benefits are not quantified in the literature.

3.5.3 Co-benefits

There are a number of side-effects that are identified in the literature for teleworking (AVV, 2004; Bannister et al., 2007; Ecofys, 2009; Sloman et al., 2004):
- Improved performance; an improvement of the employees performances is often mentioned as a co-benefit of teleworking, including higher productivity, better quality of work, higher total output and more creative work. Explanations mentioned for this performance improvements are less disruption while working and more time spent working instead of travelling.
- Improvement of (experienced) quality of life and a better balance between working life and personal life. Especially, spending more time with the partner and children is mentioned as an important contributor to the increased quality of life. However, there are also some negative impacts of teleworking on the quality of life reported, e.g. people working longer hours and feeling more isolated from colleagues than previously.
- Employees who would not be able to do office-based work are able to continue in employment. People affected include employees with responsibilities for child care, who care for ill or disabled family members, or who are themselves disabled or recovering from an illness. Also the levels of absenteeism due to sickness are lower.
- The lower traffic levels, especially during peak hours, will result in lower congestion levels. Additionally, the emissions of air pollutions and noise will be reduced and traffic safety will increase.

For virtual meetings the following side-effects are mentioned in the literature (Sloman et al., 2004; Ecofys, 2009):
- Reduced hassle, time savings and better work-life balance; the option to teleconference makes planning easier and frees up time for the individual, including reducing the stress and hassle of travel.
- Improved organisational efficiency and performance; due to virtual meetings more frequent meetings with more participants can take place at a lower cost. This means that more people with different background and perspectives can take part of the meetings, enriching the discussion and leading, eventually, to a more informed decision. Moreover, participants in virtual meetings tend to be very concentrated and focussed, enhancing the effectiveness of the decision making.

Lower traffic levels due to applying virtual meetings positively affect congestion levels and emissions of air pollutants and noise.

4 Barriers, consumer segments and policy instruments

4.1 Introduction

In this chapter we discuss the barriers related to the selected changes in mobility behaviour. This assessment is aimed to provide an overview of the main barriers with respect to the changes in mobility behaviour and will be based on a literature review. Next to a discussion on barriers, also relevant consumer segments and possible diffusion paths of the various behavioural changes will be discussed. Finally, an overview of all relevant policy instruments with regard to the various selected changes in mobility behaviour will be presented.

4.2 Buying and using an electric car or plug-in hybrid

4.2.1 Barriers

In Table 14 an overview is given of the barriers related to buying an electric car or a plug-in hybrid. The main barriers exist at both the individual as societal level.

At the individual level consumers rather negative attitude to electric and plug-in hybrid cars are a main barrier. Electric cars are perceived as less attractive than conventional cars on many dimensions: performances (e.g. range), reliability, costs, image, etc. Additionally, electric and plug-in hybrid vehicles may challenge mobility related habits of people, forcing people to change their lifestyles. For example, due to the long recharging time the use of electric cars is perceived to be less flexible than the use of conventional cars.

At the societal level structural barriers (the poor availability of charging infrastructure and the limited number of electric and hybrid vehicle models) and economic barriers (high purchase costs) are the main barriers for an uptake of electric and plug-in hybrid vehicles.

Table 14 Overview of barriers for buying an electric car or plug-in hybrid

Barrier category	Examples
Individual (internal) barriers	
Social and psychological barriers	– Rather negative attitude of consumers to electric cars due to: worse performances compared to conventional cars, doubts on reliability, safety issues, rather high costs, soft image – Electric cars challenge the mobility related habits of people
Knowledge-based barriers	– Knowledge of consumers of electric and plug-in hybrid cars is rather poor
Societal (external) barriers	
Structural and physical barriers	– Insufficient network of charging infrastructure – Limited availability of electric/plug-in hybrid cars – Not enough second-hand cars
Cultural barriers	– Uncommon in peer group

Barrier category	Examples
Economic barriers	– High initial investment costs – Uncertainties about the long-term value of the car – Perceived high maintenance costs
Institutional barriers	– Perceived reluctance of automobile dealers (and manufacturers) to actually sell electric and plug-in hybrid cars – Too little government support

Social and psychological barriers

Experts notice that individual preferences with regard to mobility may provide strong barriers to electric or plug-in hybrid vehicles. Peters at al. (2010) mention that it is not likely that that many users now or in the near future will be motivated or interested to buy electric vehicles as most users are perfectly happy with conventional cars and the range of products available on the market. Conventional cars fulfil a wide variety of needs and will probably act as a strong frame of reference. With this reference frame, electric cars might be perceived as less attractive on many dimensions.

What are the dimensions important for people when buying a new car? Lane (2005) extensively researched the literature on the car buying decision process. Although the ranking of the various influencing factors differ between studies, the general view is that the car buying decision-making process for private car purchases is predominantly driven by financial and performance considerations. In addition, emotional and symbolic values related to the car (brand, image) are important. Environmental issues play little part in the process. An overview of drivers of car purchases from DfT (2004) is shown in Table 15, distinguishing three groups of drivers: most important, important and least important[17].

Table 15 Overview of drivers of car purchase decisions

Most important	Important	Least important
Reliability	Performance/power	Depreciation
Comfort	Image/style	Personal experience
Price	Brand name	Sales package
Fuel consumption	Insurance costs	Dealership
Size/practicality	Engine size	Environment
Safety	Equipment levels	Vehicle emissions
Running costs		Road tax
Style/appearance		Recommendation
		Alternative fuel

Source: DfT (2004).

[17] As mentioned before, rankings provided by other studies slightly differ from this categorisation. However, this table provides a good general overview of drivers and their importance in the private car purchasing decision process.

As mentioned before, electric and plug-in hybrid cars might be perceived less attractive than conventional cars on many of the factors shown in Table 15. The main ones are:

- *Performance*; The (perceived) limitations of electric and plug-in hybrid cars with regard to driving performances might be an important barrier (Peters et al., 2010; Byrne and Polonsky, 2001). Especially, the limited range achieved with a battery pack (compared to conventional cars) is often mentioned as an important drawback of electric vehicles (CE, 2010; CE et al., 2011; Environics, 2009; Peters et al., 2010). Also the longevity of the batteries is an important point of concern for many consumers (CE, 2011; Kurani et al., 2007; TNS Automotive, 2011).
- *Reliability*; Consumers are often risk averse, which may be a barrier for the diffusion of innovative products like electric cars. Uncertainties on e.g. the longevity of the battery may discourage consumers to buy an electric or plug-in hybrid vehicle (BarEnergy, 2010; Peters et al., 2010). A study on the barriers to purchasing plug-in hybrid cars as perceived by Canadian car users show doubts on reliability as the main barrier (Environics, 2009). About 95% of the surveyed indicate that doubts on reliability is at least to some extent a barrier to buying a plug-in hybrid, while 64% indicate it is even a large barrier.
- *Safety*; Safety issues are often mentioned as potential barrier for the purchase of electric vehicles. It considers the safety for the user of the electric car (Axsen et al., 2010; BarEnergy, 2010; Byrne and Polonsky, 2001), but also the safety for other road users due to the higher accident risks of very silent vehicles like electric cars (CE et al., 2011; TNS Automotive, 2011). TNS Automotive shows that 52% (37%) of the people consider electric (hybrid) cars dangerous for pedestrians and cyclists.
- *Price*; the higher purchase costs are seen as a main drawback of electric vehicles (BarEnergy, 2010; CE et al., 2011; Peters et al., 2010; TNS Automotive, 2011). See also the discussion on economic barriers below.
- *Image/style*; BarEnergy (2010) mentioned that electric vehicles have a soft image. This is problematic, since for many car owners their cars reflect an important part of their identity (Bio et al., 2006). Notice that this could also be a driver to buy an electric or hybrid car; European Commission (2006) mention that in the US the overwhelming reason that people chose a particular hybrid car model was that the car was seen by consumers to make 'a statement about me'.

Furthermore, although electric and plug-in hybrid cars are seen as environmental friendly, still a significant share of the consumers doubt on the environmental benefits of these cars. According to TNS Automotive, about 38% of the car users in the Netherlands think that an electric/hybrid vehicle is less environmental friendly than usually thought.

Additionally, using electric vehicles would challenge the mobility related habits of people (Magali, 2010; Peters et al., 2010). Today's lifestyles of people are built around the car and all what it makes possible. Their activity patterns depend on the availability of a car. The use of an electric car requires more planning and anticipation concerning the trips to be made and the time of driving, due to limitations in range and charging opportunities. It requires management from the users (negotiations among family members) and a planning of mobility, which challenges the current lifestyles of people. These impacts of electric vehicles on the habitual lifestyles of people could be a main barrier for consumers to buy an electric or plug-in hybrid vehicle.

Knowledge-based barriers

Knowledge on electric and plug-in hybrid cars is often limited among consumers. TNS Automotive (2011) finds that about 67% of the car users in the Netherlands declare to have only superficial knowledge on electric cars and 3% states that they are not at all known with these cars. With regard to plug-in hybrids even 53% states that they are not known with these cars. These results for the Netherlands are in line with results found by Synovate (2011) for consumer knowledge on electric and hybrid vehicles in the United States. This study shows that the knowledge of consumers on basic aspects related to electric and hybrid cars is rather poor. For example, ca. 60% of the surveyed did not know that plug-in hybrids used fossil fuels in conjunction with an electric motor. Another example, only 50% indicates that it takes longer than 15 minutes to charge the batteries of an electric or plug-in hybrid car.

Structural and physical barriers

An important structural barrier is the lack of a (public) charging infrastructure for electric and plug-in hybrid cars (AEA et al., 2010; BarEnergy, 2010, CE et al., 2011). The currently available charging infrastructure is too limited to switch to an electric car, as stated by 76% of the Dutch car drivers (TNS Automotive, 2011). Peters et al. (2010) mention that according to experts it may be expected that individuals will mostly load their vehicles at home and at their workplace and only incidentally in public places. So, providing charging infrastructure at the place of living and working is seen as most important with regard to charging infrastructure. Especially in urban areas where apartment buildings or housing cooperatives do not have access to their own parking facilities this may be a challenge (Swedish Energy Agency, 2009). However, Peters et al. (2010) also point out that a publicly accessible infrastructure is considered as crucial for promoting electric cars, as it will increase observability of electric mobility and reduce reservations which might prevent people from buying.

Next to the availability of charging infrastructure, also the way of charging is a potential barrier to buying electric or plug-in hybrid cars. Charging infrastructure should be compatible with all kinds of electric vehicles and should contain an easy and transparent system for usage and billing (Peters et al., 2010). Also the charging time is often regarded as too long, especially if charging takes place in public places. For example, about 70% of the surveyed car users in the UK by Smart (2010) indicate that the inconvenience of recharging is a main barrier for buying an electric or plug-in hybrid car.

Another structural barrier is the current limited choice in electric and hybrid vehicles (BarEnergy, 2010; Peters et al., 2010; TNS Automotive, 2011). Whilst there are hundreds of different models of conventional vehicles, there are currently just a few electric and hybrid varieties. TNS Automotive shows that about 74% (62%) of Dutch consumers consider the number of electric (hybrid) vehicle models on the market too limited. BarEnergy (2010) noted the lack of a good second-hand market for these cars as an additional barrier. Especially in the initiation phase of the market penetration of electric and plug-in hybrid cars these types of barriers may be important.

Cultural barriers

Peer group pressure may be a barrier for consumers to buy an electric or plug-in hybrid car. Evidence suggest that main stream consumers would have some resistance to buy an electric/hybrid car as such is perceived different or deviating from the existing norm (Byrne and Polonsky, 2001). Also, BarEnergy (2010) find some support for the impact of social norms on the purchase of electric vehicles. Since the purchase of electric vehicles is seen as uncommon in their peer group, some consumers will avoid buying such a car.

Economic barriers

The high purchase price (largely due to the high costs of the battery pack) of electric/plug-in hybrid vehicles is one of the main barriers for a large-scale shift from conventional to electric/plug-in hybrid cars (AEA et al., 2010; BarEnergy, 2010; CE et al., 2011; King, 2007; Peters et al., 2010; Swedish Energy Agency, 2009). In a survey study on the attitude of car users in the Netherlands to electric vehicles, the high purchase price is often mentioned as an important drawback of these types of vehicles (TNS Automotive, 2011). For example, about 58% of the people indicate that the purchase price of a hybrid car is too high compared to the prices of conventional diesel and petrol cars. In the UK, 58% of the drivers surveyed by SMART (2010) indicate that the purchasing costs of an electric car are too high for them to buy such a car.

CE et al. (2011) shows that the lower energy costs of electric vehicles will probably not be able to compensate for the higher purchase costs of electric and plug-in hybrid vehicles. On average the total cost of ownership will probably not be comparable for electric and conventional vehicles before 2030. However, even if the total cost of ownership would be comparable for electric and conventional vehicles, consumers would probably prefer the lower purchase costs of a conventional car over the lower energy costs of an electric car. This so-called consumer myopia is caused by the fact that car buyers do not take the life-time savings from improved fuel efficiency into account, but only the first three years of fuel use. Such myopia leads buyers to choose to buy less fuel-efficient cars than if they took account of the life-time savings of more fuel-efficient cars.

Next to the higher purchase prices of electric vehicles also the uncertainties about the long-term value of these vehicles are mentioned as a barrier for buying an electric or plug-in hybrid car (e.g. BarEnergy, 2010). These uncertainties increase the financial risks consumers perceive associated with electric vehicles. Additionally, consumers perceive maintenance costs of electric cars to be higher than for conventional cars (Environics, 2009; TNS Automotive, 2011), although experts expect the contrary (CE et al., 2011).

Due to the large differences in cost structures between conventional cars and electric cars, it is likely that different business models will develop to deal with these changing cost structures (as well as other uncertainties of electric vehicles, like the longevity of the batteries). However, there is still considerable uncertainty over what business models will actually evolve in the future. CE et al. (2011) distinguish two main models of ownership for electric vehicles with a significant number of variations of ‘in between’ models. The models focus on different options for ownership of the battery (the main cost item of electric vehicles). Model 1 is similar to the conventional vehicle ownership model and is based around the concept of customers purchasing the whole vehicle, including the battery. Model 2, on the other hand, involves an organisation that sells a mobility service rather than a product. This organisation owns the battery and sets up battery charging and battery exchange infrastructure and then charges the customer in order to cover the electricity consumption and battery amortisation. This business models provides car users a sale price that is competitive with that of a conventional vehicle. In addition to these different models of battery ownership, also models referring to a de-privatisation of mobility through car-club business models are sometimes mentioned with regard to electric mobility. Car-club models are generally based around an annual membership fee followed by hourly leasing charges (incl. fuel). Especially in urban areas, this business model may be attractive to car users.

Institutional barriers
A first institutional barrier mentioned in the literature is the reluctance of automobile dealers (and manufacturers) to actually sell electric and hybrid cars, such that the market for these vehicles is not developing and hence the supply of vehicle models is limited (BarEnergy, 2010; Byrne and Podolsky, 2001). The profit margins on electric and hybrid cars are too small and therefore there is no incentive to persuade consumers to buy a hybrid or electric vehicle.

A second institutional barrier mentioned by BarEnergy (2010) is the lack of government support. Consumers argue that the government has an important role for regulating the market, since the development of electric and hybrid cars stems from an environmental point of view. Therefore the government should push producers into this direction, e.g. by fiscal measures. The fiscal treatment of these cars should also be stable and predictable, such that both car manufacturers and consumers know which taxes to take into account when making an investment decision.

4.2.2 Consumer segments and diffusion patterns

Electric and plug-in hybrid cars are typical examples of innovative products. A well known model to explain the diffusion of these types of products is the Diffusion of Innovation model by Rogers (2003). Rogers argue that, among other things, the diffusion of a product is influenced by some individually perceived attributes of the product: 1) relative advantage, 2) compatibility with the adopter’s values, experiences and needs, 3) complexity, i.e. difficulty to understand and use the innovative product, 4) trialability, and 5) observability. Based on the innovativeness of the consumer, i.e. the degree to which a person is relatively earlier in adopting an innovation compared to other consumers, Rogers divides the (potential) consumers of an innovative product into five classes: 1) innovators (ca. 2.5% of the consumers), 2) early adopters (13.5%), 3) early majority (34%), 4) late majority (34%), laggards (16%).

Based on Rogers Diffusion of Innovation model, Gärling and Thogersen (2001) state that marketing and policy making with regard to electric vehicles should in a first phase target on consumers who already perceive advantages and compatibility with values and needs of using an electric car. From that perspective, electric and plug-in hybrids are attractive for consumers using a car for urban trips where travel distances is usually within a limited range (Peters et al., 2010). First, they could be used in company fleets, especially by segments of various service providers, like mobile car services, which often have frequent and regular short trips in urban areas. Additionally, multi-vehicle households are potential target groups for a first round of policy making. In these households the electric vehicle could replace on of these conventional vehicles. Finally, also the public sector is identified as an early adopter of the electric and plug-in hybrid car (Gärling and Thogersen, 2001).

Another classification of early target groups for policy making with regard to electric vehicles made by Peters et al. (2010) is based on user attributes. Electric vehicles are supposed to be convenient and attractive for those who are wealthy and have little time (and would therefore be interested in innovative and pragmatically usable transport offers), those who are interested in new and innovative technology, want to express attitudes via their vehicle, are environmentally aware or interested in recent trends.

Since the target groups in the first phase of policy making with regard to electric vehicles already have a positive attitude to electric vehicles, policy making should focus on reducing structural and economic barriers, e.g. providing charging infrastructure and financial incentives. In a second phase the activities in these fields should be intensified (since these consumers require higher levels of convenience when shifting from conventional to electric cars) and policies focused on changing consumer attitudes should be implemented.

4.2.3 Policy instruments

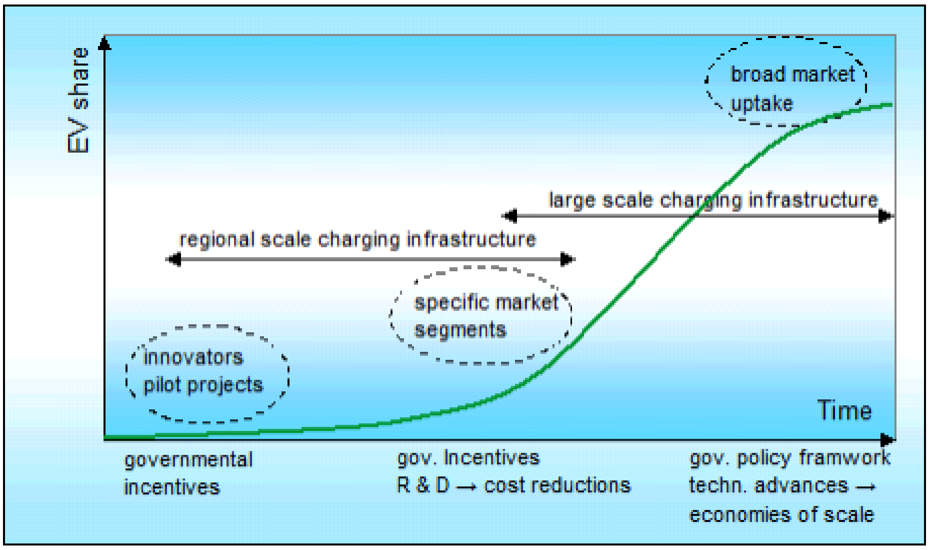
In contrast to the other behavioural transport mitigation changes the purchase of electric or plug-in hybrid cars involve quite innovative products. Therefore the timing of policy instruments is much more crucial in order to implement effective policy instruments and avoid harmful market distortions.
For example, while subsidies and support schemes can be appropriate under certain conditions if they allow nascent technologies to become market ready, financial support mechanisms are not meant for long-term development of established technologies.

The market share of new successful technologies, products and services usually follows an S-curve (see Figure 9) (CE et al., 2011). Three phases can be distinguished:

- In the first phase, market share is low and innovation is not yet mature and competitive. Therefore governmental incentives and support (e.g. subsidies, direct governmental expenditures) could be used to overcome initial barriers and set up pilot projects. Results of these pilot projects should be communicated to consumers to increase their knowledge on electric and plug-in hybrid cars. As it is usually not clear in this phase which innovation can survive in a competitive market, the government preferably does not support one single technology but various competing upcoming technologies (e.g. both electric and plug-in hybrid vehicles).
- In the second phase the initial barriers have been overcome and the market share starts to increase. In this phase, policy instruments could be focused on stimulating the purchase of electric and plug-in hybrid cars at specific market niches (e.g. people using their car only for urban mobility). Still some incentives may be needed, but in order to avoid market distortions, they should preferably be as soon as possible technology neutral. Part of this framework can be various policies, but also direct and indirect subsidies (to manufacturers and consumers). Also providing knowledge on the use and impacts of electric and plug-in hybrid cars to the specific (targeted) groups of consumers is important in this phase, as well as measures to improve the symbolic/emotional value of these cars and the social norm against its use.
- In the final phase, increasing volumes result in cost decreases because of economies of scale benefits. The electric and plug-in hybrid car has becoming available for all consumers. As the market matures, supporting subsidies need to be scaled down and eventually withdrawn. Otherwise, these fiscal measures would distort the market equilibrium and in the long-term would lead to an over-use of the given product or service. This

means, among other things, that any existing discounts or exemptions from purchase and registration taxes (implemented in the previous phases) for electric and plug-in hybrid cars would probably be abolished. Communication policies should be focused on all potential consumers, although specific strategies for various niches may be used.

Figure 9 A schematic roadmap that illustrates how an increasing electric vehicle (EV) market share can be achieved



Source: CE et al. (2011).

In the remainder of this section we will first discuss the various individual policy instruments that could be used to stimulate the purchase of electric and plug-in hybrid cars. An overview of the potential policy instruments is given in Table 16. If relevant, we will discuss in which phase of the S-curve these instruments should be applied. Finally, we discuss in which way the various instruments could be combined in effective policy packages.

Table 16 **Overview of policy instruments which can be used to stimulate the purchase of electric and plug-in hybrid cars**

Policy category	Examples
Regulative instruments	– Quota for (relative) number of electric/plug-in hybrid cars to be sold by manufacturers – Urban access restriction schemes focused on electric and plug-in hybrid cars – Use of parking policies to stimulate the purchase of electric and plug-in hybrid cars – Developing common plug and charging standards – Prescription of smart charging infrastructure – Require investments in charging infrastructure – Beneficial treatment of electric and plug-in hybrid cars with regard to vehicle emissions standards
Economic instruments	– Differentiated vehicle taxes – Energy taxes – Differentiated road charges – Subsidies on purchases of electric vehicles or the installation of charging points – Subsidies for the development of electric vehicles (e.g. battery technology)
Communication	– Information campaigns – CO_2/Energy labelling – Providing comparisons of electric and plug-in hybrid cars with conventional cars – Demonstration projects
Direct governmental expenditures	– Public investments in charging infrastructure – Green procurement: investing in electric or plug-in hybrid vehicles
Procedural instruments	– Voluntary agreements with organisations to use electric or plug-in hybrid cars

Regulative instruments

Two types of regulative instruments could be distinguished: regulative instruments that directly influence the ownership or use of electric vehicles (e.g. quota for manufacturers, green zoning in city centres) and regulative instruments that improves the infrastructure needed for electric transport (e.g. policies with regard to charging infrastructure).

Governments could use regulative instruments to oblige manufacturers to sell certain amounts of electric or plug-in hybrid cars. For example, a policy could be implemented which prescribes that electric or plug-in hybrid cars cover 10% of all car sales of a specific manufacturer. Fines could be used to coerce manufacturers to comply with this policy. This type of policy intervention could be used to overcome manufacturers' and/or dealers' reluctance to actually sell electric cars (institutional barrier). Additionally, it may result in a broader range of electric vehicles on the market, overcoming the barrier of limited availability of these cars. Finally, this policy this policy may also indirectly affect social/psychological barriers at consumers; due to this kind of policy manufacturers and/or dealers will try to improve consumers' attitude to electric cars (e.g. by providing discounts on these cars). Although this kind of policy may have relatively high welfare impacts (implicitly affecting consumer sovereignty) and public acceptance may be problematic it will be very effective (assuming that manufacturers comply to the policy).

More indirectly, governments could stimulate the purchase and use of electric and plug-in hybrid cars by restricting car use in certain areas (e.g. city centres) to environmentally friendly vehicles (including electric and plug-in hybrid cars). In this way governments could improve the attitude of consumers with respect to electric and plug-in hybrid cars (electric cars become more attractive compared to conventional cars). ISIS et al. (2009) studied a wide range of urban access restriction schemes in Europe, showing that these schemes can provide significant reductions in local emissions. No quantification of the impact of this policy instrument on (the composition of) car ownership is provided. From other studies (e.g. Goudappel Coffeng et al., 2008) quantitative results on effectiveness are available, but these results are hard to transfer to the specific case of electric and plug-in hybrid cars[18]. Closely related to urban access restriction schemes are parking policies providing exclusive places for electric or plug-in hybrid cars. Although no empirical evidence is available on the effectiveness of this specific type of instrument, there are some studies which have investigated the use of parking instruments as environmental policies (e.g. CE, 2007; CROW, 2010). Most of these studies focused on the use of parking policies to reduce air pollutant emissions in city centres. However, if these measures are applied on a large scale (to prevent that people move to other cities or park outside the city centre) they can also contribute to reducing GHG emissions.

The second type of regulative instruments refers to instruments that provide a common framework for a market penetration of electric vehicles. In the scope of this study especially instruments with regard to charging infrastructure are relevant. Charging infrastructure is considered to be a major factor in customer acceptability of electric vehicles (Kalhammer et al., 2007); lack of charging infrastructure was mentioned before as an important barrier for a large-scale implementation of electric cars. Especially common plug and charging standards are considered essential, since they provide car users the opportunity to charge their electric vehicle at every place (CE et al., 2011). Additionally, standards reduce the total number of charging stations needed to support electric transport by enabling all vehicles to be charged more easily. The European Commission intends to launch a European standard for plug and charging technologies in 2012. In addition to standardisation of plug and charging technologies, also requirements with regard to smart charging[19] is important. CE et al. (2011) report that smart charging is a necessity if electric vehicles reach a market share of 5%. Therefore, a requirement could be developed to prescribe that electricity providers implement smart charging infrastructure once the 5% threshold has been reached in their distribution district. Next to standardisation of charging infrastructure, policy could also contribute to the building of it by requiring new parking lots or office buildings to be equipped with charging infrastructure or requiring electricity providers to install a specific number of charging stations.

