TREMOVE 2

Service contract for the further development and application of the TREMOVE transport model - Lot 3

Service Contract 070501/2004/387327/MAR/C1

FINAL REPORT
PART 3: Policy runs

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Introduction

This document gives an overview of the **TREMOVE** baseline.

TREMOVE is a transport and emissions simulation model developed for the European Commission. It is designed to study the effects of different transport and environment policies on the emissions of the transport sector. The model estimates the transport demand, the modal split, the vehicle fleets, the emissions of air pollutants and the welfare level under different policy scenarios. All relevant transport modes are modelled, including air transport. Maritime transport is treated in a separate model. TREMOVE covers the 1995-2020 period, with yearly intervals.

Other reports on TREMOVE are:
- PART 1: Description of the model version 2.44
- PART 2: Description of the baseline
- PART 4: Model and policy runs - maritime transport

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Overview

This report presents scenario simulations performed under the TREMOVE 2 Lot 3 contract. Table 1 provides an overview of the simulations discussed in this document.

Most simulations discussed in this report relate to the impact assessment for “Euro 5” standards for cars and N1 vehicles, and to the impact assessment for further reductions of car and N1 CO_2 emissions beyond the current voluntary agreement with the car manufacturers. Besides, also simulations on truck road charging and fuel excise taxes are presented.

The approach of the present report is based on the "panel report" for new emission standards for Light Duty Vehicles, the "Task A" report for further reduction of CO2 emissions from light-duty vehicles, and on assumptions and other background information provided by the European Commission. The outcome of ,the TREMOVE modelling provided an essential input for the impact assessment of the related policy proposals, but this report should not be considered under any condition as an impact assessment report, on which the Commission has sole responsibility, and for which additional quantitative or qualitative analysis may have been performed.

The TREMOVE 2 model and baseline have been undergoing continuous development, resulting in subsequent model versions. Table 1 indicates which model version has been used for each of the simulations.

The remainder of this report consists of three chapters. Chapter II discusses the “Euro 5” scenario simulations. Chapter III presents the simulations on further reductions of car and N1 CO_2 emissions. Chapter IV presents the simulations on environmental policies for maritime transport. Finally, in chapter IV simulations on truck road charging and fuel excise taxes are shortly discussed.

Table 1: Overview of TREMOVE simulations performed in Lot 3

Code	Model version	Scenario	Variation
A1	v2.32b	“Euro 5”	Diesel cars - 75 mg NOx; 2.5 mg PM - min. cost - >2l : medium cost
A2	v2.32b	“Euro 5”	Diesel cars -150 mg NOx; 2.5 mg PM - min. cost - >2l : medium cost
A3	v2.32b	“Euro 5”	Diesel cars -150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 1 *33% economies of scale*
A4	v2.32b	“Euro 5”	Diesel cars - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 1 *33% economies of scale*
A5	v2.32b	“Euro 5”	Diesel cars - 150 mg NOx; 5 mg PM - avg. cost - >2l : approach 1 *33% economies of scale*
A6	v2.32b	“Euro 5”	Diesel cars - 200 mg NOx; 5 mg PM - min. cost - >2l : approach 1 *33% economies. of scale*
A7	v2.32b	“Euro 5”	Diesel cars - 150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 2 *33% economies of scale*
A8	v2.32b	“Euro 5”	Diesel cars - 150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 2 *40% economies of scale*
A9	v2.32b	“Euro 5”	Diesel cars - 150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 2 *67% economies of scale*
A10	v2.32b	“Euro 5”	Diesel cars & N1 - 150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 1 *33% economies of scale*
A11	v2.32b	“Euro 5”	Diesel cars & N1 - 150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 2 *33% economies of scale*
A12	v2.32b	“Euro 5”	Diesel cars & N1 - 150 mg NOx; 2.5 mg PM - avg. cost - >2l : approach 2 *33% economies of scale* *No effect on fuel consumption*

Code	Model version	Scenario	Variation
A13	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% econ. of scale*
A14	v2.32b	“Euro 5”	Petrol cars & N1 - 50 mg VOC; 24 mg NOx – avg. cost - >2l : approach 2
A15	v2.32b	“Euro 5”	Petrol cars & N1 - 75 mg VOC; 48 mg NOx – avg. cost - >2l : approach 2
A16	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 50 mg VOC; 24 mg NOx – avg. cost - >2l : approach 2
A17	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 33% economies of scale Petrol cars & N1 - 50 mg VOC; 24 mg NOx - avg. cost - >2l : approach 2 *No effect on maintenance cost*
A18	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 48 mg NOx - avg cost - >2l : approach 2 *No effect on maintenance cost*
A20	v2.32b	“Euro 5”	Diesel cars & N1 - 75 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 60 mg NOx - avg cost - >2l : approach 2 *No effect on maintenance cost*
A21	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 60 mg NOx – ½ avg. cost - >2l : approach *No effect on maintenance cost - Introduction in 2009*
A22	v2.32b	“Euro 5”	Diesel cars & N1 - 75 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 60 mg NOx – ½ avg. cost - >2l : approach 2 *No effect on maintenance cost - Introduction in 2009*
A23	v2.32b	“Euro 5”	Diesel cars & N1 - 150 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 60 mg NOx – ½ avg. cost - >2l : approach 2 *No effect on maintenance cost - Introduction in 2009*
A24	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 60 mg NOx – ½ avg. cost - >2l : approach *No effect on maintenance cost - Introduction in 2009* Diesel cars & N1 – from 2013 onwards 75 mg NOx
A25	v2.32b	“Euro 5”	Diesel cars & N1 - 200 mg NOx; 2.5 mg PM - min. cost - >2l : approach 2 *33% economies of scale* Petrol cars & N1 - 75 mg VOC; 60 mg NOx – ½ avg. cost - >2l : approach *No effect on maintenance cost - Introduction in 2009* Diesel cars & N1 – from 2014 onwards 80 mg NOx
C1	v2.32b	Excise duties	Increase road fuel excise tax for financing development aid 0.03 EURO per litre
C2	v2.41	Excise duties	Modified diesel excise duties
D1	v2.32b	CO_2 car and N1	Trial run - 120 g - IEEP (2004)
D2	v2.32b	CO_2 car and N1	Trial run - 120 g - IEEP (2004) EPS utility curve (pan area) - not optimised EPS curve
D3	v2.41	CO_2 car and N1	Trial run - 120g - IEEP (2004)
D4	v2.41	CO_2 car and N1	Trial run - 120g - TNO (Interim, 2005)
D5	v2.42	CO_2 car and N1	120g - IEEP(2004)
D6	v2.42	CO_2 car and N1	120g - TNO (Draft, 2006)
D7	v2.42	CO_2 car and N1	130g - TNO (Draft, 2006)
D20	v2.43b	CO_2 car and N1	135g - TNO (Final, 2006)
D21	v2.43b	CO_2 car and N1	130g - TNO (Final, 2006)
D22	v2.43b	CO_2 car and N1	125g - TNO (Final, 2006)
D23	v2.43b	CO_2 car and N1	120g -TNO (Final, 2006)
D24	v2.43b	CO_2 car and N1	125g + GSI - TNO (Final, 2006)
D25	v2.43b	CO_2 car and N1	125g + GSI + TPMS - TNO (Final, 2006)

Code	Model version	Scenario	Variation
D26	v2.43b	CO_2 car and N1	125g + GSI + TPMS +N1 -15g - TNO (Final, 2006)
D27	v2.43b	CO_2 car and N1	125g + GSI + TPMS +N1 -15g + LRRT - TNO (Final, 2006)
D28	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -15g + LRRT + MAC - TNO (Final, 2006)
D29	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -30g + LRRT + MAC - TNO (Final, 2006)
D30	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -30g + LRRT + MAC + LVL - TNO (Final, 2006)
D31	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -45g + LRRT + MAC + LVL - TNO (Final, 2006)
D32	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -60g + LRRT + MAC + LVL - TNO (Final, 2006)
E1	v2.32b	Charging	Heavy duty truck infrastructure charging Charge equal to marginal external cost (by technology)
F1	v2.32b	Retrofit	Trial run #1
F1	v2.32b	Retrofit	Trial run #2

Scenario A19 results are not included in this report, as A19 scenario inputs included errors.

Scenarios D8 to D19 were trial runs, performed with incomplete model code versions, as preparation of the final set of D20-D32 runs.

II New "Euro" emissions standards for Light Duty Vehicles

As shown in Table 1 25 policy simulations have been performed in the context of the impact assessment of possible “Euro 5” emission standards for cars and N1 vehicles.

This chapter is composed of four sections. In the first section 1 an overview of the 25 “Euro 5” scenario simulations is given. Section 2 then refers to the input data and assumptions used in the scenario modelling. Thereafter an extensive and detailed discussion on the results of simulations A16 to A25 follows in section 3, as they are the only scenarios in which the impact of a complete “Euro 5” standard on both petrol and diesel cars and N1 vehicles has been simulated. Section 4 then provides suggestions and caveats for further research work. Additionally, earlier scenario simulations A1 to A15, which consider the impacts of partial “Euro 5” standards on either petrol or diesel vehicles, are discussed shortly in Annex A. These simulations rely on alternative assumptions and are useful in the context of sensitivity analysis.

1. Overview of “Euro 5” scenarios

During the assessment of alternative “Euro 5” standards, several scenarios have been assessed using TREMOVE (see Table 1 for an overview list).

Overall, the analysis was performed in four phases. At first, the analysis focused on alternative options for diesel car standards (scenarios A1 to A9). Later on also diesel N1 vehicles were included in the assessment (scenarios A10 to A13). Scenarios A14 and A15 focused at alternative options for petrol vehicles. Finally, simulations A16 to A25 were performed to analyse the full impact of a possible "“Euro 5”" proposal that would apply to both petrol and diesel cars and N1 vehicles.

The scenarios A1 to A15 are used in this notes as a background for the discussion of some core hypothesis and alternative emission standards, in form of sensitivity analysis, while an extensive and detailed discussion of the results is presented only for the 9 scenarios (A16 to A18, A20 to A25) in which the impact of a complete “Euro 5” standard on both petrol and diesel cars and N1 vehicles has been simulated on similar modelling assumptions.

Different emission limit values have been considered. Figure 1 and Figure 2 show the limit values that have been assessed in the various scenarios for diesel and petrol vehicles respectively. In most scenarios these limit values are assumed to apply for all new sold vehicles from 2010 onwards. A21 to A25 however assume the new standards to be introduced in 2009. Furthermore, in A24 and A25 the NO_x limit value for diesel vehicles is lowered in two steps, with the second step in 2013 and 2014 respectively.

Figure 1 and Figure 2 illustrate that for several limit value combinations the European Commission specified more than one TREMOVE scenario. The differences between these simulations are varying assumptions on the costs of the required emission abatement technologies. These simulations of scenarios with varying cost assumptions enable sensitivity analysis and make it possible to study the influence of specific cost components, such as additional fuel costs and maintenance costs.

Absolute figures are valid for cars, for N1 vehicles same % reductions thus higher absolute g/km values.

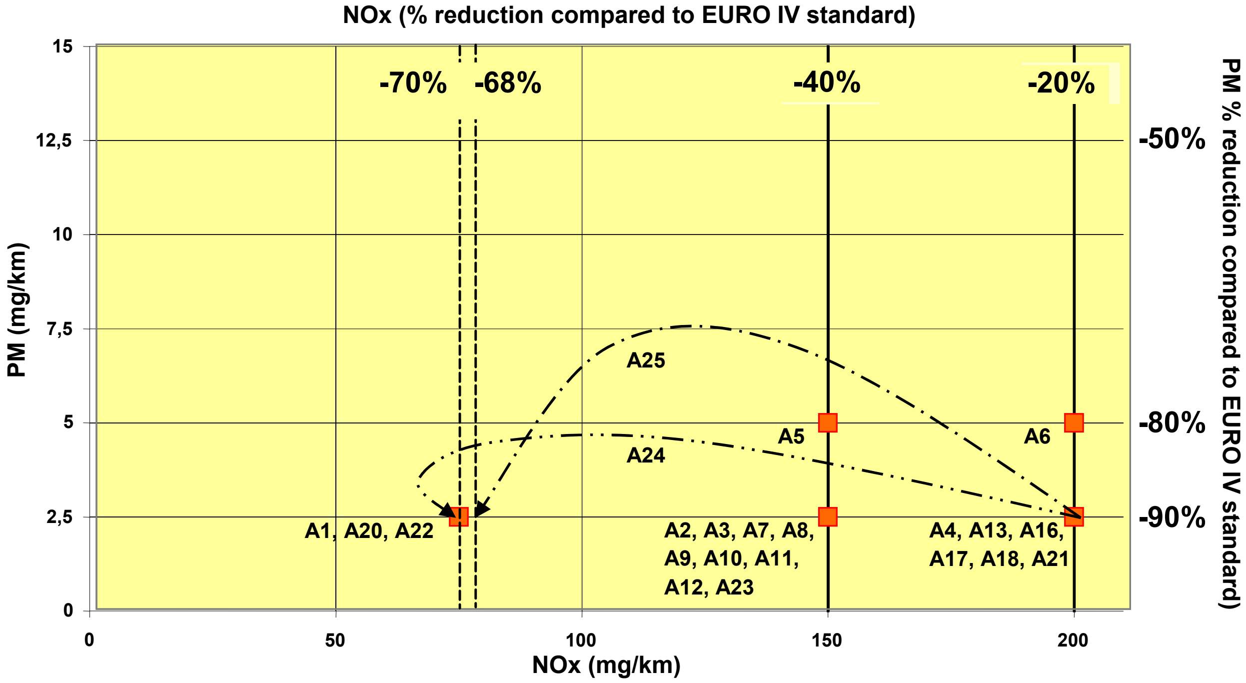

Figure 1: Limit values for diesel vehicles in the "Euro 5" scenarios

Absolute figures are valid for cars, for N1 vehicles same % reductions thus higher absolute g/km values.

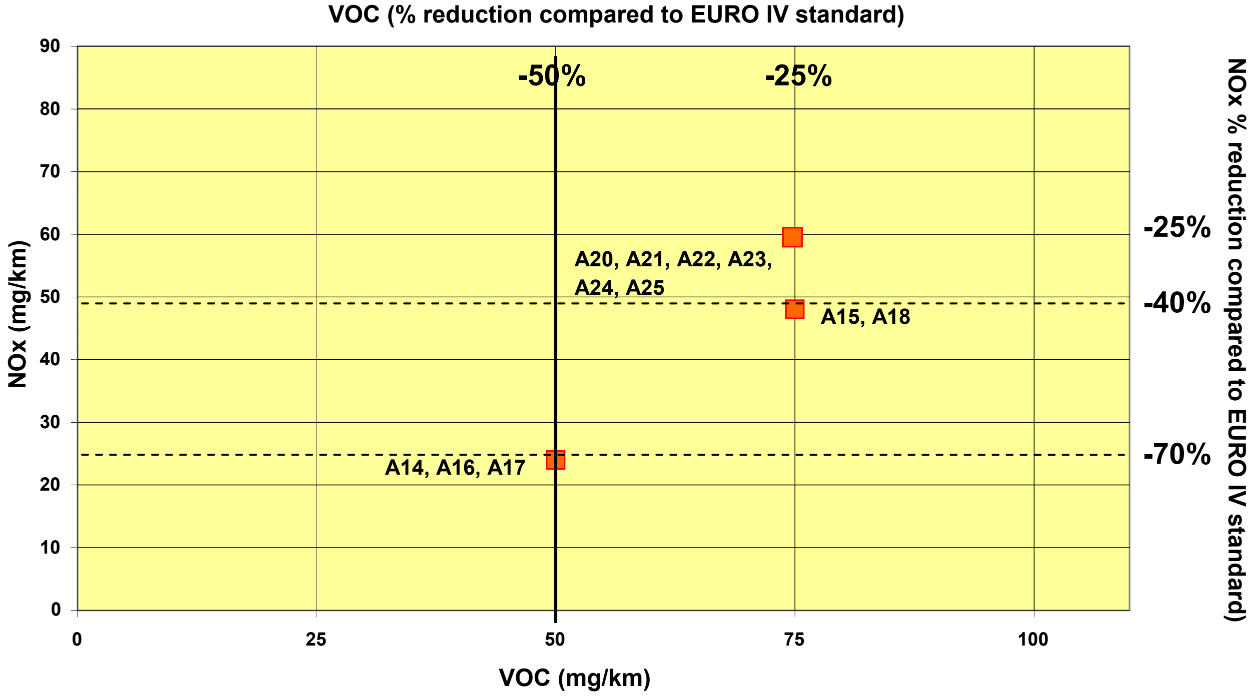

Figure 2: Limit values for petrol vehicles in the "Euro 5" scenarios

The following section will discuss in detail the assumptions underlying the different scenarios.

2. Scenario input data and assumptions

For the assessment of new "“Euro 5”" emission standard scenarios, detailed information on the availability of emission control technology and associated cost was needed. In order to obtain this information the Commission has sent out a questionnaire to specific members of the Motor Vehicles Emission Group (MVEG). The questionnaires asked for necessary technologies and involved costs in order to meet several prescribed emission standard scenarios.

The information received by the Commission in response to the questionnaires has come from several sources, making it impossible to use this basic feedback directly as input for the model calculations. The data has first been summarised and checked for reason, degree of coherence and the completeness of the total information received. A small group of independent experts in the field then has been appointed for further analysis of the data. Based on the information received and on other available information within the European Commission, an objective and coherent projection of possibilities and costs to meet the requirements of the scenarios under consideration has been established by this expert panel. This assessment resulted in a custom fit input for running the “Euro 5” simulation scenarios, in the form of a report [TNO, 2005a]. We will further refer to this report as the “*panel report*”.

In the remainder of this section we describe the scenario input data drawn from the panel report and additional scenario and model assumptions that have been made in agreement with the European Commission. We first start however with a paragraph on the TREMOVE baseline version used for the “Euro 5” scenario simulations.

2.1. Baseline for car and N1 regulated pollutant emissions

The "Euro 5" scenario simulations have been performed in the time period spanning from March 2005 to May 2006. For all simulations the same v2.32b TREMOVE baseline and model version has been used.

It should be noted that the v2.32b baseline version deviates significantly from the current v2.44 version. This is discussed in section 4. In general, following important baseline changes have been made since v2.32b :

- Introduction of the new Partial A SCENES transport forecast, based on new crude oil price and GDP forecasts
- Updated train fleet forecasts which has been developed in the context of the ASSESS project;
- Further calibration towards national statistics on road vehicle-kilometres by mode and road vehicle speeds for Belgium, Germany, France, United Kingdom and Spain;
- Introduction of blended biofuels, with up to 5.75% blending in 2010;
- Removed hybrid cars (see Chapter III, section III2.1);
- Updated the path for fuel-efficiency improvements for cars and N1 vehicles (see Chapter III, section III2.1);
- Updated well-to-tank emission factors for greenhouse gases (see Chapter III, section III2.1);
- Added low rolling resistance tyres, low value lubricants and tyre pressure monitoring technologies in the baseline (see Chapter III, section III2.1);
- Included CNG cars;
- Included extra fuel consumption and refrigerant leakage from car airconditioning equipment;
- Introduced exogenous car type market shares for years 1996 to 2005, based on statistics. And updated the car purchase choice logit models accordingly;
- Update from the road emission methodolgy from COPERT 3 to (draft) COPERT 4.

In particular the latter two baseline updates are of importance for the "Euro 5" simulations, as they have significant impact on market share of diesel vehicles and the NO_x and PM emission factors for EURO 4 cars.

In v2.32b basecase the market share of new diesel cars in the years 2001 to 2020 is similar to that in the year 2000. In v2.44 however, the 2001 to 2005 market shares are based on the available statistics. And an approximately constant new diesel car share is assumed from 2005 on. As the diesel car market share in 2005 was significantly larger in 2005 than in 2000, the new v2.44 baseline thus predicts a significanlty larger future market share for diesel cars than the v2.32b baseline. In v2.32b the 2020 market share of new diesel cars (average for EU15 and 4 new member states) is approximately 30%, in v2.44 this is rather 45%[1].

The COPERT 4 emission factors for Euro 4 cars differ significantly from those in COPERT 3. The NO_x emission factors for Euro 4 diesel cars in v2.44 are roughly 20% higher than those in v2.32b. The Euro 4 diesel car PM emission factors in v2.44 are rouhgly 25% lower than in v2.43b. The NO_x emission factors for Euro 4 petrol cars in v2.44 are roughly 40% lower than those in v2.32b. And also for Euro 4 petrol cars, the PM emission factors in v2.44 are roughly 75% lower than those in v2.43b.

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[1] Note that the first TREMOVE 2 versions (2.1) included future diesel market shares that were higher than those in v2.44. At that time these estimates have been lowered.after stakeholder consultations on the issue.

2.2. Effects on emissions and fuel consumption

2.2.1. NOx, VOC and PM10 emission factors

The NO_x, VOC and PM_{10} emission factors for "Euro 5" cars and N1 vehicles have been calculated by applying the reduction percentages in Figure 1 and Figure 2 to the COPERT III emission factors for Euro 4 vehicles.

No sufficient information is available on the difference in emission reduction performance of the technologies on the type approval driving cycle versus real-world driving cycles. As a consequence, the percentage difference between "Euro 5" and Euro 4 limit values has been used to estimate the difference between Euro 4 and "Euro 5" real-world emission factors.

For N1 vehicles the same percentage reductions are applied as for cars. As car and N1 Euro 4 limit values and emission factors differ, this will lead to different reductions when expressed in grams per kilometre for cars versus N1 vehicles.

The emission reduction percentages have been applied to both cold and hot emission factors, assuming that the "Euro 5" technologies have the same relative effect on cold and hot emissions.

For petrol vehicles, the VOC reduction percentage has been applied to the methane as well as the non-methane VOC emission factors. Thus, it is assumed that the "Euro 5" technology will not affect the fraction of methane in the total VOC emission.

In absence of specific information on LPG cars, the "Euro 5" standard is assumed not to change emission factors for these vehicles.

2.2.2. Fuel consumption, CO2 and SO2 emission factors

The panel report predicts a 1 percent to 2 percent fuel consumption increase for diesel cars and N1 vehicles equipped with particulate traps. Therefore, fuel consumption factors for "Euro 5" diesel cars and N1 vehicles have been estimated by increasing the corresponding Euro 4 vehicle fuel consumption factor by 1.5 percent.

As CO_2 and SO_2 emission factors are linear related to the fuel consumption factors in TREMOVE, the emission factors for these pollutants also increase by 1.5 percent.

The estimated fuel consumption increase relates to the effects of diesel particulate traps only. There is no convincing information on the influence of other emission abatement technologies on fuel consumption.

Sensitivity analysis

A sensitivity analysis has been performed with respect to the effects of the increase of fuel consumption for diesel vehicles equipped with PM traps. Scenario A12 assumes no fuel consumption increase, while Scenario A11assumes a 1.5% increase. All other assumptions are equal. The comparison between A11 and A12 indicates that, ceteris paribus. A12 leads to a decrease by –0.10% for total fuel consumption from cars and vans (net effect of the decrease in road transport demand due to the higher prices of vehicles) compared to an increase by 0.34% in A11. This results, for A12, in a 6% lower cost to society (2020 sum of changes in utility of households and production costs, and general marginal cost of public funding), compared to A11 in which the increase in unitary fuel consumption is introduced.

Detailed results for A11 and A12 can be found in Annex A.

2.2.3. *Other pollutants*

The panel report includes no information on the effects on emissions of the remaining non-regulated pollutants. Emission factors for "Euro 5" vehicles have been kept equal to their Euro 4 levels for these pollutants.

2.3. Technology cost

2.3.1. *Data available from questionnaire and panel report*

The differences in vehicle purchase prices between "Euro 5" and Euro 4 vehicles have been taken from the panel report. The panel report price figures, expressed in EURO 2004 purchase power, have been converted to EURO 2000 purchase power[2] using EU inflation rates.

The panel report cost figures have been considered equal to the difference in ex-tax purchase prices between Euro 4 and "Euro 5" cars. Due to lack of information no explicit mark-up or profit margin is included. Note that for example for catalysts and some additional components, the panel report actually uses market prices instead of costs, as the market for those components is that competitive that no cost information became available (even under highest confidentiality).

It is relevant to note that a number of assumptions are underlying the panel report cost figures:

- The cost estimates are based on a specific scenario on future precious metal prices;
- The cost estimates include assumptions on PM reduction measures to be applied on lean spark ignition engines;
- The cost of SCR urea infrastructure is not included in the cost estimates.

Furthermore, in the panel report, only 25% of the costs of expected engine internal measures are considered as "Euro 5" technology cost. The engine internal measures are seen to serve more purposes than reducing regulated emissions only. In addition to reducing regulated emissions, improvements in CO_2 emissions and fuel consumption, increased drive-ability and reduction of noise emissions are additional benefits of engine internal measures. It is therefore the panel's opinion that only part of the total costs for additional engine internal measures can be allocated to the "Euro 5" legislation. The panel decided to allocate 25% of the total costs for engine internal measures to "Euro 5" regulated emissions reduction.

We refer to the panel report for detailed information on the cost calculation methodology and related assumptions.

2.3.2. *Additional assumptions*

Based on the information received from the stakeholders the panel has developed minimum and maximum technology maps and related costs. The "minimum" is referred to as the case of a sophisticated, low engine out emissions base engine. The "maximum" refers to a base engine that has limited potential to be upgraded further then Euro 4.

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[2] In TREMOVE all monetary values in all model years are expressed in euro 2000 purchase power.

Scenario A1 and A2 are based upon the "minimum" cost estimates. All other scenarios are based on averages between the "minimum" and "maximum" cases, except if stated otherwise in the remainder of this paragraph.

For scenarios with a 200 mg. limit value for diesel car NO_x emissions, the "minimum" value for the corresponding 150 mg scenario has been used. This approach means that 200 mg. scenarios are not much cheaper than 150 mg. scenarios, and is supported by the fact that, looking at the technology maps at these low PM values, the choice on the part of the manufacturer as to how to reach the NO_x limit values is limited. For scenarios with less stringent PM limit values, more choices would be possible and the cost would expected to drop more strongly.

In scenario A, the final NO_x limit value for diesel cars is 80 mg. As suggested by the European Commission the cost for 75 mg. is used as a conservative estimate for this limit value.

The panel report notes that at this moment, no sufficient information is available on the difference in technology and costs to reach 2.5 mg. PM versus 5 mg. PM limit values. Therefore it has been suggested to use equal costs for scenarios with 2.5 mg. and 5 mg. PM limit values.

Scenarios A20 to A25 set limit values for petrol cars at 60 mg. NO_x and 75 mg. VOC. No cost estimates for these limit values are provided in the panel report. As proposed by the European Commission, half of the costs for the 48 mg. NO_x and 75 mg. VOC limit values have been applied.

Whereas TREMOVE (and the original questionnaire) include three engine size classes for cars, the panel report makes use of four classes. Indeed, the >2.0 litre class has been split up by the panel into two classes: '>2.0 litre medium' and '>2.0 litre large'. This split has been made in order to be able to address the issue of very large cars that need double exhaust systems for packaging reasons. In scenarios A1 and A2, the '>2.0 litre medium' cost has been applied as an estimate for the TREMOVE >2.0 litre class. For the other scenarios, two approaches have been applied to calculate weighted average >2.0 litre cost estimates:

- Approach 1 has been used in scenarios A3, A4, A5, A6 and A10, as indicated in table 1. The weighting has been based upon the assumption that 7% of total car sales are '>2.0 large' cars in the 2010-2020 period and that this percentage is equal for petrol and diesel cars.
- Approach 2 assumes that for both petrol and diesel cars, 25 percent of the >2.0 litre cars fall into the '>2.0 large' class. This approach is considered to be the most realistic one.

Sensitivity analysis

Sensitivity analyses have been performed with respect to the effects of aformentioned assumptions on technology costs for > 2.0 litre cars. Scenarios A10 and A11 are similar except for the approach used for the >2.0 litre car costs. In A10 approach 1 is used, in A11 approach 2 is used. Approach 2 leads to a cost to society (excl. pollution benefits) in 2020 that is 4.8% higher than that with approach 1. The differences in obtained emission reductions are negligible.

Detailed results for A10 and A11 can be found in Annex A.

Also A3 and A7 only differ with respecct to the aformentioned assumptions on technology costs for > 2.0 litre cars.

For petrol cars the panel report includes separate figures for lean versus stratified spark ignition engine technologies. Weighted averages have been included in TREMOVE assuming a linear evolution of the market share of lean engines starting at approximately zero for today up to 10% in 2015, and constant from 2015 onwards.

The panel report does not include specific cost figures for N1 vehicles, though it proposes to use the 1.4 litre – 2.0 litre car costs for the class I N1 vehicles, while using the '>2.0 large' figures for class II and class III. Based upon earlier research [TNO, 2005b], weighted averages for the whole N1 class have been calculated using 2002 observed European market shares of classes I, II and III (respectively 26,2%, 26,6%, and 47,2%).

2.3.3. Standard TREMOVE model assumptions

Neither the questionnaire responses nor the panel report include information on the maintenance cost of the "Euro 5" emission abatement technologies. In TREMOVE simulations, the standard assumption is that increases in vehicle ex-tax retail prices, will automatically lead to similar increases in purchase taxes, insurance costs/taxes and maintenance/repair costs. I.e. a linear relationship with the ex-tax retail price is assumed. Thus, given this assumption, maintenance/repair cost is higher for "Euro 5" vehicles than for Euro 4 vehicles. The same is true for insurance costs, insurance taxes and purchase taxes. This standard assumption has been applied in simulations A1 to A16. In A17 to A25 however maintenance/repair costs of "Euro 5" vehicles have been set equal to those for Euro 4 vehicles. The argument for this latter assumption is that the "Euro 5" legislation will require long-term durability of the technology.

Sensitivity analysis

Sensitivity analysis has been performed with respect to the effects of the assumptions on maintenance costs. Scenarios A16 and A17 assume equal limit values and technology costs for both petrol and diesel cars. The only difference between these scenarios is that A16 includes the TREMOVE standard assumption on changes in maintenacne costs, where A17 does not include changes in maintenance costs. As indicated in Table 3 *and* Table 4 *the increase in maintenance cost in A16 leads to a cost for the policy that is 54% higher than that in A17 (in 2020, with general marginal cost of public funds). The monetised pollution benefit in A16 however is only 1% higher than in A17.*

TREMOVE assumes all LPG cars to be retrofitted petrol cars. Therefore the extra costs related to the "Euro 5" standard for new petrol cars are automatically also applied to LPG cars.

2.4. Scenarios and sensitivity analysis

As indicated in Figure 1 and Figure 2 several limit values were assessed, with varying assumption on the related technology costs. This approach has been set up to enable sensitivity analysis and to get a better understanding of the influence of some specific cost components (as additional fuel and maintenance costs). In this paragraph the rationale behind the definition of the various scenarios is discussed. Table 1 summarises the core assumptions of each of the "Euro 5" scenarios.

Overall, the analysis was performed in five phases. At first, the analysis focused on alternative options for diesel car standards (scenarios A1 to A9). Later on also diesel N1 vehicles were included in the assessment (scenarios A10 to A13). Scenarios A14 and A15 then focused at alternative options for petrol vehicles. Thereafter, simulations A16 to A23 were performed to analyse the full impact of a possible "Euro 5" proposal that would apply to both petrol and diesel cars and N1 vehicles. And finally, A24 and A25 represent "Euro 5" scenarios in which the NO_x limit value for diesel cars is tightened in two steps.

2.4.1. *Diesel car scenarios: A1 to A9*

A1 is the most ambitious scenario, with 2.5 mg. PM and 75 mg. NO_x limit values. In this scenario the 'minimum' cost estimate from the panel report has been used and the '>2.0 litre medium' cost has been applied to the entire TREMOVE >2.0 litre class.

Simulations A2,A3,A7,A8 and A9 all are scenarios with 2.5 mg. PM and 150 mg. NO_x limit values for cars, though differ in cost assumptions. These scenarios thus provide a good basis for the analysis of the impacts of cost assumptions on the model outcomes.

In scenario A2 technology costs have been introduced in a similar way as in scenario A1, using the 'minimum' cost estimate and the '>2.0 litre medium' figure from the panel report for the 2.5 mg. PM and 150 mg. NO_x limit values.

In the other simulations for these PM and NO_x limit values, the average of 'minimum' and 'maximum' estimates from the panel report have been used as a starting point. Then, as suggested by the European Commission, cost reduction factors to represent economies of scale have been applied:

- Scenarios A3-A7 apply a generic cost reduction factor of 33% to all costs for diesel vehicles. This 33% factor is used in all diesel scenarios from A10 on also.
- In A8 a 40% cost reduction factor is applied.
- In A9 67% cost reduction factor is applied. This results in "Euro 5" cost figures that are in line with the earlier estimates by RICARDO [RICARDO, 2003].

Sensitivity analysis

Sensitivity analysis has been performed with respect to the effects of the assumed economies of scale. Scenarios A7, A8 and A9 only differ with respect the the assumed economies of scale, wich have been set at 33%, 40% and 66% respectively. The welfare cost (excl. pollution benefits) of scenario A9 is only 53% of that for scenario A7 (for 2020 and general marginal cost of public funds). On the other hand, the monetised pollution benefit in A9 is only 1% lower than that of A7.

Detailed results for these scenarios can be found in annex A.

The difference between A3 and A7 lies in the approach for the >2.0 litre car costs. The approaches used have already been explained in section 2.3.2. Whereas A1 and A2 restricted to simply using the '>2.0 litre medium' cost from the panel report, A3 uses approach 1 and A7 makes use of approach 2. This latter approach is considered to be the most realistic one, and therefore has been applied in all scenarios following A7 (except for A10).

Scenarios A4, A5 and A6 analysed the effects of other limit values for diesel cars:

- A4: 200 mg. NO_x and 2.5 mg. PM
- A5: 150 mg. NO_x and 5 mg. PM
- A6: 200 mg. NO_x and 5 mg. PM

It should be remembered that the panel report provides no explicit cost estimates for these sets of limit values. For 200 mg. NO_x scenarios, the 'minimum' value for the corresponding 150 mg. scenario has been used. No distinction has been made between the costs to reach 2.5 versus 5 mg. PM (as explained in 2.3.2). The other assumptions (33% economies of scale, and approach 1 for the >2.0 l class) correspond to those in A3. This means that A3, A4, A5 and A6 are a set of scenarios that could be compared to analyse the outcomes of different emission limit values for diesel cars.

2.4.2. *Diesel car and N1 vehicle scenarios: A10 to A13*

A10, A11 and A12 are scenarios combining 150 mg. NO_x and 2.5 mg. PM limit values for diesel cars, with similar emission reductions for N1 vehicles (-40% NO_x and -90% PM compared to Euro 4). Technology costs for the N1 vehicles are estimated as explained in section 2.3.2. To identify the effect of adding N1 vehicles, A10 and A11 can be compared with A3 and A7 respectively. These pairs of scenarios have the same assumptions: 33% economies of scale and >2.0 l approach 1 in A3 and A10 versus approach 2 in A7 and A11.

A12 has been simulated as a sensitivity analysis with respect to the increase of fuel consumption for vehicles equipped with PM traps. In A12 the 1.5% fuel consumption increase is not accounted for, whereas all other assumptions are equal to those in A11.

Also run A13 is very similar to A11, with the only difference being that a 200 mg. NO_x limit is set, instead of a 150 mg. value. Remember that for 200 mg. NO_x scenarios, the 'minimum' cost value for the corresponding 150 mg. scenario has been used.

2.4.3. *Petrol car and N1 vehicle scenarios: A14 and A15*

Scenarios A14 and A15 focus on the effects of emission standards for petrol vehicles. A14 is a simulation with 50 mg. VOC (-50%) and 24 mg. NO_x (-70%) limit values. A15 is less stringent with 75 mg. VOC (-25%) and 48 mg. NO_x (-40%) limits. In both scenarios approach 2 is used for the estimation of the costs for the >2.0 l segment.

No cost reduction factors related to economies of scale are applied for the petrol technologies. The argument for this is that for stratified engines the needed technology is a further development of what is being mass-produced already today. The prospect of further cost reductions due to economies of scale is minute. For lean burn engines, one could assume some cost decrease associated with the NO_x aftertreatment. However, since only a small market share of lean burn is assumed, the effect on the overall technology cost would be negligible.

2.4.4. *Combined petrol and diesel vehicle scenarios: A16 to A23*

A16 to A23 simulate the full impact of a possible "Euro 5" proposal that would apply to both petrol and diesel cars as well as N1 vehicles.

Scenario A16 is the combination of scenario A13 on diesel vehicles and scenario A14 on petrol vehicles. In relation with the set of alternative assumptions described above (sensitivity analysis), the hypothesis are the following:

- Fuel consumption factors for "Euro 5" diesel cars and N1 vehicles have been estimated by increasing the corresponding Euro 4 vehicle fuel consumption factor by 1.5 percent. As CO_2 and SO_2 emission factors are linearly related to the fuel consumption factors in TREMOVE, the emission factors for these pollutants also increase by 1.5 percent.
- For the calculation of the weighted average >2.0 litre cost, Approach 2 has been followed which assumes that for both petrol and diesel cars, 25 percent of the >2.0 litre cars fall into the '>2.0 large' class. This approach is considered to be the most realistic one.
- The scenario applies a generic cost reduction factor of 33% to all diesel technology costs in the panel figures, to represent economies of scale.

Scenario A17 differs only from A16 with respect to the treatment of maintenance/repair costs. In runs A1 to A16, the standard TREMOVE assumption is used. This means that maintenance costs are related linearly to the initial purchase cost of a vehicle. An extra technology cost for “Euro 5” vehicles thus automatically leads to an increase in maintenance cost. In scenario A17 and A18 however it is assumed that the maintenance/repair costs of “Euro 5” vehicles are equal to those for Euro 4 vehicles. The argument for supporting this latter assumption is that the “Euro 5” legislation will require long-term durability of the emission technologies.

Scenarios A18 is a variations on scenario A17. It has the same limit values for diesel vehicles. For petrol vehicles, however, A18 assumes less stringent standards, i.e. 75 mg. VOC (-25%) and 48 mg. NOx (-40%).

Scenario A20 only differs from A18 with respect to the NO_x limit values. For diesel cars this limit value is set at 75 mg., for petrol cars it is set at 60 mg. As noted in 2.3.2 the cost estimates for this petrol 75 mg. VOC, 60 mg. NOx scenario have been set at half of the costs for the 48 mg. NO_x and 75 mg. VOC scenario.

A22 then is almost equal to A20 respectively, though in this scenarios the limit values are assumed to be introduced in 2009 already. A21 and A23 then are equal to A22, except for the NO_x limit values for diesel vehicles which are set at 200 mg. and 150 mg. respectively.

2.4.5. Two-step scenarios: A24 and A25

A24 and A25 represent “Euro 5/6” scenarios in which the NO_x limit value for diesel vehicles is tightened in two steps. For both A24 and A25 the initial 2009 limit values are set as in scenario A20: 200 mg. NO_x and 2.5 mg. PM for diesel cars and 60 mg. NO_x and 75 mg. VOC for petrol cars. In scenario A24 the diesel car NO_x limit is lowered towards 75 mg. in 2013. In scenario A25 the diesel car NO_x limit is lowered towards 80 mg. in 2014. Note that, as suggested by the European Commission, the cost for a 75 mg. limit is used also for the 80 mg. limit (as a conservative estimate).