Policy interventions could also contribute to the diversity of electric car models supplied to the market. This is related to the European mandatory emission performance standards (CO_2 limits) for manufacturers of new passenger cars (Regulation (EC) No. 443/2009). An emission limit of 130 g/km

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18 Goudappel et al. (2008), for example, assumes that the introduction of a green zone only accessible for Euro-3 to Euro-5 cars would stimulate up to 30% of the people living in the area to buy a new, cleaner car and 5% of the people working in the area. However, since the differences between old (e.g. Euro-2) and new (e.g. Euro-4) conventional cars (e.g. with respect to purchase prices) are much smaller than between electric and conventional cars. Therefore it may be expected that this instrument will be less effective in stimulating the purchase of electric vehicles; however, quantifying this effect is not possible.

19 Coordinating charging of batteries with the availability of power supply.

is applied to the average of all passenger cars registered in the EU in each calendar year, starting gradually in 2012. The way electric and plug-in hybrid cars are treated under this regulation affects the number of electric and plug-in hybrid car models on the market. For example, zero counting or offering super credits[20] to these cars may stimulate manufacturers to provide and sell more electric and plug-in hybrid cars on the market. An extensive discussion on the interaction between vehicle emission standards and electric vehicles can be found in CE et al. (2011).

Economic instruments

Various economic instruments could be used to stimulate the purchase of electric and plug-in hybrid cars. In general these instruments could be used to overcome the economic barriers related to the purchase and use of electric and plug-in hybrid cars. Particularly the relatively high investment costs could be partly compensated by implementing economic instrument, like differentiated purchase taxes or purchase subsidies. Economic instruments could also help in improving consumers' attitudes with respect to electric/plug-in hybrid cars; by lowering the relative price (compared to conventional vehicles) of the acquisition and use of these cars, peoples' attitude will improve. Finally, on the long-term economic instruments may also reduce peer pressure not to buy electric/plug-in hybrid cars.

In the remainder of this section we will discuss various types of economic instruments that could be implemented to stimulate the purchase and use of electric and plug-in hybrid cars.

Differentiated vehicle taxes

Vehicle taxes like purchase/registration taxes, circulation taxes and company car taxes may be useful instruments to stimulate the purchase of electric and plug-in hybrid cars. With regard to private cars, differentiated purchase taxes are probably more effective in stimulating the purchase of electric and plug-in hybrid cars than differentiated circulation taxes (CE, 2008c; TiS, 2000), since the former directly influence the purchase price of the car (and as we saw in Section 4.2.1, purchase prices are a more important driver of car purchased than costs over the life-time of the car like circulation taxes). In several European countries discounts or exemptions on purchase and/or circulation taxes are already used to stimulate the market uptake of electric vehicles (e.g. Austria, the Netherlands, Ireland, Germany, Greece).
With regard to company cars, CO_2 differentiated company car taxation could be an effective way to stimulate the purchase/lease of electric and plug-in hybrid company cars. According to Ecorys (2011) the introduction of a CO_2 differentiated company car tax in the Netherlands is an important explanation for the large increase in hybrid company cars over the last years.

The effectiveness of differentiated vehicle taxes in stimulating the purchase of fuel-efficient vehicles is more extensively discussed in Section 4.3.3.

The design of differentiated vehicle taxes should depend on the phase of market penetration of electric and plug-in hybrid cars. In the first phase, large discounts or even complete exemptions may be implemented to ensure that the economic barrier (high purchase prices) can be (to a significant extent) overcome. Additionally, this kind of design may also contribute to an increasing awareness of consumers of these kinds of cars. However, if market

20 In the current regulation super credits are provided to cars with less than 50 g CO_2/km. In 2012 and 2013 these vehicles count for 3.5 cars, in 2014 for 2.5, in 2015 for 1.5 and from 2016 simply as one vehicle.

shares of electric and/or plug-in hybrid cars increase, tax discounts and exemptions could be expected to be reduced or withdrawn completely (i.e. tax levels will be at the same lever as current taxation levels), to avoid market distortions and significant losses in tax revenues.

Energy taxes
Energy tax policies may be a second type of economic instrument that could be used to stimulate the purchase of electric and plug-in hybrid cars (CE et al., 2011). By requesting lower energy taxes (per kilometre) for electricity than for fossil fuels (as is currently the case), a financial incentive to buy electric vehicles will be provided. The impact of energy taxation on the uptake of electric vehicles is not yet specially studied. However, there is some evidence on the impact of energy taxes on the purchase of cars in general, which shows that this kind of policy instrument can have a significant effect on car purchases. In Section 4.3.3 this issue is discussed in more detail.

In the short term taxing energy use of electric cars by the current electricity tax rates may provide a significant incentive to purchase electric or plug-in hybrid cars, since these tax rates are significantly lower than the taxes rates on fossil fuels used for transportation. However, in the medium and long-term, when electric vehicles have a significant market share, losses in tax revenues may occur. To recuperate these lost tax revenues CE et al. (2011) propose to increase over time taxation on both electricity used in transport and on fossil fuels. In this way cost advantages of electric vehicles are maintained, while in the same time revenue equivalence is guaranteed. Another option would be to introduce other taxes, like charges for road us.

An important consideration with respect to energy taxation of electric cars is that it should preferably be possible to distinguish electricity use for transportation purposes from electricity use for other (household) purposes. In this way, considerable losses in fuel taxes could be recovered without affecting other types of electricity uses. Differentiation of electricity taxation requires a special standard power plug for electric vehicles, such that these cars are not charged through the regular meter, but would have to use a separate meter instead. The requirements for such a standard power plug for electric vehicles should be set in the early introduction phase of electric vehicles, enabling separate taxation once the market moves into maturity (see also the discussion above on regulative instruments).

Differentiated road charges
Differentiation of road charges may be another economic instrument to stimulate the purchase of electric and plug-in hybrid cars. This policy instrument should in the first place be aimed to internalise the external cost of road transport, among other, by reducing the amount of transport movements (IMPACT, 2008). Stimulating the purchase of electric vehicles may be an interesting co-benefit. The effectiveness of this instrument to stimulate the purchase of electric vehicles is not yet studied. Among other things, it will heavily depend on the exact design of road charging scheme.

Subsidies
Next to implicit subsidies like tax discounts or exemptions (discussed above) also direct subsidies to manufacturers or consumers may be effective policies to stimulate the purchase of electric and plug-in hybrid cars (CE et al., 2011). Especially in the first phase of the market penetration of these cars, purchase subsidies and subsidies for installation of charging points, may provide incentives to stimulate the market uptake and enhance public trust and acceptability in electric vehicles. Subsidies to manufacturers for R&D activities

may (on the long-term) result in improved vehicle performances, which may increase the attractiveness of these cars for consumers. Although the direct mitigation potential of these types of subsidies is low, they may contribute to the development of the necessary infrastructure and may improve the visibility of these types of vehicles. This may be crucial drivers for large scale market penetration of these cars on a longer term.

As mentioned before, providing subsidies should be scaled down and eventually even abolished when market shares of electric vehicles increase. In this way market distortions due to over subsidising electric vehicles could be prevented.

Communication

Several instruments in the field of communication could be applied to stimulate the purchase of electric and plug-in hybrid cars, ranging from (large-scale) information campaigns to demonstration projects. These communication instruments could be used to overcome knowledge-based barriers, e.g. a lack of knowledge on general issues regarding electric and plug-in hybrid cars. Communication instruments may also be useful to improve peoples' attitude and social norms with respect to electric/plug-in hybrid cars, e.g. by showing people that these cars are also safe and that the operating costs are significantly lower than for conventional cars.

Information campaigns

Governmental information campaigns could help to increase the public awareness and sensitivity to environmental issues and to promote the purchase of low-emission (including electric and plug-in hybrid) vehicles (IEA, 2008). These campaigns should make the connection between the urgent need of lowering GHG emissions and specific actions required, such as the deployments of electric vehicles. In additions, information campaigns could be used to provide people more (general) information on electric and plug-in cars. As mentioned in Section 4.2.1, the knowledge of consumers on (basis concepts of) these types of vehicles is rather poor. By providing information the knowledge base as well as attitudes of these people to electric and plug-in hybrid cars could be improved.

Empirical evidence on the effectiveness of information campaigns to stimulate the purchase of electric or plug-in hybrid vehicles is not available. However, from evaluation studies on information campaigns in other transport fields (e.g. transport use, traffic safety) it follows that these campaigns may, at least in some cases, be effective (Moser and Bamberg, 2008; Tay, 2005). Effectiveness is expected to be higher for closely targeted campaigns than for more general campaigns (Cairns et al., 2008; Steg, 1996). Cairns et al. (2008) mention that the value of information campaigns is especially that it could support and intensify other (policy) initiatives.

Energy/CO_2 labels
Directive 1999/94/EC mandates the use of a visible fuel economy label on passenger cars at the point of sale. This label could provide consumers information on the benefits of electric and hybrid cars in terms of CO_2 emissions, energy use and energy costs. The effectiveness of these labels is difficult to assess, due to the wide range of other incentives and initiatives currently in operation, such as emission related vehicle taxation, etc. However, the studies (e.g. ADAC, 2005; PBL, 2009) which did study the effectiveness of labelling, show that this is quite small. See also Section 4.3.3 for a further discussion on the effectiveness of energy labels for passenger cars.

Providing comparisons of electric and conventional vehicles
Providing sound comparisons of electric and conventional vehicles is a good way to provide information to potential consumers (Ecologic et al., 2010). Especially information on performances and costs (investment costs and operating costs) should be highlighted in these comparisons, since these are important drivers in the car buying process. Independent websites or guides are good platforms to present this kind of information. No empirical evidence was available on the effectiveness of this type of information dissemination.

Training of sales persons
Ecologic et al. (2010) suggest that (mandatory) training of sales persons may help to convey environmental and fuel-cost related information at the point of sale. Sales persons are expected to have significant impact on the buying decision of consumers and hence providing these people information on environmental performances and fuel cost factors of electric and plug-in hybrid cars may be an effective way to inform and influence consumers.
No information was available on the effectiveness of this type of information dissemination.

Demonstration projects
The government could support demonstration project to promote the use of electric and plug-in hybrid cars (CE et al., 2011; IEA, 2008). Since consumer acceptance of electric vehicles is likely to increase through trial and experience (CE et al., 2011; IEA, 2010) supporting demonstration projects is an important cornerstone in early governmental policies related to electric vehicles. An additional benefit of demonstration projects is the contribution is provides to developments of new innovative technologies, like battery technologies.

Direct governmental expenditures
As mentioned before, a dense network of charging infrastructure is a prerequisite for a successful market penetration and reliable operation of electric vehicles (EEA, 2009). Given the large investment costs and lots of uncertainties with the prospects of electrically driven vehicles, governmental involvement will be necessary. Above, we already discussed several ways to secure investments in charging infrastructure:
- a requirement to provide charging infrastructure at new parking places or at new office buildings;
- a requirement for electricity providers to install a specific number of charging stations;
- subsidies for the charging infrastructure projects.

However, in addition to these instruments the government could also invest in charging infrastructure themselves.

CE et al. (2011) recommend to apply a mix of all types of measures above: public investment, a regulatory framework (private investment) and subsidies (public private partnership). In the first phase of market penetration of electric vehicles, public investment and a regulatory framework seems to be the most appropriate measures. In the medium term, assuming some market penetration, also public private partnership constructions could be possible.

Next to investments in charging infrastructure, the government could also invest in electric vehicles for their own use. Although the direct mitigation potential of this type of instruments is likely small, it may be crucial to get public acceptance for other policy instruments related to electric vehicles. Additionally, it may improve peoples' attitude to these type of vehicles by increasing peoples' confidence that these cars are good substitutes for conventional cars.

Procedural instruments

The government could enter into voluntary agreements with companies, in which the latter indicates that they would buy/lease electric or plug-in cars instead of conventional ones. Since company cars account for a significant part of the total passenger car fleet, the theoretical mitigation potential of this measure is rather large. Additionally, in the first phase of introducing these cars on the market, it may also be a good way to improve the visibility of them for the consumers (and hence improving consumers' attitude to these vehicles by increasing their confidence that these cars are good substitutes for conventional cars). Finally, the voluntary agreements could be a useful platform to exchange information on the purchase and use of electric and plug-in hybrid vehicles (and hence addressing knowledge-based barriers).

The (direct) effectiveness of this instrument with regard to the purchase of electric or plug-in hybrid cars has not been studied in the literature. However, OECD (2003) shows that in general the effectiveness of voluntary agreements in environmental policy making is rather low. This is because the main part of the behavioural change shown by the companies would also have occurred without the voluntary agreements. The performance of these approaches may be improved if there is a real threat of other instruments being used if (appropriately set) targets are not met. However, if it is likely – or widely believed – that the alternative policy would entail significant negative social impacts, the credibility of such threats may not be great.

Implementing policy packages

If the various policies are implemented in policy packages some interaction effects affecting the effectiveness of the individual instruments may occur. Some of the main interaction effects are:

- Various instruments meant to stimulate the investments in charging infrastructure are discussed (e.g. subsidies, regulatory frameworks, governmental investments). Applying these instruments at the same time may lead to an overlap and hence negative interaction effects. However, given the enormous investments needed CE et al. (2011) recommend to use a mix of these instruments.
- Regulative instruments, like electric vehicle friendly parking policies, and economic instruments like fuel taxes may reinforce each other, since they provide consumers both a comparable incentive. However, if the regulative instruments are applied on a large scale (not only in some city centres, but in whole regions or even countries), these instruments may largely overlap; in that case they would negatively affect each other.

- Economic instruments like differentiated vehicle taxes, fuel taxes and road charges may reinforce each other, but they could also overlap each other. If a combination of these instruments provides a financial incentive sufficiently large to change the consumer's behaviour, these instruments reinforce each other. However, if the needed financial incentive could also be realised by just one of these instruments the implementation of the other instruments is redundant and result in distortions. Therefore combining these measures in a policy package should be carefully considered.
- The various instruments related to communication will probably reinforce some of the other policy instruments. People with more knowledge on electric cars are probably more willing to buy one if fuel taxes increases or city centres are only available with electric cars.
- Investing in electric or plug-in hybrid cars for governmental agencies may, if visible to people, serve as a good example and may stimulate consumers to buy these kinds of cars themselves.

4.3 Buying and using a smaller car

4.3.1 Barriers

An overview of the barriers related to the purchase of smaller cars is shown in Table 17. Most of the main barriers are individual ones, indicating that consumers are often able to buy a smaller car, but that they are not always willing to.

Table 17 Overview of barriers for buying a smaller car

Barrier category	Examples
Individual (internal) barriers	
Social and psychological barriers	– Consumers prefer a large car over a small one, since large cars are more practical and safer. Additionally, for some consumers large cars have preferable symbolic/affective advantages (e.g. better image) – Fuel consumption/environmental performances are no top priority of car buyers – Small cars may challenge the mobility related habits of people
Knowledge-based barriers	– Limited knowledge of consumers on their own fuel costs
Societal (external) barriers	
Structural and physical barriers	– Limited number of small car models available on the market
Cultural barriers	– Pressure from peers to buy a large car
Economic barriers	–
Institutional barriers	– Reluctance of car dealers to sell smaller cars

Social and psychological barriers

Consumers' attitude to the size of the car may be a first barrier for buying smaller cars. From the literature it became clear that small cars score worse than average/large cars on some of the dimensions driving the car purchase decision of consumers (see also Table 15). The main ones are:

- *Size/practicality*; people prefer a large car since they can be used to carry more people or luggage. Additionally, due to the larger internal space the comfort of the car is higher.

- *Safety*; the safety of the car is an important factor for consumers in the purchase decision of a car. According to Lane (2005), about 66% of the UK car users judge safety of the car as an very important factor in their vehicle purchase choice and another 19% judge it as quite important. Since large cars are on general safer than small cars, this partly explains consumer preferences for large cars.
- *Environment*; BarEnergy (2010) states that fuel environmental performances of the car are not a top priority of car buyers. These conclusions are emphasised by Lane and Potter (2007). So, the advantageous scores of small cars in this field do not result in a big increase in consumers' preferences for these cars.
- *Style/Image and personal experiences*; the car buying decision is not only affected by instrumental factors (costs, size, performances), but also by symbolic and affective values (image of the car, brand, personal experience of the car, etc.) (Steg, 2005; Sasu and Ariton, 2011). BarEnergy (2010) mentioned that there is a sense of status associated with driving larger cars. Choo and Mokhtarian (2004) find that there are some significant differences between people driving a small and large car with respect to attitudes, personalities and lifestyles, which can explain some of the reluctance of some consumers to buy a small car instead of a large one. For example, large car drivers have weaker pro-environmental attitudes than small car drivers. The latter ones do also have weaker travel freedom (representing the ability to 'go anywhere I want to go') attitudes and they are less likely to enjoy personal vehicle travel.

Next to these attitudinal barriers, the purchase of smaller cars may also be hampered by the fact that it affects mobility related habits of people. Driving a smaller car may restrict people in their flexibility, since they can transport less luggage/people.

Knowledge-based barriers
Some studies (Lane and Potter, 2007; Lane, 2005; Turrentine and Kurani, 2006) identify limited knowledge of consumers with regard to the true cost of running their car and a low recall of their expenditure on fuel. This lack of knowledge may help explain the rather limited attention for fuel costs at the time of vehicle purchase, as a result of which a relative advantage of small cars (fuel efficiency) is not fully taken into account.

Structural and physical constraints
The purchase of smaller cars is not hampered by many structural or physical barriers. The only evidence on these kind of barriers found in the literature refer to the limited number of small car models available on the market (BarEnergy, 2010).

Cultural barriers
As for the purchase of electric and plug-in hybrid cars, pressure form peer groups may also be a barrier for consumers' purchase of smaller cars. Schemesh and Zapatero (2011), for example, finds evidence for the so-called 'keeping up with the Joness' principle, indicating that people like to buy a car that is at least as expensive as people from their neighbourhood. Moreover, this effect is larger for people living in densely populated areas, since the observability of their purchasing behaviour is larger than in thinly populated areas. Also Bakken (2008) states that the influence of peer groups on people's car purchasing behaviour is important, referring to a study for Finland which shows that the recent purchasing of a particular car brand by near neighbours ha a greater influence on car brand choice that almost all other factors.

Institutional barriers

An institutional barrier mentioned by BarEnergy (2010) is that car dealers do not support consumers' purchase of smaller cars. Since the higher profit margin for luxury and larger cars, sales people are provided a financial incentive to prioritise the sale of these cars over smaller, more efficient vehicles.

4.3.2 Consumer segments and diffusion patterns

Several demographic factors may influence the resistance of people to buy a smaller car:

- *Household size;* one- or two-person households will be more likely to buy a small car than households with children (Choo and Mokhtarian, 2004; Kitamura et al., 2000), since for the latter the internal space of the car will be more of a key factor in the car purchase decision.
- *Gender;* women are expected to be more likely to buy a small car than men (Choo and Moktharian, 2004). Women are less concerned to the status of car and, in addition, are more concerned on the environmental performance of the car (Johansson-Stenman and Martinsson, 2006).
- *Educational level;* it may be expected that higher educated people are more likely to convince smaller cars (Choo and Moktharian, 2004). According to Johansson-Stenman and Martinsson (2006) these people are less concerned on the status of their car. Additionally, environmental concern is often expected to be higher for high-educated people than for low-educated people.
- *Place of residence;* people living in the city are more willing to buy a smaller car than people living on the countryside. Since the latter group will use the car more often, they prefer a more comfortable car than citisens. Additionally, small cars are more practical in the dense urban traffic.

As we saw before, the main barrier to buying smaller cars is consumers' attitude to these types of cars. To change this attitude will take some time. For example, it will take some time to convince people that they don't need to change their lifestyle if they buy a smaller car. Also the symbolic values related to small and large cars need time to change. Therefore, it will require long-term policy instruments to stimulate the purchase of smaller cars on a large scale.

4.3.3 Policy instruments

In Table 18 an overview of policy instruments to stimulate the purchase of smaller cars is shown. In the remainder of this section we will first discuss these policy instruments individually. Next we will briefly discuss effective policy packages for the stimulation of smaller cars purchases.

Table 18 Overview of policy instruments to stimulate the purchase of smaller cars

Policy category	Examples
Regulative instruments	– Regulate maximal size/weight of cars
Economic instruments	– Differentiated purchase taxes – Fuel taxes – Differentiated registration taxes – Differentiated road charges
Communication	– CO_2/energy labels for passenger cars – Providing information via independent websites or guides – Providing information via sales persons – Mass communication
Direct governmental expenditures	– Green procurement: only buying small cars
Procedural instruments	– Voluntary agreements with companies to buy small company cars

Regulative instruments

The purchase of smaller cars could be affected by several types of regulative instruments. Like for electric and plug-in hybrid cars, governments could use regulative instruments to oblige manufacturers to sell certain amounts of small cars and hence to overcome dealers' reluctance to sell small cars. Indirectly, this instrument may also affect social/psychological barriers, since dealers are stimulated to improve consumers' attitude by smaller cars (e.g. by providing discounts). Implicitly, the current CO_2 regulation (Regulation 443/2009) already provides an incentive to manufacturers to sell smaller cars, since size/weight of the car and CO_2 emissions are correlated. Therefore, tightening the CO_2 targets will also provide an indirect incentive to manufacturers to sell more small cars. Stimulating the purchase of small cars by these kinds of regulative instruments will probably be very effective, especially if specific targets for small cars are set. However, the welfare costs of the latter policy option could be significant and public acceptability will probably be an issue.

More indirectly, governments could stimulate the purchase and use of small cars by some spatial measures. Urban access restriction zones based on the size of the car could be implemented. As discussed in Section 4.2.3 this instrument could be used to change consumers' attitude with respect to low emission cars. In this Section it is also shown that urban access restriction zones could be effective in affecting the use of specific types of cars, but the impact on car ownership is unclear (ISIS et al., 2009). No specific information for urban access restriction zones based on the size of the car is available. Next to urban access restriction schemes also the provision of small vehicle parking spaces could be used to stimulate the purchase and use of small cars. From the literature it is clear that parking instruments can be effective (depending on the scale of application) in reducing CO_2 emissions, although no evidence is available for this specific type op parking policy.

Communication instruments

Various communicational instruments could be used to stimulate people to buy smaller cars. These instruments could be used to overcome consumers' knowledge-based and social/psychological barriers to buy a smaller car. E.g. by using communication instruments people could be persuaded that they could maintain their current lifestyle if they buy a smaller car.

CO_2/energy label for passenger cars
Directive 1999/94/EC mandates the use of a visible fuel economy label on passenger cars at the point of sale. Since smaller cars are more fuel-efficient than large cars this may provide consumers an incentive to buy a smaller car.[21] As mentioned before, the effectiveness of labelling is expected to be small.

Moreover, IEEP et al. (2006) suggest that car buyers go through a two staged process: in a first step, they decide about the type of car they intend to purchase, i.e. a station wagon or a micro-car; in a second step, they decide which car they will chose, based on secondary criteria such as fuel efficiency and environmental criteria. This would imply that the information provided by the label (fuel efficiency) is not used by consumers when deciding on the size of their car and hence that labels are not effective in stimulating people to buy a small car[22].

Although fuel economy labels for passenger cars have probably no significant impact on purchase decisions of consumers, AEA et al. (2010) suggest that where the labels are used as part of a package of measures (e.g. linking vehicle taxes directly to the label's categories), there are likely to be potential synergies. Ecorys (2011) mentioned that in the Netherlands the labels did affect the purchase of business cars. Due to considerations on sustainable entrepreneurship, companies, for example, restricted the employee's choice in company cars to vehicles with an A, B, or C label (the most fuel-efficient ones).

Providing data via independent websites or guides
The internet is one of the main sources of information for people intending to buy a new car (Lane and Potter, 2007). They are especially using manufacturers' and independent websites to inform themselves. Therefore, Ecologic et al. (2010) suggest that providing clear information on vehicle characteristics, including fuel efficiency and CO_2 emissions, of all car models on an independent website might be an effective way to provide information to the car buyers. On such a website consumers may also be informed on the long-term fuel cost savings of fuel-efficient (small) cars (overcoming the consumer myopia on fuel cost, see Section 4.3.1). This information could also be provided in consumers' guides. No empirical evidence was available on the effectiveness of this type of information dissemination.

Providing information via the sales persons
As for electric and plug-in hybrid cars, training of sales persons may help to convey environmental and cost related information at the point of sales. Providing information on the environmental performances and fuel cost factors of small and large cars via these persons to consumers may be an effective strategy. No information was available on the effectiveness of this type of information dissemination.

21 Notice that this is only the case with regard to an absolute label. Absolute labels provide data on the absolute emission level of vehicles. Relative labels, on the other hand, provide information on the emission levels of cars of the same category (i.e. size or type). As a result, cars are asses in relation to factors other than emissions, and across a spectrum of vehicles. A large car may still receive a 'good' label and a small car a 'bad' label, depending on how they compare to cars in their category. Such system would not provide an incentive to buy a smaller car. On the moment, only in the Netherlands and Germany a (partly) relative label is used.

22 This was the reason for the Dutch government to choose for a (partly) relative label instead of an absolute one.

Mass communication
National information campaigns may be used to inform consumers on the advantages of small cars. These campaigns may also be used to influence the (social) norm with regard to the size of the car (as mentioned in Section 4.3.1 social norms may be a barrier for buying smaller cars), for example by using a famous person as a role model. As mentioned in Section 4.2.3 evidence on using information campaigns to use car purchasing behaviour is not available. However, from experiences with these kind of campaigns in general it is expected that its main value are in the supportive and intensifying role this instrument may provide to other policy initiatives.

Economic instruments
Several economic instruments could be applied to stimulate the purchase of smaller cars, including differentiated vehicle taxes, fuel taxes and differentiated road charges. These instruments will positively affect consumers' attitudes and social norms with respect to the purchase and use of smaller cars by enlarging the financial benefits associated to these cars. Particularly economic instruments directly affecting purchase prices will probably be effective.

Differentiated vehicle taxes
In most European countries purchase/registration taxes and circulation taxes have to be paid for passenger cars. By differentiating these taxes to the size, weight or CO_2 emission factors of the cars, the purchase of smaller cars could be stimulated (AEA et al., 2010; ECMT, 2007; Ekins and Potter, 2010). Differentiated purchase taxes are probably a more effective instrument to stimulate the purchase of smaller cars than differentiated circulation taxes (CE, 2008c; TiS, 2002), since only the former has a direct impact on the purchase price of cars; as we saw in Section 4.2.1, initial costs have a bigger impact on peoples buying decision that costs occurring over the life-time of the vehicle (due to the consumer myopia).

In various European countries differentiated purchase taxes have been implemented in the last years. ADAME (2009) performed an ex-post evaluation study of a bonus malus system for car sales in 2008. In the French system a bonus is paid for fuel-efficient vehicles (less than 130 g/km, with the bonus declining in line with CO_2 emissions per km), while on fuel-inefficient vehicles (> 160 g/km) a penalty is levied (increasing in line with CO_2 emissions per km). In the period January 2008–September 2008 the average CO_2 emissions of new passenger cars in France declined by about 6% due to this tax instrument.
CE (2009) found that a differentiation of the purchase taxes in the Netherlands could result in up to 8% lower CO_2 emissions of passenger cars, of which ca. 40% is due to the purchase of smaller cars[23].

As mentioned above the impact of differentiated circulation taxes on the purchase of smaller cars is expected to be significantly lower than the impact of differentiated purchase taxes. For example, CE (2008c) states that the impact of such a tax instrument on the CO_2 emissions per kilometre of passenger cars would be rather small.

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[23] However, it should be mentioned that this is possibly an underestimation, since the full impact of this measure is probably not realized in about eight years, which was the period taken into account by CE (2009).

Fuel taxes
An increase of the fuel taxes provides auto users an incentive to buy a more fuel-efficient and hence smaller car. PBL and CE (2010) estimate, based on a thorough literature review, that the fuel price elasticity with respect to fuel use per kilometre is 0.1–0.15 for the short term and 0.3–0.4 for the long-term.[24] This behavioural response to a fuel price increase could be explained by two factors: 1) a more fuel-efficient car, and 2) the application of a more fuel-efficient driving style. Ricardo et al. (on-going) made the (not-so-cautious) assumption that the short term impact of fuel prices on fuel efficiency (per km) could be fully allocated to driving behaviour and that the short term effect on driving behaviour is almost equal to the long-term impact. This would imply that the long-term impact of a fuel tax increase that leads to a fuel price increase of 10% would result in a 1.5 to 3% increase in the average fuel-efficiency of passenger cars. Part of this increase in fuel-efficiency is coming from a shift to smaller cars (and another part from a shift to more fuel-efficient cars from the same size).

Fuel tax policies are generally considered to be a cost-effective way to reduce the CO_2 impact of (road) transport (AEA et al., 2010). First, because this instrument influence a wide range of behavioural mitigation changes. Next to the incentive to buy a more fuel-efficient car, this policy instrument also provides incentives to drive less kilometres and apply a more fuel-efficient driving style. Second, the costs of implementing/changing this measure for the government are rather low.

Differentiated road charges
Finally, differentiated road charges (or tolls) could also have some impact on the car purchasing decision (AEA et al., 2010). Depending on the design the effectiveness of this instrument could be in line with that of increasing the fuel taxes.

Direct governmental expenditures
As for electric and plug-in hybrid cars, the government could set a good example by buying/using especially small cars by themselves. Although the direct mitigation potential of this instrument would be low, the symbolic value of it may be important (creating public acceptance for other types of policy instruments and on the long-term maybe changing attitudes and social norms with respect to smaller cars).

Procedural instruments
As for electric and plug-in hybrid cars, voluntary agreements with individual or groups of organisations to buy or lease only small cars could be concluded. For the organisations this could be a good way to show their responsibility with regard to sustainable entrepreneurship. By increasing the number of small cars on the road it may also affect peoples' attitudes and social norms with respect to smaller cars (particularly on the long-term). No evidence on the effectiveness of voluntary agreement with regard to the purchase of smaller cars is known. However, as mentioned before, on average the effectiveness of this type of environmental policy is expected to be low (OECD, 2003).

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24 A fuel price elasticity w.r.t. fuel use per kilometre of 0.15 means that a fuel price increase of 10% results in an increase of fuel efficiency of 1.5%.

Implementing policy packages

If the various policies are implemented in policy packages some interaction effects affecting the effectiveness of the individual instruments may occur. Some of the main interaction effects are:

- As for electric and plug-in hybrid cars, the various economic instruments (differentiated vehicle taxes, fuel taxes, road charges) may both reinforce and overlap each other, depending on the design of these instruments (see also Section 4.2.3). Therefore, combining these instruments in a policy package should be carefully considered.
- The various instruments related to communication will probably reinforce some of the other policy instruments. People with more knowledge on the impact of fuel efficiency on total cost of ownership are probably more willing to buy a smaller car than people without this knowledge.
- Investing in smaller cars for governmental agencies may, if visible to people, serve as a good example and may stimulate consumers to buy these kinds of cars themselves.

4.4 Applying a more fuel-efficient driving style

4.4.1 Barriers

An overview of the identified barriers for applying a more fuel-efficient driving style is shown in Table 19. Most of the main barriers are individual (internal) barriers, indicating that people perceive that they should be able to apply a more fuel-efficient driving style, but (that some of them) are not willing to do that or don't know how to do that.

Table 19 Overview of barriers for applying a more fuel-efficient driving style

Barrier category	Examples
Individual (internal) barriers	
Social and psychological barriers	– Some drivers like to apply an aggressive (non-fuel-efficient) driving style – Driving behaviour is habitual and therefore difficult to change
Knowledge-based barriers	– Gathering information on fuel-efficient driving is perceived difficult – Many drivers already think they drive well and do not realise the potential for improvement – Drivers do not know exactly how to apply the tips and tricks for fuel-efficient driving
Societal (external) barriers	
Structural and physical barriers	– The application of a fuel-efficient driving style may be hindered by traffic conditions – Some car types are more suitable to apply a fuel-efficient driving style
Cultural barriers	– Peer group pressure to apply an aggressive (non-fuel-efficient driving style)
Economic barriers	
Institutional barriers	

Social and psychological barriers

Applying a more fuel-efficient driving style is not in line with the preferences some car users have with regard to driving a car. As mentioned by various studies (e.g. Steg, 2005; Nilson and Küller, 2000) people like driving a car and some of them have a preference to drive fast and aggressive. This is emphasised by an ex-post evaluation study of a governmental programme to stimulate fuel-efficient driving in the Netherlands (Goudappel Coffeng and PWC, 2006). One of the results of the evaluation is that a significant number of people don't apply a fuel-efficient driving style because they prefer a more 'sporty' driving style.

Next to the fact that a fuel-efficient driving style is not the preferred way of driving a car for some people, also the fact that driving a car is a habitual behaviour (Hof, 2008; Van Vlierden, 2007) may be a barrier for applying a fuel-efficient driving style. The habitual character of driving a car may not only hinder the adoption of a fuel-efficient driving style, but is probably also the explanation for the fact that the long-term impact of fuel-efficient driving courses is smaller than the short-term impact (CE, 2007; TNO et al., 2006); due to the eco-driving course people change their driving behaviour, but over time they (partly) revert to their old behaviour.

Knowledge-based barriers

Based on research via focus groups and stakeholder interviews BarEnergy (2010) finds that identifying relevant information about more fuel-efficient driving was considered relatively difficult. At the same time, there is a clear lack of knowledge amongst car users about efficient driving practices and the potential fuel savings that could be achieved. Many car users think they already apply a fuel-efficient driving style, even if this is not the case. This suggests therefore that even if more information was readily available, there would be little demand for it. Finally, people do not understand all information provided to them, as becomes clear from an evaluation study on fuel-efficient driving programmes in the Netherlands (Goudappel Coffeng and PWC, 2006). Not understanding the (implementation of) tips and tricks of fuel-efficient driving was the main reason for people not adopting their driving style.

Structural and physical barriers

TNO et al. (2006) mention driving conditions in general and mainly traffic conditions as a barrier for a good application of a fuel-efficient driving style. For instance, other traffic may obstruct the fuel-efficient driver applying his driving style.

TNO et al. (2006) also mentions that some types of cars are more suitable to apply a fuel-efficient driving style than other ones. For example, diesel cars have a relatively high torque at low engine speeds and may thus be stimulating the low rev up-shifting (a way to drive more fuel-efficient) more than petrol cars would.

Cultural barriers

Although there is no specific empirical evidence found in the literature, it may be possible that peer pressure may be a barrier to applying a fuel-efficient driving style. In the literature much evidence is found on the impact of other people on driving style aspects applied by car users, like speeding (for an overview see Van Vlierden, 2007). Especially people actually present (passengers, other road users) do have significant impact on the driving style of people. It would be plausible that these people also influence the extent to which people apply a fuel-efficient driving style. Therefore peer group pressure may be a barrier to driving more fuel-efficient driving (but it may also be a stimulating factor if the peer group support this kind of driving style).

4.4.2 Consumer segments and diffusion patterns

Consumer segments

Studies on differences between consumers with regard to barriers to fuel-efficient driving are scarce. TNO et al. (2006) mentioned that especially car users already driving consciously are willing to apply a fuel-efficient driving style. Although sportive drivers may have the highest potential to reduce their fuel consumption, a fuel-efficient driving style will be less appealing to them (high social/psychological barriers) and so they may be less willing to accept and adapt their driving style. A third group of consumers identified by TNO et al. are the drivers that are not very well aware of the possibility to reduce fuel consumption by adapting their driving style, although in principle they are willing to reduce the costs and/or environmental burden. According to the authors this may be a large group, which may provide good opportunities for good results with regard to CO_2 reduction. However, no reliable figures are available as well as more information on the characteristics of this group of car users.

TNS NIPO (2006) studied the knowledge of and attitude to fuel-efficient driving in the Netherlands (based on a large scale survey). They found that a large majority of the people have a positive attitude to fuel-efficient driving. Only 4% of the men and 1% of the women declare that they judge fuel-efficient driving negatively. People also declare that they are quite well aware of the principles of fuel-efficient driving; men scoring on average higher than women. Additionally, men are more willing to receive further information on fuel-efficient driving than women. Another distinction made by TNS NIPO is between low- and high-educated people. On average, high-educated people are more positive on fuel-efficient driving and they have more knowledge on the issue (to their own opinion) than low-educated people. Finally, they are more willing to receive extra information on fuel-efficient driving. So it seems that the car users which provide larger reduction potentials are less willing to considerate an adoption of their driving style.

A group of car users mentioned by ECODRIVEN (2008) as a target group for policy making are company car users. Since especially firms are interested in cutting expenditures on mobility, they could stimulate their employees to apply a fuel-efficient driving style. ECODRIVEN (2008) mention some national projects (e.g. in Poland and the Netherlands) specifically targeted to these drivers. In addition, ECODRIVEN mention that people learning to drive a car are an interesting target group, which could be easily influenced by including eco-driving lessons into the regular driving lessons.

Diffusion patterns

As mentioned before, most barriers for applying a more fuel-efficient driving style are individual/internal, indicating that people perceive that they should be able to apply a more fuel-efficient driving style, but (that some of them) are not willing to do that or don’t know how to do that. Also the fact that driving behaviour is highly habitual is an explaining factor for people not changing their driving style.

These findings on the barriers for applying a more fuel-efficient driving style suggest that a strategy to stimulate this behavioural change should in the first place be focused on providing sound and reliable information to car users. This action could start immediately. At the same time car users should also be stimulated to really adapt the new driving style. Since driving a care is largely habitual this will take some time. Additional, the habitual character of driving a car also requires the implementation of rather coercive policy instrument. Only providing information will probably not be sufficient to change peoples driving behaviour. Therefore, other policy instruments are needed.

4.4.3 Policy instruments

An overview of policy instruments that could be used to stimulate the application of a more fuel-efficient driving style is shown in Table 20. In the remainder of this section we will first discuss the individual policy measures. Next, we will briefly discuss an effective policy package for the stimulation of a fuel-efficient driving style.

Table 20 Overview of policy instruments to stimulate the application of a more fuel-efficient driving style

Policy category	Examples
Regulative instruments	– Obligation to include eco-driving in driving lessons – Obligation to equip vehicles with ICT that facilitates eco-driving techniques
Economic instruments	– Subsidising eco-driving courses – Subsidising tools which assist a fuel-efficient driving style – Fuel tax or inclusion of transport in ETS
Communication	– Mass campaigns – Targeted information campaigns (e.g. driving schools, fleet managers) – Training of driving instructors
Direct governmental expenditures	– Eco-driving programs at governmental agencies
Procedural instruments	– Voluntary agreements with companies to apply eco-driving programmes (e.g. leasing companies) – Voluntary agreement with car manufacturers or dealers to provide a voucher for a eco-driving course to buyers of a new car

Regulative instruments

An effective policy measure is to require that eco-driving is included in all driving courses to new drivers. In Section 4.4.1 it became clear that the habitual character of peoples driving style is an important barrier for applying a fuel-efficient driving style. Since new drivers do not possess driving style habits, they are more easily affected by eco-driving courses than experienced drivers. The governmental costs of this policy instruments are limited and hence this instrument is likely to be very cost-effective.

Another regulative instrument that could be applied is the obligation to equip vehicles with ICT that facilitates eco-driving techniques. In this way car users are assisted by applying eco-driving tricks. In current regulation for new vehicles obligations for gear shift indicators and tyre pressure monitoring systems are already included. This could be expanded to other ICT applications like Eco-driver Assistance and Eco-driver Coaching (TNO, 2009).

Economic instruments

Various economic instruments could be considered to stimulate the application of a more fuel-efficient driving style. First, the government could provide subsidies for eco-driving courses (on-road training, eco-driving simulations) or ICT tools assisting the application of a fuel-efficient driving style (e.g. Eco-driver Assistance or Eco-driver coaching, see TNO (2009)). In this way car users' lack of knowledge on (the way to apply) eco-driving techniques (efficiently) could be overcome. The eco-driving courses may result in 5 to 25% (average 10 to 15%) lower fuel consumption figures directly after the course. Over time this mitigation potential may reduce to about 3% (TNO et al., 2006). A drawback of providing subsidies is that is carries the risk of many free riders, i.e. people enjoying the subsidy who would have chosen the technology/course either without subsidy. Therefore it is likely that the cost-effectiveness is lower for such subsidy schemes compared to other policy instruments for stimulating eco-driving.

Another type of economic instrument that could be applied is the increase of fuel taxes (or the inclusion of transport in EU ETS). Due to this instrument fuel prices will increase and hence this may provide car users an incentive to change their habitual driving style. Based on the discussion on fuel taxes in Section 4.3.3 we could say that a fuel tax raise that leads to a 10% higher fuel price, would probably result in 1 to 1.5% less fuel consumption due to a change in driving behaviour. As mentioned before, fuel taxes are seen as a very cost-effective way to reduce the CO_2 emissions of transport. Additionally, they are also a cost-effective way to stimulate the application of a more fuel-efficient driving style.

Communication

Information campaigns could be used to improve car user's awareness of fuel-efficient driving and teach them some of the eco-driving skills (and hence overcome knowledge-based barriers). Evaluation studies on a large-scale information campaigns on eco-driving in the Netherlands show that due to this campaign significantly more people were familiar with fuel-efficient driving than before the campaign (Goudappel Coffeng and PWC, 2006). People's awareness of the Dutch eco-driving program ('Het Nieuwe Rijden') increased in the period 2000-2006 from ca. 20% to ca. 75%. In addition, people familiar with 'Het Nieuwe Rijden' were known to significantly more of the eco-driving tricks than people not familiar with this program. Although the actual CO_2 reduction due to the information campaign is not separately estimated, it seems appropriate to assume that it had a significant effect, both in a direct and indirect (making people aware of the possibility to follow an eco-driving course) way.

Direct governmental expenditures

By applying eco-driving programmes (incl. eco-driving courses) at governmental agencies the government can act as a role-model as well as actually reducing the CO_2 emissions of road transport. If the government wants to set a (social) norm for fuel-efficient driving acting themselves in the desired way is an important prerequisite. It could be a cornerstone in gathering acceptability for other policy instruments to stimulate fuel-efficient driving (or more general: policies to reduce the climate impact of transport).

No evidence is found on the costs and effectiveness of governments applying eco-driving programmes at their own organisation. The size of the costs depends heavily on the design of the programme and on who receives the benefits of the reduced fuel costs (the government or the public servants). The latter depends on the way business travel is organised in the organisation (private car with fixed compensation per kilometre, company cars, etc.).

Procedural instruments
Voluntary agreements between the government and companies are another type of instrument to stimulate a more fuel-efficient driving style. The government could agree with companies (e.g. leasing companies) that they would provide eco-driving courses to their employees or clients (in case of leasing companies). Companies could be interested in these agreements because it could result in lower transport costs and a better (green) image. Reducing the knowledge-based barriers of the employees may also stimulate these people to apply the fuel-efficient driving style if driving another car than the company car.

No specific studies on the effectiveness of voluntary agreements with regard to fuel-efficient driving are known. However, as for the other behavioural transport changes, we expect a limited additional impact of this instrument on the application of a more fuel-efficient driving style by people.

Implementing policy packages
If the various policies are implemented in policy packages some interaction effects affecting the effectiveness of the individual instruments may occur. The main interaction effects are:
- Following an eco-driving course (as specific measure, as part of the driving lessons, as part of an eco-driving program at governmental agencies or as part of a voluntary agreement) and increased fuel taxes (or inclusion of transport in ETS) will reinforce each other. The increase in fuel taxes provides car users an incentive to actually apply the fuel-efficient driving style learnt during the course.
- Providing information (via mass or targeted campaigns) to consumers on applying a more fuel-efficient driving style may have a positive interaction with the economic instruments. If people are aware of fuel-efficient driving, they are more willing to follow a subsidised eco-driving course. Additionally, awareness of fuel-efficient driving (tricks) increase the probability that people would apply such a driving style if fuel prices increase due to increased fuel taxes.
- Providing information may also be a good way to reinforce the driving style learnt during an eco-driving course. Therefore, positive interaction effects may exist between providing information and following an eco-driving course (also if included in the regular driving lessons).
- Eco-driving programs at government agencies may, if visible, stimulate car users to follow an eco-driving course themselves or apply the driving style learnt during an eco-driving course.

The obligation to include eco-driving in regular driving lessons may on the long-term negatively affect the effectiveness of providing specific eco-driving courses to car users. The effectiveness of an eco-driving course will be lower if the fuel-efficient driving style has already been learnt in the past. However, the eco-driving course may also act as a ‘reminder’ and hence reinforce the effectiveness of the inclusion of eco-driving in the regular driving lessons.

4.5 Teleworking and applying virtual meetings

4.5.1 Barriers

In this section we will separately discuss the barriers for teleworking and applying virtual meetings.

Teleworking

In Table 21 an overview of the barriers to teleworking is given. The main barriers for teleworking are the social/psychological and institutional ones.

The social/psychological barriers refer to people's perceptions of the drawbacks of teleworking: social isolation, tendency for overworking, adverse impacts on career, mixing up private and professional life, etc.

The institutional barriers are related to the resistance of organisations and direct managers to allow their employees to work at home. Reasons for this resistance are concerns on the productivity of employees, security issues, adverse impacts on teambuilding, etc.

Table 21 Overview of barriers to teleworking

Barrier category	Examples
Individual (internal) barriers	
Social and psychological barriers	People may prefer to work not at home (permanently) due to: – Fear for social isolation – Tendency for overwork – Fear for adverse impacts on employees' careers – Stress due to more autonomy – Unwanted mixing of work and private life
Knowledge-based barriers	
Societal (external) barriers	
Structural and physical barriers	– Availability of ICT equipment and Internet connection
Cultural barriers	– Social norm against teleworking
Economic barriers	–
Institutional barriers	– Lack of support from organisation and direct manager

Social and psychological barriers

A significant share of the people already employed is interested in teleworking. Gareis (2003) shows that in 2002 about 64% of the persons employed in Europe are interested in any type of teleworking. About 40% of the persons employed are interested in permanent home-based telework. For unemployed people these percentages are larger: 76 and 55% respectively. Since teleworking has become more common the last years, it seems likely that the current percentages of interested people in teleworking are even larger.

Although a significant share of the people is interested in teleworking, there are also people who don't want to work at home. Especially permanently teleworking is not preferred by a significant share of the employees.

There are several reasons for this negative attitude against (permanently) working at home:

- *Social isolation;* the social aspects of work can be major inducements to go to the office. Therefore, a psychological barrier identified in the literature is the possible social isolation of teleworkers (Stough and Button, 2006; Tikka, 2009). This may especially be a barrier for working at home for the main part of the week.
- *Tendency to overwork;* teleworkers tend to work more hours than people not teleworking (CE, 2007; Sustel, 2004). A possible explanation for this observation is that people feel a pressure to justify for the fact that they are working at home. However, this tendency may be a barrier for people to (continue) teleworking (Hori and Ohashi, 2004; Tikka, 2009).
- *Fear for adverse impacts on employees' careers*; the fear of lack of progression and promotion within the organisation as seen as another barrier to adopt teleworking (Blakemore, 2003; Gani and Toleman, 2006). Also a perceived status loss is mentioned as a barrier to teleworking (Perez et al., 2002).
- *Stress due to more autonomy employee;* teleworking requires more autonomy of the employee and hence the complexity of their jobs increases. The teleworker has to acquire a greater level of discipline as well as a broader set of skills compared to traditional workplace-based jobs. For some teleworkers this may result in more work-related stress (Hori and Ohashi, 2004; Stough and Button, 2006).
- *Unwanted mixing of work and private life;* the boundary between work and private life becomes less strict if teleworking (Tikka, 2009). Moreover, interference with family members during work-time may reduce people's working efficiency (Hori and Ohashi, 2004; Stough and Button, 2006).

Institutional barriers

A lack of support for teleworking from the organisation and especially the direct manager is the barrier most often mentioned in the literature (AVV, 2004; Economist Intelligence Unit, 2008; Gareis, 2003; Peters and Heusinkveld, 2010; Peters and Den Dulk, 2003). For example, Ecofys (2009) show that for about 20% of the people who indicate that their job is not feasible for teleworking resistance of the company and/or manager is (one of) the barrier(s).

The resistance of organisations to teleworking may be based on various fears, ranging from the loss of perceived benefits of face-to-face contact to the costs of providing home-workers access to the organisation network (Economist Intelligence Unit, 2008; Perez et al., 2002; Stough and Button, 2006; Tikka, 2009). Also concerns with potential loss of worker productivity, security concerns and perceived threats to the organisational culture are mentioned as possible explanations for the organisational resistance to teleworking.

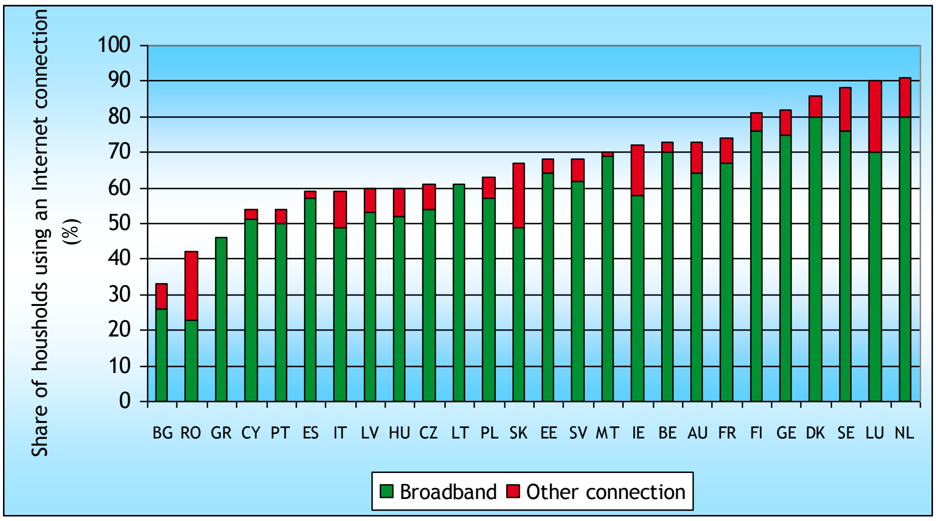
Next to these more general organisational concerns, managers also have their own specific reasons to resist teleworking (Peters and Den Dulk, 2003). First, managers may not like the uncertainty related to his employees working at home. The centralised work arrangement allowed managers to coordinate, motivate and control employees' work effort directly. When people work at home this direct monitoring of people becomes more complicated, if possible at all. So, managers lose some of their control over their employees. Second, teleworking requires that employees become more autonomous and hence that some of the power of managers is delegated to his subordinates. As a consequence, managers may fear a loss of relevance of their own function and hence some of their power and status. Third, managers may fear that their own tasks become more complicated, since he have to coordinate and control employees' work more indirectly.

Research shows that both organisational and national cultures may influence managers' (and organisations') perceptions to teleworking (Gareis, 2003; Peters and Heusinkveld, 2010; Peters and Den Dulk, 2003). Peters and Den Dulk (2003), for example, assume that national differences in telework intensity can be explained in differences in power distance and uncertainty avoidance. Power distance refers to the boss-subordinate relationship. Large power distance implies high centralisation of power among few people and hence (vertical) hierarchical organisations. Small power distances, on the other hand, imply more decentralised organisations with flat organisational structures. Since home-based teleworking implies more autonomy for the employee, this type of working structure seems more suited for organisations and/or cultures with small power distances. Additionally, organisations/cultures with a weak uncertainty avoidance seems more appropriate for teleworking than organisations/cultures with strong uncertainty avoidance.
Peters and Den Dulk classify countries as the Netherlands, UK and the Scandinavian countries as having small power distances and weak uncertainty avoidance. These are also the European countries with the highest shares of teleworkers. On the other hand, European countries with low shares of teleworkers, like Spain and Italy, are also characterised as having large power distances and strong uncertainty avoidance.