Table 2 shows the increases in ex-tax retail prices introduced in TREMOVE scenarios A16 to A25. The figures represent the price increases compared to Euro 4 vehicles for the year 2010. For A24 and A25 also 2015 figures are displayed, which are values for the tightened NO_x limit values.

Table 2: Increase in ex-tax retail price for “Euro 5/6” vehicles compared to Euro 4 vehicles, in EURO 2000 purchase power

		2010									2015	
		A16	A17	A18	A20	A21	A22	A23	A24	A25	A24	A25
petrol	small car - 1,4 l	78	78	62	31	31	31	31	31	31	31	31
	medium car 1,4 - 2,0 l	109	109	84	42	42	42	42	42	42	42	42
	big car + 2,0 l	170	170	125	63	63	63	63	63	63	63	63
	light duty truck	186	186	134	67	67	67	67	67	67	67	67
diesel	small car - 1,4 l	220	220	220	415	220	415	313	220	220	415	415
	medium car 1,4 - 2,0 l	283	283	283	504	283	504	408	283	283	504	504
	big car + 2,0 l	693	693	693	761	693	761	752	693	693	761	761
	light duty truck	799	799	799	913	799	913	895	799	799	913	913

Note that full “Euro 5” scenario input and output files are available at www.tremove.org (runs page).

3. Scenario A16 to A25 results

Scenarios A16 to A25 are the scenarios in which the impact of a complete "Euro 5" standard on both petrol and diesel cars and N1 vehicles has been simulated. The results of these scenario simulations, except A19, are discussed in detail in this section.

Scenarios A1 to A15, which consider only the impacts of partial "Euro 5" standards on either petrol or diesel vehicles are discussed briefly in Annex A.

We kick-off the analysis of the A16 to A25 scenarios with an overview of the results with respect to car and N1 vehicle exhaust emissions. Thereafter simulated changes in transport demand and fleet are assessed, as well as the effects on overall emissions. We conclude with the presentation of the welfare and cost-benefit results.

3.1. *Car and N1 vehicle exhaust emissions*

3.1.1. Regulated pollutants

Figure 3, Figure 4 and Figure 5 show the evolution in NO_x, particulate and VOC exhaust emissions from cars and N1 vehicles in the A16 to A25 scenarios, as well as in the v2.32b basecase scenario. The graph covers the EU15 countries and the 4 New Member States modelled in TREMOVE (i.e. Czech Republic, Hungary, Poland and Slovenia). In the basecase scenario the Euro 4 standard already will lead to a significant decrease in emissions. A "Euro 5" standard will enable to reach further reductions.

For NO_x, scenarios A16, A17, A18 and A21 lead to very similar emission reductions, as these scenarios are all based on a 200 mg. limit value for diesel cars. The lines of A16 and A17 fall almost together[3] in the graph, as both these scenarios are also based on the same limit values for petrol cars (24 mg.). For A18 a lower NO_x reduction is projected, which is in line with the higher 48 mg. limit value for petrol vehicles. A21 is the scenario that leads to the lowest NO_x reduction, with a 60 mg. limit value for petrol cars introduced in 2009 already.

The A23 scenario, with a 150 mg. limit value for diesel cars shows a significant larger NO_x reduction than the aforementioned scenarios.

A20 and A22 lead to the strongest NO_x reduction, with a 75 mg. limit value for the diesel cars..
Finally, A24 and A25 fall come out slightly higher than A20 and A22, as the 75 mg. (or similar 80 mg) limit value is introduced only in a second phase in 2013 and 2014 respectively.

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[3] Note that there is a limited difference in emission results, as the difference in cost assumptions leads to a different impact on fleet composition and transport demand.

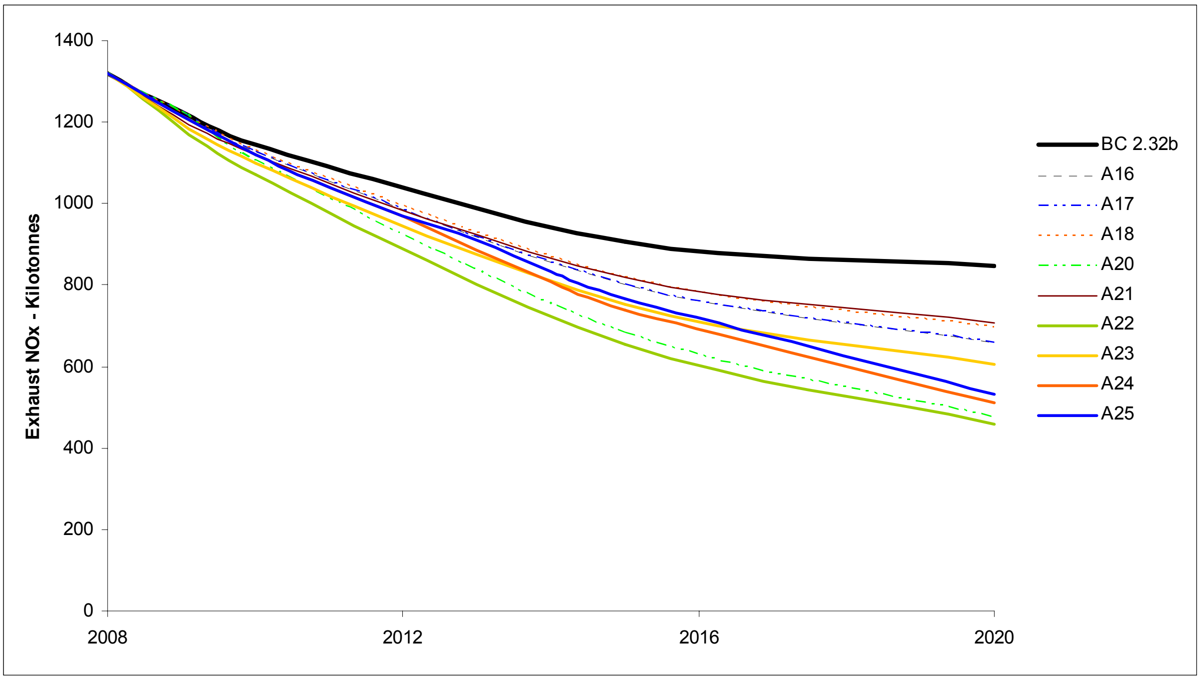

Figure 3: A16-A25 Evolution of car and N1 exhaust NOx emissions – EU15 + 4 NMS

A16 to A25 scenarios are based on the same 2.5 mg. limit value for diesel car particulates. Consequently, they all result in broadly similar emission reductions[4]. The difference in the introduction year of the emission standard (2009 for bold lines, 2010 thin dotted lines) leads to a limited difference in the outcome.

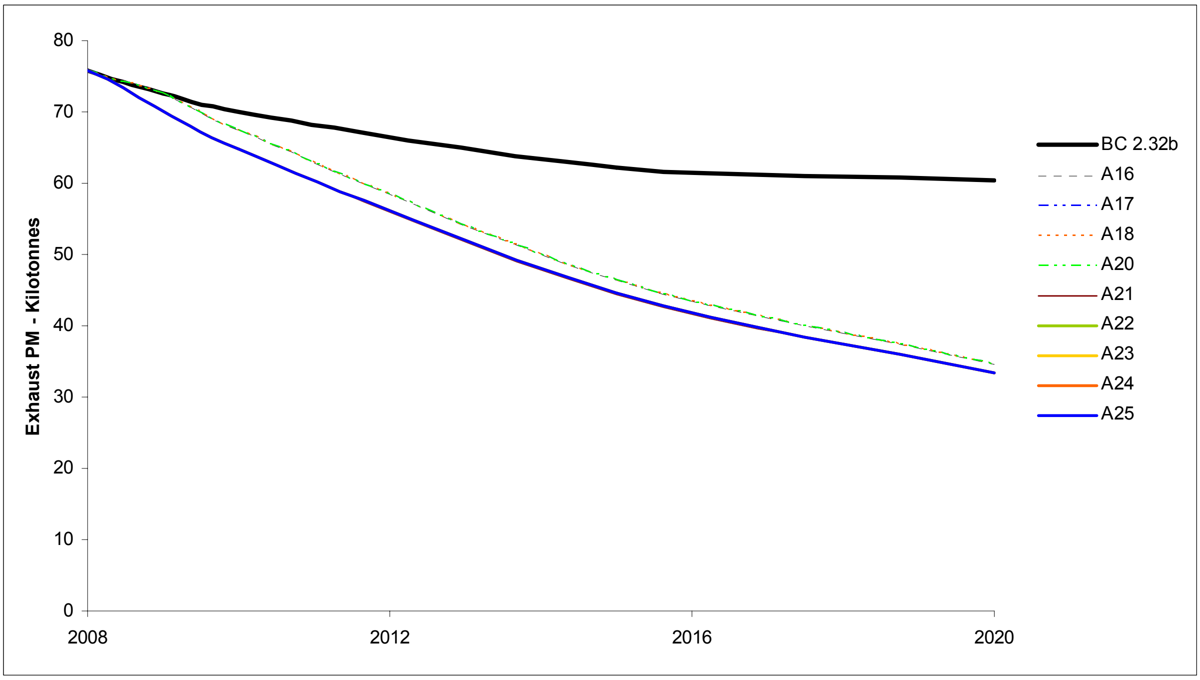

Figure 4: A16-A25 Evolution of car and N1 exhaust PM emissions – EU15 + 4 NMS

A16 and A17 lead to the lowest outcomes for VOC, as both are based on a 50 mg. limit value for the petrol cars. All other scenarios are based on a 75 mg. VOC limit value.

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[4] It should be noted that in the v2.32b basecase higher estimates for petrol car particulate emissions have been used as in the newer (v2.4) model versions.

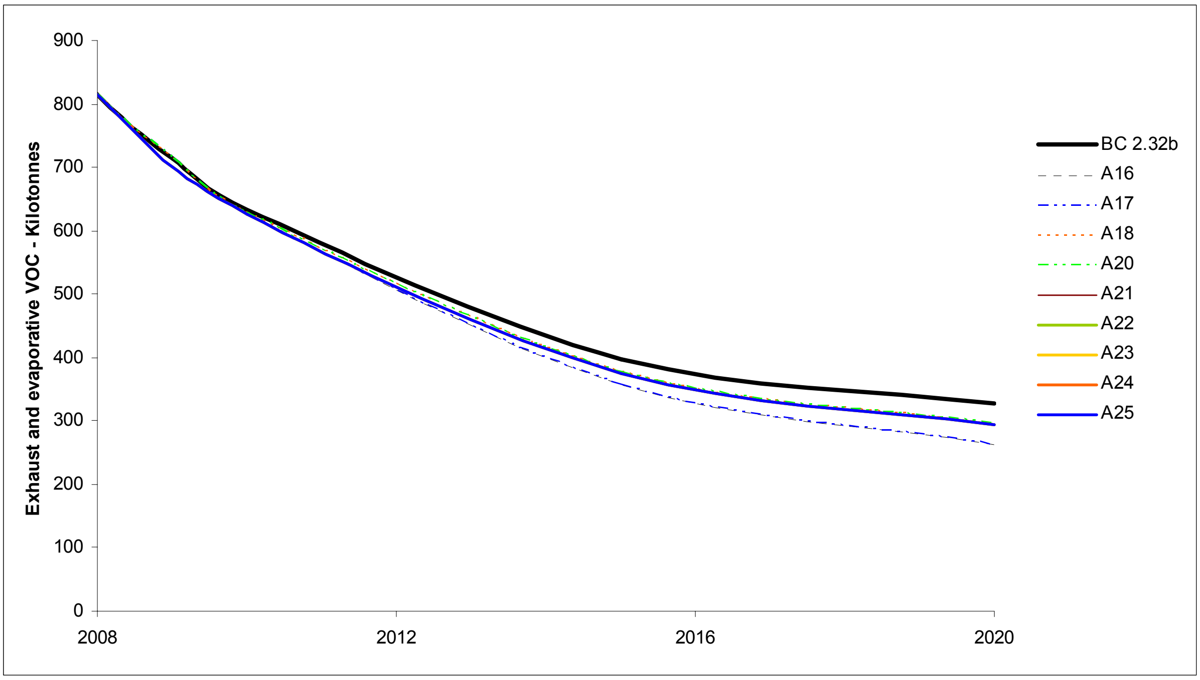

Figure 5: A16-A25 Evolution of car and N1 exhaust and evaporative VOC emissions – EU15 + 4 NMS

3.1.2. CO2, SO2 and other pollutants

In all A16 to A25 scenarios the application of particulate traps leads to an increase of 1.5% in fuel consumption and CO_2 and SO_2 exhaust emission factors for the regulated diesel vehicles. For CO_2 the resulting projections are displayed in Figure 6.

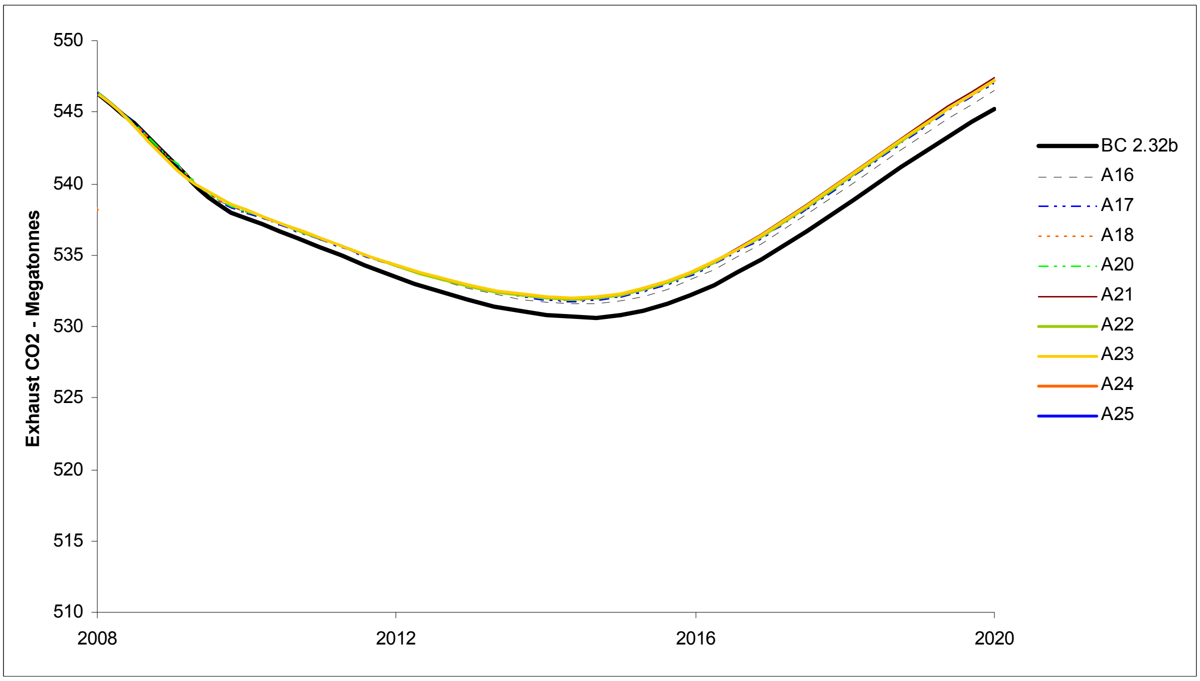

Figure 6: A16-A25 Evolution of car and N1 exhaust CO2 emissions – EU15 + 4 NMS

Although all these scenarios lead to the application of particulate traps, the graph indicates that the effects on CO_2 emissions differs slightly. The largest differences result from differences in the introduction years, i.e. 2009 or 2010. Though, there are other reasons for these differences also. The “Euro 5” policy will not only lead to a change in emission factors for the regulated vehicles. Through changes in the prices of these vehicles, the policy will also lead to changes in fleet structure and to changes in overall transport demand. These changes in fleets and transport demand have effects on the emissions of all pollutants. These are second-order effects that go beyond a simple change in emission factors. The next section will briefly discuss these changes in fleets and transport demands.

3.2. Vehicle fleets, transport demands and overall emissions

Through changes in vehicle prices, the "Euro 5" policy will lead to changes in vehicle fleet composition and transport demand. In this paragraph we first discuss the effects on fleet composition, then evaluate the changes in transport demand, and finally look into the impacts on overall emissions of the transport sector.

3.2.1. Changes in car and N1 vehicle fleets

As indicated in Table 2 the "Euro 5" technology costs for diesel vehicles are significantly higher than for petrol vehicles. Furthermore, the lower the limit values, the higher the associated technology costs. And the larger the vehicle, the higher the costs to reach the limit values.

Next to vehicle technology costs, also other components of the total price to use cars or N1 vehicles are influenced by the "Euro 5" standard. The application of particulate traps on diesel cars is assumed to increase fuel consumption, thus expenditures to fuel, by 1.5%. Furthermore, in TREMOVE, the standard assumption is that insurance costs, insurance taxes and vehicle purchase taxes are related linearly to the initial purchase cost of a car or N1 vehicle. *This is also the case for yearly maintenance/repair costs (and related VAT). However, this latter standard assumption has been altered in the final set of scenarios. In the scenarios after A16, it is assumed that maintenance costs of "Euro 5" vehicles are equal to those for Euro 4 vehicles.*

The changes in vehicle prices will lead to changes in vehicle purchase behaviour and eventually to long-term changes in the vehicle fleet composition. The most relevant effect is that the higher price increases for diesel vehicles will lead to a limited decrease in their market share, compared to the baseline. Figure 7 and Figure 8 show this evolution of the share of diesel vehicles in the car and N1 vehicle fleets. Of course, this effect is larger in scenarios with more stringent diesel (NO_x) standards. Note also that the effect in A16 is larger than in A17, as A16 accounts for a significant increase in maintenance costs.

Next to a shift from diesel towards petrol vehicles, the "Euro 5" scenarios also lead to a small substitution of larger cars by smaller cars.

Full ""Euro 5"" scenario vehicle fleet tables are available at www.tremove.org (runs page).

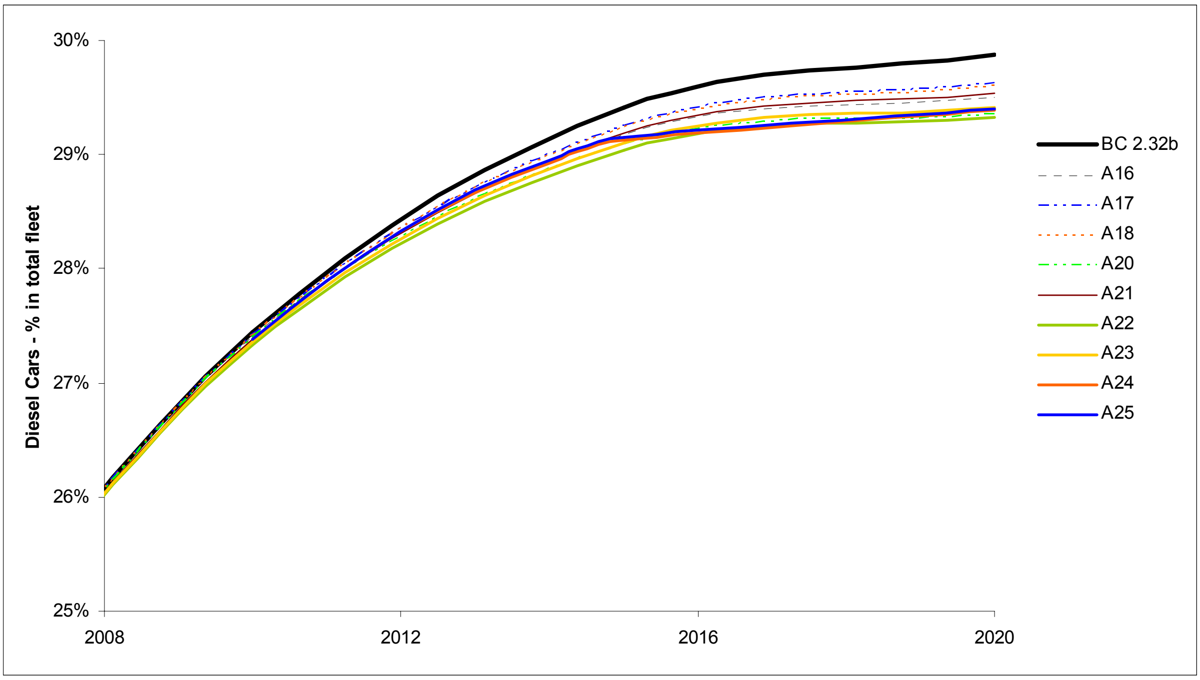

Figure 7: A16 – A25 Evolution of share of diesel cars in total car fleet – EU15 + 4NMS

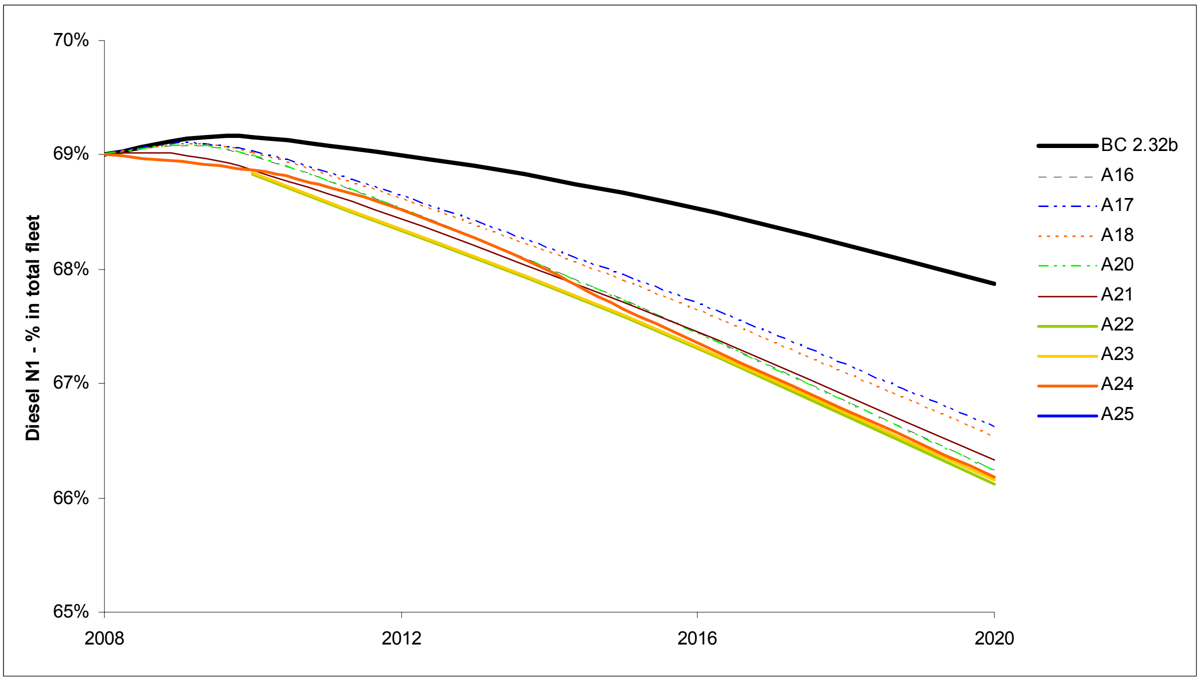

Figure 8: A16 – A25 Evolution of share of diesel N1 vehicles in total N1 fleet – EU15 + 4 NMS

It should be noted that the forecasted diesel car market share in v2.32b is significantly lower than that in the v2.43 (and later) model versions. After the "Euro 5" simulations and before the CO2CAR simulations an update of the market shares and CO_2 data and predictions has been performed.

Note also that the sensitivity coefficient of the car market shares to price changes in TREMOVE is to be considered as a lower estimate. For the estimation of the car sale logit models, only quarterly data for 1999 and 2000 on car prices was available as a coherent dataset for most EU countries (data from [COWI, 2001]). This dataset did not enable to analyse the effects of price changes in the longer term. It is recognised that the logit model coefficients could be estimated more accurate if a more extensive time series on car market shares, prices and other car parameters would be available for all modelled countries.

3.2.2. Changes in overall transport demand and its modal split

The increases in prices for car and N1 vehicle transport do not only lead to changes in vehicle purchase behaviour, but also to changes in travel behaviour. As illustrated in Figure 9, the price increases lead to a decrease in private transport passenger-kilometres compared to the base case scenario. Although this decrease is partially offset by a modest substitution to more public transport, the overall effect on passenger mobility is negative. This is easy to understand. The increase in car and N1 vehicle prices can be avoided partially by shifting to other modes (substitution effect). But, on average the price of passenger-transport increases and this causes a decrease in the overall transport demand (income effect).

Again, the effects are larger for the scenarios with more stringent limit values. And, for A16 the effect is larger than for any other scenario due to the modelled increase in maintenance costs.

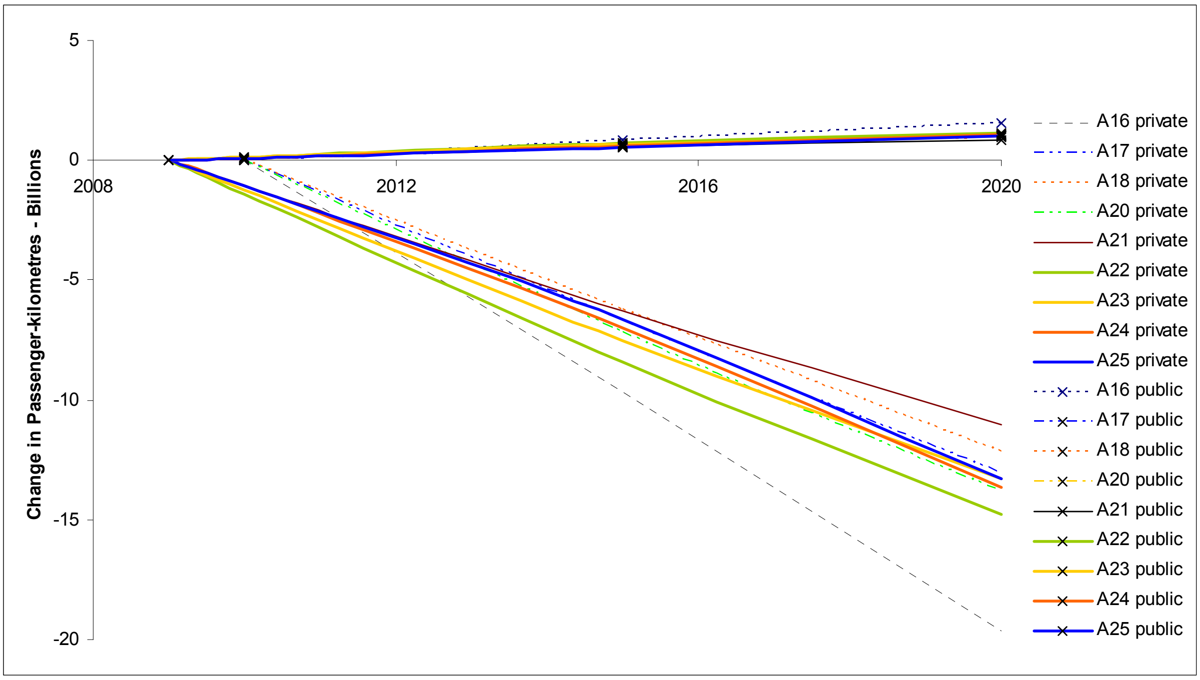

Figure 9: A16-A25 Change in passenger- kilometres compared to basecase – EU15 + 4 NMS

As N1 vehicles are used to a certain extent for freight transport, also limited changes in tonne-kilometres by mode are predicted in the scenario simulations.

Note that these decreases in road passenger and freight transport flows also lead to a decrease in congestion levels. This results in an increase in average road vehicle speeds in the TREMOVE scenarios.

3.2.3. Effects on overall emissions of the transport sector

As indicated in the previous paragraphs, the changes in exhaust emissions in the “Euro 5” scenarios are not only stemming from changes in emission factors for the regulated pollutants and vehicles. The cost of the “Euro 5” technologies also induces changes in vehicle fleets and overall transport demand, which lead to further changes in exhaust emissions and fuel consumption for all modes and vehicle types.

Furthermore, in TREMOVE, the latter changes in fuel consumption will lead to changes in the calculated well-to-tank emissions. In this context, it is interesting to note that the significant reductions in exhaust emissions, lead to an increasing importance of the well-to-tank emissions in the overall emissions.

Figure 10, Figure 11, Figure 12 and Figure 13 provide an overview of the impacts of the scenarios on total well-to-tank emissions for NO_x, particulates, VOC and CO_2. These figures include emissions from all transport modes, except maritime and high-altitude (> 3000 ft.) aircraft emissions.

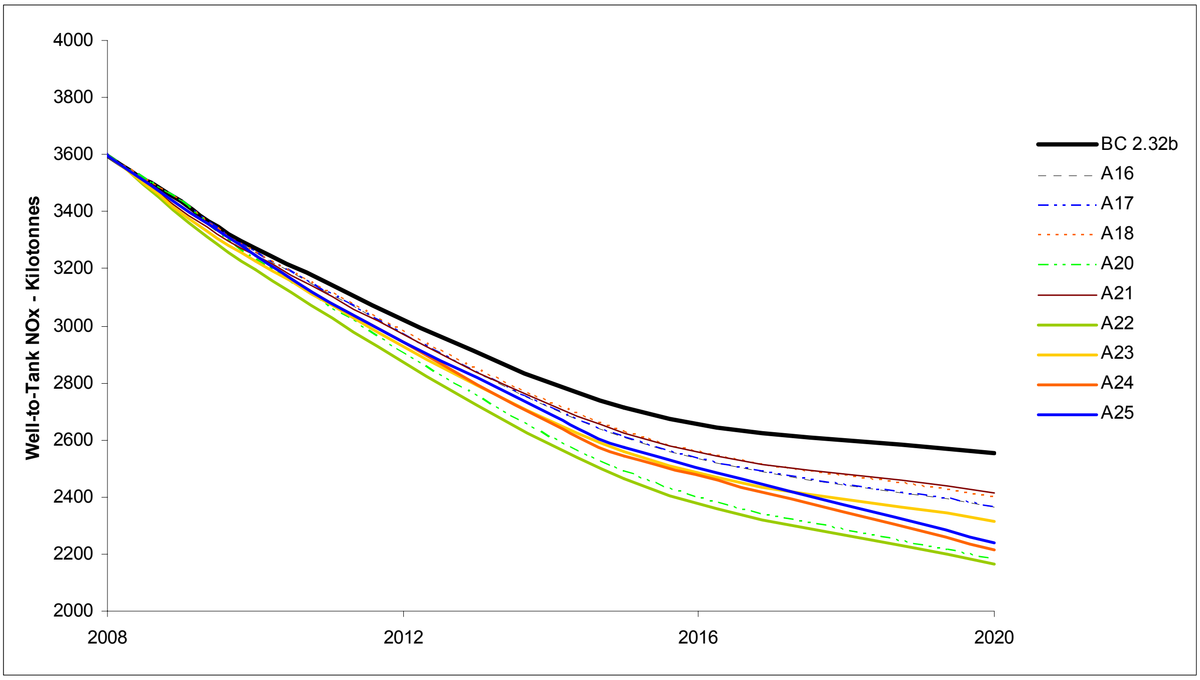

Figure 10: A16-A25 Evolution of overall well-to-tank NOx emissions – EU15 + 4 NMS

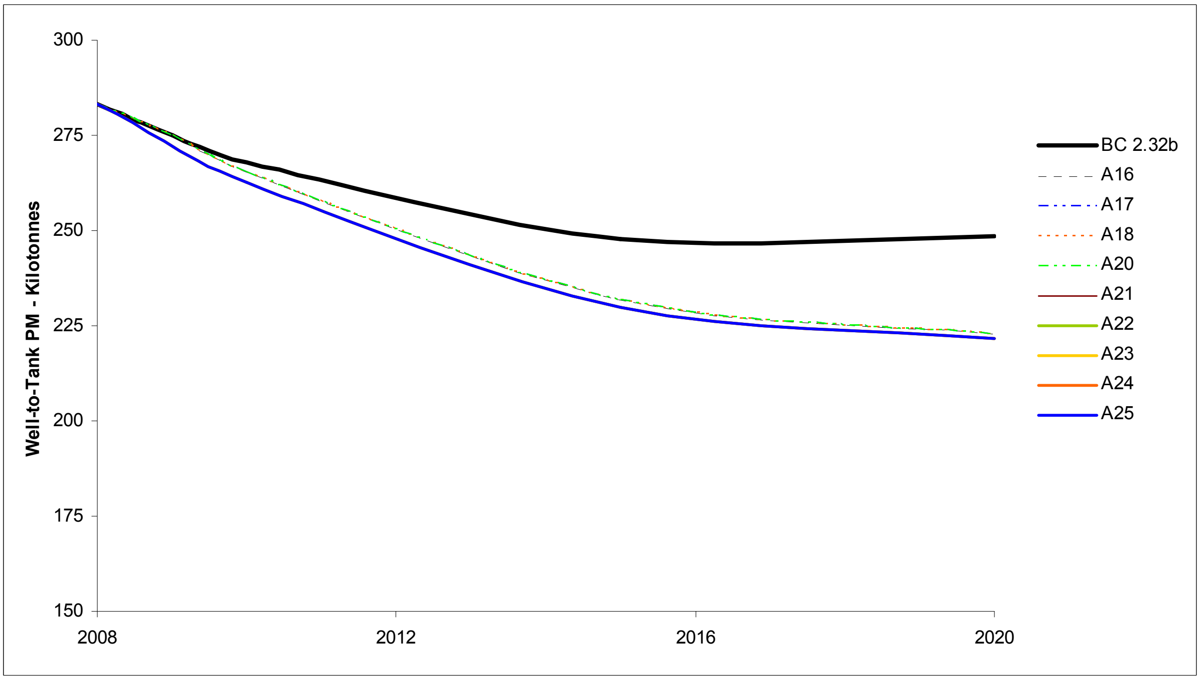

Figure 11: A16-A25 Evolution of overall well-to-tank PM emissions – EU15 + 4 NMS

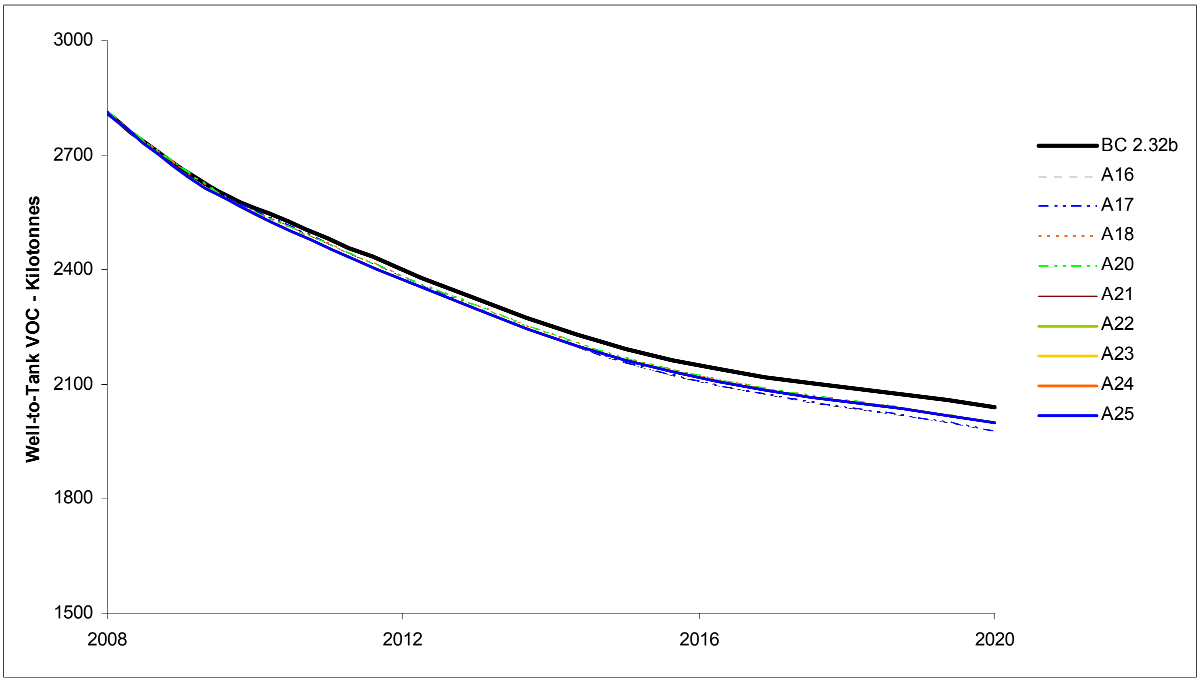

Figure 12: A16-A25 Evolution of overall well-to-tank VOC emissions – EU15 + 4 NMS

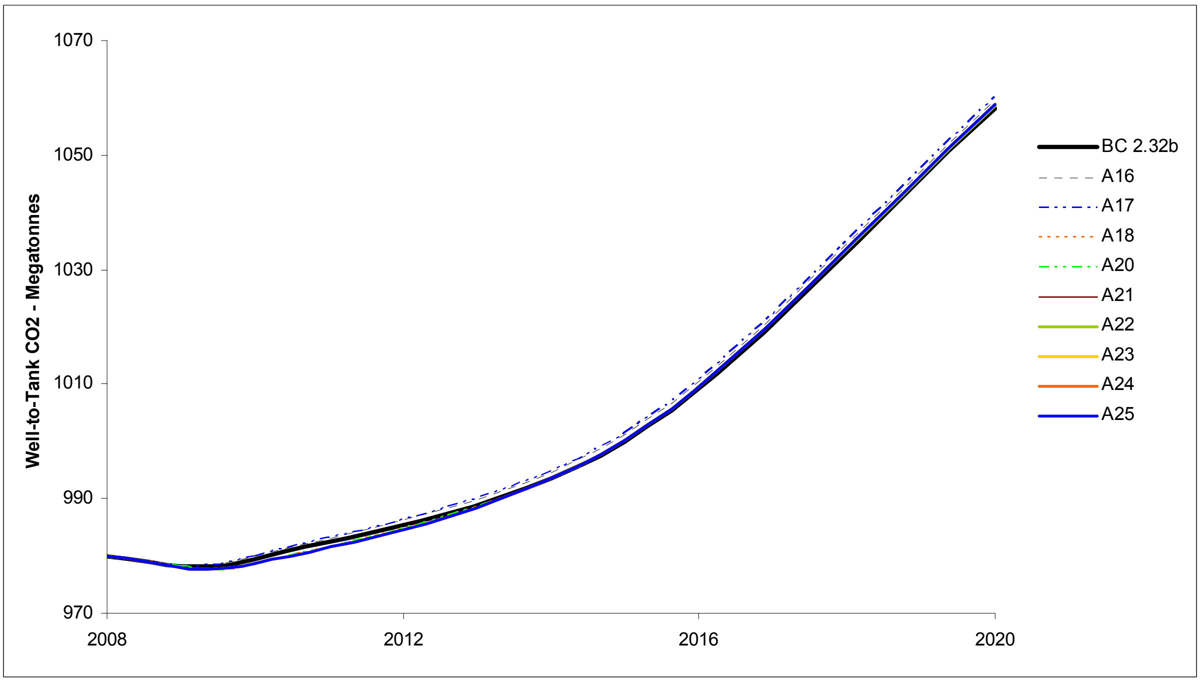

Figure 13: A16-A25 Evolution of overall well-to-tank CO2 emissions – EU15 + 4 NMS

3.3. Welfare and cost benefit analysis

The TREMOVE model is designed to analyse welfare differences between the basecase scenario and alternative policy 'simulation' scenarios. The welfare differences calculated by TREMOVE are composed of four components:

- Changes in aggregated utility level of households;
- Changes in aggregated production costs of firms;
- Welfare changes stemming from changes in government tax revenues;
- Changes in external environmental costs.