Cultural barriers
As mentioned by Gani and Toleman (2006) social norms may be a barrier for teleworking. Envious colleagues, suggesting that teleworkers were not doing 'real' work, may discourage employees to start or continue teleworking. This norm against teleworking will be more coercive if not all employees are allowed to work at home.

Structural and economic barriers
In literature from the nineties and the beginning of this century a lack of ICT technologies was sometimes mentioned as a barrier for teleworking. However, according to Peters and Van der Lippe (2004) technology does not longer seem to be a constraining factor to the application of teleworking due to technological innovations. This seems to be confirmed by figures from European Commission (2011b), which show that the broadband IT infrastructure coverage in the EU is about 95% in 2010. However, this figure also means that still around 23.5 million EU citizens cannot yet connect to a fixed access broadband network, many of them living in rural areas in Poland, Bulgaria and Slovakia. Moreover, not all people having access to the Internet do actually have a connection, as is shown in Figure 10. A significant part of these people do not use the Internet due to economic reasons (high costs of ICT equipment and Internet connection).

Figure 10 Share of households (%) using a internet connection for the various Member States in 2010



Source: Eurostat (2010).

Note: For the UK no data was available on the share of households using a broadband internet connection. Therefore, we didn't include the UK in the figure. Data was available on the share of households having connection to the Internet in the UK in 2010, which was 80%.

Applying virtual meetings

In Table 22 an overview of barriers to applying virtual meetings is presented. The main barriers exist at both the individual as societal level.

At the individual level, people's perception that virtual meetings are a poor substitute for physical meetings is a main barrier. Especially for meetings meant to exchange non-tangible values like trust or trust people often perceive virtual meeting as inappropriate.

At the societal level, the main barrier refers to the institutional context. Organisations/managers resistance to allow their employees applying virtual meeting is an important barrier for this behavioural change.

Table 22 Overview of barriers to applying virtual meetings

Barrier category	Examples
Individual (internal) barriers	
Social and psychological barriers	– Virtual meetings are in some cases perceived as poor substitutes for physical meetings – People prefer to meet people in real – Business trips are seen as advantages of a job
Knowledge-based barriers	– Lack of knowledge how to use sophisticated equipments – Lack of knowledge how to apply virtual meeting in an efficient way
Societal (external) barriers	
Structural and physical barriers	– Availability but especially quality of equipment is not always sufficient
Cultural barriers	– Cultural resistance to change current way of organising meetings
Economic barriers	– Relatively high cost for sophisticated videoconferencing equipment, especially for small and medium sized organisations
Institutional barriers	– Applying virtual meetings is not supported by the organisation and direct managers

Social and psychological barriers

Virtual meetings are sometimes seen as poor means of communication which cannot capture important non-verbal aspects of a meeting (Ecofys, 2009; Ministry of the Environment, 2001; WWF, 2009). Economist Intelligence Unit (2008) mentions the loss of the benefits of face-to-face contact as the most important barrier for substituting physical meetings by virtual ones. Especially for meetings like kick-off meetings which provide intangible values as trust, confidence and interest, virtual meetings are seen as a worse substitute for physical meetings. This will especially be the case if it concerns a meeting between agents who don't share a common social, cultural and linguistic background (Ministry of the Environment, 2001). Virtual meetings are also seen as unsuitable for making new contacts and acquaintances.

Other social/psychological barriers may be related to the fact that people like to meet other people in real and they will miss the human contacts in case of virtual meetings (Ecofys, 2009). Moreover, virtual meetings are often seen as tiresome and hence are best suited for shorter meetings (Ministry of the Environment, 2001).

Finally, Andriessen (2007) and Arnfalk (2002) mention that employees see business trips as a 'perk' of their job. One has the opportunity to see other places and to benefit from frequent fly schemes. Therefore, these people would resist to a large-scale substitution of physical meetings by virtual ones.

Knowledge-based barriers

Especially in small and medium sized firms the knowledge to apply sophisticated communication equipment, especially with regard to videoconferencing, may not be available (Ecofys, 2009).

Additionally, Economist Intelligence Unit (2008) mentioned employees' lack of training in how to conduct virtual meetings efficiently as a potential barrier for applying virtual meetings.

Structural and physical barriers

Structural barriers are related to the availability and quality of virtual meeting equipment. Due to the significant expansion and enhancement of IT infrastructure over the last decade, equipment for audio-, web- and videoconferencing are easily available for most workers. However, according to WWF (2009) room-based videoconferencing facilities, providing the highest quality of virtual meetings, are only available in some major business hubs or within multinationals. Additionally, Ecofys (2009) state that in emerging economies and developing countries also the availability of 'normal' IT infrastructure is still inadequate (lack of bandwidth, security, etc.), which may be a barrier especially for multinationals operating in these countries to use IT applications for internal meetings.

Next to the availability of virtual meeting equipment also its quality is sometimes mentioned as a barrier for applying virtual meetings (Economist Intelligence Unit, 2008; WWF, 2009). For example, about 37% of the surveyed business executives by Economist Intelligence Unit state that inadequacy of videoconferencing technology is seen as a primary factor limiting the use of virtual meetings.

Cultural barriers

According to Ecofys (2009) cultural barriers may also limit the adoption of virtual meetings, as changes in 'the way business is done' may be seen as unneeded or inappropriate. Further evidence on these kinds of barriers was not found in the literature.

Economic barriers

According to Ecofys (2009) there may also be economic barriers for the application of virtual meetings. This is especially the case with videoconferencing. Despite the substantial decrease in the costs of needed equipment, this technology still requires, in order to achieve high performances, an initial investment that small and medium businesses cannot afford.

Institutional barriers

Organisational resistance to allow their employees applying virtual meetings is sometimes a barrier to this behavioural change. Economist Intelligence Unit (2008) finds that 14% of the business executives surveyed by them sees virtual meetings as a threat to the organisation culture. Organisations/managers also fear that virtual meetings may harm their employees' efficiency in meetings.

4.5.2 Consumer segments and diffusion patterns

The relationship between barriers and consumer segments as well as diffusion patterns will again be discussed separately for teleworking and virtual meetings.

Teleworking

According to Hori and Ohashi (2004) psychological barriers are more important for women than for men. In a survey on benefits and disadvantages of teleworking, women are more likely than men to report the disadvantages. For example women states more often that teleworking leads to less time for a private life (34% of the women and 23% of the men). The larger mental stress teleworking provides women compared to men is explained by the fact that the burden of the family falls disproportionally on the woman, which is only enhanced when women works at home and hence are more often available for their family members. No information was found on the relationship between psychological barriers and age or education level of the employee.

With regard to institutional barriers to teleworking, evidence is found that organisations and direct managers tend to allow knowledge-intense workers with a high degree of autonomy to work at home (Peters and Den Dulk, 2003). For these types of jobs little need for direct supervision and face-to-face contact is needed. For the same reason workers which output can be easily measured are likely to have access to telework. Also status and experiences of the workers are affecting their opportunities on approval for teleworking. For that reason, clerical workers are expected to face greater opposition from the management to telework than professionals. In addition, the lower educational level of clerical workers may also be a signal for the manager that the person is less able to obtain the necessary skills to work successfully at home (Blakemore, 2003). Finally, as mentioned before, also cultural factors are influencing organisational opposition to teleworking, indicating that in Northern European countries employees are more allowed to telework than in Southern European countries.

Diffusion patterns

The main barriers to teleworking are related to individual attitudes to teleworking and especially organisational norms with regard to teleworking. Both types of barriers are rather consistent over time and hence take some time to change. Therefore, long-term policy instruments are needed to tackle these barriers.

Applying virtual meetings

No information on the relationship between the barriers to applying virtual meetings and employees characteristics was available in the literature.

Like for teleworking, individual attitudes and organisational norms are the main barriers for applying virtual meetings. As mentioned before, these types of barriers are consistent over time and hence take some time to change. Long-term policy instruments are needed to tackle these barriers.

4.5.3 Policy instruments

In this section we discuss policy instruments that could be used to stimulate teleworking and applying virtual meetings. We will discuss the policy instruments for both behavioural changes separately.

Teleworking

An overview of relevant policy instruments with regard to teleworking is given in Table 23.

Table 23 **Overview of policy instruments to stimulate teleworking**

Policy category	Examples
Regulative instruments	– Developing a regulatory framework concerning the employment conditions of teleworkers – Developing a regulatory framework enabling and stimulating investments in broadband IT infrastructure
Economic instruments	– Subsidies for necessary (ICT) equipment – Subsidies for home energy bills – Tax credits for companies reducing their employees' commuting kilometres due to teleworking – Innovation subsidies – Fuel taxes and road use charges
Communication	– Communicate best practices teleworking to employees and employers – Communicate the direct link between GHG reduction and teleworking – Providing training assistance
Direct governmental expenditures	– Providing civil agents the possibility to work at home
Procedural instruments	– Voluntary agreements with companies to stimulate and facilitate teleworking

Regulative instruments

Since the feasibility to perform a job at home depends heavily on the characteristics of the job, regulation obliging certain rates of teleworking is probably not appropriate. However, regulative measures could be used to provide a framework concerning the employment conditions of teleworkers. In this way teleworkers could be provided the same overall level of protection and rights as workers who carry out their activities at the employers premises, which could improve employees' attitude with respect to teleworking.

In 2002 several European social partners[25] concluded on the so-called European Framework Agreement on Telework (ETUC et al., 2002). Some of the issues taken into account in the framework are:

- *Voluntary nature of teleworking*: telework is voluntary for the worker and the employer concerned. Telework may be required as part of a worker's initial job description or it may be engaged in as a voluntary arrangement subsequently.
- *Employment conditions*; teleworkers benefit from the same rights as comparable workers at the employer's premises.
- *Privacy*; the employer respects the teleworker's privacy.
- *Training of teleworkers;* teleworkers have the same access to training and career development as comparable workers at the employer's premises and are subject to the same appraisal policies as there co-workers.
- *Organisation of work;* the workload and performance standards of the teleworker are equivalent to those of comparable workers at the employer's premises.

Although this agreement has a voluntary character, some countries (e.g. Czech Republic, Hungary) chose to implement the European Framework Agreement through national legislation, while other countries chose to implement the agreements through bipartite collective agreements (e.g. Germany, France) or

25 The European Trade Union Confederation (ETUC), BusinessEurope (formerly UNICE), the European Union of Crafts and Small and Medium-Sized Enterprises (UEAPME), and the European Centre of Enterprises with Public Participation and of Enterprises of General Economic Interest (CEEP).

voluntary arrangements (e.g. Sweden, the Netherlands). Finally, in some countries (e.g. Bulgaria, Estonia) there has been no implementation at all. Since legislation and collective agreements provide the most certainty for teleworkers, implementing such arrangements on a larger scale in Europe may stimulate the uptake of teleworking.

In addition, national governments may stimulate and enable the extension of broadband IT infrastructure, such that more enhanced and quicker internet connections are possible. In this way the structural barrier of an inadequate ICT infrastructure may be overcome.

Economic instruments

Various economic instruments could be used to stimulate teleworking. First, subsidy schemes (or tax discounts) related to (ICT) equipment needed to work at home could be provided to employers. These schemes, which could contribute to overcoming structural barriers of an inadequate ICT infrastructure, (partly) finance the equipment which can be used by employees to work at home. Several examples of subsidy schemes related to telework equipment are known for European countries. For example, in Sweden the PC tax reform of 1998 allows companies to purchase computers tax free and sell them to employees. This scheme was very successful, resulting in a fast increase of PC ownership in Sweden (Derk Halden Consultancy, 2006). Since the ownership of computers has increased highly over the last decade, the added value of this type of subsidy scheme has decreased.

Subsidies (tax discounts) could also be related to home energy bills for those working at home, improving employees' attitudes to teleworking. Some experiences with these kinds of subsidies are known from the US, but quantitative figures on their effectiveness are not available (Derk Halden Consultancy, 2006). Also schemes offering companies tax credits if the commuting kilometres of their employees decrease due to teleworking could stimulate teleworking. These types of schemes are in place in some American cities, but no effectiveness figures are known.

Innovation subsidies meant to improve teleworking solutions and tailor them to the needs of specific sectors are another example of subsidy schemes that could be implemented to stimulate teleworking (Ecofys, 2009). No evidence on the effectiveness of these schemes is available.

Next to the various subsidy schemes, which enhance the possibility and attractiveness of teleworking (pull factor), also taxes and charges that discourage commuting travel could be used to stimulate teleworking (push factor). Both increasing fuel taxes and implementing/increasing road use charges could be used to improve peoples' attitude to teleworking by making working at the employer's office less attractive. No specific effectiveness figures for these instruments with regard to stimulating teleworking are available[26].

[26] There are fuel price elasticities available with respect to commuting kilometres by car. However, these elasticities cover also behavioural changes like using other transport modes.

Communication

To overcome the resistance of organisations and direct managers to teleworking (institutional barrier), the government could provide information on best cases using examples of organisations that are successful at implementing teleworking (Ecofys, 2009). Facts about the impact of teleworking on employees' absenteeism, motivation and performances could be provided as well as information on the realised savings in office space and parking lots (AVV, 2003). Finally, clear communication on the direct link between teleworking and GHG emission reduction may provide an additional incentive to companies (based on their sustainably entrepreneurship) to provide their employees the opportunity to work at home (Ecofys, 2009). No empirical evidence of the effectiveness of these kinds of information campaigns related to teleworking are available.

Communication tools could also be applied to improve employees' attitude to teleworking. As mentioned in Section 4.5.1 employees may judge teleworking negatively due to fears for social isolation and adverse impacts on careers. By providing information on the experiences of employees already teleworking such fears may be overcome. Preferably experiences of co-workers would be used, implying that organisation specific communication plans should be developed. A second-best approach would be to apply sector or nationwide information campaigns. No empirical evidence of the effectiveness of these kinds of information campaigns related to teleworking are available.

Next to providing information, the government could also support small and medium sized businesses by providing training assistance to help them successfully implement teleworking (The Climate Group, 2008).

Direct governmental expenditures

As for the other behavioural changes, the government could set a good example by providing their employees to work at home on a regular basis (Ecofys, 2009). Since many of the government workers are so-called knowledge workers, (part-time) teleworking should be possible for a large share of them. In addition, the government could even consider requiring or encouraging government contractors to adopt flex work initiatives. Although the direct mitigation potential of this instrument would be low, the symbolic value of it may be important (increasing public acceptance for other policy instruments and improving employees' attitudes and social norms with respect to teleworking). For the latter, it is important to communicate on the governmental teleworking program and progress on a large scale.

Procedural instruments

By entering into voluntary agreements with companies, the government could stimulate teleworking at these companies. As for the other behavioural transport changes the direct impact of this policy instrument is expected to be low. However, if the voluntary agreements are concluded with groups of companies, these agreements may provide a useful platform to exchange information on teleworking and improving employers' and employees' attitudes with respect to teleworking.

Implementing policy packages

If you would like to implement a policy package, based on the individual instruments described above, to stimulate teleworking information on possible interaction effects is useful. Therefore we briefly discuss the main interaction effects between the various individual policy instruments:

- The various regulative instruments are just meant to provide an environment in which teleworking could be applied more easily. Therefore these instruments only provide positive interaction effects with other instruments. For example, higher fuel taxes will result in higher teleworking rates if there is a favourable regulatory framework on the employment conditions of teleworkers.
- Also the instruments related to communication reinforce most of the other instruments. Voluntary agreements would, for example, be more effective if employees of organisations taking part in these agreements are aware of the individual benefits associated with teleworking.
- As for some of the other behavioural changes, some of the economic instruments (affecting the same agents) may both reinforce and overlap each other (for a discussion see Section 4.2.3). Therefore, combining these instruments (e.g. increasing fuel taxes and subsidies for home energy bills) in a policy package should be considered carefully.
- Providing civil agents the opportunity to work at home may, if visible to other workers, serve as a good example to other organisations and employees and hence may reinforce the various other instruments.

Applying virtual meetings

An overview of the policy instruments to stimulate the application of virtual meetings is shown in Table 24.

Table 24 Overview of policy instruments to stimulate the application of virtual meetings

Policy category	Examples
Regulative instruments	– Developing a regulatory framework enabling and stimulating investments in broadband IT infrastructure
Economic instruments	– Subsidies for virtual meeting equipment – Tax credits for companies reducing their employees' commuting kilometres due to teleworking – Innovation subsidies – Fuel taxes, road use charges, charges for rail and air transport
Communication	– Communicate best practices to employees and employers – Communicate the direct link between GHG reduction and teleworking – Providing training assistance
Direct governmental expenditures	– Providing civil agents the possibility to apply virtual meetings
Procedural instruments	– Voluntary agreements with companies to apply virtual meetings

Regulative instruments

National governments could stimulate and enable the extension of broadband IT infrastructure, such that more enhanced and quicker internet connections are possible (Ecofys, 2009). In addition, standardisation of virtual meeting equipment may be needed to make connection between various types op equipment possible. These measures may contribute to overcoming psychical barriers to applying virtual meetings.

Economic instruments

Subsidy schemes (or tax discounts) could be used to stimulate the investments of organisations in virtual meeting equipment. As mentioned in Section 4.5.1 high investment costs are perceived as important barriers for organisations to install this equipment. Subsidies could be used to partly finance the investment costs. As for teleworking also schemes offering companies tax credits if the business kilometres of their employees decrease due to applying virtual meetings could stimulate this behavioural change (Derk Halden Consultancy, 2006). Finally, innovation subsidies could be used to improve virtual meeting solutions and tailor them to the needs of specific sectors (Ecofys, 2009). No evidence is available on the effectiveness of these kinds of subsidy schemes.

In addition to subsidy schemes also taxes and charges that discourage business trips could be used to stimulate the application of virtual meetings. Increasing fuel taxes, road user charges and charges for rail and aviation may provide companies/business travellers an incentive to apply a virtual meeting instead of a physical meeting. Both the attitude of employees and employers with respect to virtual meetings (social and institutional barriers) may be affected by these economic instruments. No specific effectiveness figures for these instruments are available.

Communication

To overcome the resistance of organisations and direct managers to applying virtual meetings (institutional barriers), the government could provide information on best cases using examples of organisations that are successful at implementing virtual meetings (Ecofys, 2009). Facts about the technical quality of virtual meetings and employees' effectiveness in these meetings could be provided. Finally, clear communication on the direct link between teleworking and GHG emission reduction may provide an additional incentive to companies (based on their sustainably entrepreneurship) to provide their employees the opportunity to apply virtual meetings (Ecofys, 2009). No empirical evidence of the effectiveness of these kinds of information campaigns related to teleworking are available.

Communication tools could also be used to improve employees' attitude to applying virtual meetings, e.g. by providing information on experiences of participants in virtual meetings.

Next to providing information, the government could also support small and medium sized businesses by providing training assistance to help them successfully implement virtual meetings into their organisation (The Climate Group, 2008). Also training of employees to apply virtual meeting in an effective way could be useful.

Direct governmental expenditures

As for the other behavioural changes, the government could set a good example by providing their employees the possibility to apply virtual meetings. This policy instruments is especially important for its symbolic value (increasing public acceptance for other policy instruments and improving peoples' attitudes and social norms with respect to virtual meetings).

Procedural instruments

As for teleworking, voluntary agreements with companies may be an instrument to stimulate the application of virtual meetings. However, the direct impact of this instrument is expected to be limited. If more companies are involved into these agreements, useful platforms for exchanging knowledge and experiences may be created and hence employers' and employees' attitudes with respect to virtual meetings may improve.

Implementing policy packages

If the various policies are implemented in policy packages some interaction effects affecting the effectiveness of the individual instruments may occur. The main interaction effects are:

- The stimulation of the improvement of ICT infrastructure (regulative instrument) is meant to provide an environment in which virtual meetings could be applied more easily. Therefore this instrument only provide positive interaction effects with other instruments.
- As for teleworking, the instruments related to communication reinforce most of the other instruments.
- As for teleworking, some of the economic instruments (affecting the same agents) may both reinforce and overlap each other (for a discussion see Section 4.2.3). Therefore, combining these instruments in a policy package should be considered carefully.
- Providing civil agents the opportunity to apply virtual meetings may, if visible to other workers, serve as a good example to other organisations and employees and hence may reinforce the various other instruments.

5 Abatement potential and costs of policy packages

5.1 Introduction

Based on the analysis of barriers and policy instruments in Chapter 4 we composed, in close agreement with the Commission, policy packages for two mobility related behavioural changes: buying and using smaller cars and teleworking. In this chapter we assess the effectiveness – in terms of decarbonisation potential – and implementation costs of these policy packages. For both behavioural measures we will first discuss the composition of the policy packages, including the EU relevance and EU policy competences of these packages. Additionally, the way the policy package addresses the (main) barriers identified in Chapter 4 will be discussed. Next, the abatement potential and implementation costs will be discussed.

5.2 Buying and using smaller cars

5.2.1 Policy package

The policy package to stimulate consumers to buy and use smaller cars consists of five policies:

1. A CO_2 differentiated purchase tax

Due to the significant correlation between CO_2 emissions and car size, a CO_2 differentiated purchase tax provides a strong (financial) incentive to consumers to buy a smaller car[27]. In order to stimulate consumers to buy smaller cars a purchase tax differentiated to absolute CO_2 emissions will probably be more effective than a purchase tax differentiated to relative CO_2 emissions (CO_2 emissions compared to cars from the same size), since the latter system doesn't provide an incentive to buy smaller cars. Finally, since setting the actual tax levels (and hence the revenues to be raised by the tax) is mainly a responsibility of the individual Member States, we assume a revenue neutral design of the CO_2 differentiations of the purchase tax.

At the EU level there are hardly any provisions regarding passenger car related (fixed) taxes. However, in 2005 the Commission presented a proposal for a directive on this issue, intending, among other things, to introduce CO_2 differentiation in national passenger car taxes on a European scale (European Commission, 2005). This proposal prescribes that Member States would differentiate their passenger car related taxes to CO_2 and that the total revenue from the CO_2 based element of the taxes shall account for a specific part of the total revenue from these taxes.

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[27] A purchase tax differentiated to the size of the car would provide an even larger incentive to consumers. However, since a differentiation to CO_2 is more effective from a broader perspective (since it also stimulates consumers to buy more fuel-efficient cars from the same size), CO_2 is chosen as the differentiation base for the purchase tax in this study.

This element of the proposal provides a good example of ways for the European Commission to stimulate the purchase of smaller cars via CO_2 differentiated purchase taxes[28].

2. A CO_2 differentiated company car tax
A company car tax differentiated to the absolute[29] CO_2 emissions of the car provides employees an incentive to choose a smaller car. Since most of the company cars become part of the private car fleet after some years, this policy instrument also (indirectly) affects the CO_2 impact of private car users. As for the CO_2 differentiated purchase tax, we assume a revenue neutral implementation of the CO_2 differentiated company car tax.

It should be mentioned that, from a welfare economic point of view, the taxes on (private use of) company cars in Europe are too low (Copenhagen Economics, 2010). In other words, the various Member States provides implicit subsidies to company car drivers (see Box 1). These implicit subsidies do have a significant impact on the size of (company) cars. Therefore we will also have a look at the impacts of removing the implicit subsidies on the average size of (company) cars in Europe. However, this will not be part of the main analysis.

Currently, the European Commission currently doesn't provide specific provisions with regard to company car taxation. However, the same kind of requirements as proposed with regard to purchase taxes could be applied on an European level.

Box 1: Implicit subsidies for company cars
Compared to private passenger cars, company cars are quite favourably treated with respect to the taxation of its private use. Copenhagen Economics (2010) reports that under-taxation of company cars is largely the norm within Europe (although with substantial variations between Member States). The under-taxation both refers to the taxes on fixed costs and fuel costs. The implicit subsidies for company cars may result in direct revenue losses of about 0.5% of EU GDP (€ 54 billion). Additionally, they have substantial impacts on the size and composition of the European passenger car fleet and hence the CO_2 emissions caused by these vehicles. Copenhagen Economics (2010) estimates that due to the under-taxation of company cars the stock of cars has been increased by 8 to 21 million in the EU, the price of company cars may be boosted with € 4,000 to 8,000 and fuel consumption may be 4 to 8% up.

3. A (CO_2 differentiated) increase of fuel taxes
An increase of fuel taxes provides consumers an incentive to buy smaller (and hence more fuel-efficient) cars as well as to make more often use of their smallest car (in case they possess more than one car). The effectiveness of this policy measure could (theoretically) be increased by differentiating the fuel tax (increase) to the CO_2 content of the fuels. In this way consumers are stimulated to buy cars using fuels with a smaller CO_2 content.

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28 However, European Commission (2005) also contains some elements that would discourage the purchase of small cars. The Commission proposes to eliminate registration/purchase taxes, since they hamper the functioning of the internal market (e.g. citizens face double payments of purchase taxes, considerable procedures and extra costs when importing or exporting cars). In order to abolish the purchase taxes in a revenue neutral way the Commission recommends to increase the annual circulation taxes. However, a (revenue neutral) shift from purchase taxes to circulation taxes will result in more and bigger cars, since consumers' purchase decisions are more affected by purchase taxes than circulation taxes (CE, 2008c).

29 For the same reasons as for the purchase tax, we assume a differentiation to absolute CO_2 emissions.

Directive 2003/96/EC (European Commission, 2003) requires Member States to respect minimum tax levels for energy products, including motor fuels for road transport. Recently, the Commission published a proposal for an amendment on this Directive (European Commission, 2011c), introducing, among other things, a differentiation of fuel taxes to CO_2. According to the proposed amendment of the Directive the minimum fuel tax levels should be partly based on the CO_2 content of the fuels. By increasing the minimum tax levels in the (amended) Directive 2003/96/EC the European Commission could stimulate the purchase and use of smaller cars.

4. *Spatial policies favourable to smaller cars*
The use and acquisition of small cars could be stimulated by applying spatial policies that are favourable to smaller cars. Two main types of instruments can be distinguished: parking policies and measures concerning urban access restrictions. In the policy package the following parking policies are taken into account: CO_2 differentiated parking tariffs (both for visitors as parking permits) and allocating parking places exclusively to small (or fuel-efficient) cars. In addition, restricted access to cities for large (or fuel inefficient) cars could also be applied to stimulate the use and acquisition of small cars.