In the remainder of this section, we will firstly discuss the results for these four components individually, before combining the results for an overall welfare assessment of the scenarios. Figure 14 to Figure 22 show the evolution of the four components and the overall welfare effect for the A16 to A25 scenarios.

3.3.1. Changes in aggregated utility level of households

TREMOVE is a 'partial' equilibrium model, not a general equilibrium model. It models the transport sector, but does not include specific links between this sector and other sectors nor the labour market. As a consequence, the model does not directly enable to assess the impact of policy scenarios on household income levels. Therefore the calculation of changes in household utility levels between scenarios is performed under the assumption that household income is equal in all scenarios. The utility level reached in each scenario, then basically[5] is calculated as a weighted sum of the consumption levels of different (transport or other) goods and services. The weights represent to what extent households associate a higher utility with the consumption of one unit of a good (e.g. one air passenger-km) than with the consumption of one unit of another good (e.g. one bus passenger-km).

A decrease in utility then can stem from an increase in consumption and/or a substitution of low utility goods by high utility goods. Both could be the results of, amongst others, changes in price[6] structures or changes in infrastructures

In the "Euro 5" scenarios, we model lower emission limits, leading to extra technology costs for cars and N1 vehicles trucks. These cost increases lead to a substitution of private transport by public transport, as well as to a decrease in overall passenger-kilometres and overall consumption. Given their fixed income, the utility level that households can reach decreases.

This negative effect on household utility is displayed in Figure 14. The decrease is larger in scenarios with more stringent limit values, as the technology costs for these scenarios are higher. Not that this negative effect is largest in A16. The increase in maintenance/repair costs assumed in scenario A16 has a significant impact on household utility.

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[5] We just describe the utility calculation as simplified as possible here. More detail can be found in the model documentation.

[6] We refer here to generalised prices, i.e. monetary costs and taxes plus time costs.

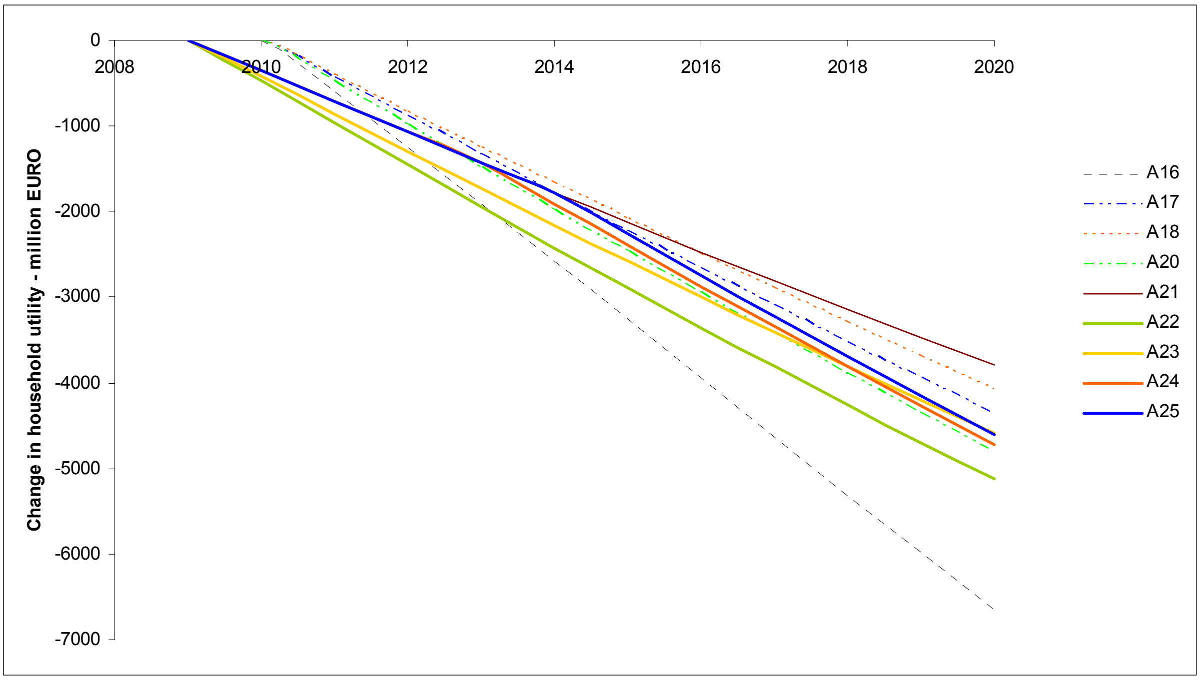

Figure 14: A16-A25 Decrease in household utility compared to basecase – EU15 + 4 NMS

As will be discussed in detail in the remainder of this section, these initial decreases in household utility levels will be compensated by decreased air pollution effects and increased tax revenues for the government.

Note that for the introduction year of the emission standard (2009/2010) no change in the utility levels is calculated by TREMOVE. The reason for this is that average prices per mode and utility levels in a year T are calculated based on the fleet composition T-1. Given the model structure of TREMOVE, it is impossible to calculate the fleet composition (and the average prices per mode) before the utility level (and household decisions on the use of transport modes) has been calculated. Therefore, in the loop over the model years, the utility level is calculated on the basis of lagged prices. I.e. TREMOVE is a model developed for the analysis of mid-term to long-term effects of policy measures. The model is not designed to analyse the effects in the first years after the implementation of a measure.

3.3.2. Changes in aggregated production costs of firms

Next to the calculation of the impact of policy scenarios on aggregate household utility, TREMOVE also calculates the impacts on the overall production costs[7] of firms and service sectors. As TREMOVE is a partial equilibrium model, it assumes that the overall production level of goods and services is not affected by the policy scenarios.

In the "Euro 5" scenarios, prices of N1 business trips, as well as for car business trips increase. On one hand, this leads to a substitution of private road transport by public transport. On the other hand this leads to an overall decrease in tonne-kilometres and business passenger-kilometres, which will be compensated by an increased use of non-transport production factors. The overall result of this restructuring of the production and logistic processes, is an increase in the total production costs.

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[7] Here as well we refer to monetary costs as well as costs in terms of time

These effects on production costs, which have a negative impact on welfare, are displayed in Figure 15. The effects are larger in scenarios with more stringent limit values, as the technology costs for these scenarios are higher. Again the effect in A16 is larger, as A16 assumes a significant increase in maintenance/repair costs.

Note that, as for the household utility levels, for the introduction years of the emission standards (2009/2010) no production cost changes are calculated by TREMOVE.

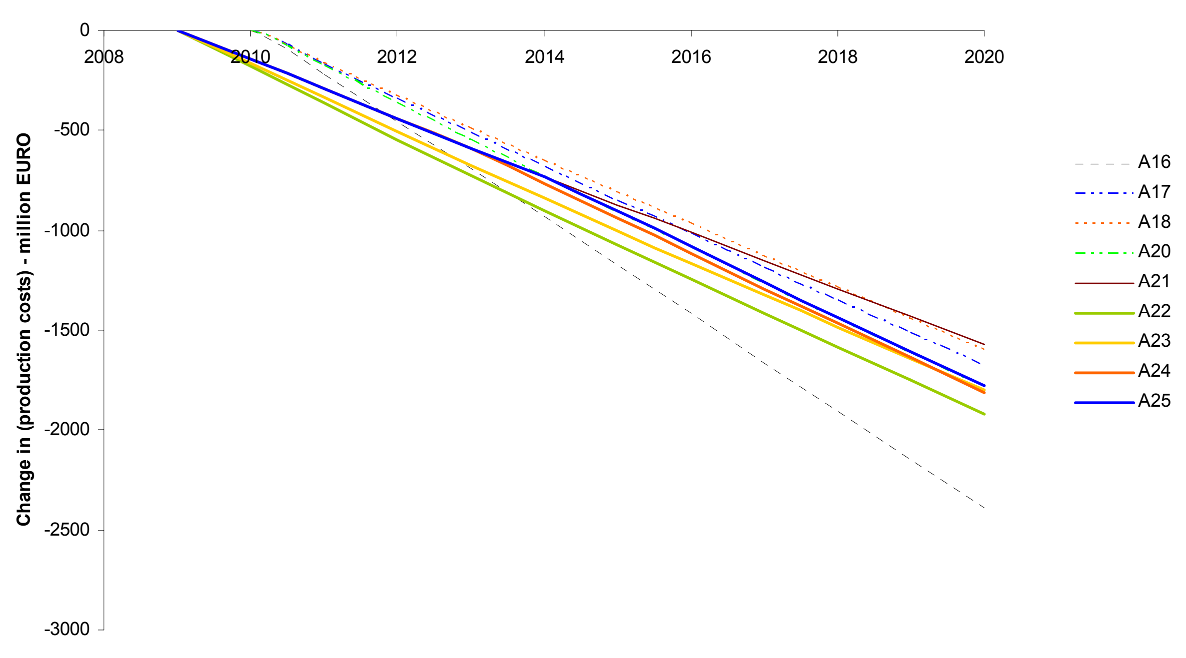

Figure 15: A16-A25 Increase in production costs compared to basecase – EU15 + 4 NMS

Table 3, Table 4 and Table 5 show in more detail the causes of the decrease in household utility and the increase in production costs. These tables present the detailed welfare components as an epample for A16, A17 and A18 respectively. Note that these tables present totals for EU15, the 4 New Member States modelled in TREMOVE and Switzerland and Norway.

The main driving forces are increases in the fix resource costs, variable resource costs, fix taxes and VAT and variable taxes and VAT for cars and N1 vehicles. The fix resource costs represent the sum of vehicle purchase costs and insurance costs, while fix taxes (and VAT) are the taxes related to purchase and insurance as well as the yearly vehicle ownership taxes. The variable resource costs are composed of maintenance/repair costs and fuel resource costs. Variable taxes (and VAT) are the sum of fuel taxes and taxes on vehicle maintenance/repair.

In A16 the change in variable costs and taxes is higher than that in A17 and A18, as A16 assumes an increase in maintenance/repair costs. Note also that the change in variable costs related to fuel is rather low for small cars, as these are mostly petrol cars for which no increase in fuel consumption is modelled.

The increases in monetary vehicle costs, are to a limited extent offset by decreases in time costs. For the road modes average travel speeds increase. Indeed, due to the general decrease in road transport the level of congestion decreases. For urban public transport also waiting times decrease, as the increase in public transport demand leads to increased frequencies of the services (the so-called Mohring effect).

3.3.3. Welfare changes stemming from changes in government tax revenues

The "Euro 5" scenario simulations result in a positive effect on the government tax revenues from the transport sector. One cause for this revenue increase are the increased tax levels on vehicle purchase, insurance and maintenance/repair.[8] Other reasons are the increase in fuel consumption factors for diesel cars and the modest shift from diesel towards petrol consumption. These positive effects on tax revenues are to a limited extent offset by the overall decrease in transport demand and the substitution towards subsidised public transport modes.

To evaluate the welfare effect of these increases in tax revenues, an assumption has to be taken on the way in which the government will make use of the additional tax revenues from the transport sector. As the government balances its revenues and expenses, changes in revenues from the transport sector will be compensated in one or another way. This way, an increase in tax revenues from the transport sector could lead to increased social security expenses, or also to decreases in labour taxes or in general taxes.

The way the initial increase is compensated determines its eventual welfare effect. High labour taxes, for example, have a distortional effect on the current EU labour markets. It can be proven that decreasing labour taxes by 1 EURO, actually leads to an increase in social welfare that is larger than one EURO. This increase in welfare is higher than when the increase in transport tax revenue is compensated by an increase in general taxes.

The welfare effects of these changes in tax revenues from the transport sector are shown in Figure 16, Figure 17, Table 3, Table 4 and Table 5. In these figures and tables these welfare effects are indicated as 'extra of public funds'. In TREMOVE it is assumed that changes in transport tax revenues are compensated by either changes in labour taxes, either changes in general taxes. Thus, two 'extra public funds' values and eventually two 'welfare' values are calculated.

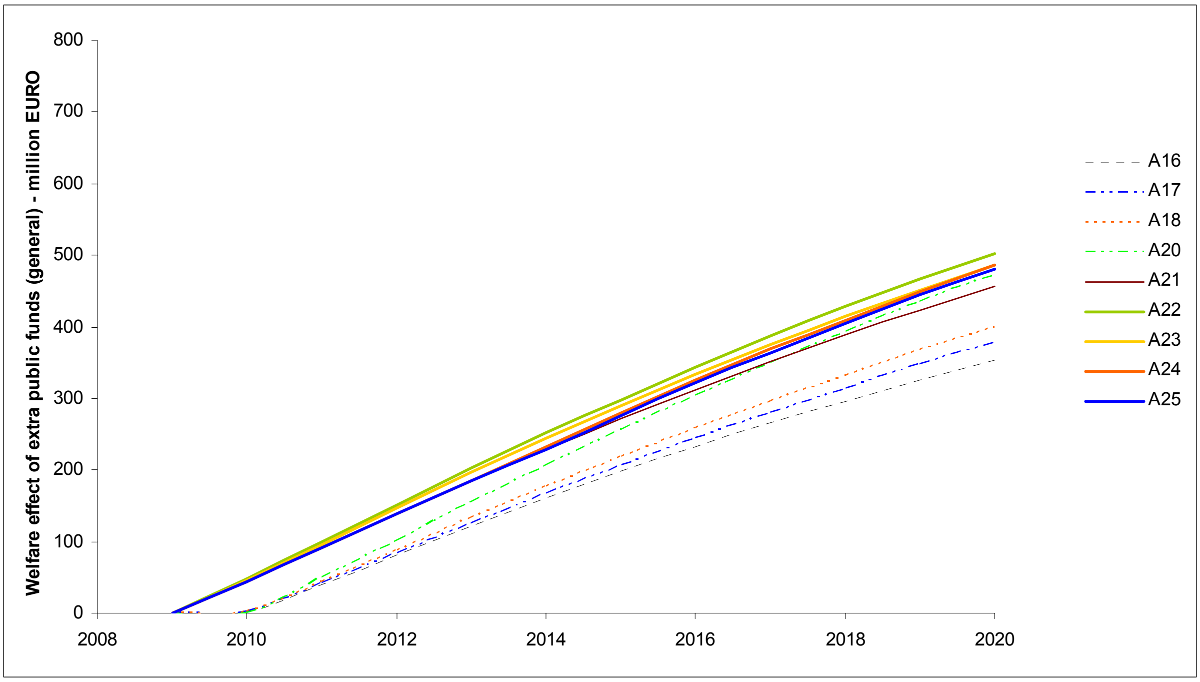

Figure 16: A16-A25 Welfare effect of increased transport tax revenues (general) – EU15 + 4 NMS

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[8] Changes in maintenance/repair costs and taxes are relevant in scenarios A1 to A16 only

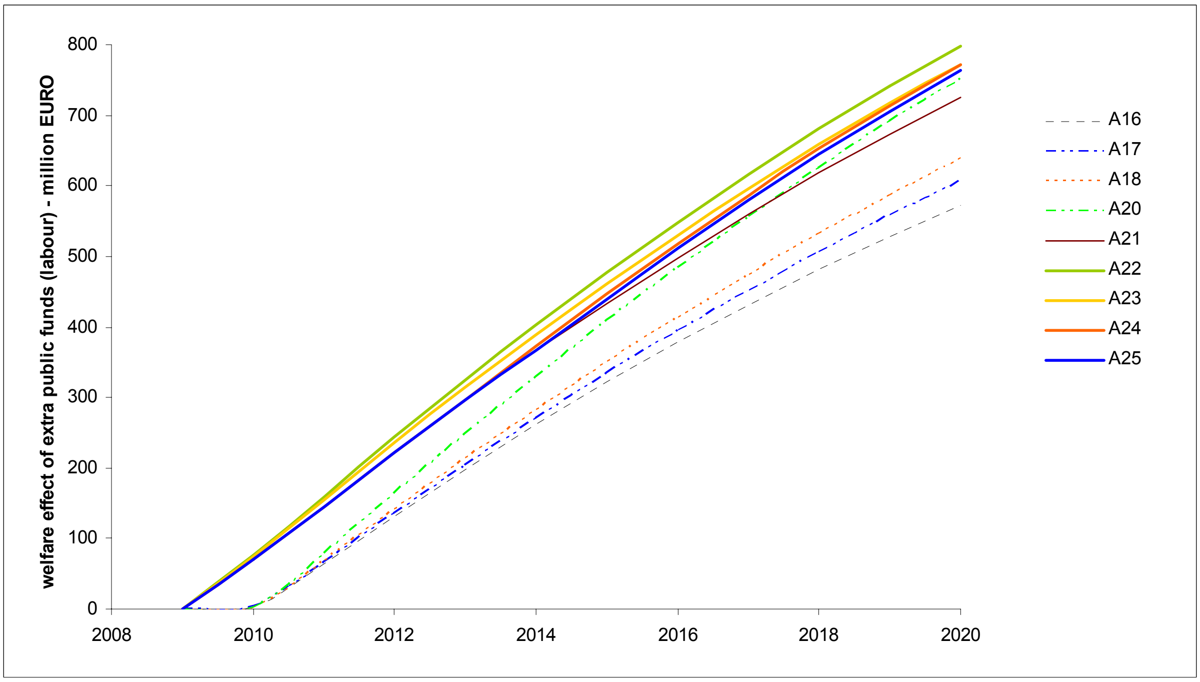

Figure 17: A16-A25 Welfare effect of increased transport tax revenues (labour) – EU15 + 4 NMS

Note that, as for household utility and production costs, for the introduction year of the emission standard (2009/2010) no significant change in public funds is calculated by TREMOVE.

3.3.4. Changes in external environmental costs

In order to include the environmental effects of the "Euro 5" policy in the welfare analysis, the emission reductions (i.e. their effect on human health, climate change, ...) have to be expressed in monetary terms. In TREMOVE, country values for external costs per ton of pollutant are derived from the cost-benefit analysis research in the Clean Air for Europe Programme [AEAT, 2004]. For all pollutants this source was used, except for CO and greenhouse gases. The external costs of CO have been taken from ExternE [IER, 2001]. For CO_2 TREMOVE uses 12 EURO per tonne and 20 EURO per tonne as monetisation estimates in 2010 and 2020 respectively. These values were suggested by the European Commisison as estimates for the marginal abatement costs in 2010 and 2020 respectively. The global warming cost of CH_4 and N_2O then were derived via their global warming potential compared to CO_2.

Significant uncertainties exist with respect to the benefits resulting from reductions in NO_x, VOC, SO_2 and PM, as well as their monetary valuations. The Clean Air for Europe cost-benefit analysis resulted in four alternative lists of external benefit estimates (BeTa table[9]). The difference between the highest values and the lowest values is nearly a factor 3. TREMOVE applies (by default) the highest benefit estimates. A sensitivity analysis on these benefit estimates is presented in section 3.3.6.

TREMOVE calculates PM_{10} particulate emissions. As suggested by the cost-benefit analysis team however, $PM_{2.5}$ external cost values have been applied to the calculated particulate emissions. This is reasonable as most of transport particulate emissions fall in the $PM_{2.5}$ size class.

Furthermore, the external costs for exhaust particulate emissions have been differentiated between the non-urban, other urban and metropolitan model regions. The Clean Air for Europe cost-benefit analysis

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[9] The BeTa tables that became available on 9-03-05 [AEAT, 2004]

researchers delivered country average external cost estimates. Factors of 0.75, 1.5 and 3 have been applied on the country values to estimate values for non-urban, other urban and metropolitan regions respectively. All lifecycle emissions are evaluated using the non-urban external cost values, as a.o. power plants and refineries are assumed to be located in less densely populated areas.

Figure 18 shows the positive welfare effects of the emission reductions in scenarios A16 to A25. For A16, A17 and A18 detailed figures per pollutant can be found in tables Table 3, Table 4 and Table 5. The major benefits in all scenarios come from the decreases in NO_x and particulate emissions. Lower limit values result in higher pollution benefits. The benefits from VOC reductions are more limited though still significant. The "Euro 5" scenarios lead to slight increases in CO_2 and SO_2 emissions and their environmental costs.

In contrast to household utility, production costs and public funds, significant changes in pollution benefits are already calculated in the year in which the "Euro 5" standard is introduced. The reason for this is that in the TREMOVE model structure, emissions in a year T are calculated using the projected fleets in year T.

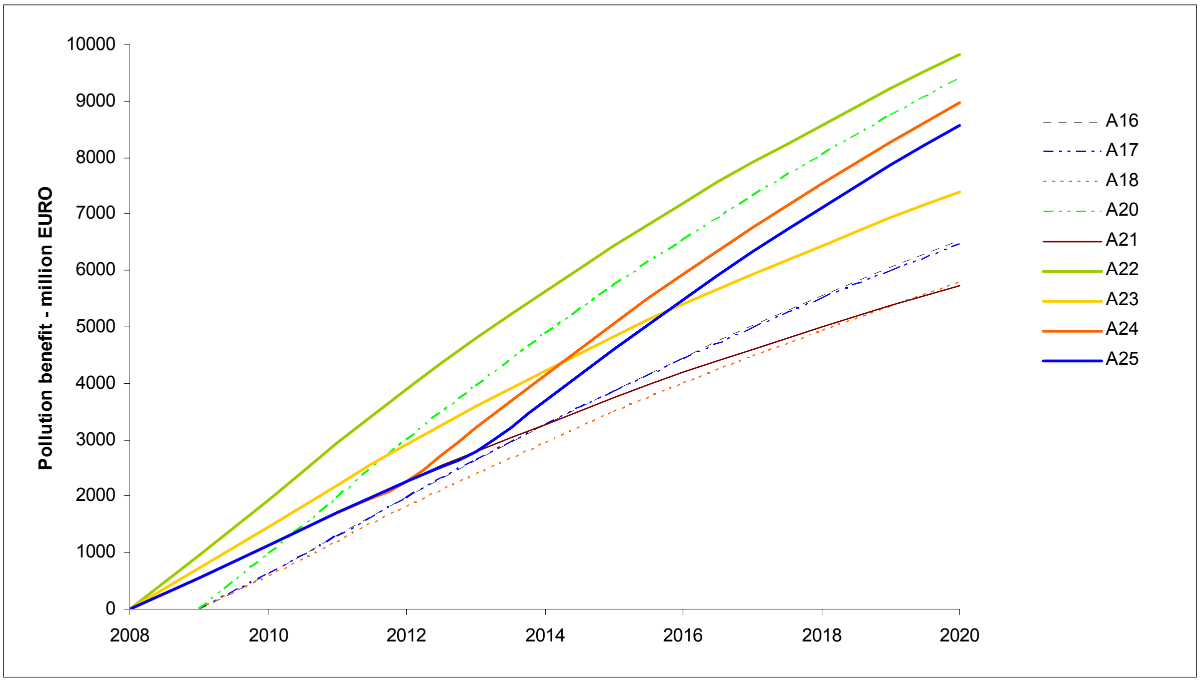

Figure 18: A16-A25 Welfare effect of decreased emissions (Set 1 external cost values) – EU15 + 4 NMS

3.3.5. Costs, benefits and overall welfare effects

The overall welfare differences between the scenarios and the base case are calculated as the sum of the four components discussed in the preceding paragraphs:

- Changes in aggregated utility level of households;
- Changes in aggregated production costs of firms;
- Welfare changes stemming from changes in government tax revenues;
- Changes in external environmental costs.

The sum of the first three of these components could be interpreted as the cost of the simulated policies. The fourth component then is the resulting environmental benefit. Figure 19and Figure 20 show the former cost estimate for A16 to A25. Figure 19 is based on the assumption that increases in government tax revenues from the transport sector are compensated by decreasing general taxes. Figure 20 assumes that the extra government funds are used to lower the labour tax level. These figures can be looked at together with Figure 18 to compare costs and benefits of the simulated "Euro 5" scenarios.

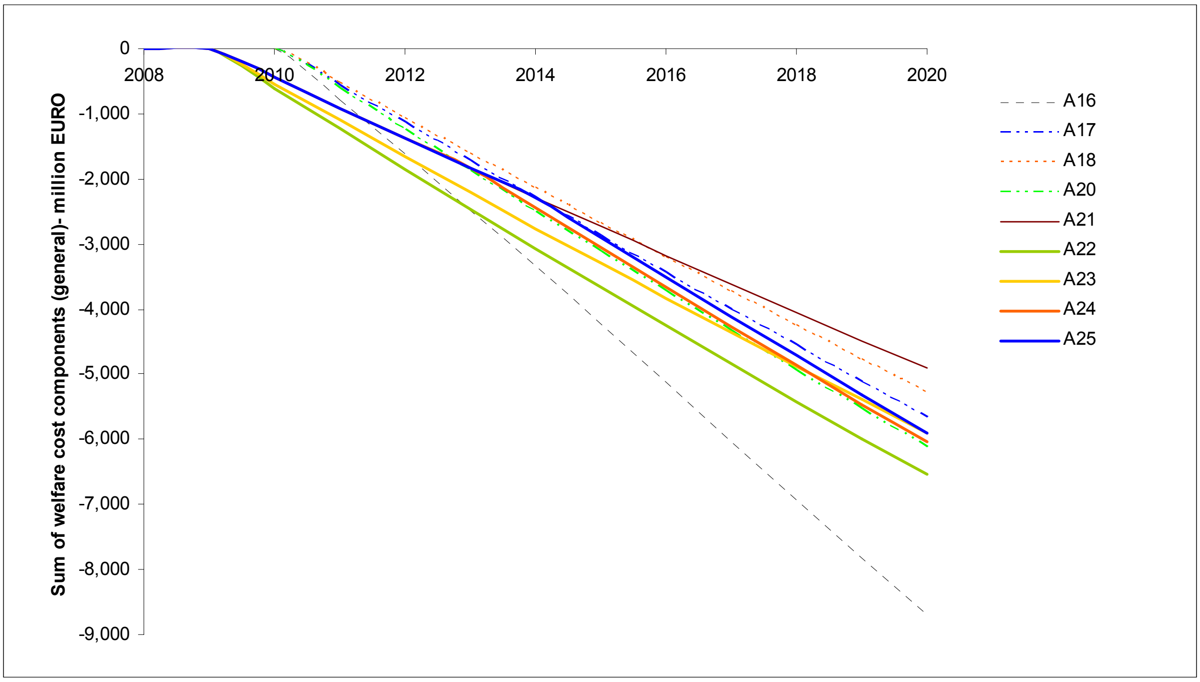

Figure 19: A16-A25 Sum of welfare cost components (general) – EU15 + 4 NMS

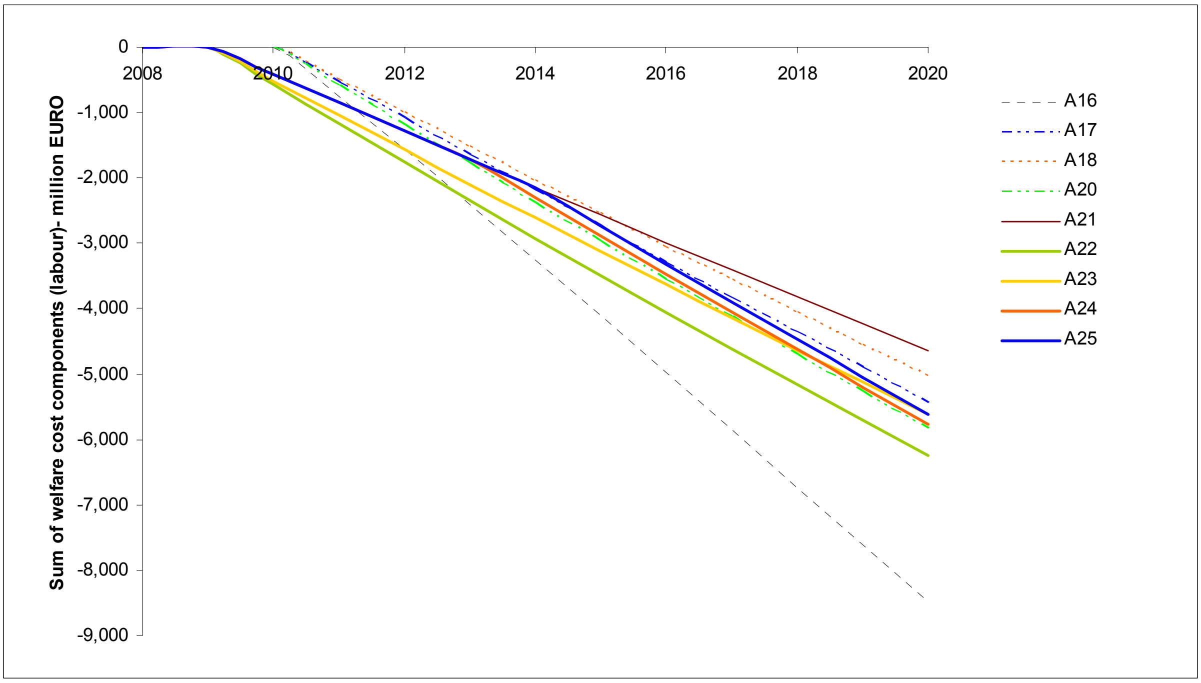

Figure 20: A16-A25 Sum of welfare cost components (labour) – EU15 + 4 NMS

Figure 21 and Figure 22 present the overall welfare results for the scenarios, i.e. the sums of all four welfare components.

As noted earlier emission benefits are calculated for the introduction year of the emission standard (2009/2010), while no changes in the other welfare components are reported in that year. This results in a slightly positive welfare outcome in 2009 or 2010 for all scenarios. This is a consequence of the model structure, which is not designed to assess short-term effects of policies. What is of importance are the long-term effects of the policy.

For all scenarios, except for A16, the estimated welfare effect is positive. I.e. the benefits from pollution reduction are higher than the costs associated with the introduction of the improved technologies. All A16-A25 scenarios are based on a 2.5 mg. PM limit value for diesel cars. The scenarios with a 75 mg. NO_x limit value for diesel cars are the ones for which the highest welfare benefits are estimated (A20, A22, A24 and A25). The scenarios with a 200 mg. NO_x limit value for diesel cars result in a significant lower welfare increase (A17, A18 and A21). Actually, for these scenarios, the cost increase over time and the (pollution) benefit increase over time are balancing out each other. The A23 scenario, with a 150 mg. NO_x limit value for diesel cars, leads to a result in between the 200 mg. and 75 mg. scenarios.

In other words, the main determinant for the welfare outcomes of the scenarios is this NO_x limit level for diesel cars. The impact of the levels of the emission standards for petrol cars (VOC and NO_x) on the overall result is smaller, though certainly not negligible. Compare e.g. the A17 (50 mg. VOC, 24 mg. NO_x and A18 (75 mg. VOC, 48 mg. NO_x) results.

In scenario A16, the benefits related to the reduction in air pollution and the increase in tax revenues from the transport sector do not compensate the decrease in household utility and the increase in production costs. This result can be explained by the increase in maintenance/repair cost that is assumed in A16.

From these model results it is clear that, at the studied limit value levels, small changes in assumptions (e.g. extra maintenance cost or not) can determine whether a welfare increase is calculated or not. Therefore it is important to emphasize that the model results are based on a number of estimates on technology costs, future precious metal prices, crude oil prices, health effects of particulates, effects of greenhouse gases, economies of scale, etc. For each of these estimates uncertainties exist. In particular, significant uncertainties exist with respect to monetary benefits of reducing air pollution. Therefore, a sensitivity analysis on the benefit values is presented in section 3.3.6.

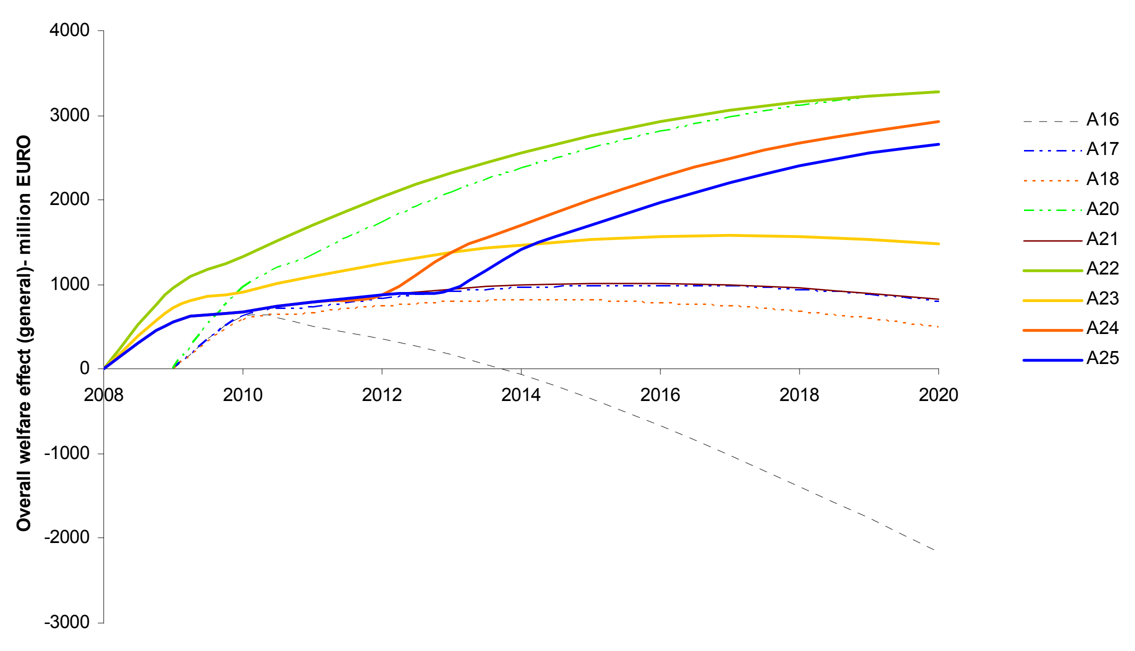

Figure 21: A16-A25 Overall welfare effect (general – set 1 external cost values) – EU15 + 4 NMS

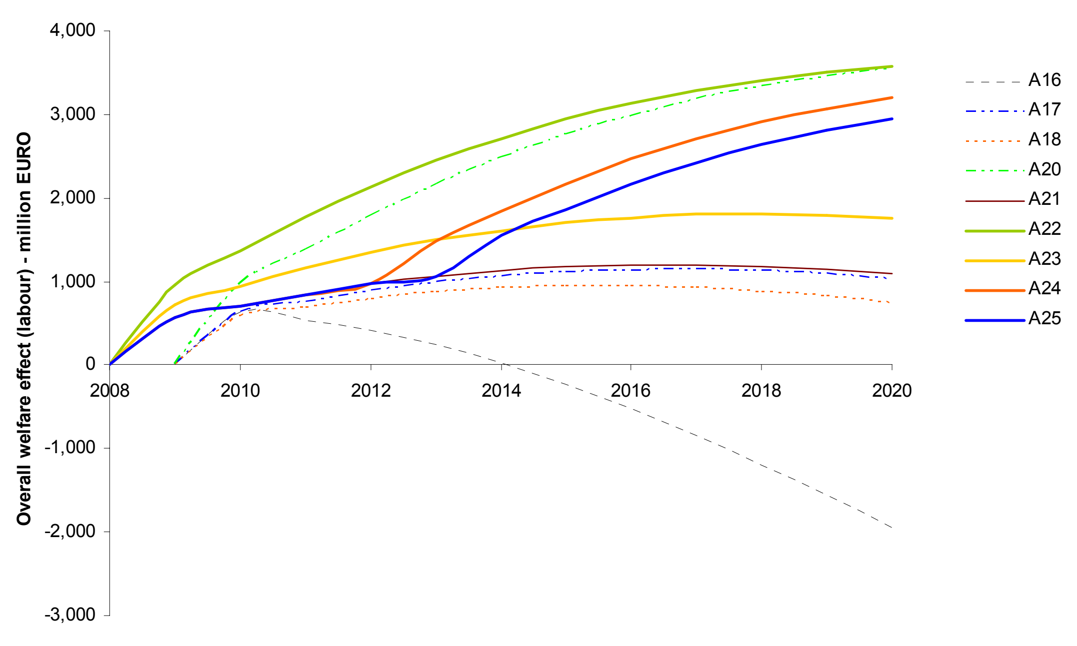

Figure 22: A16-A25 Overall welfare effect (labour – set 1 external cost values) – EU15 + 4 NMS

Table 3: A16 Welfare components, in million EURO – All TREMOVE countries

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Utility of households		-3	-620	-1277	-1952	-2639	-3336	-4043	-4757	-5460	-6154	-6837
(Production costs)		0	-230	-469	-713	-960	-1207	-1458	-1712	-1963	-2213	-2460
Extra public funds (general)		3	39	79	120	159	196	230	261	292	320	347
Extra public funds (labour)		4	63	130	196	260	319	375	426	476	522	565
Total welfare effect w/o pollution benefits (general)		**-1**	**-811**	**-1667**	**-2545**	**-3440**	**-4348**	**-5272**	**-6207**	**-7131**	**-8047**	**-8950**
Total welfare effect w/o pollution benefits (labour)		**0**	**-787**	**-1616**	**-2469**	**-3339**	**-4224**	**-5127**	**-6042**	**-6947**	**-7845**	**-8731**
Pollution benefits - Set 1		638	1317	2012	2687	3332	3948	4539	5110	5653	6169	6659
Welfare (general)		637	506	346	142	-108	-399	-733	-1097	-1479	-1878	-2291
Welfare (labour)		639	530	396	218	-7	-276	-588	-932	-1295	-1676	-2073
Welfare Net Present Value (general)	**-3462**											
Welfare Net Present Value (labour)	**-2647**											
Decomposition external pollution cost - Set 1												
Pollution benefit CO		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Pollution benefit CO2		-4.9	-7.6	-10.5	-13.3	-16.0	-18.6	-21.0	-23.3	-25.4	-27.5	-29.4
Pollution benefit N2O		0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.7	0.9	1.0	1.2
Pollution benefit Nox		269.6	561.8	869.5	1175.7	1474.7	1766.7	2051.7	2332.6	2603.8	2866.7	3119.6
Pollution benefit PM		363.2	733.9	1106.0	1459.6	1791.0	2101.2	2393.1	2670.0	2928.0	3169.2	3394.6
Pollution benefit SO2		-13.6	-20.5	-27.0	-33.0	-38.3	-43.0	-47.1	-50.8	-54.2	-57.2	-59.8
Pollution benefit VOC		24.0	49.1	74.1	97.8	120.2	141.6	161.9	181.2	199.4	216.6	232.7
Decomposition utility of households and production costs												
slow							0					0
small car												
caused by fix resource cost							*-409*					*-821*
caused by var resource cost							*-215*					*-475*
caused by fix tax							*-20*					*-39*
caused by var tax							*-25*					*-45*
caused by VAT on fix res cost							*-45*					*-92*
caused by VAT on var res cost							*-36*					*-79*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*25*					*49*
caused by waiting time price							*0*					*0*
medium/big car												
caused by fix resource cost							*-1531*					*-3055*
caused by var resource cost							*-1070*					*-2245*
caused by fix tax							*-46*					*-95*
caused by var tax							*-267*					*-473*
caused by VAT on fix res cost							*-162*					*-324*
caused by VAT on var res cost							*-184*					*-376*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*49*					*93*
caused by waiting time price							*0*					*0*
moped							1					2
motorcycle							1					2
light duty vehicle												
caused by fix resource cost							*-267*					*-573*
caused by var resource cost							*-178*					*-403*
caused by fix tax							*-11*					*-24*
caused by var tax							*-64*					*-127*
caused by VAT on fix res cost							*-9*					*-20*
caused by VAT on var res cost							*-11*					*-24*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*12*					*25*
caused by waiting time price							*0*					*0*
heavy duty vehicle							-71					-156
bus							20					36
coach							2					5
metro/tram							19					36
passenger train							12					23
freight train							0					0
inland ship							0					0
plane							0					0
caused by other effects							-62					-122

Table 4: A17 Welfare components, in million EURO – All TREMOVE countries

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Utility of households		-3	-443	-901	-1362	-1820	-2274	-2725	-3170	-3608	-4042	-4468
(Production costs)		0	-173	-350	-527	-702	-875	-1047	-1217	-1387	-1556	-1723
Extra public funds (general)		3	41	83	125	166	206	243	278	312	344	375
Extra public funds (labour)		4	66	134	203	270	333	393	450	504	556	604
Total welfare effect w/o pollution benefits (general)		**-1**	**-575**	**-1168**	**-1763**	**-2356**	**-2944**	**-3529**	**-4109**	**-4683**	**-5253**	**-5816**
Total welfare effect w/o pollution benefits (labour)		**0**	**-549**	**-1116**	**-1685**	**-2253**	**-2816**	**-3379**	**-3938**	**-4491**	**-5042**	**-5587**
Pollution benefits - Set 1		639	1314	2005	2674	3313	3922	4505	5068	5602	6109	6590
Welfare (general)		638	740	837	911	957	979	976	959	919	856	774
Welfare (labour)		639	765	889	989	1060	1106	1126	1130	1111	1068	1004
Welfare Net Present Value (general)	**6453**											
Welfare Net Present Value (labour)	**7298**											
Decomposition external pollution cost - Set 1												
Pollution benefit CO		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pollution benefit CO2		-4.6	-7.7	-11.1	-14.7	-18.2	-21.9	-25.4	-29.1	-32.6	-36.2	-39.7
Pollution benefit N2O		0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Pollution benefit Nox		267.5	556.5	860.7	1163.3	1458.4	1746.1	2026.8	2303.1	2569.8	2828.1	3076.4
Pollution benefit PM		364.3	735.8	1108.3	1461.9	1792.9	2102.5	2393.7	2669.6	2926.7	3167.0	3391.5
Pollution benefit SO2		-12.2	-19.5	-26.6	-33.4	-39.6	-45.4	-50.7	-55.8	-60.5	-64.8	-68.6
Pollution benefit VOC		24.0	48.9	73.8	97.2	119.4	140.5	160.6	179.5	197.5	214.4	230.1
Decomposition utility of households and production costs												
slow							0					0
small car												
caused by fix resource cost							*-415*					*-832*
caused by var resource cost							*-8*					*-14*
caused by fix tax							*-20*					*-41*
caused by var tax							*-21*					*-38*
caused by VAT on fix res cost							*-46*					*-93*
caused by VAT on var res cost							*-4*					*-8*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*18*					*34*
caused by waiting time price							*0*					*0*
medium/big car												
caused by fix resource cost							*-1547*					*-3081*
caused by var resource cost							*-183*					*-292*
caused by fix tax							*-54*					*-109*
caused by var tax							*-235*					*-415*
caused by VAT on fix res cost							*-163*					*-324*
caused by VAT on var res cost							*-58*					*-99*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*34*					*64*
caused by waiting time price							*0*					*0*
moped							*1*					*1*
motorcycle							*0*					*1*
light duty vehicle												
caused by fix resource cost							*-274*					*-587*
caused by var resource cost							*-36*					*-65*
caused by fix tax							*-12*					*-26*
caused by var tax							*-56*					*-111*
caused by VAT on fix res cost							*-9*					*-20*
caused by VAT on var res cost							*-4*					*-7*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*9*					*18*
caused by waiting time price							*0*					*0*
heavy duty vehicle							-56					-119
bus							14					24
coach							2					3
metro/tram							13					24
passenger train							8					15
freight train							0					0
inland ship							0					0
plane							0					0
caused by other effects							-49					-95

Table 5: A18 Welfare components, in million EURO – All TREMOVE countries

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Utility of households		-3	-414	-842	-1272	-1700	-2124	-2545	-2961	-3369	-3773	-4171
(Production costs)		0	-164	-332	-500	-667	-831	-994	-1156	-1317	-1477	-1637
Extra public funds (general)		2	43	87	132	176	217	257	295	331	366	398
Extra public funds (labour)		3	69	140	213	283	350	413	473	531	586	638
Total welfare effect w/o pollution benefits (general)		**-1**	**-535**	**-1087**	**-1640**	**-2192**	**-2738**	**-3282**	**-3821**	**-4355**	**-4885**	**-5409**
Total welfare effect w/o pollution benefits (labour)		**0**	**-509**	**-1034**	**-1560**	**-2085**	**-2605**	**-3126**	**-3643**	**-4155**	**-4665**	**-5170**
Pollution benefits - Set 1		585	1199	1823	2424	2994	3533	4046	4540	5005	5446	5864
Welfare (general)		584	664	736	784	802	795	764	718	650	561	455
Welfare (labour)		585	690	790	865	909	928	921	897	850	782	694
Welfare Net Present Value (general)	**5150**											
Welfare Net Present Value (labour)	**6029**											
Decomposition external pollution cost - Set 1												
Pollution benefit CO		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
Pollution benefit CO2		-4.6	-8.0	-11.6	-15.4	-19.3	-23.2	-27.1	-31.1	-35.0	-39.0	-42.9
Pollution benefit N2O		0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7
Pollution benefit Nox		226.7	468.4	719.9	967.4	1205.8	1435.8	1658.2	1876.1	2085.0	2286.5	2480.1
Pollution benefit PM		364.1	735.3	1107.6	1461.0	1791.9	2101.4	2392.5	2668.4	2925.5	3165.7	3390.2
Pollution benefit SO2		-12.5	-20.4	-28.2	-35.6	-42.5	-48.9	-54.9	-60.6	-65.9	-70.7	-75.2
Pollution benefit VOC		11.3	23.4	35.4	46.8	57.5	67.7	77.4	86.6	95.3	103.4	111.1
Decomposition utility of households and production costs												
slow							0					0
small car												
caused by fix resource cost							*-349*					*-703*
caused by var resource cost							*-6*					*-13*
caused by fix tax							*-17*					*-34*
caused by var tax							*-21*					*-39*
caused by VAT on fix res cost							*-38*					*-78*
caused by VAT on var res cost							*-4*					*-8*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*17*					*32*
caused by waiting time price							*0*					*0*
medium/big car												
caused by fix resource cost							*-1448*					*-2881*
caused by var resource cost							*-185*					*-300*
caused by fix tax							*-49*					*-100*
caused by var tax							*-241*					*-427*
caused by VAT on fix res cost							*-152*					*-303*
caused by VAT on var res cost							*-59*					*-102*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*33*					*60*
caused by waiting time price							*0*					*0*
moped							*1*					*1*
motorcycle							*0*					*1*
light duty vehicle												
caused by fix resource cost							*-258*					*-553*
caused by var resource cost							*-36*					*-67*
caused by fix tax							*-11*					*-24*
caused by var tax							*-58*					*-115*
caused by VAT on fix res cost							*-9*					*-19*
caused by VAT on var res cost							*-4*					*-8*
caused by network cost							*0*					*0*
caused by other costs							*0*					*0*
caused by in-vehicle time price							*8*					*17*
caused by waiting time price							*0*					*0*
heavy duty vehicle							-55					-116
bus							13					23
coach							-3149					-6191
metro/tram							12					23
passenger train							8					14
freight train							0					0
inland ship							0					0
plane							0					0
caused by other effects							-47					-93

3.3.6. *Sensitivity analysis on benefits*

As already mentioned, significant uncertainties exist with respect to the benefits resulting from reductions in NO_x, VOC and PM, as well as their monetary valuations. The Clean Air for Europe cost-benefit analysis resulted in four alternative lists of external cost estimates. These estimates are referred to as BeTa table, i.e. Benefits Table. The range in damage valuations accounts for, amongst others, the variation in the methods used to value mortality. The BeTa table values are based on modelling a uniform relative reduction in emissions of each pollutant within each country. As such, they represent an average of damages over rural and urban emissions.

The standard set of external cost estimates in TREMOVE is derived from the highest BeTa table values. $PM_{2.5}$ external cost values have been applied to the calculated particulate emissions. Factors of 0.75, 1.5 and 3 have been applied on the country values for PM to obtain specific estimates for non-urban, other urban and metropolitan regions respectively. In this paragraph we will refer to this standard set of external cost estimates as ‘Set 1’.

As a sensitivity analysis the emission benefits for A16, A17 and A18 have also been calculated with four other sets of external cost estimates for NO_x, PM, SO_2 and VOC. These are based on the four alternative valuations in the Beta table, without split of the PM values into regions. We refer to these as sets 2 to 5, with set 2 representing the lowest BeTa table values and set 5 representing the highest values. (Thus Set 5 is equal to Set 1, except for the PM desaggration factors for non-urban, other urban and metropolitan).

In all calculations the same CO_2 external cost estimates are used. In the benefit calculations with sets 2 to 5 CO and N_2O external costs are excluded. The sensitivity analysis has been performed for all modelled countries except Switzerland and Norway.

Table 6, Table 7 and Table 8 present the results of the sensitivity analysis for scenarios A16, A17 and A18 respectively. As five sets of external cost estimates are used together with two possibilities for the compensation of changes in transport tax revenues, ten overall welfare outcomes can be derived.

From the tables, it is clear that the external cost estimates have a crucial impact on the balance between the costs and the benefits of the scenarios. For scenario A16 the welfare outcome is always negative, though differs a factor three depending on the set of external costs used (in 2020). A17 and A18 are positive in case high external cost estimates (Sets 1 and 5) are used, but negative with lower estimates (Sets 2 to 4).

Table 6: A16 Benefit sensitivity analysis, in million EURO – All countries except Switzerland and Norway

Scenario A16		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-4225	-8693
Total welfare effect w/o pollution benefits (labour)	-4101	-8472
Pollution benefits - Set 1	3878	6530
Pollution benefits - Set 2	1271	2160
Pollution benefits - Set 3	1962	3334
Pollution benefits - Set 4	2450	4158
Pollution benefits - Set 5	3617	6136
Welfare - Set 1 - General	-348	-2163
Welfare - Set 1 - Labour	-223	-1943
Welfare - Set 2 - General	-2954	-6532
Welfare - Set 2 - Labour	-2830	-6312
Welfare - Set 3 - General	-2263	-5359
Welfare - Set 3 - Labour	-2139	-5139
Welfare - Set 4 - General	-1775	-4534
Welfare - Set 4 - Labour	-1651	-4314
Welfare - Set 5 - General	-608	-2557
Welfare - Set 5 - Labour	-484	-2336

Table 7: A17 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A17		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2868	-5665
Total welfare effect w/o pollution benefits (labour)	-2752	-5469
Pollution benefits - Set 1	3852	6463
Pollution benefits - Set 2	1263	2139
Pollution benefits - Set 3	1950	3302
Pollution benefits - Set 4	2435	4119
Pollution benefits - Set 5	3595	6079
Welfare - Set 1 - General	985	798
Welfare - Set 1 - Labour	1101	994
Welfare - Set 2 - General	-1605	-3525
Welfare - Set 2 - Labour	-1489	-3330
Welfare - Set 3 - General	-918	-2363
Welfare - Set 3 - Labour	-802	-2167
Welfare - Set 4 - General	-433	-1546
Welfare - Set 4 - Labour	-317	-1350
Welfare - Set 5 - General	727	414
Welfare - Set 5 - Labour	843	610

Table 8: A18 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A18		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2738	-5409
Total welfare effect w/o pollution benefits (labour)	-2605	-5170
Pollution benefits - Set 1	3483	5773
Pollution benefits - Set 2	1153	1892
Pollution benefits - Set 3	1784	2931
Pollution benefits - Set 4	2231	3663
Pollution benefits - Set 5	3302	5425
Welfare - Set 1 - General	745	364
Welfare - Set 1 - Labour	877	604
Welfare - Set 2 - General	-1585	-3517
Welfare - Set 2 - Labour	-1453	-3278
Welfare - Set 3 - General	-954	-2478
Welfare - Set 3 - Labour	-822	-2238
Welfare - Set 4 - General	-507	-1746
Welfare - Set 4 - Labour	-375	-1507
Welfare - Set 5 - General	564	16
Welfare - Set 5 - Labour	696	255

4. Interpretation of results, caveats and suggestions

Simulation of the effects of new emission standards and technologies has always been one of the core objectives of the development of the TREMOVE model. As a consequence, the model structure has been setup to analyse this kind of scenario as good as possible, within the limits of the scope of the model. Not only changes in emissions and fuel consumption are estimated, but also effects on fleets, transport demand and its modal split, and fiscal revenues are integrated in the model calculations. This way TREMOVE enables to analyse the full impact of emission standard scenarios in an integrated way. Further refinements and extensions to the model and its calibration are being performed the ongoing TREMOVE 3 Lot 1 project by TML. A number of important possibilities for improvements however are to be situated rather in the input data than in the model code.

The "Euro 5" scenario simulations have been performed in the time period spanning from March 2005 to May 2006. For all simulations the same v2.32b TREMOVE baseline and model version has been used. It should be noted that the v2.32b baseline version deviates significantly from the most recent v2.44 version. In general, following important baseline changes have been made since v2.32b :

- Introduction of the new Partial A SCENES transport forecast, based on new crude oil price and GDP forecasts
- Updated train fleet forecasts which has been developed in the context of the ASSESS project;
- Further calibration towards national statistics on road vehicle-kilometres by mode and road vehicle speeds for Belgium, Germany, France, United Kingdom and Spain;
- Introduction of blended biofuels, with up to 5.75% blending in 2010;
- Removed hybrid cars (see Chapter III, section III2.1);
- Updated the path for fuel-efficiency improvements for cars and N1 vehicles (see Chapter III, section III2.1);
- Updated well-to-tank emission factors for greenhouse gases (see Chapter III, section III2.1);
- Added low rolling resistance tyres, low value lubricants and tyre pressure monitoring technologies in the baseline (see Chapter III, section III2.1);
- Included CNG cars;
- Included extra fuel consumption and refrigerant leakage from car airconditioning equipment;
- Introduced exogenous car type market shares for years 1996 to 2005, based on statistics. And updated the car purchase choice logit models accordingly;
- Update from the road emission methodolgy from COPERT 3 to (draft) COPERT 4.

In particular the latter two baseline updates are of importance for the "Euro 5" simulations, as they have significant impact on market share of diesel vehicles and the NO_x and PM emission factors for EURO 4 cars.

In v2.32b basecase the market share of new diesel cars in the years 2001 to 2020 is similar to that in the year 2000. In v2.44 however, the 2001 to 2005 market shares are based on the available statistics. And an approximately constant new diesel car share is assumed from 2005 on. As the diesel car market share in 2005 was significantly larger in 2005 than in 2000, the new v2.44 baseline thus predicts a significanlty larger future market share for diesel cars than the v2.32b baseline. In v2.32b the 2020 market share of new diesel cars (average for EU15 and 4 new member states) is approximately 30%, in v2.44 this is rather 45%[10].

The COPERT 4 emission factors for Euro 4 cars differ significantly from those in COPERT 3. The NO_x emission factors for Euro 4 diesel cars in v2.44 are roughly 20% higher than those in v2.32b. The Euro 4 diesel car PM emission factors in v2.44 are rouhgly 25% lower than in v2.43b. The NO_x emission factors for Euro 4 petrol cars in v2.44 are roughly 40% lower than those in v2.32b. And also for Euro 4 petrol cars, the PM emission factors in v2.44 are roughly 75% lower than those in v2.43b.

Summarising, there are important differences in the predicted petrol vs diesel car market shares and in the emissions between the v2.32b baseline and the most recent v2.44 baseline. Simulating the Euro 5 policy scenarios based on the new baseline version, would lead to significant changes in the model outcomes.

Furthermore, two top priorities can be be identified for baseline improvements beyond v2.44.

- Crucial input data for a good assessment of the effects of "Euro 5" emission standards are of course the real-world emission factors for Euro 4 vehicles. The emission factors for Euro 4 cars in COPERT IV are still based on estimates not on actual emission measurements. Introducing further updated emission factors based on actual measurements would further improve the baseline predictions;.
- Whereas for cars fleet and activity data is widely available and of good quality, this is not always true for N1 vehicles.

Next to the baseline data, the specific input data for the scenarios themselves of course is of crucial importance. A number of important caveats already have been discussed in this report. In summary it concerns following issues:

At first, there are still uncertainties with respect to the technology costs to reach certain test-cycle emission reductions. We point here primarily to the uncertainties with respect to economies of scale and maintenance/repair costs. But also specific cost estimates for the heavier N1 vehicles are an open issue. Moreover, not all studied limit values are covered by the data in the panel report. For the 200 mg. NO_x for diesel cars, no specific cost estimate is provided by the panel report. The difference in costs for a 5 mg. or 2.5 mg. PM limit proved hard to tackle.

Secondly, neither the questionnaire nor the panel report provides information on the effects of emission technologies on real-world emissions. Recent measurements however tend to indicate that the relationship between test-cycle and real-world emissions is not necessarily linear.

And finally, health benefits related to PM-traps are not sufficiently known. PM traps reduce the overall PM emissions, but also alter the PM size distribution. Information on this effect on the size distribution of PM emissions is scarce. The size distribution though is an essential determinant of the nocive health effects. Furthermore the ranges for the valuation of mortality and health effects are wide (for all pollutants). This leads to a significant variability in external cost estimates.

The consequence of these uncertainties is that assumptions had to be made for each of the scenarios. And, depending on these assumptions, simulation results vary significantly, even if one compares scenarios which set similar "Euro 5" limit values. For example, scenarios A2, A3, A7, A8 and A9 all assume the

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[10] Note that the first TREMOVE 2 versions (2.1) included future diesel market shares that were higher than those in v2.44. At that time these estimates have been lowered.after stakeholder consultations on the issue.

same limit values, though results differ according to the other assumptions made. On the one hand this approach is interesting for assessing the sensitivity of the results, on the other hand it does not help us to overcome the uncertainties.

For this latter reason, we would recommend a further analysis of the issues at hand: external costs of air pollution, economies of scale, real-world impacts, maintenance/repair costs. Specific research on these issues could decrease the level of uncertainty. This would enable to identify the most realistic assumptions or, ideally, to avoid the need for assumptions.

III Reduction of CO_2 emissions from Light Duty Vehicles

The scenario simulations presented in this chapter have been performed to support the impact assessment for the preparation of a new strategy aimed at reducing the CO_2-emissions of cars to a level of 120 g/km in 2012. The work has been carried out in close cooperation with two other studies:

- “”Task A”: Review and analysis of the reduction potential of technological and other measures to reduce CO_2 emissions from passenger cars. Carried out by TNO, IEEP and LAT [TNO, 2006].
- “Task B”: Service contract in support of the extended impact assessment of various policy scenarios to reduce CO_2 emissions from passenger cars. Carried out by ZEW and B&D.

Table 9 provides an overview of the scenario simulations performed. Input data on technological and other measures has been taken from [IEEP, 2004] and from the draft, interim and final reports of the Task A study [TNO, 2006]. Simulations have been performed with several TREMOVE versions, in parallel with the development of the model and baseline during the project. The remainder of this chapter will only discuss the simulations D20 up to D32, however.

This chapter is composed of four sections. In the first section 1 an overview of the scenario simulations performed is provided. Section 2 then refers to the input data and assumptions used in the scenario modelling. In Section 3 the simulation results are presented. Finally, section 4 provides suggestions and caveats for further research work.

1. Overview of scenarios modelled

Table 9 lists all CO2CAR scenarios that have been simulated. As indicated earlier only scenarios D20 to D32 are discussed in this report, as they form part of the scenarios that are used by the European Commission for the impact assessment of the new strategy.

In D23 an average CO_2 test-cycle emission level of 120 gram per kilometre is reached, through technical measures at the car vehicle level only. This scenario thus can be interpreted as an extension of the current 140 g. voluntary agreement with the car industry towards 120 g. in 2012. Note however that it is assumed that % reduction objectives would be set for each individual manufacturer, rather than for the associations as a whole.

D20, D21 and D22 are scenarios similar to D23, the only difference being that the 2012 objectives are set at 135 g., 130 g. and 125 g. respectively.

In scenarios D24 to D32, technical measures at the car vehicle level (up to 130 g. or 125 g.) are combined with supplementary measures. These scenarios lead to decreases in GHG emissions that are in the same range of that of scenario D23. I.e. the additional measures are introduced to fill the "gap" between the 120 g. objective for car technologies and less stringent objective levels. The supplementary measures have been restricted to measures that are measurable, monitorable and accountable. The measures considered are:

- GSI: Gear Shift Indicators in 100% of new cars in 2012 (50% in 2010, 75% in 2011);
- TPMS: Tyre Pressure Monitoring Systems in cars (2010: 50%, 2011: 75%, 2012: 100%);
- LRRT: Low Rolling Resistance Tyres for cars (2010: 50%, 2011: 75%, 2012: 100%);
- LVL: Low Viscosity Lubricants for cars (2010: 50%, 2011: 75%, 2012: 100%);
- MAC: Accelerating the introduction of more fuel efficient Mobile Air Conditioning systems;
- N1: Technical measures at the vehicle level for N1 vehicles, four options are considered:
  - Reduction of test-cycle emissions by 15 g. CO_2/km;
  - Reduction of test-cycle emissions by 30 g. CO_2/km;
  - Reduction of test-cycle emissions by 45 g. CO_2/km;
  - Reduction of test-cycle emissions by 60 g. CO_2/km.

All D20-D32 scenario input data on technology costs and effectiveness are taken from [TNO, 2006].

Table 9: Overview of CO2CAR scenarios

Code	Model version	Scenario	Variation
D1	v2.32b	CO_2 car and N1	120 g - IEEP (2004)
D2	v2.32b	CO_2 car and N1	120 g - IEEP (2004) EPS utility curve (pan area) - not optimised EPS curve
D3	v2.41	CO_2 car and N1	120g - IEEP (2004)
D4	v2.41	CO_2 car and N1	120g - TNO (Interim, 2005)
D5	v2.42	CO_2 car and N1	120g - IEEP(2004)
D6	v2.42	CO_2 car and N1	120g - TNO (Draft, 2006)
D7	v2.42	CO_2 car and N1	130g - TNO (Draft, 2006)
D20	v2.43b	CO_2 car and N1	135g - TNO (Final, 2006)
D21	v2.43b	CO_2 car and N1	130g - TNO (Final, 2006)
D22	v2.43b	CO_2 car and N1	125g - TNO (Final, 2006)
D23	v2.43b	CO_2 car and N1	120g -TNO (Final, 2006)
D24	v2.43b	CO_2 car and N1	125g + GSI - TNO (Final, 2006)
D25	v2.43b	CO_2 car and N1	125g + GSI + TPMS - TNO (Final, 2006)
D26	v2.43b	CO_2 car and N1	125g + GSI + TPMS +N1 -15g - TNO (Final, 2006)
D27	v2.43b	CO_2 car and N1	125g + GSI + TPMS +N1 -15g + LRRT - TNO (Final, 2006)
D28	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -15g + LRRT + MAC - TNO (Final, 2006)
D29	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -30g + LRRT + MAC - TNO (Final, 2006)
D30	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -30g + LRRT + MAC + LVL - TNO (Final, 2006)
D31	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -45g + LRRT + MAC + LVL - TNO (Final, 2006)
D32	v2.43b	CO_2 car and N1	130g + GSI + TPMS +N1 -60g + LRRT + MAC + LVL - TNO (Final, 2006)

Scenarios D8 to D19 were trial runs, performed with incomplete model code versions, as preparation of the final set of D20-D32 runs.

2. Scenario input data and assumptions

2.1. Baseline for car and N1 greenhouse gas emissions

Before the final CO2CAR simulations were performed, the TREMOVE baseline has been updated to ensure consistency with the baseline developed in the Task A study [TNO, 2006]. Baseline modifications have also been made based on outcomes of the consultations in the "European Climate Change Panel 2 working group on the integrated approach to CO_2 reduction from light duty vehicles". This resulted in TREMOVE model version v2.43b. In this paragraph, we shortly summarise these baseline updates.

Previous TREMOVE baseline versions included hybrid cars and conventional cars as separate car types. In [TNO, 2006] this distinction is not explicitly made, as the Task A study looked into a wide range of drivetrains, from conventional engines over mild hybrids to full hybrids. To ensure consistency with the Task A study, the hybrid car types have been removed from the TREMOVE baseline. The car categories in the new baseline thus represent aggregates over conventional and hybrid cars.

All earlier TREMOVE versions already included the assumption that the 140 g. CO_2/km test-cycle target will be reached by all manufacturer associations in 2009. In the earlier model versions, this was included via a general fuel efficiency path for all petrol cars, and one for all diesel cars (see [TML, 2005] table 55). [TNO, 2006] now provides detailed data/forecasts by individual car type on the expected fuel efficiency improvements towards the 140 g. objective, as well as on the related costs. These new paths for fuel efficiency improvements, as well as the related increases in ex-tax car retail prices, have been included in the updated TREMOVE baseline.

Furthermore [TNO, 2006] indicates that additional technical measures will be needed to keep fuel efficiency at 140 g. CO_2/km in the 2009-2012 period. These measures are needed to compensate projected increases in vehicle weight. Also for this period, the reported fuel efficiency and price changes by car type have been introduced in TREMOVE.

Also for N1 vehicles the modelled path of 2002-2012 fuel efficiency improvements is taken from the business-as-usual scenario reported by [TNO, 2006]. It should be noted however that the initial 2002 real-world fuel consumption factors for N1 vehicles differ between the Task A study and TREMOVE. In TREMOVE no adaptations have been made to bring the N1 vehicle factors, which are calculated using COPERT III, in line with the estimates in [TNO, 2006]. Table 10 shows the CO_2 emission factors for N1 vehicles in TREMOVE v2.43b versus those in the Task A study. Note that the part A study used the same 'real-world versus test-cycle' ratio for N1 vehicles as for cars, due to lack of specific estimates for N1. Furthermore the Part A report does not report increases in ex-tax car retail prices related to the increases in fuel efficiency for N1 vehicles.

Table 10 : 2002 CO_2 emission factors for N1 vehicles - EU15 averages

	CO2 emissions - grammes per km.		
	Task A		**TREMOVE v2.43b**
	Test-cycle	Real-world	Real-world
Petrol N1	222	265	292
Diesel N1	191	228	225

Relevant input parameters

The paths for car and N1 fuel efficiency improvements and related ex-tax retail price increases are defined in following input parameters. Parameter values for the basecase can be found in the TREMOVE input dB :

Name	**Table_info**	**Description**
RFC_acea_2002	VEHICLE_PARAMETER	2002 measured car fuel consumption in ACEA agreement monitoring dB - l/100 km
RFACTORACEA	VEHICLE_VINTAGE_PARAMETER	Factor to include historic and projected decreases in fuel consumption for road vehicles, a.o. following ACEA voluntary 140g agreement; value is 1 for 2002
RPCS_INCREASE_2009	T_VEHICLE_PARAMETER	% Vehicle purchase cost increase to reach the 140g car test-cycle CO2 target in 2009
RPCS_INCREASE_2012	T_VEHICLE_PARAMETER	% Vehicle purchase cost increase to reach the test-cycle CO2 target in 2012 - on top of 140g costs

Low rolling resistance tyres (LRRT), tyre pressure monitoring systems (TPMS) and low viscosity lubricants (LVL) are included in the baseline for cars. Ex-tax retail prices (for TPMS), extra yearly maintenance costs (for LRRT and LVL)[11] and fuel-efficiency improvements for these technologies have been taken from the Task A study. These input values are reported in Table 11.

Table 11 : Task A Cost and fuel-efficiency impacts of LRRT, TPMS, LVL and GSI

Technology	Increase in ex-tax retail price (EURO/car)	Increase in maintenance cost (EURO/year)	Decrease in real-world fuel consumption %
LRRT	-	20.0	3.0%
LVL	-	21.0	2.5%
TPMS	61.0	-	2.5%
GSI	17.4	-	1.5%

Also the basecase market penetrations for these technologies have beeen based on the Task A report. Therefore, a "resistance technology" matrix has been specified in the model. This matrix indicates the share of cars that have these technologies, for each vintage (year in wich a car is sold) and for each model year (year in which the car is used). [TNO, 2006] provides basecase projections for the shares of these three technologies in the whole fleet. These projections are presented in Table 12.

Table 12 : Task A projected basecase shares of LRRT, LVL and TPMS [TNO, 2006]

Year	LRRT	LVL	TPMS
2008	50%	5%	5%
2009	52%	6%	6%
2010	54%	8%	8%
2011	55%	9%	9%
2012	57%	11%	11%
2013	59%	13%	13%
2014	61%	16%	15%
2015	62%	16%	16%
2016	64%	18%	18%
2017	66%	20%	20%
2018	68%	22%	22%
2019	69%	23%	23%
2020	71%	25%	25%

In TREMOVE, for LRRT and LVL the Table 12percentages for the model years 2008-2020 have been applied to cars for all vintages (except cars sold before 1996). Thus, both increasing application in new

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[11] I.e. for regular replacements of these tyres and lubricants.

cars and increasing retroffiting over time is assumed for these two technologies. For TPMS, the Part A study expects no retrofittings. Therefore, as a proxy, the TREMOVE basecase assumes that, from 2008 onwards, 30% of the new sold cars have the TPMS technology. This assumption results in TPMS market penetration figures that are similar to the Table 12 percentages.

Relevant input parameters

LRRT, LVL and TPMS technologies are introduced in the model by way of following input parameters. Parameter values for the basecase can be found in the TREMOVE input dB.

Name	**Table_info**	**Description**
RTECH_RESISTANCE_ MX	VEHICLE_RTECH_RESISTANCE_ VINTAGE_T_PARAMETER	% Vehicles equipped with technologies to reduce vehicle and engine resistance
RFC_REDUC_RESISTANCE	RTECH_RESISTANCE_PARAMETER	Real world fuel consumption reduction from utilisation of technologies to reduce vehicle and engine resistance factors – %
RPCS_INCREASE_TPMS	COUNTRY_PARAMETER	Vehicle purchase cost increase for tyre pressure monitoring system - EURO 2000
RREPMAINTC_INCREASE_ RTECH_RES	RTECH_RESISTANCE_PARAMETER	Increase in yearly maintenance cost for using technologies to reduce vehicle and engine resistance factors - EURO 2000

Also for GSI, the ex-tax retail price and fuel-efficiency improvement estimates from the Task A study have been implemented in the TREMOVE model. These input values are reported in Table 11. A "GSI" matrix has been specified in the model that indicates the share of cars that have this equipment, for each car vintage. Note however that no application of GSI equipment is modelled in the basecase, i.e. in the basecases the latter shares have been set at zero.

Relevant input parameters

The GSI technology is introduced in the model by way of following input parameters. Parameter values for the basecase can be found in the TREMOVE input dB.

Name	**Table_info**	**Description**
RTECH_GSI_SHARE	VEHICLE_VINTAGE_PARAMETER	% of new sold road vehicles equipped with Gear Shift Indicator
RFC_REDUC_GSI	RTECH_RESISTANCE_PARAMETER	Real world fuel consumption reduction from utilisation of Gear Shift Indicator - %
RPCS_INCREASE_GSI	COUNTRY_PARAMETER	Vehicle purchase cost increase for gear shift indicator – EURO 2000

Well-to-tank emission factors for the greenhouse gases (CO_2, CH_4 and N_2O) have been updated with the outcomes of the related consultations in the "European Climate Change Panel 2 working group on the integrated approach to CO_2 reduction from light duty vehicles". The new well-to-tank emission factors result from consultations between EUROPIA and the European Commission. The factors are based on the [CONCAWE/EUCAR/JRC, 2004] report and additional assumptions on the mix of fuel production pathways.

The assumed pathway mixes are reported in Table 13. The resulting well-to-tank emission factors are presented in Table 14.

Table 13: Mix of fuel production pathways and related well-to-tank emission factors

Fuel	Pathway	Pathway mix	Emission Factors (tonnes per ton fuel)			
			CO2	CH4	N2O	Total CO2-eq.
Petrol	Conventional	100%	0.54	0.000	0.000	0.54
Diesel	Conventional	100%	0.61	0.000	0.000	0.61
LPG	Imported field gas	100%	0.35	0.000	0.000	0.35
CNG	Imported NG via 4000 km pipeline	70%	0.45	0.010	0.000	0.68
	LNG from Middle East	30%	0.81	0.007	0.000	0.97
Ethanol	Wheat, NG GT + CHP, DDGS to animal feed	70%	1.61	0.004	0.001	2.00
	Wheat, NG GT + CHP, DDGS to heat & power	30%	0.89	0.001	0.002	1.52
Biodiesel	Rape, glycerine as chemical	80%	0.58	0.003	0.003	1.54
	Sunflower, glycerine as chemical	20%	0.38	0.002	0.001	0.72

Table 14: Well-to-tank emission factors – tonnes emitted per ton fuel produced

Fuel	CO2	CH4	N2O	Total CO2-eq.
Petrol	0.54	0.000	0.000	0.54
Diesel	0.61	0.000	0.000	0.61
LPG	0.35	0.000	0.000	0.35
CNG	0.56	0.009	0.000	0.77
Ethanol	1.39	0.003	0.001	1.76
Biodiesel	0.54	0.003	0.003	1.50

Relevant input parameters

The input parameters that affect the well-to-tank module are:
Well-to-tank emission factors are specified in following parameters. Parameter values for the basecase can be found in the TREMOVE input dB.

Name	Table_info	Description
LC_EMI_FACTOR_RFUEL_COMP	T_POLL_FUELCOMP_PARAMETER	Road fuel component WTT emission factor - tonnes pollutant per tonne fuel
LC_EMI_FACTOR	T_FUEL_POLL_PARAMETER	Non-road fuel and electricity WTT emission factor - tonne pollutant per tonne fuel or per kWh electricity

2.2. *Modelling of the policy scenarios*

2.2.1. *Technical measures at vehicle level – Cars*

[TNO, 2006] presents technology scenarios for different options w.r.t. further reductions of car test-cycle CO_2 emissions beyond the current 140 g./km objective. The scenarios vary w.r.t. 2012 reduction objectives, target settings and implementation measures. Targets could be set as a fixed gram per km. target, as a percentage reduction or as a function of of the utility of the car type. These targets can then further be implemented for each individual car type, for each manufacturer or for all cars together (with trading). In the TREMOVE scenarios D20 to D32, a percentage reduction target per manufacturer is considered.

For each scenario, [TNO, 2006] reports the predicted improvement paths in g./km test-cycle CO_2 emissions towards the 2012 objective. These estimates are available for each petrol and diesel car type (i.e.

small petrol, medium petrol, big petrol, small diesel, medium diesel, big diesel). These figures are aggregates for the EU15 new car sales. In TREMOVE these absolute figures have been converted to percentage fuel efficiency improvements by car type for the years 2010, 2011 and 2012. The percentages are applied equally in all modelled countries. From 2012 onwards, the fuel efficiency of new cars is assumed constant.

As in the COPERT formula's, CO_2 and SO_2 emissions follow the same downward trend as the fuel consumption. [TNO, 2006] does not provide estimates on effects on other pollutants, therefore no changes to emission factors for other pollutants are included in the scenarios.

The percentage fuel efficiency improvements are applied equally to both the test-cycle and the real-world fuel consumption and emissions modelled in TREMOVE[12]. They are applied also to both hot and cold fuel consumption and emissions.

For LPG and CNG cars, the same percentages fuel efficiency increase are assumed as for their conventional (petrol) equivalents. The market shares for LPG and CNG cars are fixed to the basecase levels.

Relevant input parameters

The paths for car fuel efficiency improvements are specified in the following input parameter. In the scenarios the 2010-2020 input values for this parameter deviate from the basecase values. These modified parameter values for the simulation are introduced via the scenario generator Excel tool (see 2.2.5) :

Name	**Table_info**	**Description**
RFACTORACEA	VEHICLE_VINTAGE_PARAMETER	Factor to include historic and projected decreases in fuel consumption for road vehicles, a.o. following ACEA voluntary 140g agreement; value is 1 for 2002

For each scenario [TNO, 2006] also reports the predicted absolute increases in manufacturer costs by car type. In part A, ex-tax price increases for the consumer then are estimated by applying a 1.16 factor on the manufacturer costs. As suggested by the European Commission, the final set of TREMOVE scenario simulations (D20 to D32) takes only account of the increase in manufacturer costs for cars.

As for the CO_2 improvements, the cost figures reported by TNO are absolute values (in EURO) and are aggregated over the EU15 countries. In TREMOVE these absolute figures have been converted to percentage cost increases by car type. These EU15 averaged increase percentages then are applied equally in all modelled countries.

For LPG and CNG cars, the same absolute cost increase is assumed as for their conventional (petrol) equivalents.

Relevant input parameters

The increases in car costs are specified in the following input parameter. In the scenarios, the 2010-2020 input values for this parameter deviate from the basecase values. These modified parameter values for the simulation are introduced via the scenario generator Excel tool (see 2.2.5) :

---

[12] TNO assumes a 19.5% difference between test-cycle and real-world fuel consumption in 2002/8, including mobile airco use. TREMOVE applies a similar assumption of 15%, to which airco use is added afterwards. Note that the increasing penetration of LRRT, TPMS and LVL technologies decreases the real-world versus test-cycle difference in the future.

Name	Table_info	Description
RPCS_INCREASE_2012	T_VEHICLE_PARAMETER	% Vehicle purchase cost increase to reach the test-cycle CO2 target in 2012 - on top of 140g costs

Note that in the basecase the 2010-2012 car cost increase – to maintain the 140 g./km level up to 2012 – is calculated using the 1.16 factor, representing the difference between ex-tax retail price increase and manufacturer cost increase (as in the Part A report). In the D20-D32 simulation scenarios however, this 1.16 factor is not accounted for. This means that the cost to maintain the 140 g. level in the scenario simulations is 16% lower than in the basecase, which leads to a small cost benefit in each to of the simulated D20-D32 scenarios. The effect of this difference on the overall scenario results is limited, as the technology cost to maintain the 140 g. level is small compared to the costs of further fuel-efficiency improvements (towards a 120 g. target).

In TREMOVE simulations, the standard assumption is that increases in vehicle ex-tax retail prices, will automatically lead to similar increases in purchase taxes, insurance costs/taxes and maintenance costs. I.e. a linear relationship with the ex-tax retail price is assumed. Using this standard assumption in the scenario simulations, would lead to a significant increase in car maintenance costs in the scenario simulations. As suggested by the European Commission, in scenarios D20-D32 it is assumed that the technical measures at the vehicle level for cars have no impact on maintenance costs.