In their Action Plan on Urban Mobility (European Commission, 2009) the Commission sets clear boundaries to the mandate of the EU when it comes to possible interventions at city level, whereby such interventions should in fact concentrate on the effective dissemination and use of all information characterising good practices and standardisation initiatives that would not directly constrain the choices of individual cities. Based on these boundaries some relevant EU actions to stimulate the purchase and use of smaller cars by spatial policies are:
- harmonise national CO_2/energy labels: this may result in more harmonised criteria for parking or urban restricted access policies, which increase public understanding and provides clear incentives to car manufacturers to build fuel-efficient cars;
- gather and disseminate information on best practices with regard to spatial policies favourable to smaller cars;
- fund pilot projects regarding these kind of spatial policies, e.g. by continuing the funding of innovation programmes like CIVITAS.

5. *A supportive communication strategy*
The policies mentioned above could be supported by a clear communication strategy, consisting of CO_2/energy labels and the provision of data via an independent website. By Directive 1999/94/EC Member States are currently mandated to provide CO_2/energy labels displayed on passenger cars at the point of sale. Further EU-wide harmonisation of these labels would be a next step forward (Adac, 2005; Ecologic et al., 2010). Harmonisation would support general awareness throughout the EU and it would equally avoid distortions and create synergies between the Member States. It would also offer lower costs for the manufacturers, for example the labels could be fixed right after the vehicle production. One issue that in this study is assumed to be harmonised is the comparison method used. We assume an absolute comparison method[30], i.e. a method comparing the absolute CO_2 emissions or

[30] Notice that such an absolute comparison method could be based on an energy efficiency index, showing the CO_2 emissions or fuel consumption of a car in comparison to the average CO_2 emissions or fuel consumption of all newly sold cars in a certain reference year (Adac, 2005).

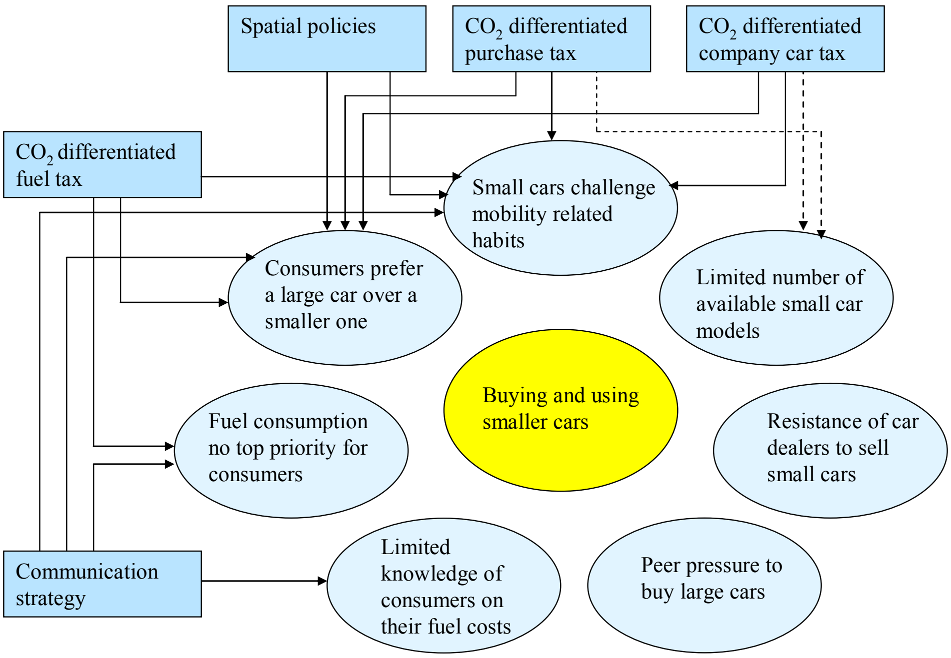
fuel consumption of cars. In contract to a relative comparison method[31] such an absolute method provides consumers an incentive to buy a smaller car. Also the design of the label should preferably be harmonised. Elements that should be presented on the label are fuel consumption and CO_2 emissions. It is recommended (Adac, 2005; Ecological et al., 2010) also to present data on (fuel) running costs (e.g. the estimated fuel costs per year or per 15,000 km), since running costs are in general more important and understandable purchase criteria for consumers than fuel consumption and environmental performance.

The changes in the design of the CO_2/energy labels could be enforced by the European Commission by an amendment of Directive 1999/94/EC. An amendment of the same Directive could be used to mandate Member States to ensure that an independent website showing relevant data on all available car models is produced.

Addressing the main barriers

The assessment of barriers (see Section 4.3) makes clear that the main barriers with regard to the purchase and use of smaller cars are psychological ones (consumers prefer a large car over a smaller one, small cars challenge mobility related habits and fuel consumptions is no top priority for consumers), indicating that consumers are often able to buy a smaller car, but that they are not always willing to. Therefore an effective policy package should provide consumers strong incentives to affect their willingness to change their car purchase and use behaviour. The policy package presented above provides these kinds of incentives, as is also illustrated by Figure 11.

Figure 11 Relationship between policies and barriers to buying and using smaller cars



31 Relative comparing methods shows the CO_2 emissions or fuel consumption of a passenger car in comparison to the average car in a specific class (e.g. family car).

The implementation of various economic instruments (purchase tax, company car tax, fuel taxes) is especially meant to overcome psychological barriers. Both the CO_2 differentiated purchase tax and company car tax address the barriers 'consumers prefer a large car over a smaller one' and 'smaller cars challenge mobility related habits'. Additionally, both instruments provide an indirect incentive for car manufacturers to increase the number of small car models. The former two barriers are also affected by a CO_2 differentiated fuel tax, an instrument which also challenges the barrier of the low priority car users attach to fuel consumption. Like the economic instruments, the spatial policies are also mainly focused on challenging the psychological barriers of people preferring large cars and smaller cars challenging mobility related habits. Finally, the communication strategy is especially meant to support the other policy instruments in challenging the psychological barriers. In addition, the communication strategy provides an instrument to increase consumers' knowledge on the fuel costs of their car.

5.2.2 Abatement potential

In this section we assess the effectiveness (in terms of GHG reduction) of the selected policy package. Therefore we will first discuss the effectiveness of the individual instruments, based on a review of the existing literature. Based on this analysis we estimate the effectiveness of the entire policy package.

A CO_2 differentiated purchase tax

Various studies have assessed the impacts of different kind of CO_2 differentiated purchase taxes. However, to our knowledge only CE (2009) distinguishes between CO_2 reductions due to a shift to smaller cars and CO_2 reduction due to a shift to more fuel-efficient cars within the vehicle size class. Based on model calculations this study assesses the CO_2 impacts of various (ex ante revenue neutral) options for a CO_2 differentiated purchase tax in the Netherlands. The most effective system, a progressive purchase tax which is completely based on the CO_2 emissions of the car, realise a CO_2 reduction of about 8% of which about 40% is due to the purchase of smaller cars[32]. Also some tax systems that levy a tax as a percentage of the purchase price of the car are investigated by this study. In these systems the percentage of the purchase price that is taxed is based on the CO_2 emissions of the car. In general, the CO_2 impacts of these kinds of systems are 3-7 times smaller compared to purchase tax systems in which the tax rates are fully based on the CO_2 emissions of the car.

In other studies on the impacts of CO_2 differentiated purchase taxes only full CO_2 reduction effects are reported. For example, Nordic Council (2010) estimates the CO_2 impact of a (ex ante revenue neutral) purchase tax fully based on the vehicle's CO_2 emissions in Denmark at 6%. ADAME (2009) estimates that a bonus malus system for car sales in France[33] results in 6% lower CO_2 emissions of passenger cars.

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[32] However, it should be mentioned that this is possibly an underestimation, since the full impact of this measure is probably not realized in about 8 years, which was the period taken into account by CE (2009).

[33] In the French system a bonus is paid for fuel-efficient vehicles (less than 130 g/km, with the bonus declining in line with CO_2 emissions per km), while on fuel-inefficient vehicles (> 160 g/km) a penalty is levied (increasing in line with CO_2 emissions per km).

Giblin and McNabola (2009) estimated the combined CO_2 impact of the CO_2 differentiation of the purchase and annual circulation tax introduced in 2008 in Ireland[34]. According to their modelling exercises, the CO_2 emissions intensity will be reduced by 3.6–3.8%.

Finally, COWI (2002) estimated the CO_2 impacts of a CO_2 differentiated purchase tax - based on some model calculations – at 2-5%. However, these impacts are estimated taken the following boundary conditions into account: budget neutrality, constant proportion of diesel cars and no downsizing. Especially due to the last condition, the CO_2 impacts found by COWI (2002) should be considered an underestimation of the actual CO_2 impacts that could be realised by a CO_2 differentiated purchase tax.
The results presented above make clear that the effectiveness of CO_2 differentiated purchase taxes are strongly dependent on the design of this instrument. In general, tax systems that use rates which are fully based on CO_2 emissions (e.g. the systems studied for the Netherlands and Denmark) have larger CO_2 impacts than tax systems using rates that are only partly based on the CO_2 emissions of the car (e.g. Ireland). A rough estimate of the CO_2 reduction that could be realised by ex-ante revenue neutral versions of the first type of systems is 6 to 10%. The CO_2 reduction that could be allocated to the purchase of smaller cars is estimated to be smaller, about 3-4%. Both effects will be larger in case a system with increasing tax revenues will be introduced.

A CO_2 differentiated company car tax

As mentioned in Section 5.2.1 we assess in this study the effectiveness of a revenue neutral CO_2 differentiation of company car taxes. Removing the implicit subsidies on company car taxes by increasing the tax levels would also be an effective way to stimulate a shift to smaller cars. Although this policy instrument is not taken into account in the main assessments in this study, we provide some estimates of its impacts in Box 2.

The effectiveness of CO_2 differentiated company car taxes has been assessed for both the UK and the Netherlands. In the UK the company car tax regime has been reformed in 2002; company cars are still taxed as a percentage of list price, as was the case prior to the tax reform, however the exact percentage of the tax is determined by the CO_2 emissions figure of the car. This percentage ranges from 15 to 35%. Additionally, the taxes on fuel use by the company car were increased. Next to a decrease in the number of company cars, the reform of the company car taxation have resulted in lower average CO_2 emission figures of new company cars. HM Revenue and Customs (2006) estimate that the CO_2 emission figures of new company cars in 2004 were close to 15 g CO_2/km (about 8%) lower in 2004 compared to the case if the reform had not taken place. If we assume that about 50% of all new passenger cars are company cars, this implies that passenger car CO_2 emissions reduce by ca. 4%. However, this effect should be seen in the context of at least two factors. First, part of the CO_2 impact is due to the increased taxes on fuel used for private use of the company car. Second, the company car taxation has shifted the purchase of fuel consuming cars to privately owned cars, resulting in higher average CO_2 emissions figures of passenger cars. Taking these two factors into account we can conclude that the actual CO_2 emission reduction of the company car taxation reform in the UK is less than 4%. No information is available which part of this emission reduction is due to a shift to smaller cars.

[34] The Irish purchase tax is a tax levied as a percentage of the open market selling price of the vehicle, ranging from 14% (0-120 g CO_2/km) to 36% (> 225 g CO_2/km). The circulation tax is based on CO_2 emissions, payable annually and ranging from € 100 for the least polluting, to € 2,000 for the most.

CE (2008c) has investigated the CO_2 impacts of various systems of CO_2 differentiation of the Dutch company car taxation. The most progressive system, comparable to the British system, results in 4-7% lower CO_2 emissions of passenger cars. It is not clear which part of this emissions reduction is due to a shift to smaller cars.

Based on the evidence of the UK and The Netherlands we roughly estimate the effectiveness of this instrument on 4–7% reduction of passenger car CO_2 emissions. However, only part of this emission reduction is due to a shift to smaller cars. Since no information is available on this effect, we apply the same percentage as for purchase taxes: 40% of the total effect is due to a shift to smaller cars, i.e. 2–3%. It should be mentioned that this estimated abatement potential is rather uncertain; first, the CO_2 impact of this instrument depends heavily on its design. Second, also the design of the current national company car system affects the CO_2 reduction that could be realised by implementing a CO_2 differentiation. Therefore, the presented abatement potential should be handled with caution.

Box 2: Impacts of removing implicit subsidies on company car taxes

Copenhagen Economics (2010) discuss the impacts on vehicle stock and CO_2 emissions of the implicit subsidies on company car taxes in Europe. They estimate that due to the under-taxation of company cars, vehicle stock in Europe is 8 to 21 million cars larger, prices of company cars have been boosted with 4,000 to 8,000 € and fuel consumption (and hence CO_2 increasing tax rates on both fixed and fuel costs of company cars) these impacts could be taken away.

This policy strategy would also stimulate a shift to smaller (company) cars. Higher tax levels would imply that employees would chose cheaper and hence smaller company cars. Copenhagen Economics (2011) estimate that the CO_2 reduction that would be realised by employees choosing cheaper cars is 2-4% (of total passenger car CO_2 emissions). Since the correlation between size and price of cars is not perfect, we assume that the CO_2 reduction that could be allocated to the shift to smaller cars will be near to the lower bound of this range, i.e. ca. 2%.

A (CO_2 differentiated) increase of fuel taxes

The effectiveness of fuel taxes to reduce fuel consumption (and hence CO_2 emissions) of passenger cars is often expressed with the help of price elasticities. Price elasticities give the impact of a change in an independent variable (e.g. fuel price) on a dependent variable (e.g. fuel consumption), both measured in percentage changes. An extensive review of the international literature on price elasticities in the field of transport is provided by PBL and CE (2010).

The impact of fuel taxes on the purchase of smaller cars could be quantified by the use of a fuel tax elasticity with respect to fuel efficiency of an new car. Based on evidence presented in PBL and CE (2010), we estimate this elasticity at 0.15 to 0.2 at the long-term[35]. This elasticity value implies that a 10% fuel tax increase will result in 1.5 to 2% reduction in fuel use and hence CO_2 emissions of new passenger cars. However, it should be noted that only part of this increase in fuel-efficiency is due to a shift to the acquisition of smaller

[35] PBL and CE (2010) present as best guess for the long-term fuel price elasticity with respect to fuel-efficiency values ranging from 0.3 to 0.4. Since about 50-55% of the fuel prices in Europe are determined by fuel taxes, the long-term fuel tax elasticity with respect fuel efficiency is equal to ca. 0.15-0.2.

cars (another part could be explained by a shift to more fuel-efficient cars of the same size or by the appliance of a fuel-efficient driving style). However, there is no evidence available on the impact of fuel taxes on car size, therefore we assume – based on CE (2009) – that about 30% of the full CO_2 impact is due to a shift to smaller cars. Therefore, the long-term fuel tax elasticity with respect to fuel efficiency improvements due to a shift to smaller cars is about 0.05, indicating that a 10% increase in fuel taxes may result in about 0.5% CO_2 reduction due to a shift to smaller cars.

Fuel taxes may also affect the use of small cars; car users could use their (small) car less often or apply a more fuel-efficient driving style to (partly) compensate the increased fuel costs. However, here we assume that in case of consumers who buy a smaller car, the additional fuel costs resulting from the fuel tax increase are completely compensated by the higher fuel efficiency of their new car. However, if increased fuel taxes are introduced combined with a CO_2 differentiated purchase tax or company car tax, there may be some interaction effects with regard to the use of the (smaller) car. We will come back to these interaction effects at the end of this section.

Finally, it should be noted that the total impact of fuel taxes on fuel consumption of passenger cars is larger, since this policy instruments stimulates also some other behavioural changes (buying less cars, buying a more fuel-efficient car from the same size, driving less kilometres, etc.). According to PBL and CE (2010) the total impact of fuel taxes on total fuel consumption could be estimated by an elasticity of -0.3 to -0.4[36].

Spatial policies favourable to smaller cars

Various spatial policies to stimulate the acquisition and use of smaller cars are considered in this study:

- *CO_2 differentiated parking tariffs*; parking pricing can have significant transportation impacts (AEA et al., 2010). However, these impacts are mainly related to vehicle kilometres and less to vehicle ownership. The contribution of parking charges to total costs of ownership of a car are relatively small and hence will probably not be considered in the car buying process. An exception may be the parking permit for inhabitants of city centres. However, since the price sensitivity of car ownership with regard to variable car costs is rather low (PBL and CE, 2010) and the low share of cars for which a parking permit is required[37], the impact of CO_2 differentiated parking permits on total CO_2 emissions of passenger cars will probably be very small. For these reasons the impact of CO_2 differentiated parking tariffs on the purchase of smaller cars will probably be small in case it will be implemented as an individual policy instrument. However, in combination with other policy instruments it may be effective. This will be discussed later in this section.
- *Allocating parking places exclusively to small cars*; the impacts of capacity related parking policies will in general be larger than the impacts of parking pricing (CROW, 2010). However, as for parking pricing these impacts are mainly related to vehicle kilometres and less to vehicle ownership. Therefore, the impact on the car purchase decision of most

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[36] According to PBL and CE (2010), the fuel price elasticity with respect to total fuel consumption ranges from -0.6 to -0.8. Assuming fuel prices that are for 50% determined by fuel taxes, fuel tax elasticities with respect to total fuel consumption of -0.3 to -0.4 are estimated.

[37] In the Netherlands only for ca. 5% of the cars a parking permit is required (IOO, 2002; CBS, 2011). Since the urbanisation level in the Netherlands is higher than in most other European countries, the average share of cars for which a parking permit is required will probably be even lower for the entire European Union.

consumers will probably be low. The impact may be significant, however, on the car purchase decisions of parking permit-holders, in case they can only receive a permit for a small car. In this way a significant shift to smaller cars could be realised. Since it is not clear for which share of the European passenger cars a parking permit is required, it is not possible to quantify the CO_2 impact of this instrument.

– *Urban access restriction zones for large cars*; no empirical evidence is available on the effectiveness of access restriction zones for large cars. However, ISIS and PWC (2010) have been investigated the impacts of various other types of urban access restriction schemes implemented in European cities. According to this study the CO_2 impacts of these schemes range from 0 to -37.6%. The wide range in CO_2 impacts is not explained by the authors, but is possibly the result of large differences in the design of the schemes (e.g. different objectives: reducing congestion, reducing air pollutant emissions, improving liveability of inner city). Potential rebound effects (e.g. people travel to other cities, without urban access restriction zones) are not taken into account, but could be significant. Moreover, it should be mentioned that the CO_2 reductions refer only to the CO_2 emissions of traffic in the restricted zones, which is only part of the total CO_2 emissions of road transport. Nevertheless, we expect that urban access restriction zones could be an effective instrument to stimulate the purchase and use of smaller cars, if they are implemented in a sufficient number of cities and are combined with other (economic) policy instruments. Due to a lack of data it is not possible to quantify the CO_2 impact of this instrument.

To conclude, restrictive spatial measures (allocation of parking places exclusively to small cars, restricted access to cities for large/fuel-inefficient cars) will be more effective in stimulating the purchase of small cars than economic spatial measures (differentiated parking fees). However, the public acceptance of these instruments will probably be low.

A supportive communication strategy

Various studies have been carried out assessing the effectiveness of the CO_2/energy labels for new passenger cars. ADAC (2005) performed an ex-post evaluation of Directive 1999/94/EC, which mandates Member States to ensure, among other things, the availability of CO_2/energy labels on new cars. This study concludes that is quite impossible to quantify the CO_2 impacts of the CO_2/energy labels, since there are a lot of other elements affecting the CO_2 emissions of new cars. However, the study reports that the realised CO_2 impact has probably been small. The same conclusions are presented by some Dutch evaluation studies on the CO_2/energy labels (CE, 2008c; MMG Advies, 2008). These studies found that the CO_2/energy labels resulted in an increase of the fuel efficiency of new cars in the Netherlands of less than 1%.

By the adjustments of the design of the CO_2/energy labels, as described in Section 5.2.1, we expect the effectiveness of the CO_2/energy labels to be larger, but still relatively small.

Information on the effectiveness of the use of independent websites to stimulate the purchase of more sustainable cars or other types of environmental friendly behaviour is not available. ADAC (2005) assessed the effectiveness of a guide providing the same kind of data, which have to be available at all car dealers (in order to comply with Directive 1999/94/EC). ADAC concludes that the impact of this guide on the CO_2 emissions of new cars is rather limited. The effectiveness of a comparable website as individual measure will probably also be limited. However, combined with economic and spatial policies this instrument may be rather useful (see below).

Policy package

To estimate the effectiveness of the total policy package we have to discuss the interaction effects between the various policy instruments:

- The CO_2 differentiated purchase tax and the CO_2 differentiated company car tax affect different segments of the passenger car market, viz. private cars and company cars. Therefore, we expect no interaction effects between these two tax instruments.
- Increased fuel taxes may reinforce CO_2 differentiated purchase taxes. However, the impact of the combination of both instruments is probably smaller than the sum of the effectiveness of both instruments. No empirical evidence exists for the size of this interaction effect. As a rough estimate we will apply a interaction effect of 50% in this study, implying a fuel tax increase on top of a CO_2 differentiated purchase tax result in a 50% lower impact on the purchase of small cars compared to the case in which only a fuel tax increase is implemented. Since a large share of the company car users do not have to pay for the fuel costs themselves, this interaction effect will be assumed to be negligible with respect to the CO_2 company car taxation.
- Increased fuel taxes and CO_2 differentiated purchase taxes may also interact with respect to reductions in fuel consumption due to changes in use patterns of the car. Based on PBL and CE (2010) we expect that the reduction in fuel consumption due to reduced use of the car and applying a more fuel-efficient driving could for an average car be estimated by an elasticity of -0.15 to -0.2[38]. Since the CO_2 differentiated purchase tax result in 3–4% more fuel-efficient cars due to the purchase of smaller cars, the financial incentive provided by the fuel tax increase will be only 96-97% of the initial incentive. The resulting elasticity values range therefore from -0.14 to -0.19. The impact on CO_2 emissions due to the changes in use patterns that can be calculated by this elasticity should be added to the CO_2 impacts due to the purchase of smaller cars. Again, we assume that this interaction effect is negligible with respect to company car taxations.
- There will probably be interaction effects between the spatial policies and the various economic instruments. Since both types of instruments provide the same incentive to consumers, they will probably reinforce each other. Particularly in case spatial policies are implemented on a large scale, the interaction effects could be significantly. However, due to a lack of information on both the effectiveness of spatial policies and the interaction effects between both types of instruments, it is not possible to present quantitative values for these interaction effects.

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38 Based on PBL and CE Delft (2010) the fuel price elasticity which could be used to estimate the relative reduction in fuel consumption due to reduced use of the car and applying a more fuel-efficient driving is estimated at - 0.3 to -0.4. By assuming that 50% of the fuel price are determined by fuel taxes, we estimated that the associated fuel tax elasticity is equal to -0.15 to -0.2.

- The supportive communication strategy may reinforce the other instruments by raising consumer awareness about e.g. fuel saving technologies. Additionally, if all economic and spatial instruments are based on the same CO_2 labels, this may improve the effectiveness of the entire policy package. If well designed and organised the reinforcing impact of this measure will probably be small but significant.
- Finally, at least in the short term there may be relevant interaction effects with the existing EU CO_2 and cars regulation (Regulation (EC) No. 443/2009). This regulation establishes emission limits for new car fleets of 130 g CO_2/km in 2015 and 95 g CO_2/km from 2020 onwards. So as long these constraints are binding, additional abatement induced by purchases of smaller cars could be compensated by purchases of higher emitting cars, which are generally more profitable for manufacturers, resulting in no net reduction in emissions.

Based on the discussion on the effectiveness of the individual policy instruments and their interaction effects, we made a rough estimation of the effectiveness (in terms of CO_2 reductions) of the entire policy package (see Table 25). Two policy packages are distinguished, differing in the fuel tax increase assumed: 10 and 20% respectively.

Table 25 Rough estimation of the relative CO_2 reductions of passenger cars of both individual instruments and policy packages for stimulating the purchase and use of smaller cars

Policy (package)	CO_2 reduction due to smaller cars	Total CO_2 reduction
CO_2 differentiated purchase tax	3-4%	6-10%
CO_2 differentiated company car tax	2-3%	4-7%
10% fuel tax increase	0.5%	3-4%
20% fuel tax increase	1%	6-8%
Spatial policies favourable to small cars	?	?
Supportive communication strategy	Not significant	Not significant
Policy package 1 (incl. fuel tax increase of 10%)	At least 6-8%	At least 13-21%
Policy package 2 (incl. fuel tax increase of 20%)	At least 6-9%	At least 16-25%

Note: Due to possible interaction effects, the CO_2 impacts of individual policy instruments do not necessarily add up to the CO_2 impacts of the various policy packages.

Implementation of the proposed policy package could result in the longer term in a 6-8% (or 6-9% in case a fuel tax increase of 20% instead of 10% is introduced) lower CO_2 emissions of passenger cars, assuming that the current indicative post 2020 emission limit is not binding (otherwise the purchase and company car tax changes could have no effect) or is overtaken by technological progress. By implementing a supportive communication strategy the actual CO_2 reduction could shift to the upper bound of the presented bandwidth, although the same caveats apply. The CO_2 impact of the spatial policy instruments is not included in the estimation of the reduction potential. Therefore, the potential could be (slightly) higher. This proposed policy package is able to realise in the longer term 30% to 40% of the realistic maximum technical abatement potential as presented in Section 3.3.1.

In the third column of Table 25 the CO_2 reduction potential of the policy packages is presented if not only the impacts on the purchase and use of smaller cars are taken into account, but also all other behavioural effects that are induced by these instruments. By taking all behavioural effects into account, the reduction potential is about 2.5 times larger compared to the case that only the behavioural effects with regard to smaller cars are considered.

Finally, it should be mentioned that the CO_2 effectiveness of the policy package to stimulate the purchase and use of smaller cars, as presented in Table 25, is a rough estimation. Particularly with regard to the interaction effects a dynamic approach to estimate the CO_2 impacts of the policy package would have been a preferable approach. For these reasons, and the interaction with CO_2 regulations, the figures presented in this table should be considered carefully.

5.2.3 Costs

In this section we discuss the implementation costs (for the government) of the selected policy package for stimulating the purchase and use of smaller cars.