Relevant input parameters

In scenario simulations, the relationship between changes in purchase costs and changes in maintenance/repair costs can be specified in following input parameter. This parameter values can be easiliy adapted via the scenario generator Excel tool (see 2.2.5) :

Name	Table_info	Description
RREPMAINTC_LINK_RPCS	COUNTRY_PARAMETER	Switch to relate vehicle repair and maintenance cost linearly to purchase cost - 1 is linear - 0 is no link

Fuel cost and fuel excise tax savings are calculated endogenously in TREMOVE, thus are not derived from the related estimates in [TNO, 2006].

It should be noted that the segmentation of the car market into small, medium and big car types is slightly different in [TNO, 2006] compared to TREMOVE. Whereas the classification in TREMOVE is based on engine capacity (as COPERT), TNO's segmentation is based on market segments. The main difference is in the small diesel cars, for which TNO uses a 1606 cc car as representative, while in TREMOVE it is the segment of < 1400 cc diesel cars.

2.2.2. Technical measures at vehicle level – N1 vehicles

Also for N1 vehicles [TNO, 2006] provides estimates of cost increases and fuel-effiency improvements for various policy scenarios. In the part A study, two types of scenarios have been considered :

- "Equal level of technology" : to each category of N1 vehicles a technically comparable package of CO_2 reducing measures is applied;

- "Least cost solution" : CO_2 reductions are divided over the different categories of N1 vehicles in such a way that a desired level of average CO_2 reduction is achieved at least costs.

In the TREMOVE simulations, the estimates for the least cost solutions to reach targets for the entire N1-market are used. The targets considered are reductions of average test-cycle CO_2 emissions by 15 g., 30 g., 45 g. and 60 g. in 2012.

The part A study desaggregates the N1 vehicle class in six segments (three for petrol vehicles, and three for diesel vehicles). TREMOVE only contains two overall categories of N1 vehicles, petrol vehicles and diesel vehicles. Therefore Task A has supplied output figures to TREMOVE that are aggregated over their three classes per fuel type, by weighing the classes according to their sale market shares. This way the Task A report provides absolute figures for fuel efficiency improvements and vehicle ex-tax price[13] increases for each of the scenarios. For the TREMOVE scenario simulations these absolute figures have further been converted to percentages for diesel and petrol N1's, which then are applied equally in all modelled countries.

Table 10 showed that the real-world emission factor for petrol N1 vehicles in TREMOVE is approximately 10% larger than that in the Part A study. This means that, in the scenarios, also the modelled emission reductions for petrol N1's are roughly 10% larger in the TREMOVE scenario, than in task A.

Relevant input parameters

The values for N1 fuel efficiency improvements and the related purchase cost increases are specified in the following input parameters. In the scenarios the 2010-2020 input values for these parameters deviate from the basecase values. Remember that in the basecase there is no N1 vehicle purchase cost increase related to the fuel-efficiency improvements, These modified parameter values for the simulation are introduced via the scenario generator Excel tool (see 2.2.5) :

Name	Table_info	Description
RPCS_INCREASE_2012	T_VEHICLE_PARAMETER	% Vehicle purchase cost increase to reach the test-cycle CO2 target in 2012 - on top of 140g costs
RFACTORACEA	VEHICLE_VINTAGE_PARAMETER	Factor to include historic and projected decreases in fuel consumption for road vehicles, a.o. following ACEA voluntary 140g agreement; value is 1 for 2002

2.2.3. *Other supplementary measures:*

a. Low rolling resistance tyres, tyre pressure monitoring systems, low viscosity lubricants

Three types of equipment to reduce real-world fuel consumption (and CO_2 emissions) by reducing vehicle and engine resistance factors are covered by the Task A study: LRRT, TPMS and LVL. These technologies are already present to a limited extent in the baseline (see 2.1). The Task A study assessed two possible approaches for accelerating the introduction of these technologies :

- "Scenario 1" : Compulsory introduction for new cars through legislative measures;
- "Scenario 2" : Purchase incentives and similar marketing instruments for old and new cars.

Scenario 2 is not applicable for TPMS, as retrofitting of TPMS is not considered.

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[13] In D20 to D32 it is only for the car vehicle technologies that only the manufacturer cost increase is accounted for. For all N1 vehicle scenarios the full ex-tax price increase – as reported by Task A - is accounted for (ex-tax price increase = 1.16 * manufacturer cost increase). And as for N1, also for LRRT, LVL, GSI, TPMS and the fuel-efficient airco policy the full ex-tax price increase is accounted for in all scenarios.

Task A describes "scenario 1" as a compulsory introduction of LRRT, TPMS and/or LVL on all new registered cars from 2010 on, while older vehicles preserve their original equipment throughout life. Task A then estimated that this would result in a yearly 8% market share increase for these technologies. In TREMOVE, the 8% estimates is not used, as car sales are calculated endogenously in the model. In TREMOVE, "scenario 1" is specified as follows :

- For cars sold in 2009 or before : basecase shares of LRRT/TPMS/LVL are kept (see Table 12);
- For cars sold in 2010 : 50% of them are equipped with LRRT/TPMS/LVL (for their full lifetime);
- For cars sold in 2011 : 75% of them are equipped with LRRT/TPMS/LVL (for their full lifetime);
- For cars sold after 2012 : 100% of them are equipped with LRRT/TPMS/LVL (for their full lifetime).

Note that task A assumed preparatory years 2008-2010, with application less than 100%. In TREMOVE D20-D32 all policy measures start taking effect in 2010 and are only fully implemented from 2012 on. Therefore TREMOVE assumes 2010 and 2011 to be preparatory years, and 100% implementation in 2012.

"Scenario 2" targets not only original, but also replacement equipment (retrofit). For these scenarios [TNO, 2006] provides projections for the shares of the LRRT and LVL technologies in the whole fleet. These projections are presented in Table 15.

Table 15 : Task A projected scenario 2 shares of LRRT, LVL [TNO, 2006]

Year	LRRT	LVL
2008	50%	5%
2009	51%	6%
2010	54%	7%
2011	58%	8%
2012	66%	12%
2013	78%	23%
2014	92%	40%
2015	98%	61%
2016	100%	79%
2017	100%	90%
2018	100%	96%
2019	100%	98%
2020	100%	99%

In TREMOVE, for "scenario 2" simulations, the Table 15 percentages for the model years 2008-2020 are applied to cars for all vintages (except cars sold before 1996)). Thus, both increasing application in new cars and increasing retroffiting compared to the basecase is assumed for these two technologies

Relevant input parameters

LRRT, LVL and TPMS technologies are introduced in the model by way of following input parameters. In the scenarios the 2010-2020 input values for the technology matrix (RTECH_RESISTANCE_MX) parameter deviate from the basecase values. These modified parameter values for the simulation are introduced via the scenario generator Excel tool (see 2.2.5) :

Name	**Table_info**	**Description**
RTECH_RESISTANCE_ MX	VEHICLE_RTECH_RESISTANCE_ VINTAGE_T_PARAMETER	% Vehicles equipped with technologies to reduce vehicle and engine resistance

RFC_REDUC_RESISTANCE	RTECH_RESISTANCE_PARAMETER	Real world fuel consumption reduction from utilisation of technologies to reduce vehicle and engine resistance factors – %
RPCS_INCREASE_TPMS	COUNTRY_PARAMETER	Vehicle purchase cost increase for tyre pressure monitoring system - EURO 2000
RREPMAINTC_INCREASE_RTECH_RES	RTECH_RESISTANCE_PARAMETER	Increase in yearly maintenance cost for using technologies to reduce vehicle and engine resistance factors - EURO 2000

The way in which the LVL/LRRT/TPMS scenarios are defined and introduced in the model, has an impact on the cost-effectiveness calculated in TREMOVE. Two relevant notes can be made on this.

First, the Task A report provides one, single value for the increase in yearly maintenance/repair costs related to the use of LRRT or LVL. This value is used for both new cars and older (retrofitted) cars. Remember however that (in TREMOVE) older cars drive less kilometres than new cars. As a consequence, the yearly CO_2 reduction, and fuel savings, achieved through using LRRT and/or LVL for older cars, are lower than for newer cars. Given that the same yearly cost is introduced, this results in a higher cost per tonne CO_2 reduction for older cars. Test simulations on LRRT for France, for example, indicated that in “scenario 1” the 2020 average mileage of the extra cars that have LRRT (compared to the basecase) is approx. 9% higher than that for “scenario 2”.

Secondly, the Task A report provides one, single value for the percentage decrease in the CO_2 emission factors related to the use of LRRT or LVL. Also this value is used for both new cars and older (retrofitted) cars. The basecase emission factor for older cars, is higher than that for newer cars. Therefore, the absolute CO_2 reduction and the fuel cost savings achieved through using LRRT and/or LVL on older cars, is higher than that for newer cars. This also leads to differences in the cost per tonne CO_2 reduction between older cars and newer cars.

Overall, these latter two effects lead to significant differences in the calculated cost per tonne CO_2 abatement between “scenario 2” and “scenario 1”. Test simulations on LRRT for France, indicate that for “scenario 1”, the yearly fuel savings per car are approximatly 18 EURO. For “scenario 2” this is rather 16 EURO. As the yearly extra maintenance cost per car in both scenarios is 20 EURO, the net costs are about 2 EURO and 4 EURO for “scenario 1” and “scenario 2” respectively. However, the annual CO_2 emission savings in “scenario 1” is only a bith higher than that for “scenario 2” (due to the higher annual mileage). This leads to a cost per tonne CO_2 abatement for “scenario 2”, that is roughly double of that for scenario “1”.

For these LRRT and LVL technologies, it might be worth putting effort in searching and applying different fuel-efficiency and maintenance/repair cost estimates for cars of different vintages. E.g. an alternative approach might be to specify an extra maintenance/repair cost per vehicle-kilometre rather than per year.

b. Gear shift indicators

GSI equipment can reduce real-world fuel consumption by influencing drivers gear-changing behaviour. This equipment is not present in the baseline. In the GSI simulation scenarios it is assumed that 50% and 75% of the new cars will have GSI in 2010 and 2011 respectively. From 2012 onwards, all new cars will be equipped with GSI. Ex-tax retail prices, and fuel-efficiency improvements for GSI equipment are reported in Table 11.

Relevant input parameters

The GSI technology is introduced in the model by way of following input parameters. Parameter values for the basecase can be found in the TREMOVE input dB. In the scenarios the 2010-2020 input values for the GSI market shares (RTECH_GSI_SHARE) parameter deviate from the basecase values. These modified parameter values for the simulation are introduced via the scenario generator Excel tool (see 2.2.5) :

Name	**Table_info**	**Description**
RTECH_GSI_SHARE	VEHICLE_VINTAGE_PARAMETER	% of new sold road vehicles equipped with Gear Shift Indicator
RFC_REDUC_GSI	RTECH_RESISTANCE_PARAMETER	Real world fuel consumption reduction from utilisation of Gear Shift Indicator - %
RPCS_INCREASE_GSI	COUNTRY_PARAMETER	Vehicle purchase cost increase for gear shift indicator – EURO 2000

c. Fuel-efficient airconditioning equipment

The MAC measure in the TREMOVE simulations corresponds with the 'additional policy' scenario developed by Task A. It is a scenario in which a stricter policy would be put in effect that aims at accelerating the introduction of more fuel efficient mobile air conditioning systems. Increases in ex-tax retail prices and decreases in fuel consumption for the improved equipment are derived from [TNO, 2006] The Task A values and the values introduced in TREMOVE are displayed in Table 16. Note that in the TREMOVE basecase the fuel-efficiency of airconditioning equipment is assumed constant throughout the 2008-2020 period, whereas the Task A basecase assumes an improvement. To reproduce in the TREMOVE scenario similar absolute reductions in CO_2 emissions as in the Task A report, the Task A reductions have been converted to percentages relative to the 2008 fuel consumption.

Table 16 : Task A Cost and fuel-efficiency impacts of fuel-efficient airconditioning equipment

	MAC fuel cons. (Task A) litre/100 km	MAC fuel cons. decrease relative to 2008 *Input in TREMOVE*	Increase in car ex-tax retail price - EURO *Input in TREMOVE*
2008 Basecase (absolute value)	0.256		
2010 Scenario (diff. scenario vs basecase)	-0.034	-13%	24
2011 Scenario (diff. scenario vs basecase)	-0.048	-19%	35
2012-2020 Scenario (diff. scenario vs basecase)	-0.021	-8%	19

Relevant input parameters

The fuel-efficient MAC scenario is introduced in the model by way of following input parameters. The parameter values for the basecase are set at zero in the TREMOVE input dB. Parameter values for the simulation scenario are introduced via the scenario generator Excel tool (see 2.2.5) :

Name	**Table_info**	**Description**
RFCairco_REDUC_SCENARIO	VEHICLE_VINTAGE_PARAMETER	Reduction in real-world airco. fuel consumption for policy scenario - %
RPCS_INCREASE_AIRCO_SCENARIO	VEHICLE_VINTAGE_PARAMETER	Absolute vehicle purchase cost increase for airco policy – EURO 2000

For each of the supplementary measures(LRRT, LVL, TPMS, GSI, MAC), the effect on the real-world fuel consumption and related emissions (CO_2 and SO_2) is modelled in TREMOVE. None of these measures is assumed to have an impact on the type approval test-cycle measurements..

2.2.4. *Treatment of well-to-tank emissions*

As agreed in the European Climate Change Panel 2 working group, only well-to-tank emissions of greenhouse gases (CO_2, CH_4 and N_2O) have been included in the scenario analysis. Effects on well-to-tank emissions of the other pollutants have been calculated, but are not reported in the TREMOVE output tables nor accounted for in the cost-effectiveness and welfare calculations.

Also cruising emissions of aircrafts above 3000 feet have been excluded from the analysis and the reporting.

2.2.5. *Scenario input and output files*

A user-friendly Excel tool has been developed to define/select CO2CAR policy packages and translate these into scenario input files for TREMOVE. This excel file, as well as all D20-D32 scenario input and output files are public available at www.tremove.org (runs page).

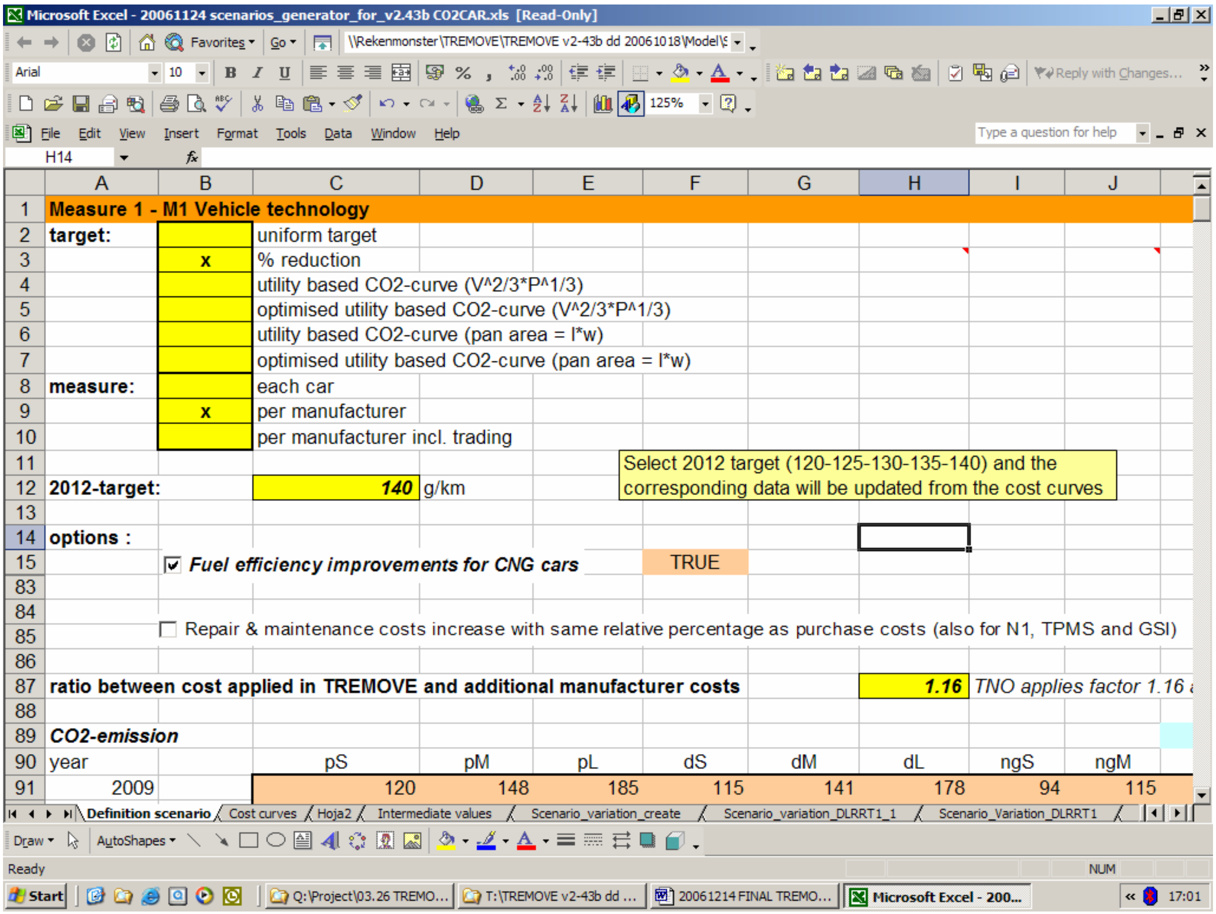
In this section, we shortly the functionality of this excel scenario generator. The Excel tool contains several sheets, of which sheet "definition scenario" and "scenario_variation_create" are relevant to external model users. Firstly, in sheet "definition scenario" users can specify the policy scenario they want to simulate, by clicking the available check boxes and adapting the yellow cells. Overall this sheet contains :

- Check boxes : for the choice of scenario/model options;
- Yellow cells : for scenario input values;
- Pink cells : these represent results of automated intermediate calculations – not to be changed;
- Green and blue cells : these contain input values that are of interest to the model user, but that cannot be changed (e.g. basecase values) – not to be changed.

The check boxes and yellows cells for specifying policy scenarios will be discussed in more detail in the next paragraphs. Secondly, the sheet "scenario_variation_create" contains the scenario input code for the TREMOVE GAMS model. This sheet is automatically updated when users make changes in the "definition scenario" sheet. After specifying a policy package in sheet "definition scenario" sheet, users then can export the scenario_variation_create file as a formatted text (scenario_variation.prn) file, which then can be read in by the TREMOVE model.

Figure 23 shows where scenarios for the technical measures at the vehicle level for cars can be specified. First the user can select the way of target setting. Targets can be set as a fixed gram per km. target, as a percentage reduction or as a function of of the utility of the car type. These targets can then further be implemented for each individual car type, for each manufacturer or for all cars together (with trading). Thereafter the 2012 target value itself can be set, expressed in grammes CO_2 per car-kilometre. The user can also specify following optional assumptions :

- Increase in fuel-efficieny (CO_2) is or is not relevant for CNG cars;
- Repair and maintenance costs are or are not increasing with increasing pruchase price;
- Ratio between (ex-tax retail) price increase applied in TREMOVE and manufacturer costs (this is specified at 1.16 by Task A and in the TREMOVE basecase; in the D20-D32 simulation scenarios it is set at 1.00).



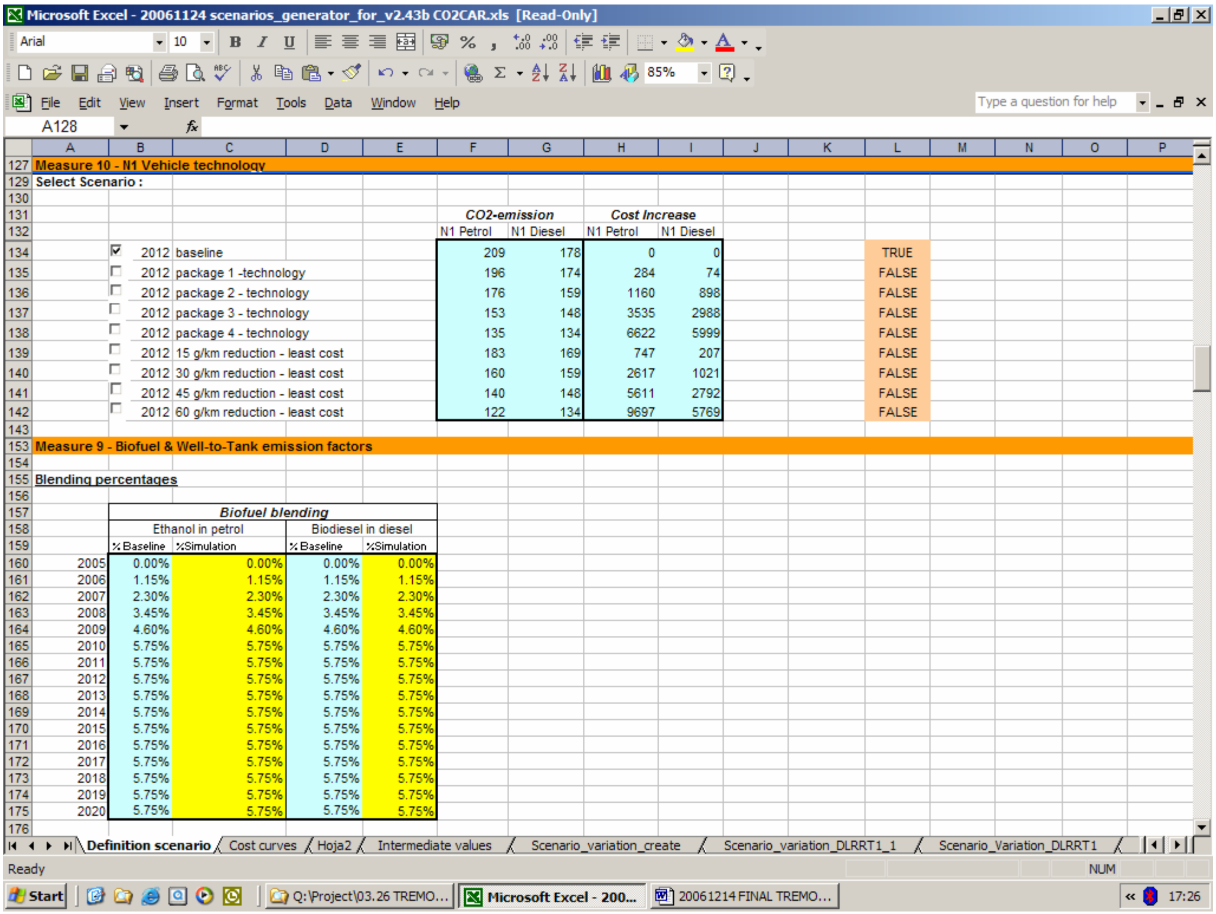
	A	B	C	D	E	F	G	H	I	J
1	**Measure 1 - M1 Vehicle technology**									
2	**target:**		uniform target							
3		x	% reduction							
4			utility based CO2-curve (V^2/3*P^1/3)							
5			optimised utility based CO2-curve (V^2/3*P^1/3)							
6			utility based CO2-curve (pan area = l*w)							
7			optimised utility based CO2-curve (pan area = l*w)							
8	**measure:**		each car							
9		x	per manufacturer							
10			per manufacturer incl. trading							
11										
12	**2012-target:**		***140***	g/km						
13										
14	**options :**									
15		☑ ***Fuel efficiency improvements for CNG cars***				TRUE				
83										
84										
85		☐ Repair & maintenance costs increase with same relative percentage as purchase costs (also for N1, TPMS and GSI)								
86										
87	**ratio between cost applied in TREMOVE and additional manufacturer costs**							***1.16***	*TNO applies factor 1.16*	
88										
89	***CO2-emission***									
90	year		pS	pM	pL	dS	dM	dL	ngS	ngM
91	2009		120	148	185	115	141	178	94	115

Select 2012 target (120-125-130-135-140) and the corresponding data will be updated from the cost curves

Definition scenario / Cost curves / Hoja2 / Intermediate values / Scenario_variation_create / Scenario_variation_DLRRT1_1 / Scenario_Variation_DLRRT1

Figure 23 : Scenario generator – Technical measures at vehicle level for cars

Figure 24 shows the check boxes in which a scenario for technical measures at vehicle level for cars can be specified. The possible scenarios have been discussed in section 2.2.2, and correspond with those in specified by Task A.



Measure 10 - N1 Vehicle technology

Select Scenario :

			CO2-emission		Cost Increase		
			N1 Petrol	N1 Diesel	N1 Petrol	N1 Diesel	
☑	2012	baseline	209	178	0	0	TRUE
☐	2012	package 1 -technology	196	174	284	74	FALSE
☐	2012	package 2 - technology	176	159	1160	898	FALSE
☐	2012	package 3 - technology	153	148	3535	2988	FALSE
☐	2012	package 4 - technology	135	134	6622	5999	FALSE
☐	2012	15 g/km reduction - least cost	183	169	747	207	FALSE
☐	2012	30 g/km reduction - least cost	160	159	2617	1021	FALSE
☐	2012	45 g/km reduction - least cost	140	148	5611	2792	FALSE
☐	2012	60 g/km reduction - least cost	122	134	9697	5769	FALSE

Measure 9 - Biofuel & Well-to-Tank emission factors

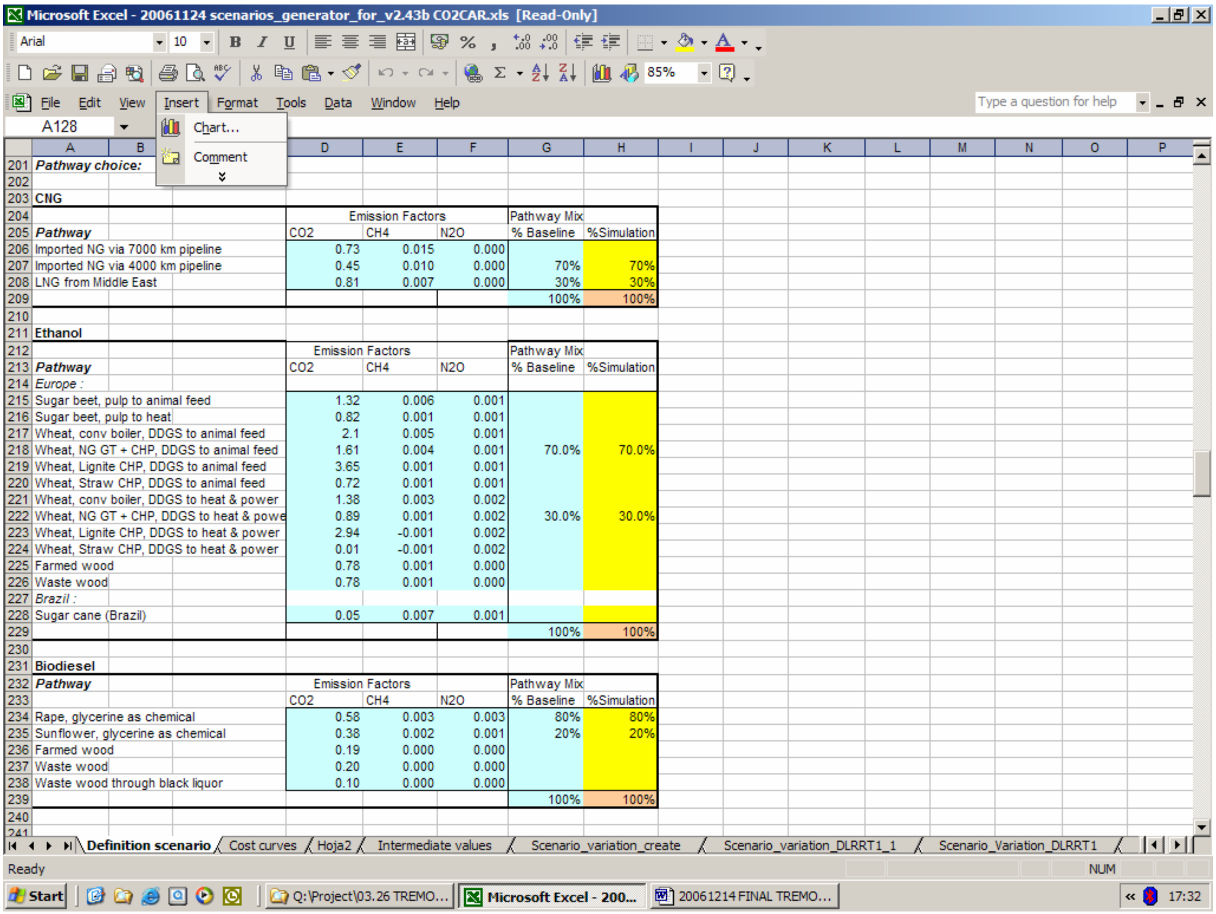
Blending percentages

	Biofuel blending			
	Ethanol in petrol		Biodiesel in diesel	
	% Baseline	%Simulation	% Baseline	%Simulation
2005	0.00%	0.00%	0.00%	0.00%
2006	1.15%	1.15%	1.15%	1.15%
2007	2.30%	2.30%	2.30%	2.30%
2008	3.45%	3.45%	3.45%	3.45%
2009	4.60%	4.60%	4.60%	4.60%
2010	5.75%	5.75%	5.75%	5.75%
2011	5.75%	5.75%	5.75%	5.75%
2012	5.75%	5.75%	5.75%	5.75%
2013	5.75%	5.75%	5.75%	5.75%
2014	5.75%	5.75%	5.75%	5.75%
2015	5.75%	5.75%	5.75%	5.75%
2016	5.75%	5.75%	5.75%	5.75%
2017	5.75%	5.75%	5.75%	5.75%
2018	5.75%	5.75%	5.75%	5.75%
2019	5.75%	5.75%	5.75%	5.75%
2020	5.75%	5.75%	5.75%	5.75%

Figure 24 : Scenario generator – Technical measures at vehicle level for N1 vehicles and biofuel blending

Figure 24 also shows the yellow cells in which, for the scenario, the % blending of biofuels in petrol and diesel can be specified.

Furthermore, as shown in Figure 25, teh user can change well-to-tank emission factors by modifying the fuel procution pathway mixes.



Pathway choice:

CNG

	Emission Factors			Pathway Mix	
Pathway	CO2	CH4	N2O	% Baseline	%Simulation
Imported NG via 7000 km pipeline	0.73	0.015	0.000		
Imported NG via 4000 km pipeline	0.45	0.010	0.000	70%	70%
LNG from Middle East	0.81	0.007	0.000	30%	30%
				100%	100%

Ethanol

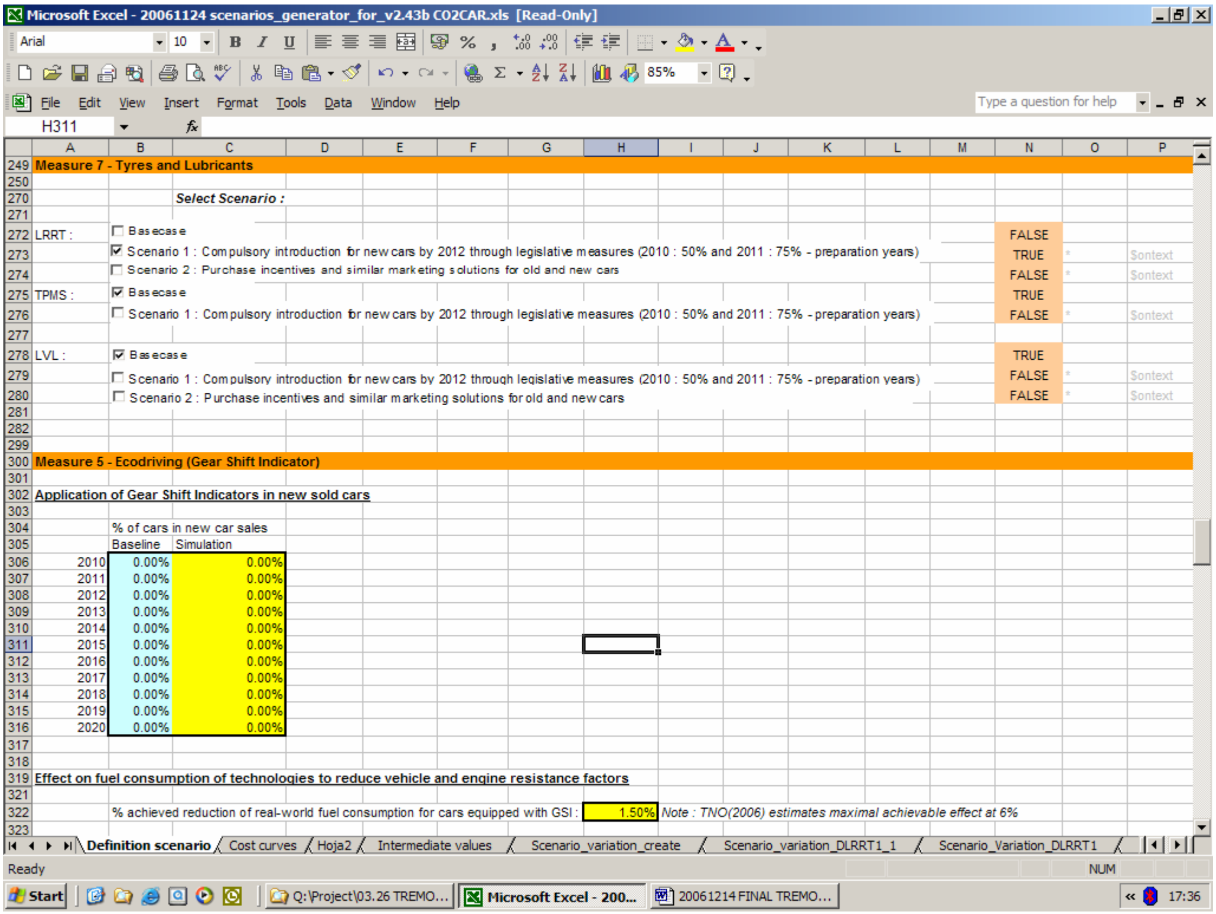
	Emission Factors			Pathway Mix	
Pathway	CO2	CH4	N2O	% Baseline	%Simulation
Europe :					
Sugar beet, pulp to animal feed	1.32	0.006	0.001		
Sugar beet, pulp to heat	0.82	0.001	0.001		
Wheat, conv boiler, DDGS to animal feed	2.1	0.005	0.001		
Wheat, NG GT + CHP, DDGS to animal feed	1.61	0.004	0.001	70.0%	70.0%
Wheat, Lignite CHP, DDGS to animal feed	3.65	0.001	0.001		
Wheat, Straw CHP, DDGS to animal feed	0.72	0.001	0.001		
Wheat, conv boiler, DDGS to heat & power	1.38	0.003	0.002		
Wheat, NG GT + CHP, DDGS to heat & powe	0.89	0.001	0.002	30.0%	30.0%
Wheat, Lignite CHP, DDGS to heat & power	2.94	-0.001	0.002		
Wheat, Straw CHP, DDGS to heat & power	0.01	-0.001	0.002		
Farmed wood	0.78	0.001	0.000		
Waste wood	0.78	0.001	0.000		
Brazil :					
Sugar cane (Brazil)	0.05	0.007	0.001		
				100%	100%

Biodiesel

Pathway	Emission Factors			Pathway Mix	
	CO2	CH4	N2O	% Baseline	%Simulation
Rape, glycerine as chemical	0.58	0.003	0.003	80%	80%
Sunflower, glycerine as chemical	0.38	0.002	0.001	20%	20%
Farmed wood	0.19	0.000	0.000		
Waste wood	0.20	0.000	0.000		
Waste wood through black liquor	0.10	0.000	0.000		
				100%	100%

Figure 25 : Scenario generator – fuel production pathways for well-to-tank emissions

Users can specify the scenarios on LRRT, LVL and TPMS presented in 2.2.3 by check boxes (as presented in Figure 26. For GSI, percentages for the penetration of this technology in the new car fleets can be specified. Besides, also an assumption on the achieved reduction in fuel consumption for GSI can be specified.



Microsoft Excel - 20061124 scenarios_generator_for_v2.43b CO2CAR.xls [Read-Only]

H311

Measure 7 - Tyres and Lubricants

Select Scenario :

LRRT : ☐ Basecase FALSE
☑ Scenario 1 : Compulsory introduction for new cars by 2012 through legislative measures (2010 : 50% and 2011 : 75% - preparation years) TRUE * Sontext
☐ Scenario 2 : Purchase incentives and similar marketing solutions for old and new cars FALSE * Sontext

TPMS : ☑ Basecase TRUE
☐ Scenario 1 : Compulsory introduction for new cars by 2012 through legislative measures (2010 : 50% and 2011 : 75% - preparation years) FALSE * Sontext

LVL : ☑ Basecase TRUE
☐ Scenario 1 : Compulsory introduction for new cars by 2012 through legislative measures (2010 : 50% and 2011 : 75% - preparation years) FALSE * Sontext
☐ Scenario 2 : Purchase incentives and similar marketing solutions for old and new cars FALSE * Sontext

Measure 5 - Ecodriving (Gear Shift Indicator)

Application of Gear Shift Indicators in new sold cars

% of cars in new car sales

	Baseline	Simulation
2010	0.00%	0.00%
2011	0.00%	0.00%
2012	0.00%	0.00%
2013	0.00%	0.00%
2014	0.00%	0.00%
2015	0.00%	0.00%
2016	0.00%	0.00%
2017	0.00%	0.00%
2018	0.00%	0.00%
2019	0.00%	0.00%
2020	0.00%	0.00%

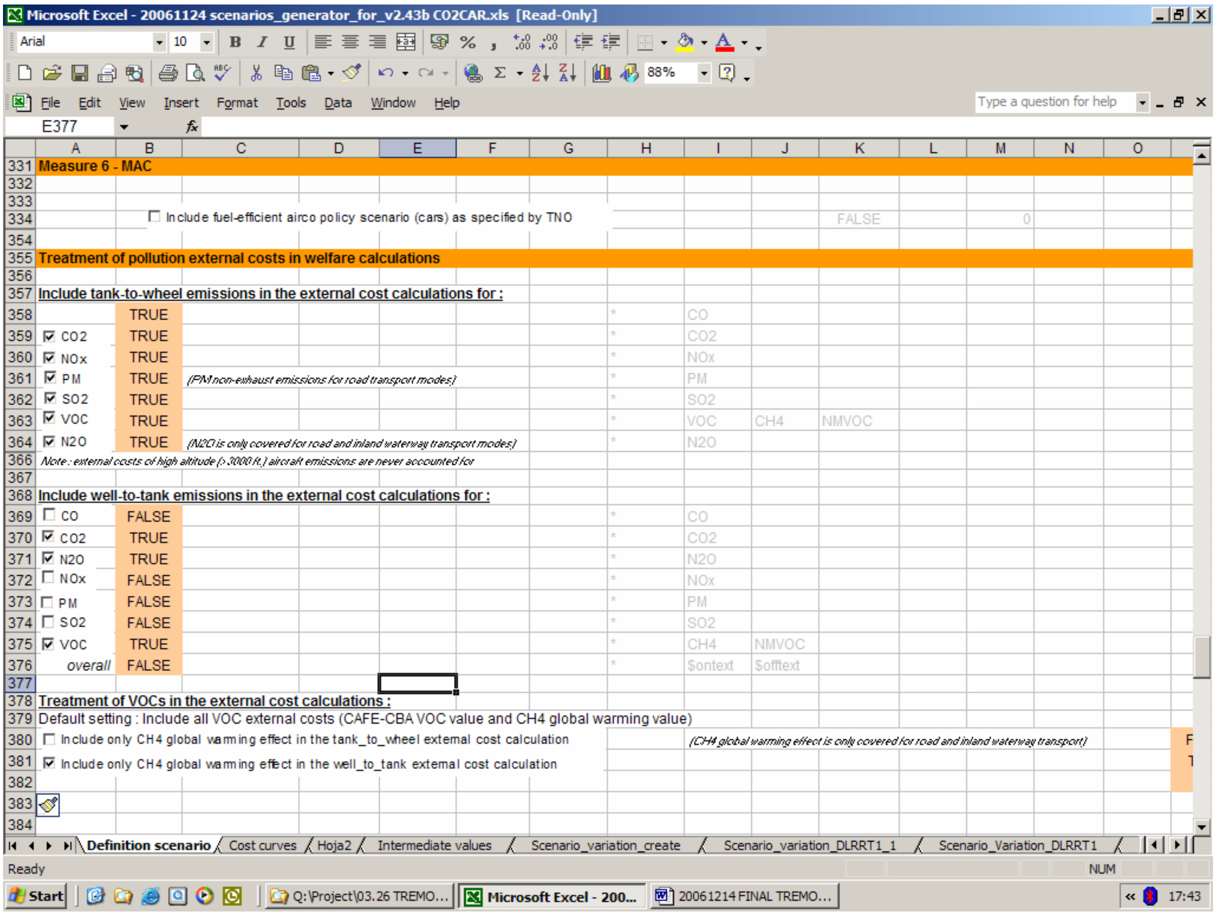
Effect on fuel consumption of technologies to reduce vehicle and engine resistance factors

% achieved reduction of real-world fuel consumption for cars equipped with GSI : 1.50% *Note : TNO(2006) estimates maximal achievable effect at 6%*

Figure 26 : Scenario generator – LRRT, LVL, TPMS and GSI

As shown in Figure 27, the user can choose whether or not to include the fuel-efficient MAC scenario (see 2.2.3.a).