Economic instruments

The implementation costs of the various economic instruments (CO_2 differentiated purchase and company car tax and increase of fuel taxes) are expected to be limited. Since these types of economic instruments are already available in most Member States, the required infrastructure is already available. Increasing or changing the structure of the tax levels will therefore only leas to very marginal implementation costs.

In some Member States currently no purchase/registration taxes for passenger cars exist (e.g. Germany) and hence the necessary tax infrastructure is (partly) missing. The implementation costs of CO_2 differentiated purchase taxes in these countries could be significant. No empirical information is available on the administrative costs of purchase taxes in European countries. However, Evans (2003) conclude on basis of a review of an extensive number of tax measures that the administrative costs of tax measures rarely exceed 1% of the revenue yield, and more usually come in well below 1%.

Spatial measures favourable to small cars

The investment and operational costs of spatial measures favourable to small cars depends heavily on the design of the respective scheme including the way monitoring and enforcement is organised. Therefore, it is hard to provide general figures on the implementation costs of these measures. The figures presented below have therefore particularly an illustrative purpose.

According to CROW (2010) the implementation costs of differentiated parking fees could be significantly, in case some (old) car park ticket machines have to be replaced. A rough estimation of the investment costs of these machines is € 10,000. Additionally, the costs of monitoring and enforcing the parking fees may slightly increase. The costs of differentiated parking permits are expected to be limited. No information was found on the implementation costs of allocating parking places exclusively to small cars. However, we expect that these costs will be limited.

ISIS and PWC (2010) report some figures on the investment costs of restricted access areas in three European cities (Stuttgard, La Rochelle and Perugia). The investment costs in these cities range from € 0.2 million to € 0.45 million.

Goudappel Coffeng and CE (2008) present significantly higher cost estimates, particularly in case cameras are used for monitoring and enforcement purposes. In the latter case investment cost estimates range from € 0.9–2.1 million for small areas (ca. 2–5 km^2) and € 1.8-4.3 million for large areas (ca. 30–50 km^2). Additionally, annual operating costs are estimated at € 40,000-60,000 for small areas and € 120,000-300,000 for large areas.

Supportive communication strategy

As mentioned in Section 5.2.1, the supportive communication strategy consist of two elements: changing the design of the currently compulsory CO_2/energy labels for passenger cars and the provision of data on fuel consumption and CO_2 emission figures of all new car models on an independent website. The implementation costs of both actions are rather limited; since CO_2/energy labels for passenger cars are already implemented, changing its design may not result in high costs for the governments. And with regard to the website, information from the currently compulsory guide on fuel consumptions of new passenger cars could be used in developing the independent website.

5.3 Teleworking

5.3.1 Policy packages

The policy package to stimulate teleworking consists of six policies:

1. *An increase of fuel taxes*

An increase of fuel taxes provides consumers an incentive to avoid commuter kilometres and instead work at home. As for buying and using smaller cars, the European Commission could affect this instrument by increasing the minimum tax levels to be respected by the Member States in Directive 2003/9/EC.

2. *Development of a regulatory framework concerning employment conditions of teleworkers*

A framework concerning the employment conditions of teleworkers provides employees certainty on (tele)work related issues like privacy, career development, rights and duties, etc. As discussed in Section 4.5.1, several European social partners concluded on the European Framework Agreement on Telework, which considers many of these issues. Some of the Member States implemented this agreement through legislation or bipartite collective agreements, while other Member States used voluntary agreements. Finally, some Member States have not implemented the agreement at all. Increasing the implementation of this agreement by national governments or social partners, preferably by hard instruments (legislation or bipartite collective agreements) would be a good measure to stimulate teleworking. Also further dissemination of the agreements to employers and employees would be useful.

The European Commission provides a framework (the ‘open method of coordination’ (OMC)) for EU countries to share information, discuss and coordinate their employment policies. Under this intergovernmental method, Member States can jointly identify and define objectives to be achieved (e.g. guarantee the employment conditions of teleworkers) and they are evaluated by one another. The Commission’s role is being limited to coordinating and surveillance. Also the policies with regard to teleworking – like the Framework Agreement on Telework, are part of the OMC, and hence the Commission has no formal power to enforce the implementation of the agreements on telework. However, by identifying the lack of implementation plans in Member States, and coordinating contacts between Member States as well as the exchange of experiences and best practices, the Commission could influence this process.

3. Support provision of (broadband) IT infrastructure and equipment
Access to (fast) internet is a prerequisite for teleworking. As we showed in Section 4.5.1 the (broadband) Internet coverage in the EU is about 95%. This implies that still 5% of the EU citizens have no possibility to connect to the Internet. The IT infrastructure network should be extended to provide also these people access to the Internet. Additionally, the average speed of Internet connections should preferably be increased to improve the facilities for teleworking.

More important than improving the (fast) broadband IT infrastructure coverage in the EU is to increase the number of people actually using the Internet. In seven Member States the share of households having connection to the Internet is still below 60% (see Section 4.5.1). For some of the households having no connection to the Internet this is due to the relatively high costs of ICT equipment and Internet connection. To stimulate teleworking the government could therefore provide subsidies (tax exemptions) on ICT equipment or Internet connections.
The EU objectives with regard to the provision of IT infrastructure are described in the Digital Agenda for Europe (European Commission, 2010). One key target of the Digital Agenda is to provide every European access to basis broadband by 2013 and fast and ultra fast broadband by 2020. To realise this objective the Commission has a fund of about € 9 billion for the period 2014-2020 to co-finance selected IT infrastructure projects in the EU (European Commission, 2011b). This strategy of the European Commission is in line with and supportive to the policy instruments described above.

4. EU communication campaign
To improve employers' and employees' perception with respect to teleworking the European Commission could, possibly in cooperation with Member States, implement targeted communication campaigns. These campaigns should be focused on providing information on best practices to employers and employees. Additionally, in close cooperation with individual Member States information on the employment conditions for teleworkers could be distributed.

5. Voluntary agreements with private organisations
National governments could arrange voluntary agreements with private organisations to realise specific targets to teleworking. These targets could be related to the number of teleworkers within their organisation or to a decrease in the number of work-related kilometres of their employees by a specific percentage due to implementation of teleworking.

Voluntary agreements with private organisations on teleworking targets are the responsibility of national governments. However, the European Commission could support these types of agreements by providing a framework for Member States to share information and discuss approaches to implement these voluntary agreements. This role of the Commission is in line with the open method of coordination, mentioned before.

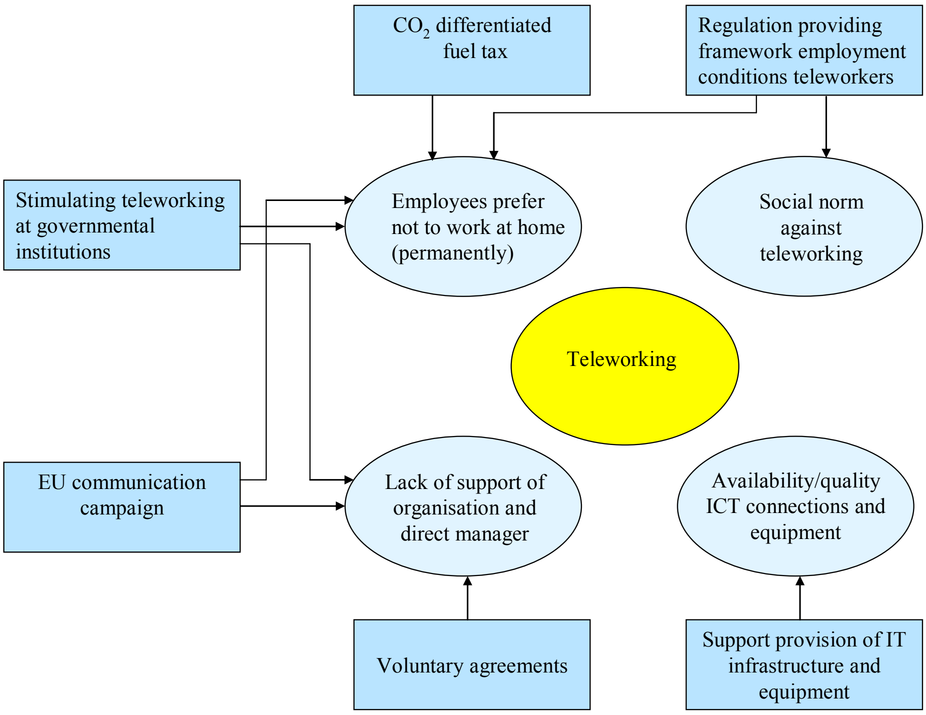
6. Stimulating teleworking at governmental institutions
National and EU governmental organisations could set a good example by setting up teleworking programmes, meant to stimulate their own employees to work at home on a regular basis. In addition, they could encourage

government contractors to adopt flex work initiatives (e.g. by include teleworking targets in procurement arrangements).

Addressing the main barriers

The assessment of barriers (see Section 4.5.1) shows that the main barriers to teleworking are psychological and institutional ones. The psychological ones refer to people's perceptions of the drawbacks of teleworking: social isolation, tendency for overworking, adverse impacts on careers, etc. The institutional barriers are related to the resistance of organisations and direct managers to allow their employees to work at home. Since these barriers are both linked to employers and employees, the proposed policy packages contains policies targeted to both type of actors (see Figure 12).

Figure 12 Relationship between policies and barriers to teleworking



The psychological barrier related to employees' doubts on some aspects of teleworking (e.g. social isolation, adverse impacts on one's career) are addressed by four types of policy instruments. First, by providing a clear set of employment conditions for teleworkers, such that the legal position of teleworkers is comparable to the position of the 'conventional' employee, fears with respect to adverse impacts on one's career are tackled. Some other negative perceptions of employees with regard to teleworking (tendency to overwork, mixing up of work and private life) are addressed by providing experiences from other employees (including civil agents) and information on best cases (EU information campaigns and stimulating teleworking at governmental organisations). Finally, by increasing the fuel taxes also a push factor is introduced to change employees' perception to teleworking.

The lack of support of managers/organisations is addressed by arranging voluntary agreements between governments and private organisations and by providing information on the advantages of teleworking for organisation (increased productivity of employees, less office spaced needed, etc.).

The barrier with respect to the social norm against teleworking (envious colleagues) is addressed by providing a clear set of employment conditions for teleworkers. By making clear the rights and duties of teleworkers, conflicts between (envious) colleagues could be avoided.

Finally, the lack of (broadband) IT infrastructure and/or IT equipment in some Member states is addressed by instruments as co-funding of IT infrastructure projects and specific financial incentives (subsidies, tax exemptions) for IT infrastructure.

5.3.2 Abatement potential

In this section we assess the effectiveness (in terms of GHG reduction) of the selected policy package. Therefore we will first discuss the effectiveness of the individual instruments, based on a review of the existing literature. Based on this analysis we estimate the effectiveness of the entire policy package.

An increase of fuel taxes

The impact of fuel tax levels on teleworking are scarcely investigated in the international literature. Based on fuel price elasticities with respect to the number of commuter car trips from De Jong and Gun (2001), we estimated a fuel tax elasticity with respect to CO_2 reduction due to increased teleworking levels of -0.05[39 40]; this implies that a 10% fuel tax increase results in ca. 0.5% CO_2 reduction due to increased teleworking levels.
As was already mentioned in Section 5.2.1 the total impact of fuel taxes on fuel consumption of passenger cars is larger (due to other behavioural changes like buying less cars or buying more fuel-efficient cars), which could be estimated by an elasticity of -0.3 to -0.4 (see Section 5.2.1).

Development of a regulatory framework concerning employment conditions of teleworkers

Providing a framework concerning employment conditions of teleworkers is an important condition for a wide-spread uptake for telework by employees. By implementing the European Framework Agreements on Telework most of the Member States have met this condition, at least to some extent. However, as mentioned in Section 5.3.1, there is a wide variety of implementation measures used to implement this framework (e.g. enforceable legislation, collective agreements, voluntary measures like guidelines, etc.) which results

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39 Based on a review of the literature and some transport models, De Jong and Gunn (2001) present fuel price elasticities with respect to the number of commuter trips by cars. For the long run values in the order of -0.15 to -0.25 are presented. The reduction in commuter car trips due to fuel price increases can be caused by a shift to other modes or by an actual reduction in number of trips, which is probably the result to teleworking. Based on results from the Dutch project 'Spitsmijden' (Dutch term for avoiding peak traffic; in this project daily car commuters are financially rewarded if they avoid motorways on selected routes during peak hours. Drops in the share of car use due to this project are for 50% replaced by other modes and for 50% by teleworking (Spitsmijden, 2009)), we estimate that about 50% of the decline in car trips is due to increased teleworking levels. The impact of increased fuel prices on the number of avoided trips due to an increase in teleworking could therefore be estimated by an elasticity of -0.075 to -0.125. Based on the assumptions that ca. 50% of the fuel prices are determined by fuel taxes and that the average length of commuter car trips remains equal, this elasticity could be converted to a fuel tax elasticity with respect to CO_2 reduction due to increased levels of teleworking of ca. -0.04 to -0.06.

40 Notice that according to PBL and CE (2010) the fuel tax elasticity with respect to total car kilometres is about -0.1 to -0.2. Taking into account that commuting traffic is less price sensitive than other types of traffic, this strengthens the reliability of the elasticity estimated with respect to teleworking.

in different coverage rates (and probably also in different compliance rates) of the telework regulation; in some Member States, coverage of the regulations concerning telework reaches up to 100% of all workplaces due to extension mechanisms or legally binding provisions in national labour codes, while in other countries only a small proportion of employment relationships is covered by the Framework Agreements (this is particularly due to the voluntary nature of implementing measures applied or the low representativeness of social partners). Therefore, Visser and Ramos Martin (2008) and Eurofound (2010) conclude that national law-making (combined with consultation of social partners to realise better compliance) or making collective agreements binding by the government provide more certainty on the effectiveness of the Framework Agreements. However, these studies do not provide quantitative estimates for the impact these 'hard' implementation strategies may have on the extent teleworking will be applied by employees. We expect that providing certainty on the employment conditions of teleworkers should be regarded as a necessary precondition of realising a large shift to teleworking, but that in itself it will not stimulate many employees to apply teleworking. Therefore, this measure should particularly be regarded as a (necessary) supportive instrument to other policy instruments in the proposed policy package.

Support provision of (broadband) IT infrastructure and equipment

As mentioned in Section 5.3.1 broadband Internet is a vital factor in telework as it allows workers to remotely connect to their employers and clients, and to have access to and store information (OECD, 2008). To comply with the increasing expectations of employees and employers with regard to teleworking the increase of the speed of broadband IT infrastructure is a key challenge for the future. However, although the availability of a (fast) broadband IT infrastructure is an important condition for employees to take up teleworking, in most cases it is not the key factor preventing employees to start teleworking. Therefore, we consider investments in (fast) broadband IT infrastructure particularly as a supportive instrument to the other policy instruments in the proposed policy package.

In some Member States employees don't have appropriate ICT equipment (computers, smart phones) or Internet connections to start teleworking. Economic instruments (subsidies, tax exemptions) could be used to increase the rate of people having access to these types of ICT equipment at home. Experiences with financial schemes to promote teleworking show that these can be rather effective. Booz Allen Hamilton (2002), for example, shows that the Swedish PC tax reform of 1998, which allows companies to purchase computers tax free and sell them to employees, led PC ownership growing from 41% (in 1998) to 76% (in 2002), the worlds highest penetration of home PCs at that time. Also in the UK and The Netherlands supporting schemes have been applied successfully in the past (Derk Halden Consultancy, 2006). Therefore, we expect that the barrier of a lack of adequate ICT equipment could (to a large extent) be solved by these kind of economic instruments. However, it should be mentioned that these schemes are characterised by rather large number of free-riders. Therefore, they should be targeted to selected consumer groups very carefully.

EU communication campaign

To our knowledge no empirical evidence is available on the effectiveness of communication campaigns in stimulating teleworking. However, there are several evaluation studies available about the impacts of communication measures on other types of behavioural changes:

– Bamberg et al. (2011) mention two meta-analyses of studies evaluating the impact of different kind of communication tools (work place travel plans, school travel plans, travel awareness campaigns, marketing of public transport) on car use. In these studies it was found that these instruments have a significant impact on car use (6–11% decrease in trips conducted by car). However, Bamberg et al. notion that both studies are characterised by several methodological flaws, as a consequence of which the reliability of these results is uncertain.

– Brannigan et al. (2009) reviews the evidence on the effectiveness of
– communication campaigns with respect to environmental measures in transport. They report that these kind of campaigns have had varying success in the past (no quantitative results are presented). However, in general it is supposed that it is unlikely that this type of instrument will have any substantial role to play in GHG reduction when implemented alone.
– The TAPESTRY project (TAPESTRY, 2003) finds varying results with regard to the effectiveness of communication campaigns in affecting car and public transport use. Some of the fifteen case studies carried out in this project show decreasing car use or increasing use of public transport due to the implementation of communication tools, while for other case studies no significant impacts were found. However, in qualitative terms it is concluded that overall there were more positive changes than negative ones. Additionally, it was concluded that communication measures can be effective not only on their own but also in support of other (hard) measures.
– EST (2002) presents varying results with respect to the effectiveness of communication campaigns. On the one hand, EST (2002) refers to some studies showing that communication campaigns do not foster behavioural change. However, on the other hand, this study discusses (in qualitative terms) some projects providing significant behavioural changes due to the implementation of communication strategies. Additionally, EST (2002) refers to a project on energy saving behaviour for which it was found that a tailored information campaign result in 16% less energy use. Based on the literature review carried out by EST (2002), it was concluded that it is hard to be conclusive about the effects of soft measures on transport-related behaviour.
– Snyder (2007) discusses the level of effectiveness of media based campaigns with respect to health-related behaviour. She finds that the effectiveness depends heavily on the specific behaviour that is promoted. For example seatbelt campaigns results in a 15 percentage point increase in people wearing seatbelts, while the effectiveness of youth drug and marijuana campaigns is only 1 to 2 percentage point. Some of the other successful campaigns are the ones promoting dental care (13 percentage point) and adult alcohol reduction (11 percentage point). No explanation for the differences in effectiveness between different types of behaviour is presented by Snyder.
– Various studies (Delaney et al., 2004; Elder et al., 2004; Nathanail and Eliou, 2008) on the effectiveness of (mass) communication campaigns (both aimed at reducing drinking when driving and speeding) on traffic accidents have been carried out. In general, these studies find that the number and severity of traffic accidents decrease due to these kind of campaigns; relative reductions ranging from 5 to 17% are found by these studies.

The results presented above show that the effectiveness of communication campaigns in fostering behavioural changes varies widely. This is, among other things, due to differences in targeted behavioural changes, type and design of communication measures implemented, local characteristics, etc. Since teleworking have significant benefits to both employers and employees once initial barriers are overcome, we expect that communication measures could be rather effective in stimulating teleworking. Moreover, because some of the main barriers to teleworking could be (partly) overcome by providing targeted information. By providing information on best practices some of the fears of employers (e.g. lower productivity of employees) and employees (e.g. adverse impacts on one's career) may be (partly) overcome. Based on the result above we estimate that a communication campaign (e.g. involving the presentation of best practices) may increase the number of people (partly) teleworking by 10–20% at the targeted population. It should be noted that this is a very rough estimation and that more research on this topic is recommended. Besides, it should be noted that, to be effective, the communication should be focussed on specific target groups, such that identification with the presented best practices is maximised. Additionally, the communication campaigns should be combined and synchronised with other policy instruments, like voluntary agreements.

Voluntary agreements with private organisations

The available evidence on the effectiveness of voluntary agreements with respect to teleworking is rather scarce. For the Netherlands an evaluation study (Rijkswaterstaat, 2010) is available on the impacts of (voluntary) covenants between the government and companies with respect to applying mobility management measures (including teleworking). This study shows that the share of employees teleworking is about 30% higher at the companies participating in these covenants than at companies not participating in these covenants. In the Dutch regions were these covenants are implemented about 16% of the employees are employed at firms participating in these covenants. This share differs widely between regions, ranging from 5 to 30%, which is explained by the fact that these covenants are not implemented at the same time in all regions. Therefore it may be expected that in the long-term the average share of employees employed at firms participating in the covenants will increase.

Studies on the effectiveness of voluntary agreements with respect to other types of environmental impacts of firms show, in general, significant lower levels of effectiveness (e.g. Borkey et al., 1998; Dijkgraaf et al., 2009; OECD, 1999; OECD, 2003). The low levels of effectiveness are due to lack of credible sanctions of non compliance, participants are involved in target setting, often non or poor monitoring and reporting framework, large number of free-riders, etc. However, it should be mentioned that most of the reviewed voluntary agreement schemes are meant to stimulate firms to invest in costly abatement measures. Teleworking, on the other hand, has some possible (financial) benefits for employees, like increased productivity of employees and reductions in office space required (see Section 3.5.2). Hence, organisations may be more willing to comply with the teleworking targets than they are with regard to the targets in other voluntary agreement schemes. In addition, voluntary agreements are likely to generate significant 'soft effects' in terms of dissemination of information and awareness raising (Borkey et al., 1998), which could in the case of teleworking significantly contribute to overcoming managers' and organisations' lack of support for teleworking (by showing them the benefits of teleworking from the perspective of the employer).

Based on the limited empirical evidence available on the impact of voluntary agreements we estimate that in firms participating in covenants the number of people working at home will be about 30% higher than in firms not participating in covenants. This is a very rough estimation and more research on this issue is required. The effectiveness of these schemes may be reinforced by (Borkey et al., 1998; Dijkgraaf et al., 2009; OECD, 2003):
- Setting clear defined targets.

– Include credible threats or rewards for compliance, e.g. a threat to publish worse performances on a website.
– Maximise the informational soft effects of the voluntary agreements, by using workshops and publishing best practices.

Stimulating teleworking at governmental institutions
The effectiveness of stimulating teleworking at governmental institutions in terms of direct GHG reduction of total passenger transport is limited. Since commuter transport by civil agents is only a fraction of total passenger transport in the EU, reducing the climate impacts of these trips will only have a small decarbonisation impact on total passenger transport.

However, this instrument may have an important exemplary function to both employers and employees in private organisations. First, it may provide useful information on success and failure factors of organisational teleworking strategies as well as benefits and drawbacks of teleworking for both employers and employees. Disseminating this information (particularly best cases) to employers and employees may increase the implementation rate of teleworking at private organisations. Second, implementing teleworking programmes at governmental institutions may reinforce the acceptance and hence effectiveness of other policy instruments, like voluntary agreements and information campaigns.

Policy package
As was mentioned in Section 4.5.1 the main barriers concerning teleworking are social/psychological barriers (people's perceptions of the drawbacks of teleworking: social isolation, tendency for overworking, etc.) and institutional barriers (resistance of organisations and direct managers). The main policy instruments in the proposed package to tackle these barriers are the EU information campaign, the voluntary agreements and (to a lesser extent) the increased fuel taxes. The other policy instruments should be considered supportive measures, among other things, meant to remove minor barriers (e.g. inadequate ICT infrastructure). Therefore, the effectiveness of the policy package proposed depends mainly on the impacts of the EU communication campaign and the voluntary agreements.

Above we presented rather rough estimations of the effectiveness of a communication campaign and voluntary agreements. With respect to an EU communication campaign we estimated that it could stimulate 10-20% of the employers to work at home. For voluntary agreements it was estimated that it would increase the number of people working at home by 30% at firms participating at these agreements. If we assume that on the long-term 30-50% of all jobs will be at firms participating in these voluntary agreements[41], this policy instrument will stimulate 9-15% of the employees to work at home. Since the impacts of the communication campaign and voluntary agreements (partly)overlap, the effects of both instruments cannot be simply summed up. Taking this interaction effect into account we roughly estimate the share of people stimulating by this policy package to apply teleworking at 15-30%[42].

41 As mentioned in Section 3.5.1 about 50% of the jobs in the EU are considered to be suitable for teleworking, therefore we used 50% as an upper bound of the range. The lower bound is based on the share of jobs already covered by voluntary agreements in some Dutch regions.

42 To check the reliability of these figures we compared them with the share of employees willing and able to apply teleworking. Gareis (2003) shows that about 66% of the employees in the EU are interested in telework. If we take into account that about 50% of the jobs are not suitable for teleworking (see Section 3.5.1), we estimate that about 35-45% of the employees is willing and able to apply teleworking (it may be expected that a larger share of the people able to telework will be interested in teleworking than of the people not able to telework;

It may be expected that most of these people will not work at home permanently, since both the institutional and social/psychological barriers will be rather high with respect to such an extent of teleworking. Based on PWC (2011) we assume that the people who are stimulated to telework by the proposed policy package will on average work 2 days per week at home. This implies that the proposed policy package will result in 6–12% less commuter kilometres and hence 0.7-1.3% less passenger kilometres and CO_2 emissions[43]. In this way about 20% of the realistic maximum reduction potential, as estimated in Section 3.5.1, is realised.

Finally, we would like to emphasise that the effectiveness of the policy package as presented above is a rather rough estimation. Due to a lack of available data on the effectiveness of policy instruments in stimulating teleworking a more detailed estimation of the impacts of the proposed policy package was not possible. More research on this issue is recommended.

5.3.3 Costs

The following implementation costs are associated to the proposed policy package for teleworking:

- The implementation costs for *increasing fuel taxes* are expected to be very marginal, since this policy could be implemented by using existing tax infrastructures in the Member States.
- The government costs of the *provision of a framework for the employment conditions of teleworkers* are probably low. In case this framework is based on collective agreements of social partners, the involvement of the government in the process is very limited. In case of national law-making, the implementation costs for the government will be higher, but still be relatively limited.
- *Support provision of (broadband) IT infrastructure and equipment* will probably result in high implementation costs for the government. For example, the European Commissions budget about € 9 billion for the period 2014–2020 to co-finance selected IT infrastructure project in the EU (European Commission, 2011b). Also national governments have to budget significant amounts for these kind of projects. Subsidies or tax exemptions to stimulate the acquisition of ICT equipment by employees will probably also result in large implementation costs. However, these costs are highly dependent on the exact design of the supporting scheme and hence could not be quantified here.
- A rough estimation of the implementation costs of *EU information campaigns* is provided based on OECD (2010). They estimate the costs of European mass campaigns on € 0.38 to 1.54 per capita. Since the number of people employed in the EU-27 is ca. 213 million (Eurostat), of which about 50% is able to work at home (see Section 3.5.1), the implementation costs of information campaigns is roughly estimated at € 40 to 160 million.
- The implementation costs of many v*oluntary agreement schemes* are very low, primarily because monitoring is often light; progress is often monitored through annual self reporting (Borkey et al., 1998). However, in Section 5.3.1 we argued that clear monitoring and reporting methods should be applied to increase the effectiveness of these schemes. This will probably also involve government actions and hence higher

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therefore we expect the share of employees which is able and willing to telework will be larger than 33%). If we compare this share with the share of employees stimulated to teleworking by the proposed policy package, we see that the proposed policy package would successfully affect about 50-75% of the employees willing and able to work at home, which is rather reasonable.

43 Commuter kilometres contribute about 11% to the total number of passenger kilometres (of all modes) in the EU (see Table 11)

implementation costs. Additionally, an effective voluntary agreement scheme also provides relevant information and technical assistance to the private parties. Thus, by designing effective voluntary agreements, the implementation costs will rise. The strong dependency of implementation costs of voluntary agreements on design and size of the scheme is also illustrated by Bertoldi and Rezessy (2010), which shows that administrative costs of national voluntary agreement schemes in the field of energy efficiency in Europe range from € 300,000 to 25 million. Based on the large scope of the national voluntary agreement schemes to be implemented in order to stimulate teleworking we expect that its implementation costs are at least in the order of the upper bound presented by Bertoldi and Rezessy (2010).

- *Stimulating teleworking at governmental institutions* could results in negative implementation costs, since the government organisations will benefit from increased productivity of the civil agents and reduced costs due to smaller offices and less parking places.

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Annex A Factsheets behavioural options

A.1 AEA et al. (2010)

AEA, CE Delft, TNO, ISIS and Milieu (2010), EU Transport GHG: Routes to 2050?	
Description of study	
Description of behavioural mitigation measure	In this study the following behavioural measures are quantified: – Buying a smaller car. – Buying electric cars and plug-in hybrids. – Travel by train instead of by car. – Applying a fuel-efficient driving style. In addition the following behavioural measures are discussed in qualitative terms: – Travel by foot or bicycle instead of by car. – Teleworking and teleconferencing.
Description of BAU scenario applied	No specific BAU scenario was presented, since the presented mitigation potentials are based on results from the literature with for all sources a specific BAU scenario.
Time horizon of the study	The study uses a long-term time horizon (2050).
Scope of the study	The geographical scope of the study is the EU-27.
Assessment method applied	All results presented by this study are based on a literature review.
Data sources used	The most important data sources used are: *Buying a smaller car* – CE (2008), State-of-the-art CO_2 en Mobiliteit. *Buying electric cars and plug-in hybrids* – JEC Well-to-Wheels (2008), Assessment of a wide range of automotive fuels and powertrains relevant to Europe in 2010 and beyond. – Seikei University (2001), Automobiles: Electric vs. Gasoline. – Electric Power Research Institute (2007), Environmental Assessment of Plug-in Hybrid Electric Vehicles. – ECMT (2007), Cutting transport emissions – What progress? *Travel by train instead of by car* – ETC-ACC (2008), Potentials for a modal shift from road to rail and ship – A methodological approach. *Applying a fuel-efficient driving style* – ECOdriven (2008), ECODRIVEN Campaign Catalogue for European Ecodriving & Traffic Safety Campaigns. – TNO, IEEP, LAT (2006), Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2 emissions from passenger cars. – UKERC (2009), What polices are effective at reducing carbon emissions from surface passenger transport? A review of interventions to encourage behavioural and technological change. *Teleworking and teleconferencing* – CE (2008), Duurzaam leasen – Effecten van het Duurzame Mobiliteitsplan van Athlon Car Lease.
Mitigation potential	
Direct effects	*Buying a smaller car* A prudent (realistic) estimate of the potential of buying a smaller class car is 10-20%. However, theoretically this potential is larger. *Buying electric cars or plug-in hybrids* – Electric: the mitigation potential of electric cars depends on the energy mix. If only renewable electricity is used, the direct CO_2 emissions of these cars are zero. However, even with the current mix electric cars already produce less CO_2 per kilometre than petrol and diesel cars, due to the more energy-efficient drivetrain of these kind of cars. – Plug-in hybrid: Well-to-Wheel emissions could be 40 to 65% lower in 2050 for plug-in hybrids than conventional vehicles.

	Travel by train instead of by car The potential of modal shift from the car to the train in 2050 is estimated at 17 to 33% of the total road and rail transport volume (for more information, see the factsheet on ETC-ACC (2008)). A rough estimation of the (WTW) CO_2 reduction potential is 2 to 14% (assumption: CO_2 per pkm is 30 to 60% lower for the train compared to the car). *Applying a fuel-efficient driving style* The reduction in fuel consumption (and hence CO_2 emissions) that can be achieved by following an eco-driving course, in the current vehicle fleet, ranges from 5 to 25%. The magnitude of this effects heavily depends on the original driving style of the driver. On average the impact is about 10%. This could be seen as a maximum potential. As vehicle technology progresses more and more aspects of fuel economic driving will be automated, and hence the mitigation potential of this measure will be reduced. No future reduction potentials are presented in this study. *Travel by foot or bicycle instead of by car* No quantitative estimate of the mitigation potential was presented. *Teleworking and teleconferencing* No quantitative estimates of the direct effects were presented. However, some interesting exemplary calculations are presented, showing the possible impacts of teleworking in the Netherlands, taking into account the increased heating at home. With a commuting distance of 45 km (one way), the net effect of working at home is a CO_2 reduction of ca. 40%. For shorter commuting distances, the reduction potential becomes smaller due to the larger relative impact of the heating; at a commuting distance of about 25 km (one way) the net reduction is zero. In these calculations the possible increase in commuting distances (rebound effect) was not included.
Indirect effects	Indirect effects are not discussed.
Rebound effects	For most behavioural mitigation measures no discussion on rebound effects was included. An exception is the discussion on teleworking and teleconferencing, for which the rebound effects are discussed in qualitative terms. Two main rebound effects are mentioned: – Increase of CO_2 emissions from heating at home. – Average commuting distances increase in the long run, because of the lower number of day that need to be travelled to work and people tend to accept longer travel times per day.
Costs and side-effects	
Cost estimates	*Buying electric cars and plug-in hybrids* – Electric: the additional costs are estimated on £ 6,500 to 20,000 for small cars and £ 30,000 to 50,000 for large cars – Plug-in hybrids: for medium cars (no small cars are currently close to the market) the additional costs are estimated at £ 8,500 to 14,000 *Applying a fuel-efficient driving style* The 'investment' costs (following an eco-driving course) are low (ca. € 100 per course) and these cost could be recovered by lower fuel costs.
Side-effects included	*Buying electric cars and plug-in hybrids* Less noise and air pollution (no quantification) *Applying a fuel-efficient driving style* A positive side-effect of fuel-efficient driving is an increase in traffic safety. However, no quantitative figures are presented. *Teleworking and teleconferencing* Some co-benefits of teleworking which are qualitatively mentioned are lower illness rates and higher attractiveness of employers.
Additional remarks	

A.2 AVV (2004)

AVV (2004), Telewerken: De stand van zaken (Teleworking: current situation)	
Description of study	
Description of behavioural mitigation measure	Teleworking
Description of BAU scenario applied	No specific BAU scenario is defined in this study.
Time horizon of the study	No specific time horizon is defined in this study.
Scope of the study	The study focus on commuting transport. The geographical scope of the study is the Netherlands.
Assessment method applied	The study provides an overview of results from the literature.
Data sources used	The most important data sources used in this study are: – Martens et al. (2002), Telework put into practice. An international exploration of telework business cases. – Hague Consulting Group (1992), Minder woon-werkverkeer door Telewerken: rapportage van de Nederlandse telewerk experimenten. – Kropman et al. (1992), Flexibilisering van tijdroosters: een instrument voor beïnvloeding mobiliteit? – Van Reisen (1997), Ruim baan voor Telewerken? Effecten van flexibele werkvormen op ruimtelijke ordening en mobiliteit als gevolg van veranderend tijd-ruimtegedrag.
Mitigation potential	
Direct effects	AVV (2003) presents a wide range of results with regard to the reduction in commuting car kilometres. Martens et al. (2002) predict a direct reduction effect in commuting kilometres of 0 to 5%. However, due to a rebound effect (additional business and private trips), the net effect is estimated at ca. 0.5%. Hague Consulting Group (2000), on the other hand, estimate the reduction potential of teleworking at 14% to 16% of the commuting car kilometres. No impact on CO_2 emissions is estimated.
Indirect effects	Indirect effects are not estimated.
Rebound effects	Contrary results are found with respect to the rebound effects of teleworking. As mentioned above, Martens et al. (2002) estimates that the rebound effect is almost equal to the direct effect. However, Mokhtarian (in Kropman et al., 1992) found no evidence for the so-called generating effect (more private or business kilometres). Van Reisen (1997) shows another rebound effect: after two years of teleworking about 15% of the participants are moving to a house farther away from their job.
Costs and side-effects	
Cost estimates	No cost estimates are presented.
Side-effects included	Some side-effects are identified in this study: – Less cars are purchased, since households are better able to share one car. – Labour participation of women and disabled people could increase. – Less congestion due to a dispersal of commuting traffic. – Positive health effects teleworkers.
Additional remarks	

A.3 Bouwman and Mol (2000)

Bouwman and Mol (2000), Energy use reduction potential of passenger transport in Europe, Transport	
Description of study	
Description of behavioural mitigation measure	The behavioural mitigation measures considered in this study are: – Travel by public transport instead of by car. – Increase average vehicle lifetime from 12.5 to 15 years. – Choose smaller cars (on average 850 kg). – Increase the average vehicle occupancy rate (doubling).
Description of BAU scenario applied	In this study two BAU scenarios are applied, which are described in more detail in Ybema et al. (1997): – The scenario Rational Perspective (RP) is ecologically driven: new technologies can penetrate quickly due to a policy shift that facilitates implementation. Transportation growth is limited, and a shift to an increased use of public transport is assumed. – In the Market Drive (MD) scenario the market mechanism allows new technologies to compete only in term of price. Consumption grows more rapidly than in the RP scenario, as does the mobility demand. No modal shift changes are assumed. In this study an average OECD Europe passenger car is used in some of the calculations. It is assumed that the direct and indirect energy use of this car is equal to 1.9 and 0.4 MJ per passenger kilometre (pkm) respectively in 1990. In the BAU scenario this energy use increase due to an increase in the average vehicle weight (1,000 kg in 1990 to 1,220 kg in 2020 and 1,270 kg in 2050). In 2050 the energy use will be 17% than in 1990.
Time horizon of the study	The study presents reduction potentials for the individual mitigation measures for the years 2000, 2015, 2030 and 2050. The reduction potentials of packages of mitigation measures are presented for 2020 and 2050.
Scope of the study	The geographical scope of this study is the OECD Europe
Assessment method applied	In this study first the reduction potentials per pkm of both individual technological and non-technological measures are determined. Next, the CO_2 reduction potential of combinations of these measures is calculated. The reduction potential of individual technological measures are derived from a database on technological efficiency improvements in transport. With regard to the non-technological measures the penetration ratios of the various measures were presented like scenarios (e.g. doubling of occupancy rate), for which the resulting reduction potentials are calculated. Based on the reduction potentials of the individual measures the total CO_2 reduction potential of the measure packages are calculated. In this factsheet we only discuss the potentials related to non-technological measures.
Data sources used	– Ybema et al. (1995), Prospects for energy technologies in the Netherlands, vol. 2: technology characterisations and technology results. – Ybema et al. (1997), Scenarios for Western Europe on long-term abatement of CO_2 emissions. – Bouwman and Moll (1997), Status quo and expectations concerning the material composition of road vehicles and consequences for energy use. – Moll and Kramer (1996), Naar een optimale levensduur van de personenauto.

Mitigation potential	
Direct effects	With regard to the various individual (non-technological) mitigation measures, the following reduction potentials (related to penetration scenarios) per pkm are presented: – It is assumed that the share of public transport in passenger mobility double from 14 to 28%. For these kilometres the energy efficiency per pkm would improve by 61% in 2020 and 73% in 2050. – An increase of the average vehicle lifetime from 12.5 to 15 years would reduce the energy use per vkm by 2%. The gain from dividing the production energy of the vehicle over a larger number of kilometres is partly lost by the need for increased maintenance. – Choosing a smaller car result in 15, 20, 21 and 22% CO_2 reduction per pkm in 2000, 2015, 2030 and 2050 respectively. The increase in reduction potential over the years is the result of the decrease in fuel efficiency due to the increase in average vehicle weight. – Doubling the occupancy rate of passenger cars reduces the energy use per pkm by 50%. In addition to the reduction potential per pkm also the total reduction potential for various policy packages are presented. For all non-technological measures the reduction potentials also includes the technological measures considered in the study.

Table 26 Reduction potentials of various measure packages

Set of measures	2020	2050
Without non-technological measures	37%	54%
With increased vehicle life (+ 2.5 year)	39%	56%
With 850 kg passenger car	46%	60%
With higher average occupancy rate	68%	77%
Doubled public transport share	40%	57%
With all non-technological measures combined	72%	80%

Indirect effects	Indirect energy use (fuel production, vehicle production) are taken into account.
Rebound effects	Rebound effects are not taken into account.
Costs and side-effects	
Cost estimates	No cost estimates are presented.
Side-effects included	Side-effects are not considered in this study.
Additional remarks	

A.4 CE (2008)

CE (2008), State-of-the-art CO_2 en Mobiliteit (State-of-the-art $CO_{2=}$ and Mobility)	
Description of study	
Description of behavioural mitigation measure	In this study the following behavioural mitigation measures are considered: – Buying smaller cars. – Apply a fuel-efficient driving style.
Description of BAU scenario applied	The current situation is used as BAU scenario.
Time horizon of the study	No clear indication of the time horizon is given.
Scope of the study	The geographical scope of the study is the Netherlands.
Assessment method applied	The estimation of the mitigation potential of the various behavioural measures is based on a literature review.
Data sources used	*Buying smaller cars* – IEEP (2005), Service contract to carry out economic analysis and business impact assessment of CO_2 emissions reduction measures in the automotive sector. *Applying a fuel-efficient driving style* – TNO (2006), Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2 emissions from passenger cars/
Mitigation potential	
Direct effects	*Buying smaller cars* Based on a detailed overview of new passenger car models sold in Europe in 2005, this study estimates a 'realistic' potential: 10-20% CO_2 reduction. The theoretical potential of buying smaller cars may even be bigger. *Applying a fuel-efficient driving style* Applying a fuel-efficient driving style could result in 10% higher fuel efficiency. This could be considered the maximum potential. According to the study, the maximal potential would only be realised just after following an eco-driving course. The results slowly diminish over time as the drivers revert to their original driving style. The effect a year or more after the course are estimated to be in the range of 3%. In addition to applying a fuel-efficient driving style car drivers could also reduce the CO_2 emissions of their car by maintaining the right tyre pressure. The potential of this measure is 2 to 3%.
Indirect effects	With regard to alternative fuels also the GHG-emissions of the fuel production are taken into account.
Rebound effects	Rebound effects are not discussed.
Costs and side-effects	
Cost estimates	*Buying smaller cars* No cost estimates are presented. *Applying a fuel-efficient driving style* The mitigation costs of this behavioural measure are assumed to be negative.
Side-effects included	Applying a more fuel-efficient driving style could result in an increase in traffic safety.
Additional remarks	

A.5 Ecofys (2008)

Ecofys (2008), Potential global CO_2 emission reductions from ICT use: Identifying and assessing the opportunities to reduce the first billion tonnes of CO_2 emissions	
Description of study	
Description of behavioural mitigation measure	The following (relevant) behavioural mitigation measures are considered by this study: – Telecommuting. – Making use of virtual meetings. – Making use of e-commerce. – Behavioural changes resulting in demateralisation in the field of paper and media.
Description of BAU scenario applied	With regard to the transport flows and emissions in 2030 the BAU scenario was based on WBCSD projections (WBCSD Mobility 2030: meeting the challenges of sustainability). Among other issues, these projections assume that 30% of total CO_2 emissions of light duty vehicles are due to commuting trips. In addition, Ecofys (2008) assumed that in OECD countries 30% of air travel is for business purposes. No information on the BAU scenario for the paper and media sector is presented.
Time horizon of the study	The mitigation potentials are estimated for 2030.
Scope of the study	In the study various geographical regions are distinguished, including OECD Europe and Eastern Europe. Since it is not clear which countries make up Eastern Europe, we will not present the figures for this region here. The European countries which are member of the OECD are in 2008: Belgium, Denmark, Germany, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Austria, Portugal, Spain, Turkey, UK, Iceland, Sweden, Switzerland, Finland, Hungary, Poland, Slovakia, and the Czech Republic.
Assessment method applied	The assessment of the mitigation potential of the various measures was based on a review of available literature. Based on this literature review some scenarios are constructed of the rate at which the behavioural measure will be applied by consumers. For these scenarios the reduction of CO_2 emissions are estimated. Since the amount of literature is in some cases quite limited, it is difficult to judge which scenario is most plausible. Due to these uncertainties it is not clear whether some of the scenarios present the maximum mitigation potential.
Data sources used	*Telecommuting* – Fuhr and Pociask (2007), Broadband services: economic and environmental benefits, The American Consumer Institute. – Dodgson et al. (2000), Motors and modems revisited: the role of technology in reducing travel demands and traffic congestion. – AeA (2007), Advanced electronics and information technologies: the innovation-Led Climate Change Solution. *Virtual Meetings* – Cairns et al. (2004), Smarter choices – changing the way we travel. *E-commerce* – Romm (2002), The internet and the new energy economy; Resources, Conservation and Recycling 36, 197-210. – Matthews et al. (2002), Energy implications of online book retailing in the US and Japan; Environmental Impact Assessment Review, 493-507. – Gay et al. (2005), Modelling Paradigm for the environmental impact of the digital economy; Journal of organisational and electronic commerce, 61-82. – Ministry of the Environment (2001), Dematerialisation: the potential for ICT and services; The Finnish Environment 533. – Siikavirta et al. (2003), Effects of E-Commerce on Greenhouse Gas Emissions: A case study of grocery home delivery in Finland. – Persson et al. (2000), Future CO_2 savings from on-line shopping jeopardised by bad planning. *Dematerialisation* – Romm (1999), The internet economy and global warming. – Boston Consulting Group (1999), Paper and the electronic media. – Romm (2001), The Internet economy and global warming: a scenario of the impact of e-commerce on energy and the environment.

Mitigation potential

Direct effects

Telecommuting

Based on some case studies three scenarios were constructed, which differ in the share of commuters adopting telecommuting: 5%, 10% and 30%. It is assumed that telecommuters would avoid 75% of their commuting emissions. The resulting CO_2 reductions in OECD Europe is equal to 6 Mton (1% of total passenger car CO_2 emissions), 12 Mton (2%) and 36 Mton (7%) respectively.

Telecommuting also results in changes in energy use at commercial buildings and residential buildings. However, due to a lack of data on these effects, the authors decided not to include these effects in their assessments.

Virtual meetings

Based on some case studies three scenarios were constructed for the substitution of air travel by virtual meetings (substitution of business trips by car or public transport by virtual meetings are not considered). In these three scenarios the GHG reductions are calculated for a 5%, 15% and 30% substitution of business travel by virtual meetings. The potential GHG emission reductions are equal to 5.0 (2% of all GHG emissions of air travel), 15.1 (5%) and 30.1 (9%) Mton CO_2e.

E-Commerce

Based on the results of the literature review three scenarios are considered for which the reduction in transport-related GHG emissions are estimated. In these scenarios it is assumed that 2%, 10% and 20% of daily household goods are bought by e-commerce. In addition, it is assumed that that all delivery of goods is done by vans or trucks. The resulting GHG emission reductions are 12.7 (1%), 63.6 (7%) and 127.3 (14%) Mton CO_2e.

All non-transport-related GHG emissions (e.g. due to reduced floor space in warehouses, more waste for packaging, optimal stock management) are not taken into account.

Dematerialisation

Three scenarios with regard to dematerialisation in the field of paper and media are considered: 20%, 60% and 100% dematerialisation. The global emission reductions which could be realised in these scenarios are shown below for various products.

Product	Emission reduction from dematerialisation (Mton CO_2)		
	20%	60%	100%
CDs and DVDs	0.69	2.06	3.44
Answering machines	0.06	0.18	0.30
Utility invoices	0.12	0.36	0.60
Banking invoices	0.14	0.41	0.68
Tax returns	0.50	1.49	2.48
Daily papers	8.07	24.22	40.37
Weekly papers	3.93	11.80	19.66
Catalogues	0.51	1.53	2.56
Brochures advertising	1.35	4.06	6.77
Books	2.14	6.43	10.72
Medical records	0.18	0.54	0.90
Total	32	95	158

Indirect effects

For none of the behavioural measures the indirect effects are included in the analysis. This means for example that Well-to-Tank emissions associated to the use of fossil fuels are not considered.

Rebound effects	*Telecommuting* Three important rebound effects are mentioned: – Latent demand from people who decide to travel as congestion, thanks to telecommuting, decreases. – Leisure travel from telecommuters that take advantage of the commuting time saved thanks to telecommuting. – Increased urban sprawl, facilitated by the diminished need to live in proximity to offices. These rebound effects are not quantified. It is, however, mentioned that they are smaller than the direct transport-related effects. In addition, it is mentioned that these rebound effects could be restricted by implementing flanking policies and measures. *Virtual meetings, E-commerce and dematerialisation* No specific rebound effects are mentioned and hence quantified.
Costs and side-effects	
Cost estimates	No cost estimates are presented for the various measures.
Side-effects included	Possible side-effects of the various measures are not discussed.
Additional remarks	

A.6 ETC/ACC (2008)

ETC/ACC (2008), Potentials for a modal shift from road to rail and ship – A methodological approach. Technical Paper 2008/18, Öko-Institut e.V., Berlin	
Description of study	
Description of behavioural mitigation measure	A shift of passenger transport from road to rail transport.
Description of BAU scenario applied	No BAU scenario was constructed. The maximum market share of rail transport as estimated in this study was compared to the current market share of rail transport.
Time horizon of the study	No specific time horizon is defined in the study. However, since the authors notice that the estimated potential can only be realised if the existing rail infrastructure is (at least) doubled it seems appropriate to assume that this potential could only be realised on the medium to long-term (2030/2050).
Scope of the study	The geographical scope of the study is the EU-27. The potential of modal shift estimated in the study refers only to passenger transport between NUTS 2 regions. According to TREMOVE this is only 26% of the passenger transport demand with regard to road and rail transport in the EU-27. Therefore, the potential estimated by the study should be regarded as a lower bound of the actual maximal potential.
Assessment method applied	A so-called 'segmentation approach' was used to estimate the modal shift potential. In fact, a two-step approach was used in this approach: 1. Segmentation of the passenger transport market, based on parameters influencing the modal choice. Several segmentation factors are identified, but due to a lack of data only three of these factors could be taken into account: rail infrastructure availability and service quality (population density was used as a proxy), travel time ratio for road to rail and cost ratio of road to rail. 2. The market share of rail in passenger transport in the segments with favourable conditions to rail transport is used to estimate the modal shift potential in the segments with less favourable conditions. This was done in four consecutive steps: • First, it was assumed to the precondition for rail infrastructure, service quality etc. could be brought into line with the conditions in high population density regions (> 400 persons/km^2). The average share of rail transport in these regions is equal to 20.6%, therefore this assumption leads to an average market share of rail transport in the EU-27 of 20.6%. • Second, it was assumed that a travel time ratio of road to rail could be improved to > 1 (train is faster than car). Based on an analysis of densely populated areas it was found that an improvement of this ratio could result in 8.1% increase in market share of rail. • Third, it was assumed that a lowering of costs for rail trips to a lower level than the costs for the same trip by car would result in an additional shift to rail. Based on a correlation analysis between the OD trips among the highly populated regions with a travel time ratio > 1, an increase in market share of train transport by 4.1% was estimated. • Based on the assessments described above, the modal share in every segment could at least be equal to 32.8%. However, it should be taken into account that in some segments the market share of rail transport is already above 32.8%. Correcting for this, it was found that the maximum market share of rail transport is equal to 33% (i.e. 336.3 billion pkm).
Data sources used	To apply the segmentation approach mobility data from the ETIS Base was used. This database contains OD pairs between NUTS 2 regions, the number and the distance of the trips and the mode for the year 2000. Additionally data on costs, rail service frequency and travel time for the different modes for the year 2003 are included.