This figure also shows that the user can specify which tank-to-wheel and well-to-tank emissions should be accounted for in the calculation of the external costs. For VOC, there is also the option to limit the analysis to only the global warming effects of CH_4. Remember that, as shown in Figure 27, in the D20 to D32 scenarios the non-greenhouse gas well-to-tank emissions have not been included in the analysis.



	A	B	C	H	I	J	K	M
331	**Measure 6 - MAC**							
332								
333								
334		☐ Include fuel-efficient airco policy scenario (cars) as specified by TNO					FALSE	0
354								
355	**Treatment of pollution external costs in welfare calculations**							
356								
357	**Include tank-to-wheel emissions in the external cost calculations for :**							
358		TRUE		*	CO			
359	☑ CO2	TRUE		*	CO2			
360	☑ NOx	TRUE		*	NOx			
361	☑ PM	TRUE	*(PM non-exhaust emissions for road transport modes)*	*	PM			
362	☑ SO2	TRUE		*	SO2			
363	☑ VOC	TRUE		*	VOC	CH4	NMVOC	
364	☑ N2O	TRUE	*(N2O is only covered for road and inland waterway transport modes)*	*	N2O			
366	*Note : external costs of high altitude (> 3000 ft.) aircraft emissions are never accounted for*							
367								
368	**Include well-to-tank emissions in the external cost calculations for :**							
369	☐ CO	FALSE		*	CO			
370	☑ CO2	TRUE		*	CO2			
371	☑ N2O	TRUE		*	N2O			
372	☐ NOx	FALSE		*	NOx			
373	☐ PM	FALSE		*	PM			
374	☐ SO2	FALSE		*	SO2			
375	☑ VOC	TRUE		*	CH4	NMVOC		
376	*overall*	FALSE		*	$ontext	$offtext		
377								
378	**Treatment of VOCs in the external cost calculations :**							
379	Default setting : Include all VOC external costs (CAFE-CBA VOC value and CH4 global warming value)							
380	☐ Include only CH4 global warming effect in the tank_to_wheel external cost calculation				*(CH4 global warming effect is only covered for road and inland waterway transport)*			
381	☑ Include only CH4 global warming effect in the well_to_tank external cost calculation							
382								
383								
384								

Figure 27 : Scenario generator – MAC and treatment of external costs

3. Scenario results

In this section the results of scenarios D20 to D32 are presented.

This section is composed of four paragraphs. The effect of the simulated policies on total transport greenhouse gas emissions is presented in 3.1. Paragraph 3.2 discusses the cost-effectiveness of the simulated emission abatement scenarios. The welfare effects calculated by TREMOVE are shown in paragraph 3.3. Finally, in paragraph 3.4 we briefly look into more detailed model results, i.e. the second-order effects on car fleet and car transport demand, differences in outcomes over countries and decomposition of the abatement costs.

3.1. Effects on overall transport greenhouse gas emissions

Figure 28 shows the evolution of total greenhouse gas emissions in the baseline (v2.43b) and the D20 to D32 scenarios. The graph presents the sum of well-to-wheel emissions of CO_2, CH_4 and N_2O, expressed in CO_2-equivalents. All transport modes (except maritime and cruising aircrafts) are covered, for all countries in TREMOVE except Switzerland and Norway.

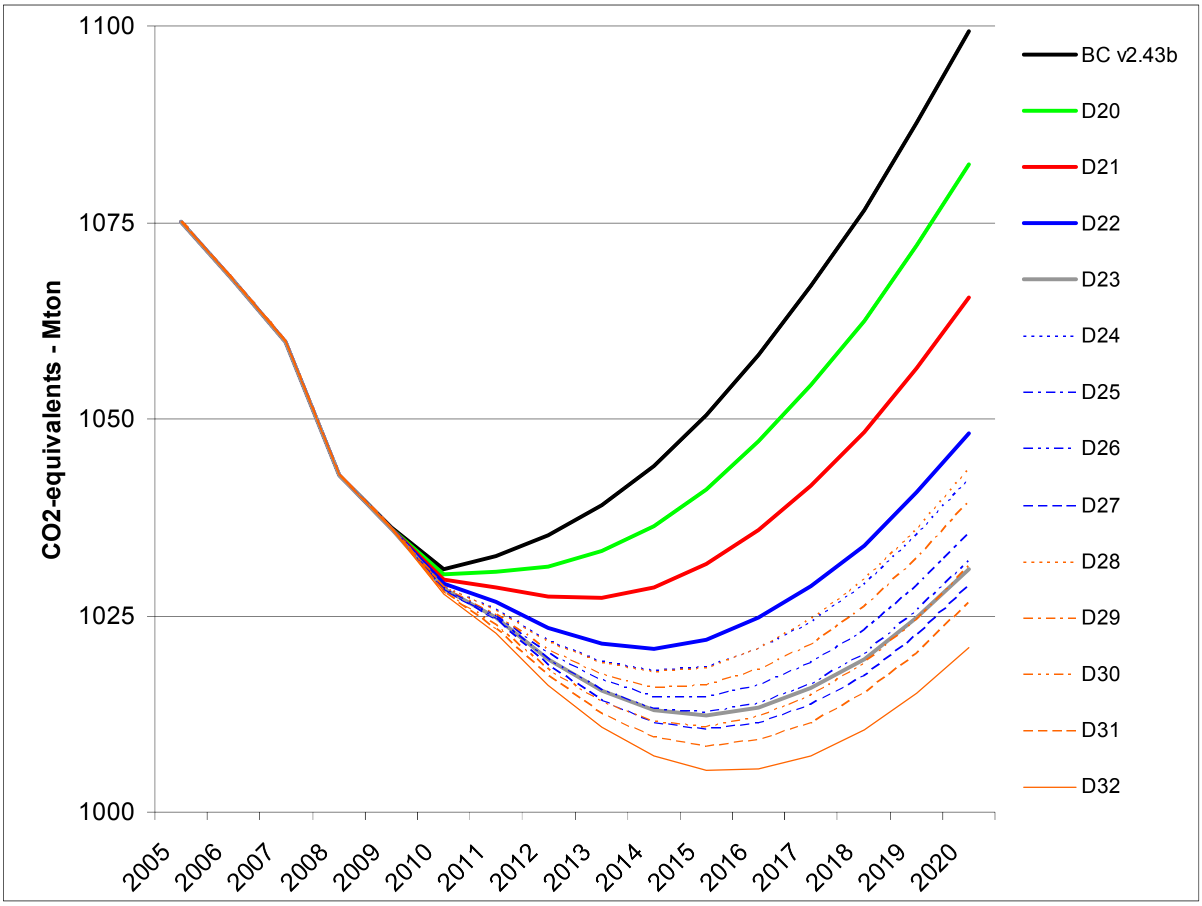


Figure 28: D20-D32 Evolution of well-to-tank GHG emissions – EU15 + 4 NMS

In the baseline, fuel efficiency improvements for road vehicles (mainly resulting from the voluntary agreement with the automotive industry) lead to a downward trend in the greenhouse gas emissions up to 2009. After 2009, no further fuel efficiency improvements for new vehicles are modelled. Old, pre-2009 vehicles, however will be more and more replaced by newer, fuel-efficient ones. This increasing share of more fuel-efficient vehicles however, does not offset the increasing transport demand. The net result is an increase of the greenhouse gas emissions after 2009.

D20, D21, D22 and D23 (bold lines) are scenarios where new car test-cycle emissions are further reduced by technical measures at the vehicle level. These reductions go down to 135 g. , 130 g., 125 g. and 120 g. CO_2/km. in 2012 respectively. The introduction of these technologies extends the downward trend in the emissions beyond 2009. In each of the scenario's though, there is a point in time after which the increasing share of more fuel-efficient vehicles, will not offset the increasing demand.

In scenarios D24 to D32, technical measures at the vehicle level are combined with supplementary measures (see Table 9). Scenarios D24 to D27 (blue thin lines) combine a 125 g. target with supplementary measures. Scenarios D27 to D32 (red thin lines) combine a 130 g. target with supplementary measures.

Figure 28 shows that these scenarios lead to emission reductions that come close or even are larger than the reductions achieved with technical measures at the car level up to 120 g. (D23 scenario).

Note that in all scenarios, the reduction in emissions not only stems from improved technology. They are to a certain extent also the result from changes in transport demands and changes in fleet composition, caused by the increased vehicle costs. These second-order effects are discussed in paragraph 3.4.

3.2. Cost-effectiveness

Figure 29 plots for D20 to D32 the reduction in greenhouse gas emissions against the calculated abatement costs per tonne. These are figures calculated for the year 2020.

The graph is based in 2020 outcomes for two reasons. Firstly, the simulated measures are only fully implemented in 2012. It will take several years after 2012 before the more fuel-efficient vehicles will represent a major share of the fleet. Secondly, TREMOVE is a model developed for the analysis of mid- to long-term effects of policy measures. The model is not designed to analyse the effects in the first years after the implementation of a measure.

The abatement cost presented in the graph is the sum of changes in household utility level, changes in production costs and costs of public funds. The changes in household utility stem mainly[14] from increased costs for vehicle purchase and maintenance on one hand, and fuel savings on the other hand. Production costs for companies alter as also companies make use of cars and N1 vehicles for a.o. business trips. The cost of public funds represents the fact that governments income from a.o. fuel tax excises will decrease. It is assumed that this loss in government income is compensated by an increase in general taxes[15], which has a negative impact on overall welfare.

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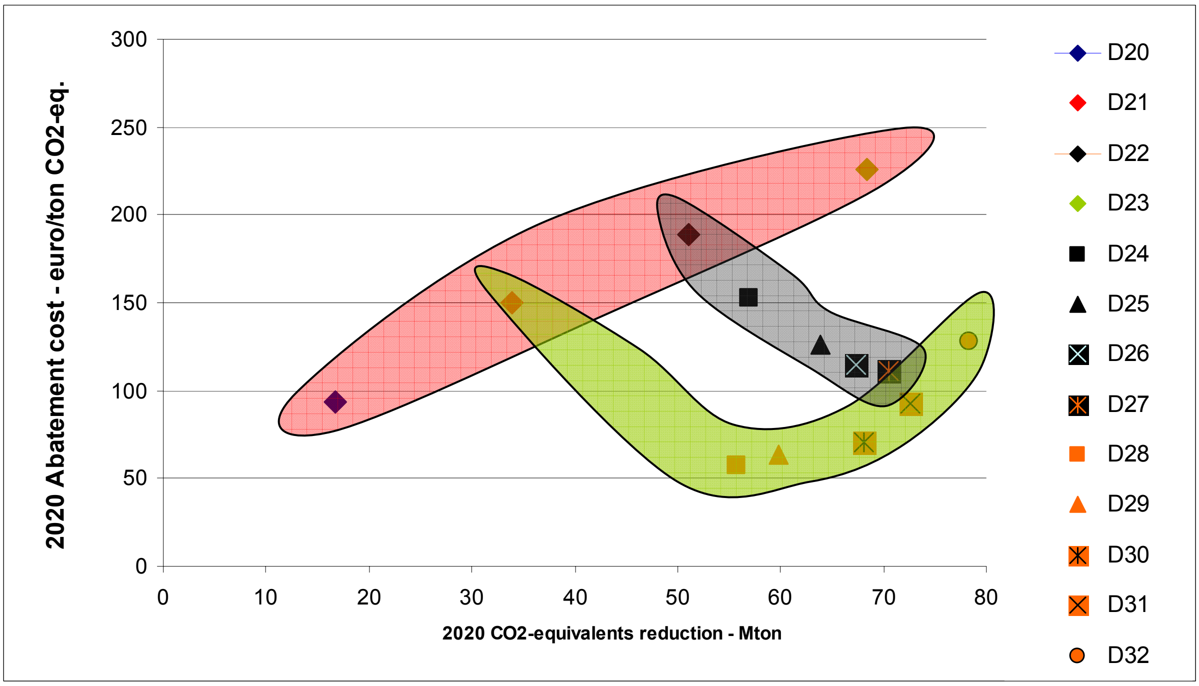
[14] The indicated factors are only the main reasons for changes in household utility. Besides, household utility is also affected by second-order effects of the policies, such as changes in transport demand patterns, related changes in congestion and travel times, changes in fleet composition, ... The same holds for the cost of companies.

[15] The calculation has also been performed with an alternative assumption, i.e. the loss is compensated by an increase in labour taxes. Results with this alternative assumption can be found in Table 18 to Table 30.

Figure 29: D20-D32 Cost-effectiveness in 2020 – EU15 + 4 NMS



In Figure 29 the scenarios have been grouped in 'clusters'. The red cluster (D20-D23) contains scenarios in which test-cycle fuel consumption is reduced only through technical measures at the vehicle level for cars. The results clearly indicate an increasing marginal abatement cost. Reduction up to 135 g./km. comes at a cost of 94 EURO per ton CO_2 equivalent, while reduction up to 120 g./km. costs 226 EURO per ton CO_2 equivalent.

The gray cluster (D24-D27) includes scenarios in which technical measures on the vehicle level for cars up to 125 g./km. are combined with supplementary measures. In e.g. scenario D27 these supplementary measures are GSI, TPMS, N1 (-15g.) and LRRT. Compared to D22, these scenarios reach a larger reduction at a lower cost. D26 and D27 even lead to an emission decrease similar to D23 (120 g. through technical measures on vehicle level for cars), but at a significantly lower abatement cost than D23. I.e. a package of technical measures at the vehicle level and the supplementary measures is more cost-effective than just technical measures at the vehicle level.

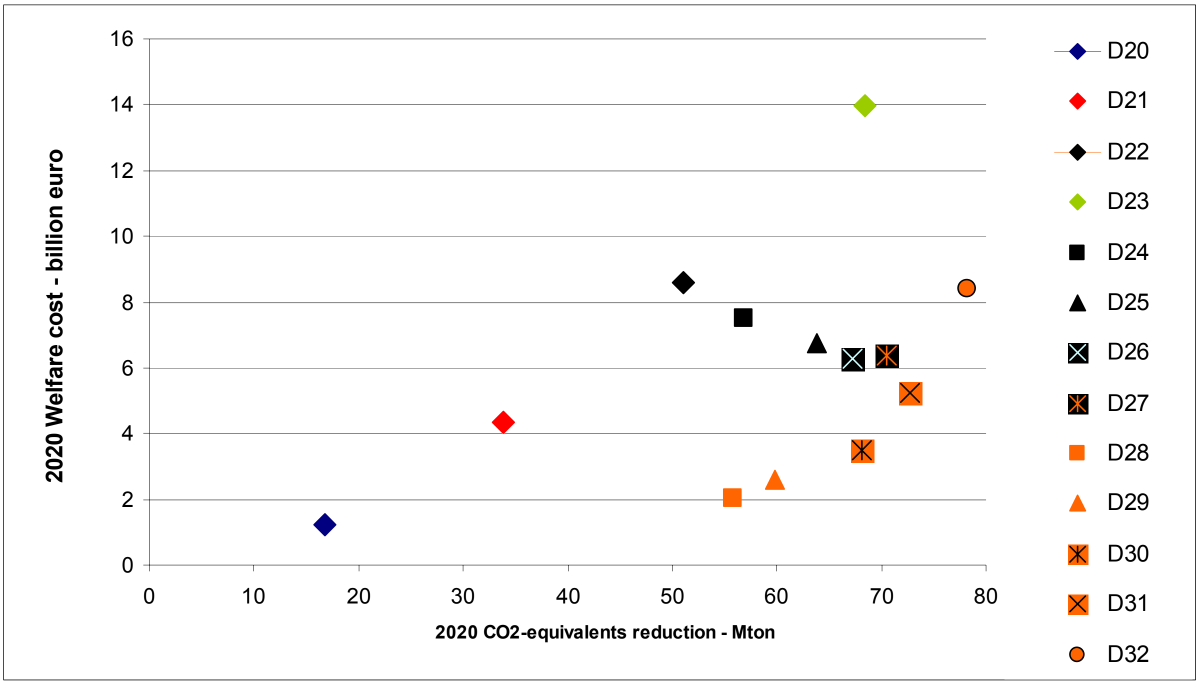
The green cluster (D28-D32) includes scenarios in which technical measures on the vehicle level for cars up to 130 g./km. are combined with supplementary measures. As for the gray cluster, these packages can lead to emission reduction similar to D23, and this at an even lower abatement cost. Note however that to go beyond the D23 reduction level (D31 and D32), it is needed to include strong reductions for N1 vehicles in the package (-45 g. and -60 g.). According to [TNO, 2006] limited reductions in N1 test-cycle fuel consumption can be reached at a cost lower than that for cars. Though, given increasing marginal abatement costs, strong reductions for N1 vehicles also come at a high cost. Therefore, including strong N1 reductions in the package of measures, increases the average abatement cost of the package.

3.3. Welfare effects

Figure 30 shows the welfare effects in the year 2020 for the simulated scenarios. All simulated scenarios lead to negative welfare effects. These welfare costs are calculated in TREMOVE as the abatement costs minus the benefits from reductions in pollutant emissions. For conventional pollutants the latter benefits are the decreases in external costs (health effects, damage to crops and buildings, ...) as estimated by the Cost Benefit Analysis research within the Clean Air for Europe Programme [AEAT, 2004]. For greenhouse gases, the benefit values used represent rather the costs of emission rights, than the negative effects on health and environment. For CO_2 these 'benefit' values have been specified by the European Commission to grow from 12 EURO per ton in 2010 to 20 EURO per ton in 2020.

For greenhouse gas policies, the welfare cost calculated in TREMOVE thus should be rather interpreted as the cost of reducing greenhouse gas emissions by the simulated policy measures instead of purchasing emission rights.

Figure 30: D20-D32 Welfare cost in 2020 – EU15 + 4 NMS



3.4. Decomposition of abatement costs, second order effects and country specific results

It is not the purpose of this report to present exhaustively the detailed model results for each country. Nevertheless, in this paragraph we briefly point to some more detailed results: the decomposition of the abatement costs, second-order effects on car fleets and on transport demands and differences in outcomes over countries.

Table 18 to Table 30 provide summaries of the results of scenarios D20 to D32. Note that full D20-D32 scenario input and output files are public available at www.tremove.org (runs page).

3.4.1. Decomposition of the abatement costs

It is interesting to note that, except for D21 to D24, the D20-D32 scenarios show a positive effect on the calculated household utility in all modelled years. This means that, for households, the extra costs for the improved vehicle technology and equipment (as GSI, LVL, LRRT, ...) is more than compensated by the resulting fuel savings.

It is not surprising that this is not the case in D21 to D24. The latter are scenarios that mainly depend on strong reductions by technical measures at the vehicle level for cars. In D25 – D32 these measures are combined with supplementary measures, which are more cost-effective in reducing fuel consumption, and lead to a benefit for the households.

For the overall society, the welfare effect is negative. This stems from the decrease in fuel excise payments. For households this is (in first instance) a utility benefit, which is reported in the TREMOVE output. Though for the government it leads to a loss in revenues. TREMOVE assumes that this latter loss is compensated by either increases in general taxes, either increases in labour taxes to maintain the level of government funds. In both cases this leads to a negative effect on overall welfare (thus, in second instance household utility decreases). Note that this welfare loss is larger in case labour taxes are increased (i.e. increasing distortionary taxes in the labour market) than in case general taxes are increased.

3.4.2. Effects on car fleet composition

Table 17 shows the evolution of the market shares of the modelled car types and their real-world emissions in the v2.43b baseline scenario. Table 18 to Table 30 provide similar tables for the D20 to D32 scenarios.

Table 17: BC v2.43b car sale market shares and CO2 emissions– EU15 + 4NMS

								Car sale market shares (%)			
	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.6%	4.8%	6.3%	31.5%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.4%	19.4%	5.1%	6.2%	30.4%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.6%	18.9%	5.6%	6.2%	28.3%	10.5%	0.9%	0.6%	0.4%	0.1%	100%
								New car real-world CO2 emissions (g/km)			
	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	144	169	180	128	158	204	144	120	137	147	160.8
2015	144	168	179	127	157	203	143	118	136	145	160.3
2020	142	167	177	126	156	201	142	115	135	143	159.1

In these tables it can be observed that the effects of the scenarios on car market shares are limited. E.g. scenario D23 (120 g. measure at car vehicle level) results in a 0.1% increase of the share of petrol cars. Such a limited increase of petrol cars can be observed in most of the scenarios. It is a consequence of the Part A outcome that fuel efficiency improvements for petrol cars are less costly than for diesel cars (see [TNO, 2006] figure 3.3).

That the resulting effects on market shares are limited is mainly due to two reasons. Firstly, in the scenarios all car types become more expensive. For some types (i.e. diesel cars) this price increase is somewhat higher than for others (i.e. petrol cars). But, in general, the existing price differences between the car types are not changed strongly. Secondly, the sensitivity coëfficient of the car market shares to price changes in TREMOVE is to be considered as a lower estimate. For the estimation of the car sale logit models, only quarterly data for 1999 and 2000 on car prices was available as a coherent dataset for most EU countries (data from [COWI, 2001]). This dataset did not enable to analyse the effects of price changes in the longer term. It is recognised that the logit model coefficients could be estimated more accurate if a more extensive time series on car market shares, prices and other car parameters would be available for all modeled countries.

3.4.3. *Effects on transport demand*

In Table 18 to Table 30 it is can be observed that, except for D21 to D24, the D20-D32 scenarios all show a limited increase in car transport demand in all modelled years. This is related to the calculated increase in household utility for these scenarios. As explained in paragraph 3.4.1 these are scenarios for which the extra costs for the improved vehicle technology and equipment (as GSI, LVL, LRRT, ...) is more than compensated by the resulting fuel savings. I.e. the introduction of the new technologies lowers the cost of driving cars, which leads to an increase in car kilometres. In e.g. scenario D23 the opposite is true. This scenario leads to a decrease in car kilometres in the long-term.

3.4.4. *Differences between countries*

Figure 31 displays the 2020 cost-effectiveness results for scenarios D23 and D30 by country. Remember that D23 is the scenario with technical measures at vehicle level for cars towards 120g. D30 is a scenario that reaches a similar emission decrease at a lower cost, by combining 130g. technology with supplementary measures.

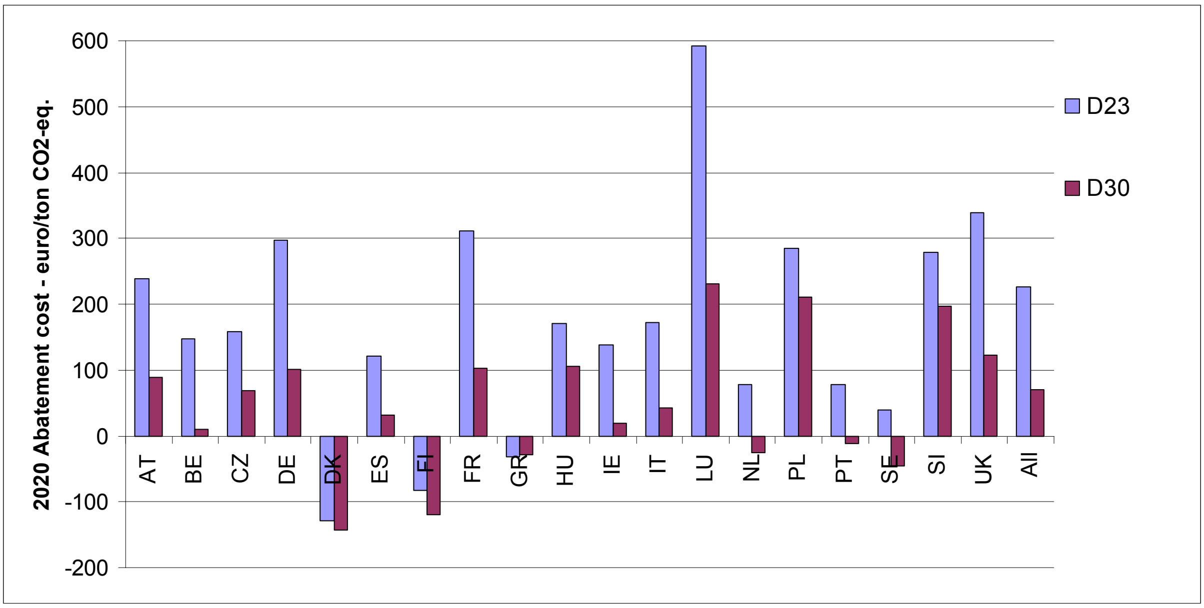


Figure 31: D23 & D30 Cost-effectiveness in 2020 - by country

Significant variation exists between the outcomes for the individual countries. The main reasons for these variations are differences in market share for the different car types. From the graph it is clear that the lowest cost (or even benefit) figures are calculated for the countries with the lowest shares of diesel cars in their fleet (Denmark, Finland, Greece and Sweden). Luxembourg on the other hand is the country with the highest share of diesel cars and has the highest cost.

This dependency of the cost on the share of diesel cars is in in line with the part A study. TNO reports that abatement costs for diesel cars are significantly higher than for petrol cars (see [TNO, 2006] figure 3.3). The rationale behind this result is more complex than it might seem however... If a similar reduction target is set for each manufacturer, the manufacturers will search for a least cost combination of technology packages for each car type in order to reach the target. A least cost combination should be a combination for which the marginal abatement cost is equal for all the car types produced by the manufacturer[16]. Furthermore, we know that the abatement costs curves for diesel cars are above those for petrol cars. Thus, the marginal abatement cost level will be higher for manufacturers that produce a large number of diesel cars, than for manufacturers that have a larger share of petrol cars. As a consequence, the overall (all manufacturers) average abatement cost for diesel cars will be higher than that for petrol cars. And therefore, the abatement costs are higher in countries with a larger share of diesel cars.

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[16] As [TNO, 2006] does not report results by manufacturer, it cannot be confirmed whether this is actually the case in the least-cost solutions reported by Part A.

Table 18: D20 Results summary - EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	80	188	569	729
(Production costs)		2	7	14	23	-40
Pollution benefits		9	28	58	157	350
Cost of public funds (general)		-4	-97	-284	-1122	-2266
Cost of public funds (labour)		-7	-164	-480	-1887	-3790
Welfare (general)		19	18	-24	-374	-1227
Welfare (labour)		16	-49	-220	-1138	-2751
Welfare Net Present Value (general)	-3043					
Welfare Net Present Values (labour)	-8143					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-614	-1745	-3471	-8264	-14705
Tank-to-Wheel CH4	0.000	0.000	-0.001	-0.001	-0.004
Tank-to-Wheel N2O	0.000	0.004	0.010	0.028	0.036
Well-to-Tank CO2	-81	-229	-456	-1085	-1932
Well-to-Tank CH4	-0.038	-0.111	-0.225	-0.560	-1.071
Well-to-Tank N2O	-0.022	-0.060	-0.118	-0.278	-0.491
Tank-to-Wheel GHG (CO2-equivalents)	-614	-1744	-3468	-8256	-14695
Well-to-Tank GHG (CO2-equivalents)	-88	-250	-496	-1181	-2102

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	168	434	1300	1502
Pass.km all modes	0	154	391	1158	1269

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.6%	4.8%	6.3%	31.4%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.4%	19.4%	5.2%	6.2%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.6%	18.9%	5.6%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	138	162	171	124	153	198	138	114	132	140	155.1
2015	137	161	170	124	153	197	138	112	131	138	154.7
2020	136	160	169	123	152	195	136	110	129	137	153.4

Table 19: D21 Results summary - EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	105	251	443	-185
(Production costs)		2	5	4	-83	-375
Pollution benefits		18	55	115	320	716
Cost of public funds (general)		-4	-191	-571	-2243	-4520
Cost of public funds (labour)		-7	-323	-962	-3765	-7547
Welfare (general)		28	-26	-201	-1562	-4364
Welfare (labour)		25	-158	-593	-3085	-7392
Welfare Net Present Value (general)	-11883					
Welfare Net Present Values (labour)	-22035					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-1190	-3489	-6938	-16599	-29609
Tank-to-Wheel CH4	0.000	-0.001	-0.002	-0.006	-0.020
Tank-to-Wheel N2O	0.000	0.005	0.014	0.025	0.002
Well-to-Tank CO2	-156	-458	-911	-2179	-3886
Well-to-Tank CH4	-0.074	-0.222	-0.450	-1.121	-2.145
Well-to-Tank N2O	-0.041	-0.119	-0.235	-0.558	-0.991
Tank-to-Wheel GHG (CO2-equivalents)	-1190	-3487	-6934	-16592	-29609
Well-to-Tank GHG (CO2-equivalents)	-170	-498	-990	-2370	-4229

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	223	561	810	-1178
Pass.km all modes	0	195	483	571	-1558

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.7%	4.8%	6.3%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.4%	19.5%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.0%	5.6%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	131	155	163	121	149	192	133	108	126	133	149.5
2015	131	155	162	121	149	191	132	106	125	131	149.1
2020	129	153	161	119	147	189	131	104	124	130	147.9

Table 20: D22 Results summary - EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	139	255	-64	-2018
(Production costs)		2	4	-16	-260	-879
Pollution benefits		26	82	173	485	1087
Cost of public funds (general)		-4	-281	-849	-3352	-6758
Cost of public funds (labour)		-7	-475	-1431	-5624	-11275
Welfare (general)		36	-55	-438	-3191	-8568
Welfare (labour)		33	-249	-1020	-5463	-13084
Welfare Net Present Value (general)	-23843					
Welfare Net Present Values (labour)	-38985					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-1741	-5171	-10353	-24944	-44624
Tank-to-Wheel CH4	-0.001	-0.002	-0.004	-0.014	-0.042
Tank-to-Wheel N2O	0.000	0.008	0.015	0.004	-0.076
Well-to-Tank CO2	-228	-679	-1358	-3272	-5852
Well-to-Tank CH4	-0.108	-0.329	-0.670	-1.678	-3.218
Well-to-Tank N2O	-0.060	-0.176	-0.349	-0.837	-1.490
Tank-to-Wheel GHG (CO2-equivalents)	-1741	-5168	-10349	-24943	-44648
Well-to-Tank GHG (CO2-equivalents)	-249	-738	-1477	-3558	-6368

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	300	550	-698	-6292
Pass.km all modes	0	260	438	-1008	-6762

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.8%	4.8%	6.2%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.6%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.1%	5.7%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	125	149	155	117	145	186	126	103	120	126	143.9
2015	124	148	154	117	144	186	126	101	119	124	143.5
2020	123	147	153	116	143	183	124	99	118	123	142.4

Table 21: D23 Results summary - EU15 + 4NMS

	Welfare components - million euro					
	2005	2010	2011	2012	2015	2020
Utility of households		12	132	189	-999	-4887
(Production costs)		2	-4	-51	-518	-1573
Pollution benefits		35	110	230	652	1470
Cost of public funds (general)		-4	-373	-1130	-4465	-8995
Cost of public funds (labour)		-7	-631	-1905	-7485	-14992
Welfare (general)		45	-136	-762	-5330	-13985
Welfare (labour)		42	-394	-1538	-8350	-19981
Welfare Net Present Value (general)	-39456					
Welfare Net Present Values (labour)	-59576					

	Greenhouse gas abatement - kton				
	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2305	-6885	-13800	-33359	-59783
Tank-to-Wheel CH4	-0.001	-0.003	-0.006	-0.024	-0.069
Tank-to-Wheel N2O	0.001	0.008	0.012	-0.038	-0.200
Well-to-Tank CO2	-302	-903	-1810	-4374	-7836
Well-to-Tank CH4	-0.143	-0.438	-0.891	-2.239	-4.299
Well-to-Tank N2O	-0.080	-0.234	-0.465	-1.119	-1.996
Tank-to-Wheel GHG (CO2-equivalents)	-2305	-6883	-13796	-33371	-59844
Well-to-Tank GHG (CO2-equivalents)	-329	-983	-1968	-4757	-8525

Only emissions below 3000 ft.

	Effect on transport demand - million pass.km				
	2010	2011	2012	2015	2020
Pass.km cars	-2	262	306	-3407	-14174
Pass.km all modes	0	213	174	-3746	-14653

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	26.9%	19.9%	4.8%	6.3%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.2%	19.7%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.3%	19.2%	5.7%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	119	142	147	114	141	180	121	97	115	119	138.3
2015	118	141	146	113	140	180	120	96	114	118	138.0
2020	117	140	145	112	139	177	119	94	113	116	136.9

Table 22: D24 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	244	514	742	-476
(Production costs)		2	20	23	-141	-660
Pollution benefits		31	93	193	534	1193
Cost of public funds (general)		-4	-332	-976	-3762	-7550
Cost of public funds (labour)		-7	-562	-1647	-6318	-12605
Welfare (general)		41	26	-246	-2627	-7493
Welfare (labour)		38	-204	-917	-5182	-12548
Welfare Net Present Value (general)	-20072					
Welfare Net Present Values (labour)	-37091					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2078	-5978	-11760	-27966	-49771
Tank-to-Wheel CH4	-0.001	-0.001	-0.002	-0.009	-0.033
Tank-to-Wheel N2O	0.000	0.012	0.027	0.039	-0.011
Well-to-Tank CO2	-273	-785	-1545	-3673	-6536
Well-to-Tank CH4	-0.129	-0.380	-0.759	-1.878	-3.579
Well-to-Tank N2O	-0.073	-0.206	-0.402	-0.950	-1.683
Tank-to-Wheel GHG (CO2-equivalents)	-2078	-5974	-11752	-27955	-49775
Well-to-Tank GHG (CO2-equivalents)	-297	-855	-1681	-3997	-7116

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	561	1189	1262	-2622
Pass.km all modes	0	508	1048	872	-3223

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.8%	4.8%	6.2%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.6%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.1%	5.7%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	123	147	152	116	143	184	124	101	118	124	141.8
2015	123	146	152	115	142	183	124	100	118	122	141.4
2020	121	145	150	114	141	181	122	97	116	121	140.3

Table 23: D25 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	302	697	1444	892
(Production costs)		2	29	49	-46	-489
Pollution benefits		34	103	214	591	1322
Cost of public funds (general)		-4	-367	-1089	-4218	-8474
Cost of public funds (labour)		-7	-622	-1838	-7086	-14155
Welfare (general)		44	68	-129	-2229	-6748
Welfare (labour)		41	-187	-878	-5096	-12430
Welfare Net Present Value (general)	-17455					
Welfare Net Present Values (labour)	-36560					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2307	-6696	-13206	-31414	-55888
Tank-to-Wheel CH4	-0.001	-0.001	-0.001	-0.005	-0.026
Tank-to-Wheel N2O	0.000	0.015	0.035	0.070	0.047
Well-to-Tank CO2	-303	-880	-1736	-4129	-7347
Well-to-Tank CH4	-0.143	-0.425	-0.851	-2.105	-4.007
Well-to-Tank N2O	-0.081	-0.232	-0.456	-1.079	-1.912
Tank-to-Wheel GHG (CO2-equivalents)	-2307	-6692	-13195	-31393	-55875
Well-to-Tank GHG (CO2-equivalents)	-330	-959	-1890	-4497	-8004

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	700	1626	2904	476
Pass.km all modes	0	639	1463	2437	-254

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.8%	4.8%	6.2%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.6%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.1%	5.7%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	121	144	150	114	140	181	122	99	116	122	139.4
2015	121	143	149	113	140	180	122	98	115	120	139.0
2020	119	142	148	112	139	177	120	96	114	119	137.9

Table 24: D26 Results summary – EU15 + 4NMS

Welfare components - million euro	2005	2010	2011	2012	2015	2020
Utility of households		12	311	729	1586	1159
(Production costs)		2	47	113	229	6
Pollution benefits		36	111	230	636	1425
Cost of public funds (general)		-4	-381	-1137	-4430	-8889
Cost of public funds (labour)		-7	-643	-1910	-7402	-14771
Welfare (general)		46	89	-65	-1980	-6299
Welfare (labour)		44	-173	-837	-4951	-12180
Welfare Net Present Value (general)	-15855					
Welfare Net Present Values (labour)	-35639					

Greenhouse gas abatement - kton	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2406	-7027	-13893	-33127	-58867
Tank-to-Wheel CH4	-0.001	-0.001	-0.002	-0.002	-0.017
Tank-to-Wheel N2O	0.001	0.019	0.045	0.102	0.108
Well-to-Tank CO2	-316	-925	-1828	-4359	-7747
Well-to-Tank CH4	-0.148	-0.443	-0.889	-2.198	-4.167
Well-to-Tank N2O	-0.086	-0.248	-0.488	-1.159	-2.058
Tank-to-Wheel GHG (CO2-equivalents)	-2406	-7021	-13880	-33097	-58835
Well-to-Tank GHG (CO2-equivalents)	-345	-1008	-1993	-4753	-8452

Only emissions below 3000 ft.

Effect on transport demand - million pass.km	2010	2011	2012	2015	2020
Pass.km cars	-2	727	1719	3308	1210
Pass.km all modes	0	679	1602	3044	859

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.8%	4.8%	6.2%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.6%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.4%	19.1%	5.7%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	121	144	150	114	140	181	122	99	116	122	139.4
2015	121	143	149	113	140	180	122	98	115	120	139.0
2020	119	142	148	112	139	177	120	96	114	119	137.9

Table 25: D27 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	307	766	1769	1458
(Production costs)		2	47	117	243	23
Pollution benefits		36	114	241	670	1487
Cost of public funds (general)		-4	-372	-1168	-4680	-9339
Cost of public funds (labour)		-7	-628	-1963	-7821	-15523
Welfare (general)		46	97	-44	-1998	-6371
Welfare (labour)		43	-159	-838	-5139	-12555
Welfare Net Present Value (general)	-15965					
Welfare Net Present Values (labour)	-36796					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2351	-7228	-14596	-35070	-61694
Tank-to-Wheel CH4	-0.001	-0.001	-0.002	-0.002	-0.017
Tank-to-Wheel N2O	0.001	0.019	0.047	0.109	0.120
Well-to-Tank CO2	-309	-951	-1921	-4616	-8121
Well-to-Tank CH4	-0.145	-0.455	-0.933	-2.326	-4.365
Well-to-Tank N2O	-0.084	-0.256	-0.514	-1.232	-2.163
Tank-to-Wheel GHG (CO2-equivalents)	-2351	-7222	-14582	-35038	-61659
Well-to-Tank GHG (CO2-equivalents)	-337	-1037	-2094	-5034	-8862

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	722	1801	3649	1704
Pass.km all modes	0	675	1679	3359	1313

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.8%	4.8%	6.2%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.6%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.4%	19.1%	5.7%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	120	142	148	112	138	178	120	98	115	120	137.6
2015	119	142	147	112	138	178	120	97	114	119	137.4
2020	118	141	147	111	138	176	119	95	113	118	136.7

Table 26: D28 Results summary – EU15 + 4NMS

Welfare components - million euro	2005	2010	2011	2012	2015	2020
Utility of households		12	316	879	2506	3650
(Production costs)		2	55	158	457	579
Pollution benefits		30	96	196	530	1162
Cost of public funds (general)		-4	-321	-990	-3768	-7426
Cost of public funds (labour)		-7	-540	-1662	-6295	-12340
Welfare (general)		40	147	243	-275	-2035
Welfare (labour)		38	-73	-429	-2802	-6949
Welfare Net Present Value (general)	-3415					
Welfare Net Present Values (labour)	-20127					

Greenhouse gas abatement - kton	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2049	-6180	-12023	-28118	-48802
Tank-to-Wheel CH4	-0.001	0.000	0.001	0.007	0.008
Tank-to-Wheel N2O	0.001	0.019	0.051	0.141	0.214
Well-to-Tank CO2	-270	-814	-1584	-3706	-6434
Well-to-Tank CH4	-0.124	-0.383	-0.760	-1.849	-3.417
Well-to-Tank N2O	-0.074	-0.221	-0.429	-1.002	-1.738
Tank-to-Wheel GHG (CO2-equivalents)	-2049	-6174	-12007	-28075	-48739
Well-to-Tank GHG (CO2-equivalents)	-294	-888	-1728	-4045	-7028

Only emissions below 3000 ft.

Effect on transport demand - million pass.km	2010	2011	2012	2015	2020
Pass.km cars	-2	759	2124	5757	7728
Pass.km all modes	0	721	2024	5517	7399

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.7%	4.8%	6.2%	31.4%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.5%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.0%	5.6%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	125	148	155	115	142	183	127	103	120	127	142.4
2015	125	148	155	115	142	183	126	102	119	125	142.2
2020	124	147	154	114	141	181	125	100	118	124	141.5

Table 27: D29 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	320	892	2563	3705
(Production costs)		2	57	165	474	447
Pollution benefits		32	103	210	569	1252
Cost of public funds (general)		-4	-339	-1052	-4039	-7977
Cost of public funds (labour)		-7	-567	-1754	-6698	-13159
Welfare (general)		42	141	215	-433	-2573
Welfare (labour)		39	-88	-487	-3092	-7755
Welfare Net Present Value (general)	-4760					
Welfare Net Present Values (labour)	-22359					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2158	-6551	-12804	-30116	-52393
Tank-to-Wheel CH4	-0.001	-0.001	0.000	0.007	0.007
Tank-to-Wheel N2O	0.002	0.020	0.053	0.146	0.214
Well-to-Tank CO2	-284	-863	-1688	-3971	-6912
Well-to-Tank CH4	-0.130	-0.403	-0.803	-1.959	-3.616
Well-to-Tank N2O	-0.079	-0.238	-0.463	-1.086	-1.891
Tank-to-Wheel GHG (CO2-equivalents)	-2158	-6545	-12788	-30073	-52329
Well-to-Tank GHG (CO2-equivalents)	-310	-943	-1843	-4338	-7555

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	765	2147	5842	7688
Pass.km all modes	0	728	2050	5603	7235

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.7%	4.8%	6.2%	31.4%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.5%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.0%	5.6%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	125	148	155	115	142	183	127	103	120	127	142.4
2015	125	148	155	115	142	183	126	102	119	125	142.2
2020	124	147	154	114	141	181	125	100	118	124	141.5

Table 28: D30 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	358	989	2754	3866
(Production costs)		2	58	167	460	380
Pollution benefits		39	120	243	651	1415
Cost of public funds (general)		-4	-416	-1248	-4654	-9071
Cost of public funds (labour)		-7	-698	-2085	-7731	-14984
Welfare (general)		49	120	151	-790	-3409
Welfare (labour)		46	-162	-686	-3866	-9323
Welfare Net Present Value (general)	-7242					
Welfare Net Present Values (labour)	-27526					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2645	-7774	-14966	-34707	-59557
Tank-to-Wheel CH4	-0.001	-0.001	0.000	0.005	0.000
Tank-to-Wheel N2O	0.002	0.022	0.057	0.153	0.217
Well-to-Tank CO2	-348	-1025	-1973	-4577	-7857
Well-to-Tank CH4	-0.160	-0.479	-0.939	-2.258	-4.111
Well-to-Tank N2O	-0.097	-0.283	-0.543	-1.257	-2.156
Tank-to-Wheel GHG (CO2-equivalents)	-2644	-7768	-14949	-34662	-59493
Well-to-Tank GHG (CO2-equivalents)	-380	-1119	-2155	-5001	-8590

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	819	2287	5968	7341
Pass.km all modes	0	773	2169	5680	6819

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.7%	4.8%	6.2%	31.4%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.5%	5.2%	6.1%	30.4%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.0%	5.6%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	122	145	152	113	139	179	124	101	117	124	139.2
2015	122	144	151	113	139	179	124	99	117	123	139.2
2020	121	144	151	112	138	178	123	98	116	122	138.8

Table 29: D31 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	354	973	2677	3597
(Production costs)		2	35	89	105	-640
Pollution benefits		40	126	255	690	1509
Cost of public funds (general)		-4	-438	-1321	-4967	-9719
Cost of public funds (labour)		-7	-731	-2194	-8195	-15946
Welfare (general)		50	77	-4	-1494	-5253
Welfare (labour)		48	-217	-877	-4723	-11481
Welfare Net Present Value (general)	-12518					
Welfare Net Present Values (labour)	-33829					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2757	-8166	-15797	-36885	-63562
Tank-to-Wheel CH4	-0.001	-0.001	-0.001	0.001	-0.013
Tank-to-Wheel N2O	0.001	0.020	0.051	0.129	0.153
Well-to-Tank CO2	-363	-1077	-2083	-4866	-8388
Well-to-Tank CH4	-0.166	-0.501	-0.985	-2.379	-4.339
Well-to-Tank N2O	-0.102	-0.300	-0.578	-1.348	-2.322
Tank-to-Wheel GHG (CO2-equivalents)	-2757	-8160	-15782	-36847	-63517
Well-to-Tank GHG (CO2-equivalents)	-397	-1177	-2277	-5320	-9175

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	794	2204	5584	6185
Pass.km all modes	0	730	2025	5014	4847

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.7%	4.8%	6.2%	31.4%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.3%	19.5%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.5%	19.0%	5.6%	6.2%	28.2%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	122	145	152	113	139	179	124	101	117	124	139.2
2015	122	144	151	113	139	179	124	99	117	123	139.2
2020	121	144	151	112	138	178	123	98	116	122	138.8

Table 30: D32 Results summary – EU15 + 4NMS

Welfare components - million euro

	2005	2010	2011	2012	2015	2020
Utility of households		12	342	931	2481	3021
(Production costs)		2	-13	-72	-598	-2509
Pollution benefits		42	132	269	738	1625
Cost of public funds (general)		-4	-466	-1414	-5350	-10515
Cost of public funds (labour)		-7	-772	-2331	-8764	-17126
Welfare (general)		52	-5	-286	-2729	-8378
Welfare (labour)		49	-312	-1203	-6143	-14989
Welfare Net Present Value (general)	-21634					
Welfare Net Present Values (labour)	-44197					

Greenhouse gas abatement - kton

	2010	2011	2012	2015	2020
Tank-to-Wheel CO2	-2890	-8632	-16786	-39493	-68392
Tank-to-Wheel CH4	-0.001	-0.002	-0.002	-0.008	-0.037
Tank-to-Wheel N2O	0.001	0.015	0.039	0.082	0.035
Well-to-Tank CO2	-381	-1139	-2215	-5213	-9030
Well-to-Tank CH4	-0.173	-0.526	-1.040	-2.526	-4.617
Well-to-Tank N2O	-0.108	-0.320	-0.622	-1.463	-2.533
Tank-to-Wheel GHG (CO2-equivalents)	-2889	-8628	-16775	-39469	-68382
Well-to-Tank GHG (CO2-equivalents)	-417	-1245	-2423	-5704	-9886

Only emissions below 3000 ft.

Effect on transport demand - million pass.km

	2010	2011	2012	2015	2020
Pass.km cars	-2	738	2020	4771	3979
Pass.km all modes	0	640	1719	3657	1171

Car sale market shares (%)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	total
2002	29.8%	23.6%	4.9%	1.9%	30.5%	8.1%	1.0%	0.1%	0.0%	0.0%	100%
2008	27.4%	19.0%	4.1%	6.5%	32.8%	9.1%	0.8%	0.2%	0.1%	0.0%	100%
2012	27.0%	19.7%	4.8%	6.3%	31.3%	9.5%	0.8%	0.3%	0.2%	0.0%	100%
2015	27.4%	19.5%	5.2%	6.1%	30.3%	9.9%	0.9%	0.4%	0.3%	0.1%	100%
2020	28.6%	19.0%	5.6%	6.2%	28.1%	10.4%	0.9%	0.6%	0.4%	0.1%	100%

New car real-world CO2 emissions (g/km)

	pcgs	pcgm	pcgb	pcds	pcdm	pcdb	pcl	pcgs_cng	pcgm_cng	pcgb_cng	average
2002	183	214	237	134	170	229	186	167	208	247	192.1
2008	150	175	193	117	145	195	150	128	144	161	157.8
2012	122	145	152	113	139	179	124	101	117	124	139.2
2015	122	144	151	113	139	179	124	99	117	123	139.2
2020	121	144	151	112	138	178	123	98	116	122	138.7

4. Interpretation of results, caveats and suggestions

Simulation of the effects of fuel-efficiency improvements has always been one of the core objectives of the development of the TREMOVE model. As a consequence, the model structure has been setup to analyse this kind of scenario as good as possible, within the limits of the scope of the model. Not only changes in emissions and fuel consumption are estimated, but also effects on fleets, transport demand and its modal split, and fiscal revenues are integrated in the model calculations. This way TREMOVE enables to analyse the full impact of CO_2 abatement scenarios in an integrated way. Further refinements and extensions to the model and its calibration are being performed the ongoing TREMOVE 3 Lot 1 project by TML.

In the remainder of this section we present a number of caveats, suggestions for further data and model improvements, and suggestions for other further research work.

4.1.1. *Caveats and suggestions for further research w.r.t. the v2.43b basecase*

The TREMOVE v2.43b basecase, which was used for the scenario simulations, is based on the COPERT III emission calculation methodology. As COPERT III dates from the year 2000, its fuel consumption and emission factors for more recent cars are based on estimates, not on actual measurements. Another limitation of COPERT III is that it only provides one fuel consumption factor for all diesel car types, i.e. no specific factors are provided for small (<1400cc), medium (1400cc-2000cc) and big (>2000cc) diesel cars. To overcome these limitations, the v2.43b baseline includes a number of additions to the COPERT III methodology :

- The one diesel car fuel-efficiency factor has been desaggregated into factors for the three diesel car size classes. This desaggregation is based on the test-cycle measurements available in the EU CO_2 monitoring dB for the voluntary agreement of the car industry;
- For all diesel and petrol cars, the COPERT III fuel-efficiency factors for 2002 cars have been upscaled to come in line with estimated 2002 real-world factors. The latter factors are estimated as the 2002 CO_2 monitoring dB test-cycle factors, increased with 15% to cover the difference between real-world and test-cycle fuel consumption[17]. This rescaling has not not been done for N1 vehicles, as the monitoring dB covers cars only;
- For new cars and N1 vehicles, fuel efficiency improvements in the 2002-2012 period have been introduced based on the Task A study (as explained in section 2.1).

Clearly, there is room for further improvement of the fuel consumption and CO_2 emission factors in v2.43b. A number of improvements have already been made in the new v2.44 baseline, which is based on a new (draft) COPERT IV version. But COPERT IV still has its limitations. It provides different fuel consumption factors for <2000cc and >2000cc diesel cars, but still does not provide information on the differences between the small and medium engined cars within the <2000cc class. Also the set of real-world measurements for the newest car types (EURO 3 and EURO 4 technologies) on which COPERT 4 is based is very limited. Therefore, we suggest further research work on fuel-efficiency and emission factors, not only for cars, but also for N1 and other road vehicles. We see opportunities in the further analysis of the measurements performed in the ARTEMIS project and in additional measurements.

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[17] In the Task A study TNO assumes a 19.5% difference between test-cycle and real-world fuel consumption in 2002, including mobile airco use. TREMOVE applies a similar assumption of 15%, to which airco use is added afterwards. Note that the increasing penetration of LRRT, TPMS and LVL technologies decreases the real-world versus test-cycle difference in the future.

Besides, after the Task A project, still a number of uncertainties on LRRT, LVL, TPMS, GSI and more fuel efficient MAC technologies remain. The largest uncertainty is in their expected basecase market penetration. As these are technologies which have potential to reduce CO_2 emissions at low cost, further research on the expected market penetration of these technologies, and their effects on fuel consumption and emissions would be useful.

Furthermore, it is important to repeat that the v2.43b basecase deviates from the Task A basecase on two specific points. as indicated earlier in section 2.1, no adapations have been made to bring the COPERT III N1 vehicle CO_2 emission factors in line with the Task A estimates for 2002. Also, TREMOVE v2.43b basecase assumes a constant fuel-efficiency of airconditioning equipment, while in Task A an improvement is predicted. Both for N1 fuel consumption as for fuel-efficient airconditioning equipment, the uncertainties are considered to be high. Further research on both issues could be useful.

Finally, note that the assumed future fuel ressource costs (and taxes) can have a significant impact on the cost-effectiveness results of the scenario simulations. The current crude oil price forecast in TREMOVE is taken from the EU Energy Outlook. As future crude oil prices are uncertain, sensitivity analysis (as has been done in Task A) might be useful. Note however that this is not a straightforward exercise. Changes in crude oil prices might lead to significant changes in transport patterns and car ownership. In principle, a forecast from a transport forecast model (as SCENES or the forthcoming TRANSTOOLS) is needed to assess these impacts, and to provide the necessary baseline data for TREMOVE.

Model input parameters related to the fuel costs and taxes

Name	Table_info	Description
RFCOST_COMP	T_FUELCOMP_PARAMETER	Road fuel component resource cost - euro 2000 per litre - except CNG in euro 2000 per m³
RFVAT	T_FUEL_PARAMETER	Road fuel VAT rate - %
RFTAX_COMP	T_FUELCOMP_PARAMETER	Road fuel component excise tax - euro 2000 per litre - except CNG in euro 2000 per m³

The fuel costs have been derived from the Energy Outlook crude oil prices and refinery costs. All fuel prices (and future evolution) have been made consistent with the Energy Outlook, albeit that we included 2001, 2002 and 2003 prices from statistics when available, whereas the Energy Outlook did not (they use forecasts from 2000 onwards).

Fuel resource costs differ per country depending on the refinery costs, except for CNG where all countries have the same (German) value of 0.69 euro/m^3.

Excise taxes are assumed to remain constant from 2003 onwards, except for a strong tax-exemption for biofuels. CNG excise taxes are derived from DG TAXUD statistics and are assumed constant over time.

The table below gives the crude oil prices as they are now in TREMOVE. The prices are derived form the Energy Outlook / PRIMES model, June 2005.

Table 31: Energy import prices in (2000)$ / boe: preliminary 2005 energy baseline

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Oil	18.49	22.01	19.97	13.16	18.16	28.24	23.67	23.79	28.13	35.75	44.56	43.42	41.77	40.11	38.48	36.82
Gas	9.09	12.99	13.36	13.36	13.36	13.36	22.70	15.75	27.61	30.48	36.97	35.48	33.99	32.49	31.07	29.57
Coal	11.40	11.51	10.43	9.23	8.04	7.60	7.49	7.82	7.91	8.09	9.23	9.32	9.40	9.48	9.57	9.66

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Oil	36.85	36.93	36.97	36.98	37.06	37.54	38.06	38.63	39.15	39.66	40.66	41.76	42.81	43.88	44.92	45.45	46.02	46.48	46.99	47.54
Gas	29.81	30.07	30.41	30.64	30.91	31.30	31.77	32.09	32.50	32.95	33.79	34.72	35.60	36.50	37.39	37.96	38.64	39.27	39.87	40.51
Coal	9.83	9.90	10.01	10.16	10.29	10.39	10.53	10.66	10.80	10.84	10.91	10.94	11.08	11.10	11.23	11.25	11.36	11.35	11.43	11.51

4.1.2. *Caveats and suggestions for further research w.r.t. the scenario input data*

Next to the baseline data, the specific input data for the scenarios themselves of course is of crucial importance. A number of caveats already have been discussed in this report. In summary it concerns following issues :

At first, there are still uncertainties with respect to the technology costs to reach certain test-cycle emission reductions at the vehicle level. We point here primarily the uncertainty with respect to effects on maintenance/repair costs.

Also the treatment of the difference between manufacturer cost increases and the eventual ex-tax retail price increase paid by the consumer is an issue. In the Task A study, ex-tax price increases for the consumer are estimated by applying a 1.16 factor on the manufacturer costs. These ex-tax price increases then are used to calculate the overall cost of the policy. As suggested by the European Commission, the final set of TREMOVE scenario simulations (D20 to D32) takes only account of the increase in manufacturer costs for cars. Remember that in the v2.43b basecase the 2010-2012 car cost increase – to maintain the 140 g./km level up to 2012 – is calculated using the 1.16 factor, representing the difference between ex-tax retail price increase and manufacturer cost increase. In the D20-D32 simulation scenarios however, this 1.16 factor is not accounted for. This means that the cost to maintain the 140 g. level in the scenario simulations is 16% lower than in the basecase, which leads to a small cost benefit in each to of the simulated D20-D32 scenarios. The effect of this difference on the overall scenario results is limited, as the technology cost to maintain the 140 g. level is small compared to the costs of further fuel-efficiency improvements (towards a 120 g. target).

W.r.t. the potential emission reductions from technical measures at the vehicle level, the Task A study is restricted to the effects on test-cycle emissions. More specificly, the study uses a fix 19.5% difference between real-world and test-cycle emissions for these technical measures. The Task A report notes that, in reality, this factor may change as a result of CO_2-reduction technologies, though this aspect is difficult to quantify within the aggregated approach of the Task A study and is therefore neglected. This issue may require further study in a future project. For LVL, LRRT, TPMS, GSI and airconditioning equipment, Task A of course does assess the potential effects on real-world emissions. A caveat however is that the impact of GSI on fuel consumption and CO_2 emissions is uncertain, as the effect eventually depends on how the GSI affects drivers gear changing behaviour. Via the scenario generator sensitivity analysis on this latter GSI effect can be performed easily.

The technology cost and efficiency improvement figures in the Task A report are aggregates for the EU15. Task A did not assess the impact of differences between countries w.r.t. vehicle prices, fleet composition, driver behaviour, ...In TREMOVE however, vehicle prices, fleet composition, driving speeds, etc. differ significantly between countries. As an approach to deal with these differences, the Task A absolute figures have been converted to percentages, which then are applied equally in all modelled countries. As indicated in section 3.4.4 this approach proves that their are important differences in the cost-effectiveness of the measures between countries. Further analyisis of these differences would require further country specific research. A desaggregation of the Task A calculations by country, could lead to country specific input data for TREMOVE, and more in-depth insight in the effects of the policy packages in individual countries.

The way in which the LVL/LRRT/TPMS scenarios are defined and introduced in the model, has an impact on the cost-effectiveness calculated in TREMOVE. Two relevant notes were made on this in section 2.2.3.a. First, the Task A report provides one, single value for the increase in yearly maintenance/repair costs related to the use of LRRT or LVL. This value is used for both new cars and older (retrofitted) cars. Remember however that older cars drive less kilometres than new cars. Secondly, the Task A report provides one, single value for the percentage decrease in the CO_2 emission factors related to the use of LRRT or LVL. Also this value is used for both new cars and older (retrofitted) cars. However, the emission factor for older cars, is higher than that for newer cars. For these two reasons, the calculated cost-effectiveness for LRRT and LVL on older cars, is different from that for for newer cars. For these LRRT and LVL technologies, it might be worth putting effort in searching and applying different fuel-efficiency and maintenance/repair cost estimates for cars of different vintages. E.g. an alternative approach might be to specify an extra maintenance/repair cost per vehicle-kilometre rather than per year.

4.1.3. *Caveats and suggestions on other input data and assumptions*

The sensitivity coëfficient of the car market shares to car price changes in TREMOVE is to be considered as a lower estimate. For the estimation of the car sale logit models, only quarterly data for 1999 and 2000 on car prices was available as a coherent dataset for most EU countries (data from [COWI, 2001]). This dataset did not enable to analyse the effects of price changes in the longer term. It is recognised that the logit model coefficients could be estimated more accurate if a more extensive time series on car market shares, prices and other car parameters would be available for all modeled countries.

For greenhouse gases, the benefit values used in TREMOVE represent rather the costs of emission rights, than the negative effects on health and environment (see section 3.3) For greenhouse gas policies, the welfare cost calculated in TREMOVE thus should be rather interpreted as the cost of reducing greenhouse gas emissions by the simulated policy measures instead of purchasing emission rights. There is an need for further research to narrow the range of external cost estimates for greenhouse (and other) pollutants.

To estimate the cost-effectiveness of the policy packages, it is necessary to specify clearly the way in which the loss of excise tax revenues will be compensated. Indeed, for the government the decreased fuel consumption leads to a loss in excise tax revenues. TREMOVE assumes that this latter loss is compensated by either increases in general taxes, either increases in labour taxes to maintain the level of government funds. In principle, also other ways of revenue loss compensation can be added in the model. It is important to realise that this revenue compensation can have significant impacts on the cost-effectiveness results, and thus is an important scenario assumption.

4.1.4. *Notes on comparisons with Task A estimates for costs per tonne of CO_2*

Also the Task A report provides estimates for the cost-effectiveness of the measures to reduce CO_2 emissions. Table 32 shows an extract of the cost-effectiveness estimates in the Task A report, for technical measures at the vehicle level for cars, and for low rolling resistance tyres.

Table 32 : Extract from Task A abatement cost tabel [TNO, 2006 – page 14]

	Cost per tonne of CO_2-eq. abatement (EURO/tonne)			
Oil price (EURO/bbl)	**25**	**36**	**50**	**74**
Tech. options at car level – 135g.	166	143	114	65
Tech. options at car level – 130g.	187	164	135	86
Tech. options at car level – 125g.	209	186	157	108
Tech. options at car level – 120g.	233	210	181	132
Low rolling resistance tyres	139	109	73	15

As indicated in section 2.2, information on technology costs and effectiveness for the TREMOVE scenarios has been taken from the Task A report. Thus, this technology data is equal in TREMOVE and Task A. However, the TREMOVE and Task A cost-effectiveness calculations are based on numerous other inputs and assumptions for which there are differences. Vehicle mileages and vehicle lifetimes used in the Task A report differ from the TREMOVE v2.43b baseline figures. Also the market shares of the different car types in 2008 and 2012 in the Task A report are not exactly equal to those in TREMOVE v2.43b. Furthermore, the predicted future fuel prices differ. Also, the costs associated to losses in governments excise tax revenues are treated differently. In general, the task A calculations are rather back-of-the envolope calculations, while the TREMOVE results are based on extensive and detailed modelling.

Nevertheless, comparison of Figure 29 and Table 32 shows that the estimated cost-effectiveness for technical measures at the vehicle level for cars are broadly in the same range. I.e. the TREMOVE results are roughly similar to the Task A estimates for the central oil price levels.

For the more cost-effective measures, such as LRRT, it should be noted that small differences in scenario assumptions, can lead to significant changes in the calculated cost-effectiveness. TREMOVE test simulations on LRRT for France, indicated that for “scenario 1”, the yearly fuel savings per car are approximately 18 EURO. For “scenario 2” this is rather 16 EURO. As the yearly extra maintenance cost per car in both scenarios is 20 EURO, the net costs are about 2 EURO and 4 EURO for “scenario 1” and “scenario 2” respectively. However, the annual CO_2 emission savings in “scenario 1” is only a bith higher than that for “scenario 2” (due to the higher annual mileage). This leads to a cost per tonne CO_2 abatement for “scenario 2”, that is more than double of that for scenario “1”. More specificly, the cost-effectiveness in France for scenario 1 is approx 25 euro per tonne, while for scenario 2 it is rather 60 euro per tonne.

In other words, for the most cost-effective measures, for which fuel savings are almost equal to technology costs, small changes in model or scenario assumptions will lead to signifcant changes in cost-effectiveness outcomes (when expressed relatively, in %). Therefore, when comparing TREMOVE and Task A outcomes for these measures, one should be aware that the differences between TREMOVE and Task A cost-effectiveness outcomes can be significant.

IV Other simulations

1. Heavy duty truck road infrastructure charging

1.1. General scenario setup

Scenario E1 is a test simulation on heavy duty truck road infrastructure charging, where tax levels are set according to environmental criteria.

In the demand module, the generalised price for heavy duty truck transport is increased by an extra road charge per vkm, which depends on road type. The policy is introduced from 2005 onwards. The extra road charge per vkm introduced in the demand module is calculated as follows:

For each "truck type – technology" combination charge levels in year T are set equal to the marginal external pollution cost of a truck of this type and technology in year T-1 in the simulation scenario . This marginal external cost is a weighted average over road types and peak/offpeak periods. The marginal external costs refer only to exhaust emissions, not to lifecycle and/or non-exhaust emissions.

The charge level for each truck type then is calculated as the weighted average of the charge levels per technology. Consistent with the marginal cost estimation the weights are here also derived from year T-1 information.

The aggregate charge level for heavy duty trucks by road type then is calculated as the weighted average of the charge levels per truck type. This aggregate charge level is different for different road types as the traffic composition (i.e. share of different truck types in total vkm) differs over road types.

1.2. Assumptions and caveats related to the scenario setup

The charge level introduced in the demand module will decrease over time, as average HDV marginal external costs will decrease through introduction of cleaner technologies.

The TREMOVE version used (v2.32b) for this simulation could not assess the possible effects of the charge scheme with respect to earlier penetration of cleaner technologies (Euro IV, Euro V) and increased scrapping of older trucks. In TREMOVE 2.3 truck technologies are assumed not to be introduced before the year in which the related emission standard is introduced. The version of TREMOVE used also does not model scrappage of trucks endogenously (ie the scrap rates per vehicle vintage are independent of the policy scenario).

For each road type the share of the four HDV truck types in total traffic is exogenous in TREMOVE 2 and is not dependent on the policy scenario. However, note that shifts of truck traffic between road types will lead to changes in the overall truck fleet composition.

An important remark is that in the v2.32b model version, the charge on HDV will not lead to a shift towards N1 (i.e. the vehicle class including trucks < 3.5 tonnes) freight transport, although for the latter the network tax does not increase in principle. This is due to the limitations of the link between SCENES and TREMOVE. Given that SCENES does not distinguish between HDV and N1 trucks, it was impossible to model substitution between HDV and N1 truck correctly in the demand module. It should be noted that the major share of total N1 vehicle traffic are passenger movements. The importance of N1 freight movements in total road tkm is limited.

1.3. E1 results

Figure 32 and Table 33 show that the policy leads to a decrease of total tkm. As can be expected from a road charge scheme, a substitution effect from road freight transport towards rail and inland waterways appears. The influence of the policy is larger in 2005 than in 2020. This is a result of the lower average emissions of the 2020 fleet, resulting in lower marginal external costs and thus lower charge levels.

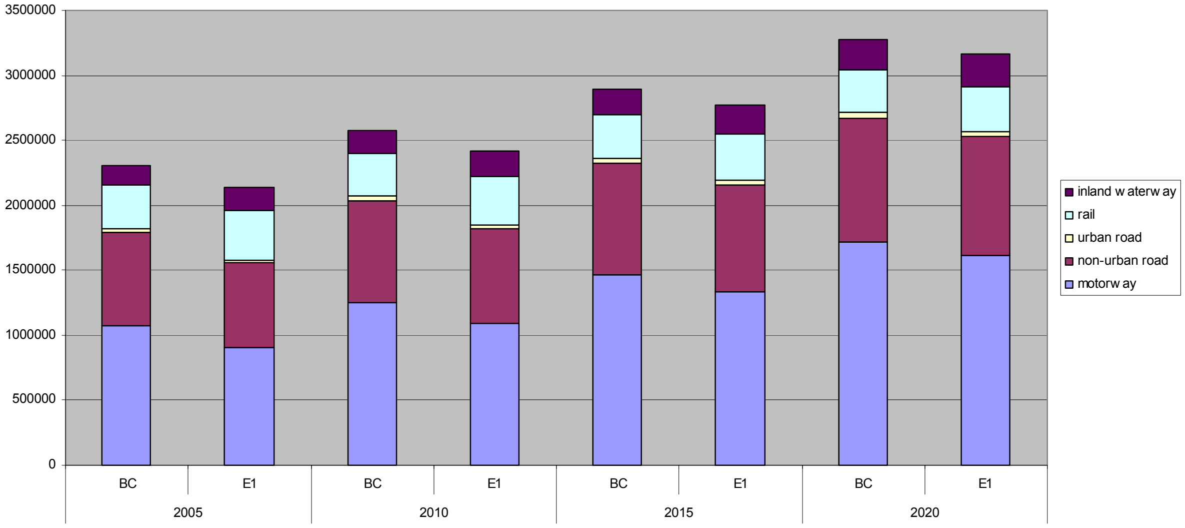

Figure 32: Tonne-kilometres by network – All TREMOVE countries, million tkm

Table 33: % Change in tonne-kilometres from base case to D1 by network – All TREMOVE countries

	motorway	rural road	urban road	rail	inland waterway	Total
2005	-15.4%	-9.8%	-12.5%	13.1%	19.3%	**-7.2%**
2020	-6.3%	-4.2%	-5.7%	5.7%	7.6%	**-3.5%**

The figures below indicate that the policy affects larger heavy duty trucks more than smaller heavy duty trucks. As the load factors are assumed constant, the effects on tkm by truck type are similar to the effects on vkm.

Note that TREMOVE indicates a limited downward effect on total N1 vehicle usage. This is due to the weak link between the demand module vehicle categories and the vehicle stock module vehicle type classification for road freight vehicles. This leads to the fact that the simulation results in a decrease of N1 freight vkm. It should be noted that the major share of total N1 traffic are passenger movements, for which the simulation outcomes indicate a small increase (due to less congestion). The importance of N1 freight movements in total road tkm is limited, as is the importance of the change in N1 vehicle tonne-kilometres in this simulation.

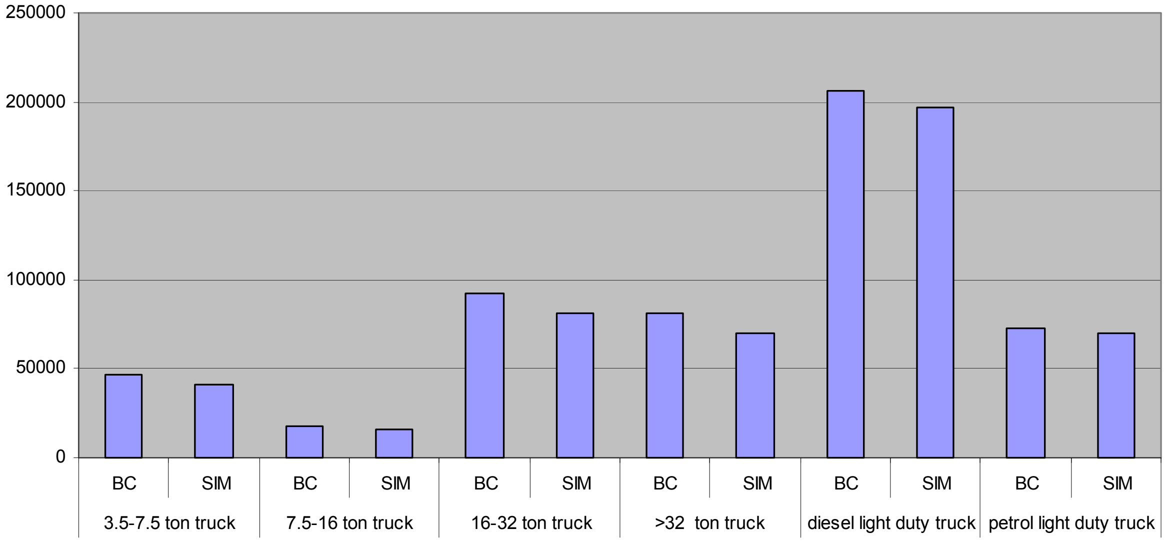

Figure 33: 2005 Vehicle-kilometres by truck type – All TREMOVE countries, million vkm

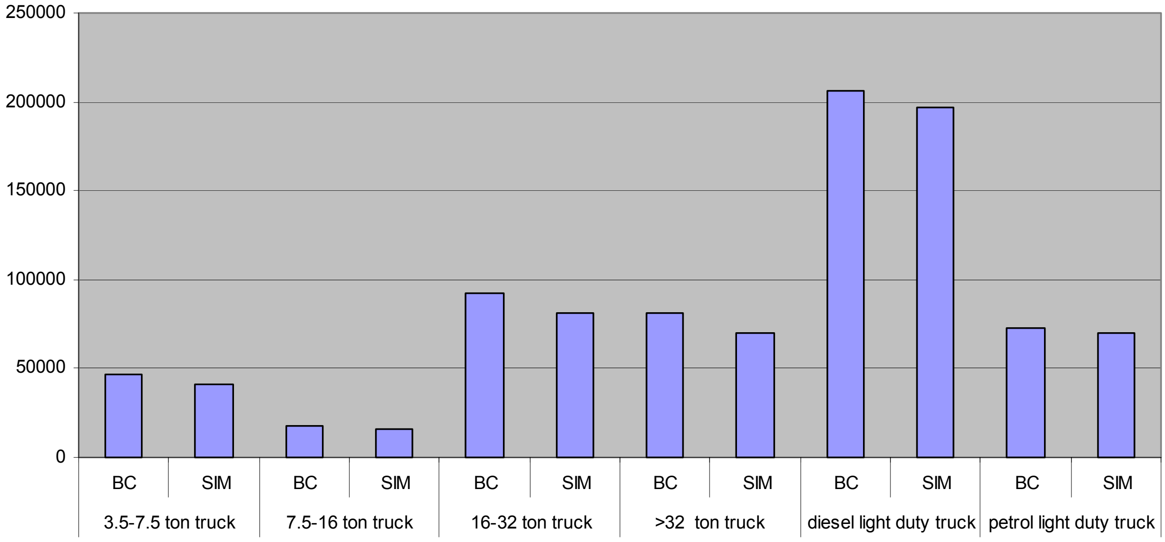

Figure 34: 2020 Vehicle-kilometres by truck type – All TREMOVE countries, million vkm

Table 34: % Change in vehicle-kilometres from base case to D1 by network – All TREMOVE countries

	3.5-7.5 ton truck	7.5-16 ton truck	16-32 ton truck	>32 ton truck	diesel LDT	petrol LDT
2005	-11.3%	-11.3%	-12.5%	-13.3%	-4.2%	-3.4%
2020	-4.8%	-4.8%	-5.2%	-5.6%	-2.1%	-1.5%

With respect to passenger transport, TREMOVE predicts a modest increase for all networks. For roads this is mainly the effect of reduced congestion, thus a direct decrease in time costs, resulting from a decrease in truck transport, with the largest effect on motorways. For non-road modes the increases result from a more general income effect. Overall, the average cost (time + money) of passenger-transport decreases, which makes it possible to travel more given a fixed income.

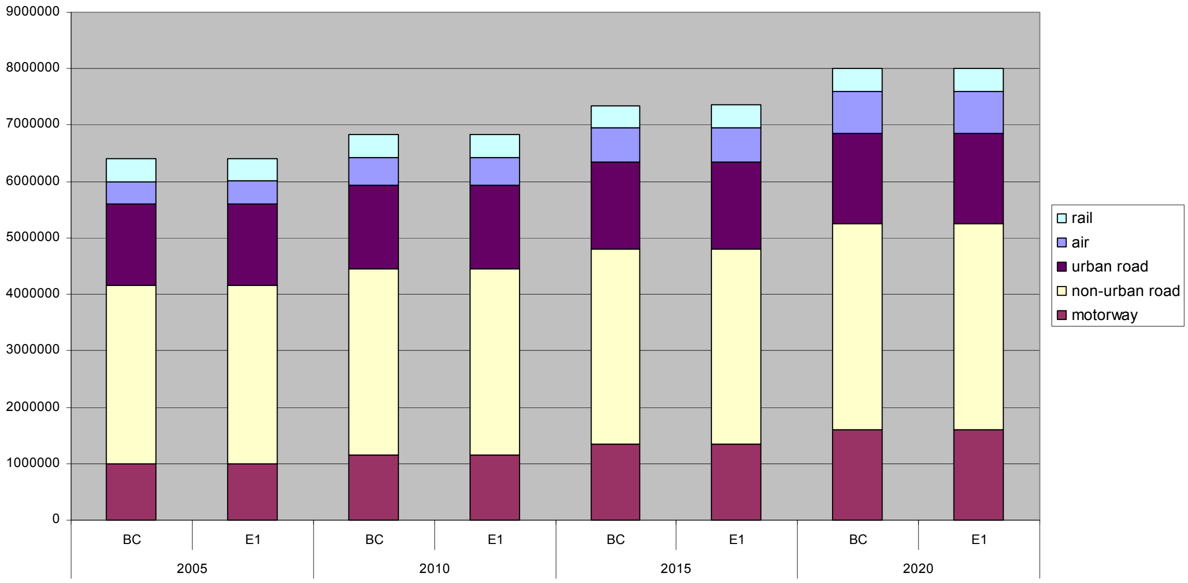

Figure 35: Passenger-kilometres by mode – All TREMOVE countries, in million pkm

Table 35: % Change in passenger-kilometres from base case to D1 by network – All TREMOVE countries

	Motorway	Rural road	Urban road	Rail	Air	Total
2005	0.20%	0.08%	0.03%	0.03%	0.10%	0.09%
2020	0.03%	0.02%	0.01%	0.02%	0.03%	0.02%

As indicated in Figure 36 to Figure 38, the policy leads to a decrease in total transport exhaust emissions for PM, NO_x and CO_2 of around 3% in 2005, which is significant. The graphs and figures include all tail-pipe emissions, except high-altitude aircraft emissions.