Mitigation potential	
Direct effects	No CO_2 reduction potential was estimated. However, as mentioned above a maximum market share of rail transport of 33% (in passenger kilometres) is presented. If this is compared to the current market share of 9.5%, a maximum potential of 23.5% is found. Notice that a part of this potential is realised in the BAU scenario. However, these BAU developments are not identified in this study. To realise the maximum potential, a large increase in rail infrastructure capacity is needed (more than 300% for some OD pairs). According to the authors, this may not be feasible. Therefore they estimated another 'maximum' market share of rail transport assuming that the increase in current rail capacity is maximum 200%. In this case the maximum market share of rail transport is equal to 17.3% (246.7 billion pkm). Two important remarks with regard to the estimated modal shift potentials: – No further shift for high population density regions is assumed; therefore, perhaps, it does not reflect a maximum potential. – As said before, the potential estimated refers only to transport between NUTS 2 regions. Transport within these regions are not taken into account.
Indirect effects	No indirect effects are taken into account in this study.
Rebound effects	No rebound effects are taken into account in this study.
Costs and side-effects	
Cost estimates	No cost estimates were presented in this study.
Side-effects included	No specific side-effects were identified and/or quantified in this study.
Additional remarks	

A.7 King (2007)

King (2007) – The King Review of low-carbon cars. Part 1: the potential for CO_2 reduction	
Description of study	
Description of behavioural mitigation measure	The following behavioural measures are discussed in this study: – Buying electric cars. – Applying a fuel-efficient driving style.
Description of BAU scenario applied	In this study the mitigation potentials are in general presented as relative CO_2 reductions of new cars compared to today's (=2007) equivalent models.
Time horizon of the study	With regard to the behavioural mitigation measures mentioned above, especially a short term (ca. 2015) time horizon has been applied.
Scope of the study	The geographical scope of the study is the UK. The scope of the study is restricted to cars and vans.
Assessment method applied	All estimates of mitigation potentials and costs are based on a review of the available literature and consultation of experts/stakeholders. The mitigation potentials estimated are defined as relative CO_2 reductions of new cars compared to today's equivalent models. The impact on the total car fleet in the various years was not estimated.
Data sources used	The following data sources and experts/stakeholders are used/consulted: – Institute of European Environmental Policy (IEEP). – Department for Transport (DfT).
Mitigation potential	
Direct effects	*Buying electric cars* The mitigation potential of electric cars depends on the way the electricity is generated. However, emissions are likely to be lower than for conventional fuels if the electricity is generated from any form of primary energy, with the exception of coal. If the electricity is generated from renewable energy, such as wind power, the mitigation potential could be almost 100%. *Applying a fuel-efficient driving style* It is estimated that a more fuel-efficient driving style can reduce CO_2 emissions up to 15%. This potential could be realised on the short term (2015). On the longer term, many of these driving efficiencies will become electronically automated in cars, helping drivers to realise these savings. However, some of the CO_2 reductions related to these techniques are also taken into account by 'more fuel-efficient cars'. Therefore care should be taken to avoid double counting of reduction potentials.
Indirect effects	It is mentioned that the CO_2 emissions from car manufacture and disposal is in general about 15% of total life cycle CO_2 emissions from cars. However, as CO_2 emissions from car use decline, these emissions will become more important. In this study the CO_2 emissions related to the manufacturing and disposal of the car/technological improvements are not assessed.
Rebound effects	Rebound effects are not identified and hence quantified.
Costs and side-effects	
Cost estimates	Electric cars: the costs of electricity as car fuel are difficult to judge. However, it is likely that using electricity to power a car would be cheaper than petrol and diesel. In that case the abatement costs will be negative.
Side-effects included	Possible side-effects are not discussed.
Additional remarks	

A.8 Nuyts and Van Hout (2007)

Nuyts and Van Hout (2007), Bicycle or car? The potential for cycling in Flanders	
Description of study	
Description of behavioural mitigation measure	Modal shift from the car to the bicycle
Description of BAU scenario applied	No specific BAU scenario is defined in this study. To estimate the modal shift potential the potential market share of cycling was compared to the existing market share (in 2000). In 2000 the market share of cycling in Flanders was equal to 14.6%. Total CO_2 emissions of transport in Flanders were equal to 14.5 Mton.
Time horizon of the study	No specific time horizon is defined in this study.
Scope of the study	The geographical scope of the study was Flanders (northern Dutch speaking part of Flanders).
Assessment method applied	To estimate the potential of a shift from the car to the bicycle the following assumptions were made in the report: – if one trip in a trip chain is not substitutable, none of the trips of that chain is substitutable; – the number of kilometres people are willing to cycle depend on the duration of the activity they are cycling to: • 3 km (two way) if the time at the destination is shorter than 15 minutes; • 5 km (two way) if the time at the destination is between 15 and 60 minutes; • 5 km (one way) if the time at the destination is between 1 and 4 hours; • km (one way) if the time at the destination is more than 4 hours. – only 60% of the shopping trips could be done by bicycle; – only 50% of the trips to drop off or fetch someone can be done by bicycle; – no modal shift to bicycle can be expected for people older than 75; – at night (i.e. from 20.00 to 6.00) no modal shift to bicycle can be expected for men older than 65 and for women of all ages. Based on these assumptions and travel statistics for Flanders on car trips, estimates were made for the number of kilometres that could be shifted from the car to the bicycle. In addition to the basic approach described above some sensitivity analyses were made for the list of assumptions mentioned above.
Data sources used	In this study travel statistics for the year 2000 were used. These statistics are coming from the Flemish Travel Behaviour Study.
Mitigation potential	
Direct effects	According to the study about 17% of the car trips in Flanders could be shifted to the bicycle. This would induce a growth in the modal share of the bicycle from the current 15 to 25%. The number of car kilometres would reduce by about 4%. The transport CO_2 emissions would decrease by 1,8% (0,26 Mton). Based on the sensitivity analyses also a best and worse case was defined. In the best case about 21% of the car trips were considered substitutable; in the worst case 12% of the car trips could be replaced by bicycle trips. As mentioned by the authors, the potential estimated shouldn't be looked upon as the absolute maximum achievable, e.g. since changes in spatial planning (resulting in smaller average distances) are not taken into account.
Indirect effects	Possible indirect effects (related to the energy use of producing bicycles/cars, Well-to-Tank CO_2 emissions) are not quantified
Rebound effects	No rebound effects are identified.
Costs and side-effects	
Cost estimates	No cost estimates were provided by the study.
Side-effects included	No identification and quantification of side-effects are provided by the study.
Additional remarks	

A.9 Siikavirta (2003)

Siikavirta (2003), Effects of e-commerce on greenhouse gas emissions. A case study of grocery home delivery in Finland	
Description of study	
Description of behavioural mitigation measure	In this study the mitigation potential of applying grocery e-commerce is estimated.
Description of BAU scenario applied	Based on national statistics it is estimated that the current (2003) GHG emissions from grocery shopping travel by car is about 1.1 Mton, which is ca. 10% of total road traffic GHG emissions. Next to CO_2 also the greenhouse gasses CH_4 and N_2O are taken into account. The following emission factors are applied for these pollutants: – CO_2: 159 g/km for passenger car (gasoline) and 297 g/km for van (diesel). – CH_4: 0.014 g/km for passenger car (gasoline) and 0.0015 g/km for van (diesel). – N_2O: 0.03 g/km for passenger car (gasoline) and 0.008 g/km for van (diesel). The one-way distance to the grocery store averages 3.5 kilometres in Finland.
Time horizon of the study	The mitigation potential is estimated for the current situation (2003). It is assumed that this behavioural measure could be introduced immediately at a large scale (big bang).
Scope of the study	The geographical scope of the study is Finland.
Assessment method applied	To estimate the mitigation potential of applying grocery e-commerce a two-step approach was applied: 1. With the help of a routing simulation model the impact of e-commerce on the number of kilometres per order are estimated. This was done for metropolitan Helsinki. In this analysis four different kind of operating models of grocery e-commerce where identified: – E-grocery home delivery in three two-hour time slots between 17:00 and 21:00; – E-grocery home delivery in one-hour time slots between 12:00 and 21:00; – E-grocery home delivery to reception boxes between 8:00 and 18:00; – E-grocery home delivery once a week per customer between 8:00 and 18:00 to reception boxes. By comparing the number of kilometres per order for these cases with the number of kilometres per order in the BAU scenario the relative reduction in kilometres due to applying grocery e-commerce could be calculated. 2. The impacts estimated in step 1 are translated to the impacts on total kilometres in Finland by multiplying the number of kilometres associated to shopping by the relative reduction in kilometres due to grocery e-commerce. It should be mentioned that by applying this approach only the road traffic kilometres associated to shopping are included. However, some people will use other transport modes, like public transport, to travel to the grocery store. The mitigation potential of a switch of these people to grocery e-commerce is not included in the assessment.
Data sources used	
Mitigation potential	
Direct effects	Depending on the operating model applied e-grocery home delivery services can result in a reduction of kilometres per order in the range of 54 to 93%. A market share of e-grocery of 100% is assumed. For Finland this would lead to a GHG reduction of 0.19 to 0.95 Mton CO_2, which is 17 to 86% of the GHG emissions associated to grocery shopping travel. Total road transport emissions would decrease by 2 to 9%. Finally, the reduction in total GHG emissions of Finland is estimated at roughly 0.3 to 1.3%. The potential of e-grocery home delivery services could be higher in countries where the share of GHG emissions due to transport of the grocery products is higher than in Finland. It should be mentioned that not all direct impacts on GHG emissions of e-grocery delivery services are quantified in this study. However, these additional impacts are (qualitatively) identified: – reduction of overproduction; – less energy consumption by warehouses (since fewer warehouses are needed due to a reduction of inventory levels and centralisation of inventories);

	– less energy consumption by stores; – Internet's own use of energy; – energy consumption of refrigerated reception boxes.
Indirect effects	Consumers will be better able to base their decisions on environmental data (easier to compare the environmental impact of various products) and this may result in consumers influencing the emissions from the whole supply chain. This indirect effect is only discussed in qualitative terms. Indirect effects like the GHG emissions of fuel and car production are not taken into account.
Rebound effects	The fact that people may use the car for other purposes if they don't use it for shopping is mentioned (in qualitative terms) as a rebound effect.
Costs and side-effects	
Cost estimates	No cost estimates are presented in this study.
Side-effects included	Side-effects are not considered in this study.
Additional remarks	

A.10 Sloman (2003)

Sloman (2003), Less traffic where people live: how local transport schemes can help cut traffic	
Description of study	
Description of behavioural mitigation measure	In this study the following behavioural mitigation measures are considered: – Travelling by bus instead of by car. – Travelling by tram or light rail instead of by car. – Teleworking. – Participating in car clubs; car clubs provide individuals with access to a fleet of vehicles whenever needed, without the high fixed costs of individual car ownership. – Modal shift from the car to cycling. – Modal shift from the car to walking.
Description of BAU scenario applied	The calculations of the impacts of the various behavioural mitigation measures are based on the traffic levels in 2003 (based on national Statistics). Although the impacts are for the year 2010, this approach makes it possible to estimate approximate traffic reduction factors for 2010.
Time horizon of the study	In general, this study uses a short/medium term time horizon (about 7 years: 2003-2010). However, in some cases the impacts of the measures will not be fully realised by 2020. Where this is the case, an estimate is also made for the longer term maximum impact.
Scope of the study	The geographical scope of the study is the UK.
Assessment method applied	In fact, this study investigates the potential of local policies to realise the various behavioural mitigation measures. Therefore, the potential estimated for most of the measures cannot be regarded as maximum potential but should be seen as 'realistic' potential in the UK. In this study two scenarios for national application of the various mitigation measures were developed: 'enlightened business as usual' and 'ambitious change'. In the enlightened business as usual scenario it is assumed that local authorities do what the best ones in the UK are doing already. Ambitious change assumes that both national and local authorities pull out all the stops to achieve the maximum behaviour change, in line with the best that is being achieved internationally. Since the latter scenario provides mitigation potentials which correspond to a larger extent to the maximum potential than the former scenario, we will only present the results from the 'ambitious change' scenario here.
Data sources used	*Travelling by bus instead of by car* – Dublin Transportation Office (2002), personnel communication. – Fitzroy et al. (1998), Public transport demand in Freiburg: why did patronage double in a decade?, Transport Policy 5 (3), 163-173. – Fitzroy et al. (1994), The demand for public transport: some estimates from Zurich, International Journal of Transport Economics 21 (2), 197-207. – Ott (2002), The Zurich experience in Alternatives to congestion charging: proceedings of a seminair held by the Transport Policy Committee. *Travelling by tram or light rail instead of by car* – House of Commons ETRA Committee (1999), Eight Report on Light Rapid Transit Systems. – Knowles (1996), Transport impacts of Greater Manchester's Metrolink light rail system, Journal of Transport Geography 4 (1), 1-14. – Transport for London (2002), Croydon Tramlink Study: a summary of the main findings. – West Midlands Joint Committee (2002), West Midlands Local Transport Plan 2002: The Transport Monitor. *Teleworking* – DTLR (2002), The impact of information and communications technologies on travel and freight distribution patterns: review and assessment of literature. – Lake et al. (1997), Assessing the impact of advanced telecommunications on work related travel. *Participating in car clubs* – Muheim (1998), CarSharing – the key to combined mobility. – Shaheen et al. (2002), Shared use vehicle services: a survey of North American Market. – Steininger et al. (1996), Car-sharing organisations. The size of the market segment and revealed change in mobility behaviour, Transport policy 3(4), 177-185.

	Modal shift from the car to cycling – CfIT (2001), European best practice in the delivery of integrated transport. – ADONIS (1998), Analysis and development of new insight into substitution of short car trips by cycling and walking. *Modal shift from the car to walking* – Curtis (1996), Can strategic planning contribute to a reduction in car-based travel? Transport Policy 3 (1/2), 55-65. – Meurs en Haaijer (2001), Spatial structure and mobility, Transportation Research Part D 6, 429-446. – Winter et al. (1995), Compact but sustainable, Planning Week 8.
Mitigation potential	
Direct effects	*Travelling by bus instead of by car* Based on the situation with regard to bus travel in Dublin, Freiburg and Zurich, it was estimated that bus patronage could be doubled in metropolitan areas and increase by 30% in shire counties. Based on empirical data it was assumed that about 1/3 of the new bus travellers are coming from the car. Based on this assumption it was estimated that car travel would fall by 0.9%. *Travelling by tram or light rail instead of by car* Based on the statistics on the six existing light rail or tram schemes in the UK, it was estimated that a growth on the existing lines and construction of 25 new ones could reduce travel demand by 0.03% in 2010. Construction of more lines before 2010 was judged not to be realistic. *Teleworking* Based on a review of (case) studies on teleworking, it was assumed that an additional 35% of the UK labour force could be working at home for 2 days in 2010. This would result in a decrease in total car traffic by 2.8% in 2010. Possible rebound effects are assumed to be negligible or are due to a lack of evidence not taken into account (see below). *Participating in car clubs* Based on Austrian and Swiss studies it was estimated that on the long run 10 to 20% of adult driving-licence holders might join a car club in large urban areas where public transport is good enough to make car club membership feasible. This would result in a reduction of total car kilometres of about 1.6%. For the short term (2010) a more prudent estimation was presented of 0.04% of total car mileage. The rather large difference between these two estimations may be explained by the lack of experience with car clubs in the UK, so that applying this kind of behaviour by a large share of car drivers may take some time. *Modal shift from the car to cycling* About 16% of total car mileage is on trips of less than eight kilometres and many of these trips could be cycled (not all, for example because it involves carrying a heavy load). It is estimated that if just one third of these trips were made by bike, total car traffic would be cut by more than 5%. For the short term (2010) it was estimated – based on experiences in Germany – that total car kilometres could be reduced by 1.2% by a modal shift to cycling. *Modal shift from the car to walking* In the UK very short car trips of two miles or less make up about 3% of all car mileage. Some of these short car trips cannot be made on foot (e.g. they involve carrying a heavy load), but no indication of the share of them is given by the study. Additionally, it is estimated that ca. 3% of all car mileage refers to trips for which a switch of destination and hence travel mode is possible (e.g. replacing a longer car trip to the supermarket by a shorter trip on foot to the shop on the corner). So, the total car mileage potentially transferable to walking is therefore around 6%. However, some of these trips would switch to cycling, which is estimated to be ca. 1%. The maximum potential of a modal shift from the car to walking is about 5% of all car mileage, which should be considered an upper bound since no correction is made for short trips which have to be done by the car (e.g. since they involve carrying a heavy load). In the study also a more realistic potential (1.7%) is estimated.

Indirect effects	Indirect effects are not considered.
Rebound effects	For most of the behavioural mitigation measures no attention is paid to rebound effects. An exception is teleworking, for which the rebound effects are extensively discussed. The following possible rebound effects are identified: – The employee may make other (additional) journeys by car during the day (e.g. to take the children to school). These journeys might have been made as part of a linked trip if she/he had been driving to work. – Another family member may take advantage of the fact the car is available. – Teleworking could encourage people to live further from their work, which could increase the commuting distance on days when the employee travelled to work. Based on a literature review, it was concluded that teleworking does reduce car mileage amongst teleworkers; in other words, the direct effects are larger than the rebound effects. More specifically, it was assumed that teleworking neither increases nor reduces car use for non-work journey purposes. With regard to people moving further away from their work, no evidence for this effect was found in the literature. Therefore, this rebound effect was not taken into account.
Costs and side-effects	
Cost estimates	No cost estimates are presented in this study.
Side-effects included	Side-effects are not systematically discussed for the various behavioural mitigation measures. Only for the modal shift from the car to walking the accompanying health benefits are mentioned as an important co-benefit.
Additional remarks	

A.11 The Climate Group (2008)

The Climate Group (2008), SMART (2020): Enabling the low carbon economy in the information age	
Description of study	
Description of behavioural mitigation measure	In this study the following behavioural mitigation measures are considered: – Making use of online media instead CD/DVD. – E-commerce. – E-paper. – Videoconferencing. – Telecommuting.
Description of BAU scenario applied	The BAU scenario is constructed based on a literature review and interviews with experts and stakeholders. All assumptions on the BAU scenario could be found in Annex 2 of the report.
Time horizon of the study	The study applies a medium term (2020) time horizon
Scope of the study	The study applies a global scope.
Assessment method applied	The mitigation potentials of the various behavioural measures are based on expert and company interviews, regional interviews and site visits, as well as extensive literature reviews. Since specific literature references are often lacking, it is not clear on which sources the various assumptions for estimating the mitigation potentials are based. Although not clearly indicated in the report it seems that not the maximum potential but a (high) realistic potential is estimated.
Data sources used	In this study a large amount of literature is used, as well as interviews and workshops with experts and stakeholders. Due to a lack of specific literature references in this study, it is not possible to identify the most important data sources.
Mitigation potential	
Direct effects	*Making use of online media instead of CD/DVD* A global reduction of GHG emissions of 0.02 Gt CO_2e is estimated, which is 0.04% of total global GHG-emissions. To make this estimation it was assumed that 7 billion DVDs and 10 billion CD are sold per year, that these are all eliminated, and that the GHG emissions per CD/DVD equals 1 kg CO_2e. *E-commerce* A global reduction of GHG emissions of 0.03 Gt CO_2e is estimated, which is 0.06% of total global GHG-emissions. To find this figure it was assumed that the emissions from shopping transport declines by 3%. Shopping transport is assumed to be 20% of all private transport. The emissions from additional delivery vans and packaging materials are not taken into account. *E-paper* A global reduction of GHG emissions of 0.07 Gt CO_2e is estimated, which is 0.13% of total global GHG-emissions. To find this figure it was assumed that about 25% of all paper was eliminated. *Videoconferencing* A global reduction of GHG emissions of 0.08 Gt CO_2e is estimated, which is 0.15% of total global GHG-emissions. It was assumed that 30% of business travel (by rail and aviation) can be avoided through videoconferencing, which is about 9% of total rail and aviation passenger transport. *Telecommuting* A global reduction of GHG emissions of 0.26 Gt CO_2e is estimated, which is 0.5% of total global GHG-emissions. The following assumptions are made: – Work related car travel decrease by 80%, while non-work-related car travel increases by 20%. – In developed countries 10% of existing vehicles are affected, equivalent to 20% of people and 30-40% of working population, and 7% in developing countries. – A 15% increase in residential building emissions and a 60% reduction in office emissions is assumed, applied to 10% of residential buildings and 80% of office buildings.
Indirect effects	By estimating the mitigation potential, a cradle-to-grave approach to carbon emissions was applied, indicating that emissions from manufacture, transport, use and disposal are incorporated wherever possible.
Rebound effects	As described above, the rebound effects of telecommuting are taken into account. With regard to the other behavioural mitigation measures no reference to rebound effects is made in the study.

Costs and side-effects	
Cost estimates	No cost estimates are presented by this study.
Side-effects included	Possible side-effects are not discussed.
Additional remarks	

A.12 TNO et al. (2006)

TNO, IEEP and LAT (2006), Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2 emissions from passenger cars	
Description of study	
Description of behavioural mitigation measure	The behavioural mitigation measure assessed in this study is: – Applying a fuel-efficient driving style. Both the impact of in-car equipment as driver trainings are considered.
Description of BAU scenario applied	To estimate the overall CO_2 reduction the BAU scenario from TREMOVE is used.
Time horizon of the study	The emission reduction per kilometre is estimated for the time frame 2008-2012. The overall impact on CO_2 emissions of passenger cars is estimated for 2012 and 2020.
Scope of the study	The geographical scope of the study is the EU-15
Assessment method applied	The estimation of mitigation potential is based on a review of existing literature and insights.
Data sources used	The most important data sources are: – AVL-MTC (2003), Impact of EcoDriving on emissions. – ETH (2003), Auswirkungen von Eco-Drive bei Fahrzeugen im Jahr 2010. – Goudappel (2005), Monitoring en evaluatie Het Nieuwe Rijden. – TNO (2000), Driving style, fuel consumption and tailpipe emissions. – TNO (2002), Interpretation of driving style tips: application of the majar driving style tips of 'New Style Driving' by passenger car drivers and the effect on fuel consumption and tailpipe emissions. – VITO (2003), Eco-driving in a company fleet.
Mitigation potential	
Direct effects	Based on a literature review it was estimated that the mitigation potential of adapting a fuel-efficient driving style is about 10%. Using a gear shift indicator (GSI) provides a maximum reduction potential of 6%. However, this potential could not be added to the mitigation potential of fuel-efficient driving, since GSI should be seen as a tool that may help drivers to adequately apply eco-driving. Therefore, the total mitigation potential of fuel-efficient driving is 10%. Based on the TREMOVE baseline it is assumed that the WTW GHG emissions of passenger cars in the EU15 could be reduced by 7.5 and 18.1 Mton per year.
Indirect effects	The GHG emissions of fuel production are taken into account.
Rebound effects	Rebound effects are not discussed.
Costs and side-effects	
Cost estimates	The costs of a eco-driving course range s from € 50 to 100 (excl. VAT). The costs of mass communication is equal to ca. € 25 per affected driver. Finally, the cost of a GSI is estimated at € 15. Cost-effectiveness figures ranging from -128 to 8 €/tonne are presented, depending on the fuel price assumed and policy instruments applied (eco-driving course, mass communication).
Side-effects included	Side-effects are not discussed.
Additional remarks	
As mentioned in the study, the driving style in Northern countries is known to be generally less dynamic/aggressive than in Southern European countries. The potential CO_2 reduction of fuel-efficient driving in Southern countries therefore may be higher. These possible differences between countries are neglected in the present analysis.	

A.13 UBA (2010)

UBA (2010), CO_2-Emissionsminderung im Verkehr in Deutschland. Mögliche Maßnahmen und ihre Minderungspotenziale	
Description of study	
Description of behavioural mitigation measure	In this study the following behavioural mitigation measures are discussed: – Modal shift from the car to the train. – Modal shift from the car to local public transport. – Modal shift from the car to walking/cycling. – Car-sharing. – Car-pooling. – Fuel-efficient driving.
Description of BAU scenario applied	The BAU scenario used in this study is based on the TREMOD Trend scenario. The main traffic data used in this scenario is presented in the table below.

	2005	2020	2030
Passenger kilometres (bln.)			
Road	963	1,063	1,055
Rail	90	104	104
Aviation	168	270	355
Vehicle kilometers (bln.)			
Passenger car	579	661	671
Motorcycle	17	25	25
Bus	4	4	4
LCV	37	42	46
HGV	55	62	66
Other	8	11	11

	The total CO_2 emissions of passenger transport (road, rail and aviation) in Germany are equal to 140.7 in 2005, 147.7 in 2020, and 140.7 in 2030. Some CO_2 reduction measures are included, like the use of biodiesel (9,5% in 2020 and 10% in 2030) and bio-ethanol (4.7 in 2020 and 5.4% in 2030).
Time horizon of the study	For all behavioural mitigation measures potentials for 2020 and 2030 are estimated.
Scope of the study	The geographical scope of the study is Germany.
Assessment method applied	The mitigation potential of the various behavioural measures were estimated by using results from the literature, results from front runner German cities or other countries and expert guesses. Per measure a set of policy measures was presented which should be implemented to realise the potentials. *Modal shift from the car to the train* It was assumed that in 2030 people in Germany travel as much kilometres by train as the people in Schweiz (ca. 2000 km per year). The additional train kilometres replace car (80%) and aviation kilometres (10%), and are also the result of 'new' trips (10%). *Modal shift from the car to local public transport* Based on the modal shift in front runner cities in Germany it was assumed that the number of car kilometres within cities could be reduced by 10% due to a shift to public transport. *Modal shift from the car to walking/cycling* Based on the modal shift in front runner cities in Germany and the literature, it was assumed that the number of car kilometres related to trips < 5km could be reduced by 50% due to a shift to walking/cycling. *Car-sharing* Car-sharing is mentioned as a possible behavioural mitigation measure, but no quantification of the potential of this measure is performed. *Car-pooling* Only commuting trips are included in the estimation of the car-pooling potential. It was assumed that the seat occupancy could increase from 1.07 to 1.26. *Fuel-efficient driving* It is assumed that due to policies about 50% of the car drivers could be encouraged to apply a fuel-efficient driving style. In the literature it was found that the maximum potential to reduce the fuel use of a passenger car by applying a fuel-efficient driving style is 25%, of which about

	50% is actually realised. Due to technical improvements of the car, the maximal reduction potential decrease to 20% in 2020 and 15% in 2030. In the end, the fuel reduction potential is estimated to be equal to 5% in 2020 and 4% in 2030.
Data sources used	Transport and emissions data are all from a national emission model, i.e. TREMOD (Transport Emission Model).
Mitigation potential	
Direct effects	The direct mitigation potentials of the various measures are shown in the table below. These potentials cannot be regarded as maximum potentials, since the assumptions underlying these potentials refer to specific policy packages.

Table 27 Reduction potential for various behavioural measures in Mton and as share of the total CO_2 emissions of passenger transport.

	Reduction potential 2020		Reduction potential 2030	
	Mton	%	Mton	%
Modal shift to rail	1.9	1.3%	3.2	2.2%
Modal shift to public transport	2.6	1.8%	1.9	1.3%
Modal shift to walking/cycling	5.0	3.4%	4.0	2.7%
Car-pooling	2.5	1.7%	3.2	2.2%
Fuel-efficient driving	4.7	3.2%	3.7	2.5%

Indirect effects	Indirect effects are not mentioned and hence quantified.
Rebound effects	Rebound effects are not taken into account in this study.
Costs and side-effects	
Cost estimates	No cost estimates are provided by the study.
Side-effects included	No side-effects are identified and quantified by the study.
Additional remarks	