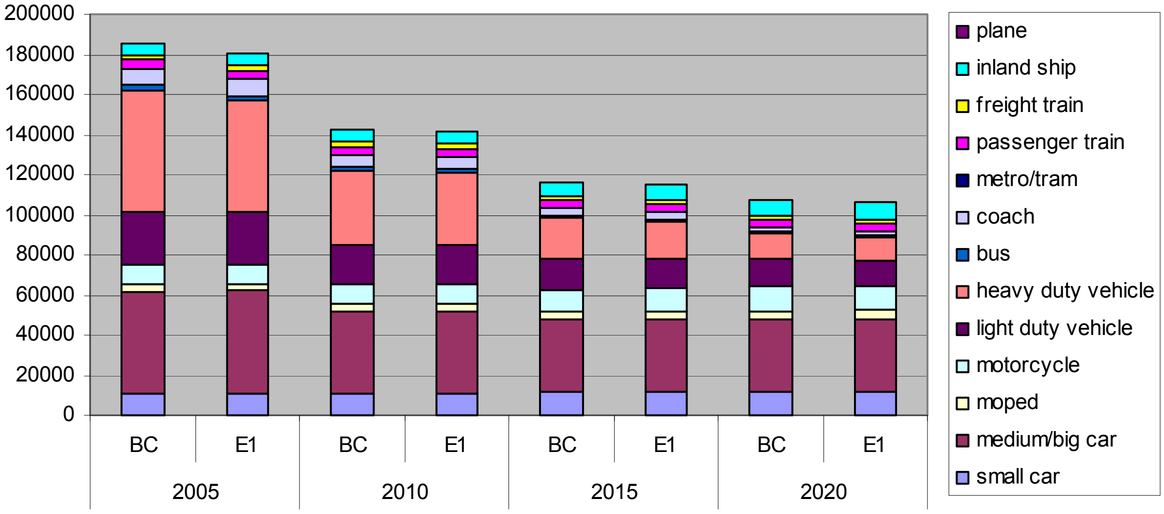

Figure 36: Exhaust PM emissions by mode – All TREMOVE countries - tonnes -

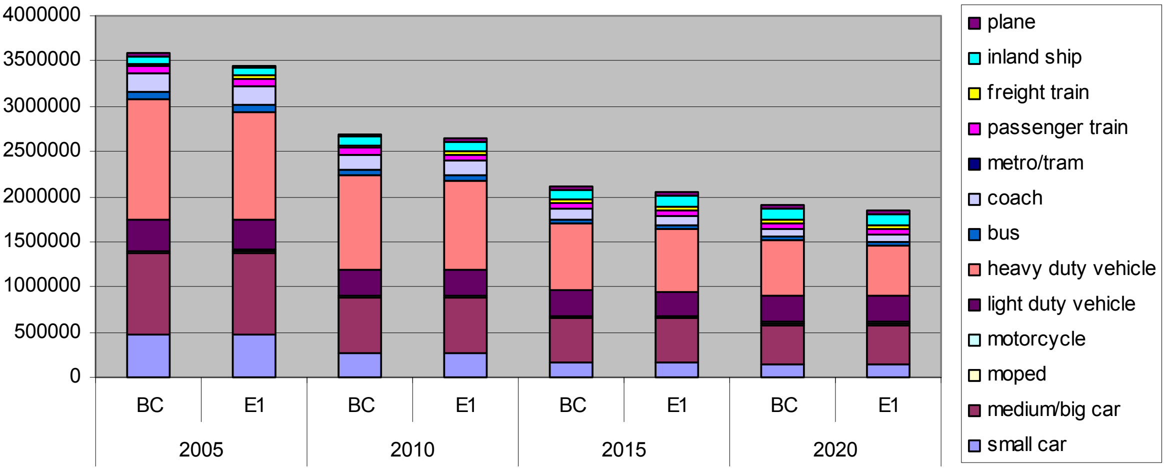

Figure 37: Exhaust NOx emissions by mode – All TREMOVE countries - tonnes -

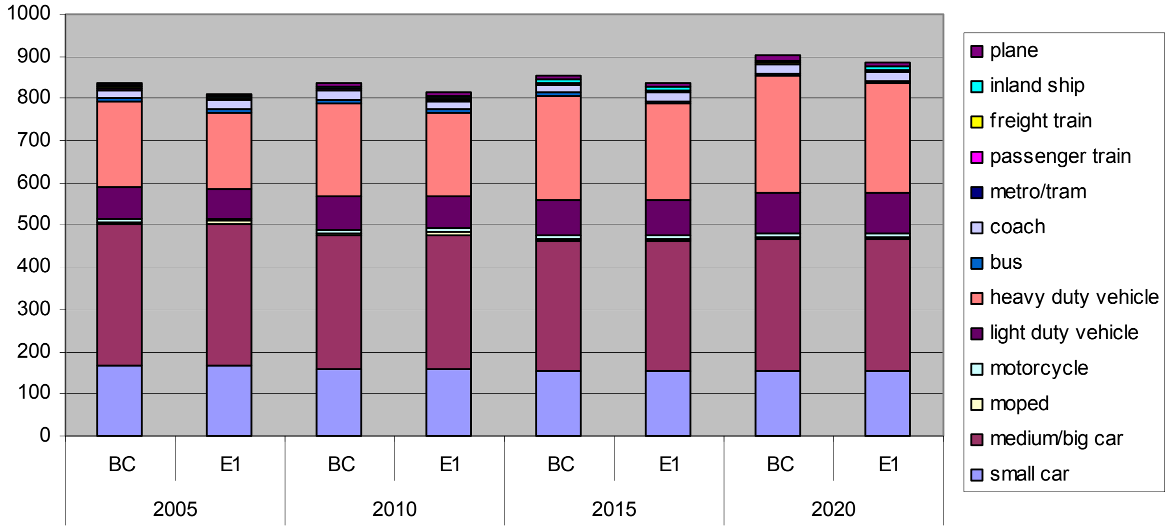

Figure 38: Exhaust CO_2 emissions by mode – All TREMOVE countries – million tonnes

The E1 welfare analysis is displayed in Table 36, Figure 39 and Figure 40.

The direct effect of the policy is a significant increase in the production costs. This increase results on one hand from increased charges for the remaining truck transport movements and on the other hand from costs related to the induced substitution from road freight towards rail and inland waterway.

In second instance the policy leads to a limited increase in household utility. The decrease in truck traffic leads to a relief of congestion problems for road passenger transport and eventually to a decrease in the overall average (time) cost of passenger transport.

The reduction in emissions leads to a decrease in external pollution costs. Note that the pollution benefit is calculated using the ‘Set 1’ external cost estimates (see II3.3.6).

The effect of the charge policy on the government revenues from the transport sector and its eventual welfare effect is interesting. If the additional government revenues are used to decrease the level of general taxes, the welfare effect of that is lower than the decrease in producer surplus. In this case the policy leads to a modest welfare loss (modest in comparison with the total amount of charges paid). On the other hand, using the revenues to reduce the distortionary labour taxes leads to a significantly larger welfare effect. The overall effect then is significantly positive.

The overall conclusion from this simulation thus is that the charges can lead to emission reduction, congestion reduction and increasing welfare in case the charge revenues are used to lower distortionary taxes in other sectors (e.g. labour taxes). But, other uses of the revenues might lead to welfare losses.

Table 36: E1 Welfare components – All TREMOVE countries, million EURO

	2005 Difference (euro)	2010 Difference (euro)	2015 Difference (euro)	2020 Difference (euro)
Utility of households	673	408	294	252
Production costs	34,315	30516	22072	19648
Pollution benefits	4,691	2683	2790	2452
Extra public funds (general)	27,325	24574	18059	16023
Extra public funds (labour)	45,978	41798	30336	26681
Welfare (general)	-1,626	-2,851	-929	-921
Welfare (labour)	17,026	14,373	11,347	9,737
Welfare NPV (general)	**-22450**			
Welfare NPV (labour)	**142875**			

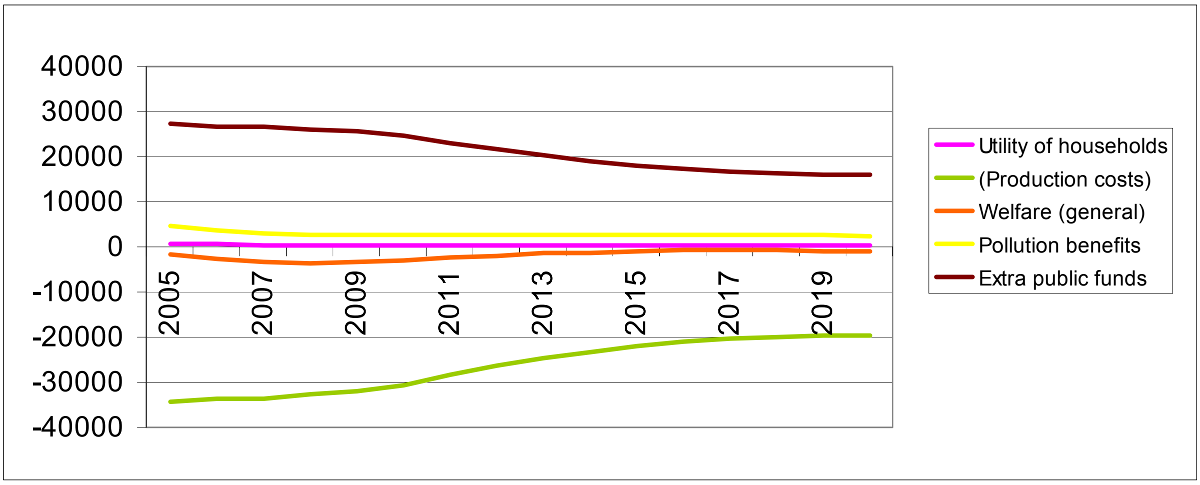

Figure 39: E1 Welfare components – General mcpf, million EURO

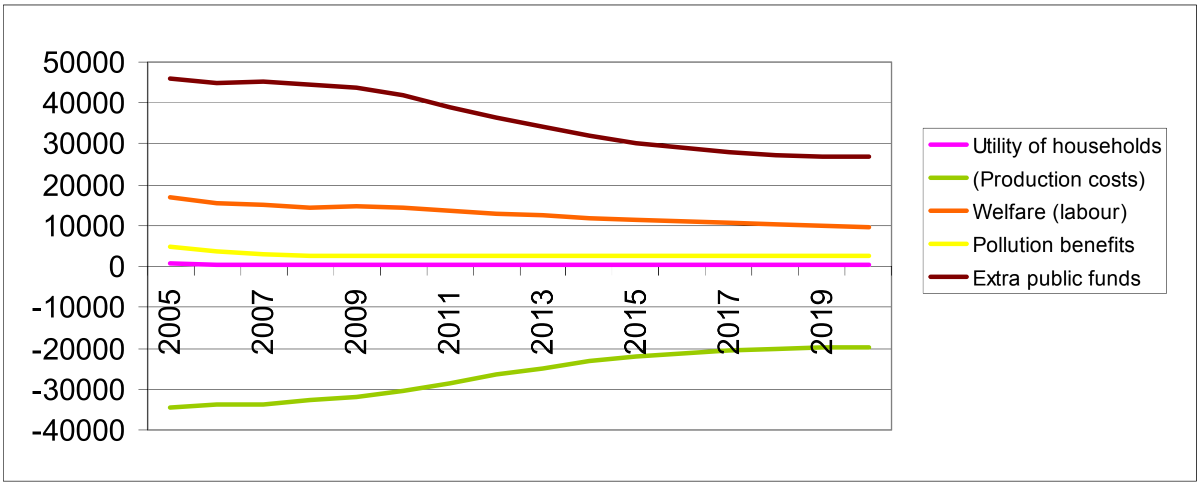

Figure 40: E1 Welfare components – General mcpf, million EURO

1.4. Interpretation of results, caveats and suggestions

Introducing a road charging scheme for trucks will lead to a decrease in truck transport, a modal shift towards other freight modes, reductions in congestion and emission externalities as well as to further second-order effects such as increases in road passenger transport. The TREMOVE simulation captures all these effects in a good way. Moreover, the model enables to compare the effects of different manners to redistribute the charge revenues. The simulation results indicate that the way in which the tax revenues are redistributed is a very important determinant of the eventual welfare effect of the charging policy.

TREMOVE covers well the effects of the charging policy on overall transport demand and its modal split. The current model version is limited however when it comes to simulating impacts on the truck fleet structure. For each road type, the share of the four HDV truck types is fixed in the model. Also substitution processes between N1 freight vehicles and HDV are not represented in the current model. There are opportunities to further improve the model so that it would cover these substitution processes between different truck types. This is currenlty being done done in the TREMOVE 3 project. In a new demand module the CES trees are further extended, by explicitly splitting the lower truck nodes into more detailed size classes.

An interesting path might also be to simulate charging schemes that differentiate between peak and off-peak periods. Such simulations could lead to higher welfare benefits, as they tackle the congestion externalities more effectively. And TREMOVE is perfectly capable of simulating this kind of differentiated charging schemes.

2. Road fuel excise tax for financing development aid

Scenario C1 has been used to analyse the idea to raise road fuel excise taxes and use the extra tax revenues for development side outside the EU. It considers here a quick simulation run, where a number of simplifications have been made in order to speed up the (urgent) delivery of the results.

This scenario simulation has been performed for the EU15 countries and the 4 New Member States modelled in TREMOVE only.

2.1. Scenario setup

An excise tax increase of 0.03 EURO (2000 purchase power) per litre fuel has been simulated. This tax increase is applied on all petrol, diesel, CNG and LPG consumption by road transport. VAT on road fuel sales increases accordingly.

The governments extra tax income from this excise (and VAT) increase is used for development aid outside Europe.

2.2. C1 results

The aim of this quick scenario analysis was not to perform a full welfare analysis. The objective was to focus on and analyse only changes in transport demand, fuel consumption and emissions. Therefore we just restrict to a very brief presentation of these results in Figure 41.

The fuel tax policy leads to an overall decrease in transport demand. The increase in road transport costs leads to a 0.45% decrease in vehicle-kilometres by 2020. As the remaining budgets of households (after paying for road transport) decreases, there is also a decrease for the non-road modes (income effect). As a result total well-to wheel emissions of CO_2, NO_x and particulates decrease by approximately 0.4% to 0.45%. This is also the case for fuel consumption. The decrease in fuel consumption indicates that the resulting extra tax revenue from the fuel excise increase will be about 0.45% lower than what would be expected initially, i.e. it will be lower than base case fuel consumption times tax increase.

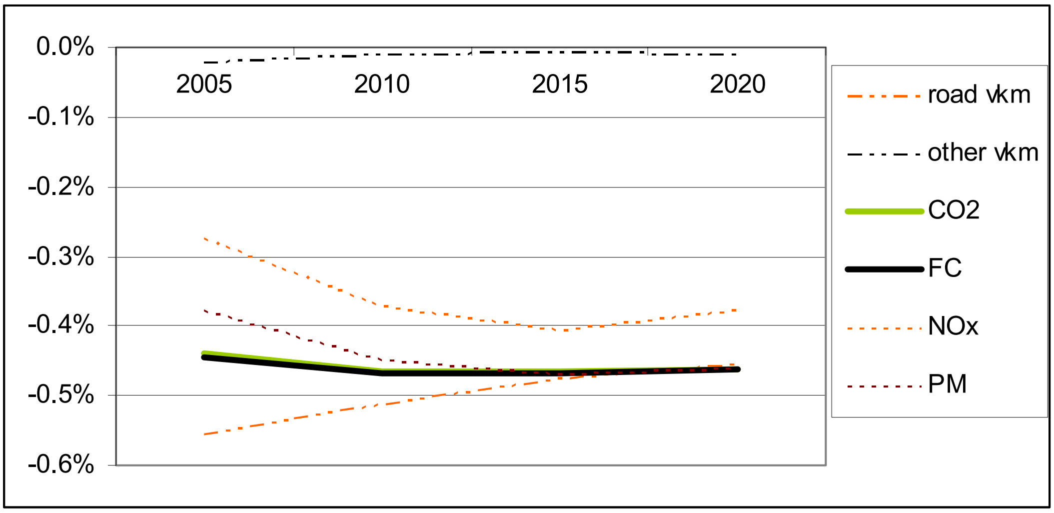

Figure 41: C1 scenario main variables - % reduction compared to base case

2.3. Remarks

TREMOVE enables easily to simulate the direct and indirect effects of road fuel tax policies, as is illustrated by this scenario C1. It is worth to note here that during the Auto-Oil II programme, the TREMOVE 1 model has been used extensively for in-depth analysis of the effects of fuel tax policies.

No EU welfare assessment has been performed for this scenario C1, due to the strict time constraint for this exercise. Though it could be done with a few minor changes in the model. The fact that the extra tax revenues are used for development aid outside the EU could be accounted for in the EU welfare effect calculation. In short, the basic model assumption that tax revenues are redistributed via decreases in labour or general taxes could then be replaced by the assumption that the tax revenues are not redistributed in Europe. Thus, they do not contribute to EU welfare. Estimating the welfare effect of these extra funds in the developing countries (outside EU) of course is outside the scope of the TREMOVE model.

References

AEAT [AEAT, 2004]. *Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. Updated results for BeTa, the Benefits Table Database.* Report to the European Commission, DG Environment.

CONCAWE, EUCAR, JRC [CONCAWE, EUCAR, JRC, 2004]. *Well-to-wheels analysis of future automotive fuels and powertrains in the european context.*

COWI [COWI, 2001]. *Fiscal Measures to Reduce CO_2 Emissions from new Passenger Cars.* Final Report to the European Commission, DG Environment.

Holland M., Hunt A., Hurley F., Navrud S., Watkiss P. (2005). *Final Methodology Paper (Volume 1) for Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme,* report to EC – DG Environment.

IEEP, TNO, CAIR [IEEP, 2004]. *Service contract to carry out economic analysis and business impact assessment of CO_2 emissions reduction measures in the automotive sector.* Final Report to European Commission, DG Environment.

RICARDO [RICARDO, 2003]. *Support for updating the RAINS model concerning road transport.* Final Report.

TML, KUL, WSP, TRT [TML, 2005]. *TREMOVE 2.30 Model and Baseline Description.* Final Report to the European Commission, DG Environment.

TNO, IEEP, LAT [TNO, 2006]. *Review and analysis of the reduction potential and costs of technical and other measures to reduce CO_2 emissions from passenger cars.* Final Report to European Commission, DG Entreprise.

TNO (Gense N.L.J. TNO), RICARDO (Jackson N.), LAT (Samaras Z.) [TNO, 2005a]. *"“Euro 5”" technologies and costs for Light-Duty Vehicles. The expert panels summary of stakeholders responses.* Report to European Commission, DG Environment.

TNO [TNO, 2005b] *Measuring and preparing reduction measures for CO2 emissions from N1 vehicles.* Final report to European Commission, DG Environment.

IER, University of Stuttgart. Friedrich R., Bickel P. [IER, 2001] *Environmental External Costs of Transport.* Springer, 2001.

Proost S. (1997) *Economic evaluation of community options to limit CO_2, SO_2 and NO_x emissions at the horizon 2005 and 2010 – Transport Sector.* Internal report to EC.

Proost S., Van Regenmorter D. (1999) *Are there cost-efficient CO_2 reduction possibilities in the transport sector? – Combining two modelling approaches.* International Journal of Pollution Control, Vol 11 n°23.

Annex A : Analysis of scenario A1 to A15 results

Scenarios A1 to A15 consider the impact of partial "Euro 5" standards on either diesel, either petrol vehicles. In some of the scenarios N1 vehicles trucks are included, in others they are not. Table 1 gives an overview of the scenario definitions. Table 37 to Table 63 summarise the model results for each of the scenarios with the standard (set 1) external cost estimates, and present the sensitivity analysis on external costs (for scenarios A3 to A15). All A1 to A15 scenarios include the basic TREMOVE assumption that maintenance costs are linearly related to vehicle purchase costs, thus increase for "Euro 5" vehicles.

Sections IV1, 2 and 3 discuss the results obtained with the Set 1 external cost estimates. From the sensitivity analysis tables it can be seen that the external cost estimates have a crucial impact on the eventual welfare outcomes, as indicated earlier for A16, A17 and A18.

1. Diesel car emission standards

Scenarios A1 to A9 are settings in which only for diesel cars "Euro 5" limit values would be set.

Of these 9 scenarios, A1 is the scenario with the highest technology costs, as it is the scenario with the most stringent NO_x and PM limit values and as it does not account for possible cost reductions due to economies of scale. As a consequence, this scenario leads to the highest pollution benefits, but also to the highest negative impacts on households and production and service sectors. The overall welfare impact of A1 is strongly negative, with a predicted welfare loss of 6.3 to 7.3 billion EURO.

Scenario A2 is setup identically to A1, except for the fact that it assumes a higher NO_x limit value (150 mg. instead of 75 mg. in A1). As the costs of technology to reach a 75 mg. objective are significantly higher than the costs to reach a 150 mg. standard, the negative effect on household utility and production costs is about 32% lower in A2 compared to A1. The A2 pollution benefits though are only 25% lower than those in scenario A1. Compared to A1, the negative effect on welfare in A2 thus is smaller, i.e. in the order of 1.7 to 2.5 billion EURO. Given the assumptions in these scenarios (no economies of scale, significant extra maintenance costs, ...), the model results thus suggest that the pollution benefits of a 75 mg. .NO_x limit value do not compensate the technology costs. From the A17-A25 results in II3.3.5 however, we remember that with other assumptions (economies of scale and no extra maintenance/repair costs) the outcome is positive.

Scenarios A3, A7, A8 and A9 have the same limit values as A2, but different assumptions on the costs to reach this objective. They thus could be considered as a set of sensitivity analysis scenarios on the cost assumptions. Varying estimates for the cost reductions that could result from economies of scale are used. These scenarios use the average of the costs reported by the expert panel, instead of the min. values used in A2. Also different ways of aggregating the >2.0 litre car costs have been applied. In all these scenarios, the pollution benefits are in the same order of magnitude but not equal. The reported differences in pollution stem from differences in the effects on fleet and demand, which are determined by the level of the "Euro 5" technology costs. The model results indicate that, if average costs and an economies of scale of 40% are assumed (A8 and A9), a positive welfare effect could be attained, even with the assumption of increasing maintenance/repair costs..

Scenario A4 is the scenario with the lowest NO_x limit value for diesel cars (200 mg.). The same assumptions as in A3 are used to calculate the costs. The welfare costs of scenario A4 is lower than that of scenario A3. This indicates that, given the assumptions that are used, the technology costs to reduce NO_x emissions from 200 mg. to 150 mg. are larger than the resulting environmental benefits. Again, from the A17-A25 results in II3.3.5 however, we remember that with other assumptions (economies of scale and no extra maintenance/repair costs) the outcome is different.

Scenarios A5 and A6 are similar to scenarios A3 and A4 respectively, expect for the PM limit value which increases from 2.5 mg. in A3 and A4 mg. to 5 mg. .in A5 and A6. It is important to note however that the panel report indicates that no sufficient information is available on the difference in technology and related costs to reach 2.5 mg. versus 5 mg. Therefore the same costs estimates have been used in scenarios A3 and A5 and in scenarios A4 and A6. As can be seen in the Table 39 and Table 43 this approach results in identical model results for scenario A3 and A5, except for the car particulate emission reductions and the related monetised benefits. These couples of scenarios could be seen as sensitivity analyses on the particulate abatement potential of particulate trap technologies.

2. Diesel car and diesel N1 vehicle emission standards

Scenarios A10 to A13 are settings in which only for diesel cars and diesel N1 vehicles “Euro 5” limit values would be set.

A10 and A11 are similar to A3 and A7 respectively, with the only difference being that in the former scenarios also limit values are set for diesel N1 vehicles. As indicated in section II2.2.1 the same percentages reductions are applied to N1 vehicles as to cars. A11 and A10 differ with respect to the methodology to aggregate the costs for the ‘>2.0 litre standard’ and ‘>2.0 litre large’ car classes. As indicated in section II2.3.2 the approach of A11 is considered to be the most realistic one.

For both A10 and A11 an increase in welfare is calculated, while A3 and A7 lead to a welfare decrease. These results also indicate that, with the assumptions used, it is more cost-effective to reduce diesel N1 vehicle emissions than to reduce diesel car emissions.

Scenario A12 is a sensitivity analysis on the impact of the emission standard on fuel consumption. The comparison between A11 and A12 indicates that, ceteris paribus, the expected 1.5% increase in fuel consumption leads to a welfare decrease of 1.6 to 2.3 million EURO.

3. Petrol car and petrol N1 vehicle emission standards

Scenarios A14 and A15 study the impact of possible “Euro 5” limit values for petrol cars and N1 vehicles. Although, in general, the costs to reach the standards are lower for petrol vehicles than for diesel vehicles, the calculated welfare effect is negative for petrol vehicles. I.e. in these scenarios, and given the assumptions used, the costs to reduce petrol vehicle emissions beyond the Euro 4 levels, is expected to be higher than the predicted environmental benefits.

Table 37: Model results for scenario A1

Scenario A1							
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2138	-1.50%	-12433	-10.70%	-20289	-18.86%
	small car	-187	-1.79%	-1127	-9.97%	-1914	-15.77%
	medium/big car	-1951	-4.74%	-11285	-30.73%	-18323	-51.00%
	moped	0	0.00%	-2	-0.06%	-4	-0.11%
	motorcycle	0	0.00%	-9	-0.08%	-18	-0.15%
	light duty vehicle	0	0.00%	-12	-0.08%	-37	-0.27%
	heavy duty vehicle	0	0.00%	-2	-0.01%	-1	-0.01%
	bus	0	0.00%	0	0.04%	1	0.16%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	3	0.07%	8	0.19%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.01%	1	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-38	-0.11%	-76	-0.19%
Life Cycle emissions	all fuels and electricity	36	0.04%	100	0.10%	121	0.11%
Total emissions		-2101	-0.77%	-12371	-4.88%	-20244	-7.93%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-22797	-0.85%	-131361	-6.23%	-212902	-11.16%
	small car	-2119	-0.82%	-12480	-7.59%	-20900	-15.45%
	medium/big car	-20678	-3.34%	-118484	-24.56%	-191178	-42.95%
	moped	0	0.00%	-13	-0.11%	-27	-0.16%
	motorcycle	0	0.00%	-17	-0.07%	-37	-0.15%
	light duty vehicle	0	0.00%	-443	-0.16%	-989	-0.35%
	heavy duty vehicle	0	0.00%	-33	0.00%	-19	0.00%
	bus	0	0.00%	46	0.12%	91	0.35%
	coach	0	0.00%	16	0.01%	28	0.04%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	45	0.07%	126	0.19%
	freight train	0	0.00%	2	0.00%	3	0.01%
	inland ship	0	0.00%	6	0.01%	11	0.01%
	plane (ground level)	0	0.00%	-6	-0.01%	-10	-0.02%
	plane (high altitude)	0	0.00%	-58	-0.02%	-107	-0.04%
Life Cycle emissions	all fuels and electricity	228	0.04%	618	0.09%	733	0.10%
Total emissions		-22569	-0.64%	-130801	-4.35%	-212276	-7.33%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	100	0.01%	688	0.05%	1268	0.12%
	small car	4	0.00%	316	0.18%	667	0.49%
	medium/big car	97	0.03%	490	0.24%	870	0.49%
	moped	0	0.00%	-75	-0.01%	-150	-0.04%
	motorcycle	0	0.00%	-41	-0.03%	-86	-0.07%
	light duty vehicle	0	0.00%	-10	-0.03%	-57	-0.21%
	heavy duty vehicle	0	0.00%	-9	-0.01%	-13	-0.01%
	bus	0	0.00%	13	0.25%	25	0.59%
	coach	0	0.00%	2	0.02%	5	0.04%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.07%	7	0.19%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.01%	1	0.01%
	plane (ground level)	0	0.00%	-1	-0.01%	-1	-0.02%
High Altitude	plane (high altitude)	0	0.00%	-4	-0.03%	-8	-0.04%
Life Cycle emissions	all fuels and electricity	295	0.03%	714	0.07%	766	0.07%
Total emissions		396	0.01%	1402	0.06%	2033	0.10%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-4233		-8568	
(Production costs)		0		-848		-1612	
Extra public funds (general)		0		210		373	
Extra public funds (labour)		0		352		623	
Total welfare effect w/o pollution benefits (labour)		0		-4870		-9807	
Total welfare effect w/o pollution benefits (general)		0		-4729		-9557	
Pollution benefits - Set 1		672		3921		6346	
Welfare (general)		672		-950		-3461	
Welfare (labour)		672		-808		-3211	
Welfare NPV (general)	**-7275**						
Welfare NPV (labour)	**-6345**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		-0.1		-0.1	
Pollution benefit CO2		-4.0		-12.0		-15.2	
Pollution benefit N2O		0.0		0.6		1.6	
Pollution benefit Nox		394.9		2274.8		3685.4	
Pollution benefit PM		296.8		1705.6		2738.2	
Pollution benefit SO2		-14.1		-43.7		-57.7	
Pollution benefit VOC		-1.5		-4.7		-6.2	

Table 38: Model results for scenario A2

Scenario A2

PM emissions - All Countries

		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2158	-1.52%	-12497	-10.75%	-20348	-18.91%
	small car	-190	-1.83%	-1146	-10.13%	-1942	-15.99%
	medium/big car	-1968	-4.78%	-11337	-30.87%	-18371	-51.13%
	moped	0	0.00%	-1	-0.04%	-3	-0.07%
	motorcycle	0	0.00%	-6	-0.05%	-12	-0.10%
	light duty vehicle	0	0.00%	-8	-0.05%	-26	-0.19%
	heavy duty vehicle	0	0.00%	-1	-0.01%	-1	-0.01%
	bus	0	0.00%	0	0.03%	1	0.11%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.00%	1	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-26	-0.07%	-51	-0.13%
Life Cycle emissions	all fuels and electricity	31	0.03%	104	0.10%	139	0.13%
Total emissions		-2127	-0.78%	-12419	-4.90%	-20259	-7.94%

NOx emissions - All Countries

		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-13285	-0.49%	-76753	-3.64%	-124433	-6.52%
	small car	-1257	-0.49%	-7364	-4.48%	-12308	-9.10%
	medium/big car	-12028	-1.95%	-69120	-14.33%	-111563	-25.06%
	moped	0	0.00%	-9	-0.07%	-18	-0.11%
	motorcycle	0	0.00%	-11	-0.05%	-25	-0.10%
	light duty vehicle	0	0.00%	-302	-0.11%	-675	-0.24%
	heavy duty vehicle	0	0.00%	-22	0.00%	-13	0.00%
	bus	0	0.00%	31	0.08%	62	0.23%
	coach	0	0.00%	11	0.01%	19	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	32	0.05%	87	0.13%
	freight train	0	0.00%	1	0.00%	2	0.01%
	inland ship	0	0.00%	4	0.00%	8	0.01%
	plane (ground level)	0	0.00%	-4	-0.01%	-7	-0.01%
	plane (high altitude)	0	0.00%	-39	-0.02%	-73	-0.03%
Life Cycle emissions	all fuels and electricity	194	0.03%	650	0.10%	869	0.12%
Total emissions		-13091	-0.37%	-76142	-2.54%	-123636	-4.27%

VOC emissions - All Countries

		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	64	0.00%	417	0.03%	769	0.07%
	small car	2	0.00%	200	0.12%	426	0.32%
	medium/big car	62	0.02%	295	0.15%	522	0.30%
	moped	0	0.00%	-49	-0.01%	-98	-0.03%
	motorcycle	0	0.00%	-27	-0.02%	-57	-0.05%
	light duty vehicle	0	0.00%	-7	-0.02%	-39	-0.15%
	heavy duty vehicle	0	0.00%	-6	0.00%	-8	0.00%
	bus	0	0.00%	9	0.17%	17	0.40%
	coach	0	0.00%	2	0.01%	3	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-3	-0.02%	-6	-0.03%
Life Cycle emissions	all fuels and electricity	262	0.03%	840	0.09%	1093	0.10%
Total emissions		326	0.01%	1258	0.06%	1862	0.09%

Welfare analysis - All Countries

	2005	2010	2015	2020
		Difference (euro)	Difference (euro)	Difference (euro)
Utility of households		0	-2861	-5802
(Production costs)		0	-573	-1091
Extra public funds (general)		0	178	316
Extra public funds (labour)		0	298	527
Total welfare effect w/o pollution benefits (labour)		0	-3256	-6577
Total welfare effect w/o pollution benefits (general)		0	-3137	-6366
Pollution benefits - Set 1		511	2970	4792
Welfare (general)		511	-287	-1786
Welfare (labour)		511	-167	-1575
Welfare NPV (general)	**-2547**			
Welfare NPV (labour)	**-1761**			
Decomposition external pollution cost - Set 1				
Pollution benefit CO		0.0	0.0	-0.1
Pollution benefit CO2		-3.6	-14.9	-23.9
Pollution benefit N2O		0.0	0.4	1.1
Pollution benefit Nox		228.8	1323.0	2144.4
Pollution benefit PM		298.4	1706.2	2732.7
Pollution benefit SO2		-11.4	-40.3	-56.3
Pollution benefit VOC		-1.3	-4.5	-6.4

Table 39: Model results for scenario A3

Scenario A3							
				PM emissions - All Countries			
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2159	-1.52%	-12499	-10.75%	-20350	-18.91%
	small car	-191	-1.83%	-1146	-10.14%	-1943	-16.00%
	medium/big car	-1968	-4.78%	-11339	-30.87%	-18373	-51.14%
	moped	0	0.00%	-1	-0.04%	-3	-0.07%
	motorcycle	0	0.00%	-6	-0.05%	-12	-0.10%
	light duty vehicle	0	0.00%	-8	-0.05%	-25	-0.18%
	heavy duty vehicle	0	0.00%	-1	-0.01%	-1	-0.01%
	bus	0	0.00%	0	0.03%	1	0.11%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.00%	1	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-25	-0.07%	-50	-0.13%
Life Cycle emissions	all fuels and electricity	31	0.03%	104	0.10%	140	0.13%
Total emissions		-2128	-0.78%	-12421	-4.90%	-20260	-7.94%
				NOx emissions - All Countries			
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-13280	-0.49%	-76712	-3.64%	-124345	-6.52%
	small car	-1254	-0.49%	-7350	-4.47%	-12286	-9.08%
	medium/big car	-12026	-1.94%	-69096	-14.32%	-111506	-25.05%
	moped	0	0.00%	-9	-0.07%	-17	-0.10%
	motorcycle	0	0.00%	-11	-0.05%	-24	-0.10%
	light duty vehicle	0	0.00%	-299	-0.11%	-665	-0.24%
	heavy duty vehicle	0	0.00%	-22	0.00%	-12	0.00%
	bus	0	0.00%	31	0.08%	60	0.23%
	coach	0	0.00%	10	0.01%	19	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	31	0.05%	85	0.13%
	freight train	0	0.00%	1	0.00%	2	0.01%
	inland ship	0	0.00%	4	0.00%	8	0.01%
	plane (ground level)	0	0.00%	-4	-0.01%	-7	-0.01%
	plane (high altitude)	0	0.00%	-38	-0.02%	-72	-0.03%
Life Cycle emissions	all fuels and electricity	194	0.03%	650	0.10%	874	0.12%
Total emissions		-13086	-0.37%	-76100	-2.53%	-123542	-4.27%
				VOC emissions - All Countries			
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	63	0.00%	406	0.03%	746	0.07%
	small car	2	0.00%	196	0.11%	416	0.31%
	medium/big car	61	0.02%	287	0.14%	506	0.29%
	moped	0	0.00%	-48	-0.01%	-96	-0.03%
	motorcycle	0	0.00%	-27	-0.02%	-56	-0.05%
	light duty vehicle	0	0.00%	-7	-0.02%	-39	-0.14%
	heavy duty vehicle	0	0.00%	-6	0.00%	-8	0.00%
	bus	0	0.00%	8	0.17%	17	0.39%
	coach	0	0.00%	2	0.01%	3	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-3	-0.02%	-6	-0.03%
Life Cycle emissions	all fuels and electricity	261	0.03%	844	0.09%	1106	0.11%
Total emissions		324	0.01%	1250	0.06%	1852	0.09%
				Welfare analysis - All Countries			
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2824		-5702	
(Production costs)		0		-566		-1072	
Extra public funds (general)		0		177		314	
Extra public funds (labour)		0		296		523	
Total welfare effect w/o pollution benefits (labour)		0		-3213		-6460	
Total welfare effect w/o pollution benefits (general)		0		-3094		-6251	
Pollution benefits - Set 1		511		2969		4790	
Welfare (general)		511		-243		-1671	
Welfare (labour)		511		-125		-1461	
Welfare NPV (general)	**-2218**						
Welfare NPV (labour)	**-1437**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		-0.1	
Pollution benefit CO2		-3.6		-15.0		-24.2	
Pollution benefit N2O		0.0		0.4		1.0	
Pollution benefit Nox		228.7		1322.3		2142.9	
Pollution benefit PM		298.4		1706.2		2732.5	
Pollution benefit SO2		-11.3		-40.1		-56.2	
Pollution benefit VOC		-1.3		-4.5		-6.4	

Table 40: A3 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A3		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-3163	-6354
Total welfare effect w/o pollution benefits (labour)	-3045	-6145
Pollution benefits - Set 1	2939	4739
Pollution benefits - Set 2	951	1543
Pollution benefits - Set 3	1473	2389
Pollution benefits - Set 4	1824	2961
Pollution benefits - Set 5	2710	4399
Welfare - Set 1 - General	-224	-1615
Welfare - Set 1 - Labour	-105	-1406
Welfare - Set 2 - General	-2212	-4811
Welfare - Set 2 - Labour	-2094	-4602
Welfare - Set 3 - General	-1690	-3965
Welfare - Set 3 - Labour	-1572	-3756
Welfare - Set 4 - General	-1339	-3393
Welfare - Set 4 - Labour	-1221	-3184
Welfare - Set 5 - General	-453	-1955
Welfare - Set 5 - Labour	-334	-1746

Table 41: Model results for scenario A4

Scenario A4							
PM emissions - All Countries							
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2167	-1.52%	-12524	-10.78%	-20372	-18.93%
	small car	-192	-1.84%	-1153	-10.20%	-1953	-16.08%
	medium/big car	-1975	-4.79%	-11360	-30.93%	-18391	-51.19%
	moped	0	0.00%	-1	-0.03%	-2	-0.06%
	motorcycle	0	0.00%	-4	-0.04%	-9	-0.08%
	light duty vehicle	0	0.00%	-7	-0.04%	-20	-0.15%
	heavy duty vehicle	0	0.00%	-1	0.00%	-1	-0.01%
	bus	0	0.00%	0	0.02%	1	0.09%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	4	0.10%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-20	-0.06%	-40	-0.10%
Life Cycle emissions	all fuels and electricity	28	0.03%	105	0.10%	148	0.14%
Total emissions		-2138	-0.78%	-12439	-4.90%	-20264	-7.94%
NOx emissions - All Countries							
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-6839	-0.25%	-39757	-1.89%	-64580	-3.39%
	small car	-666	-0.26%	-3842	-2.34%	-6392	-4.73%
	medium/big car	-6173	-1.00%	-35703	-7.40%	-57747	-12.97%
	moped	0	0.00%	-7	-0.05%	-14	-0.08%
	motorcycle	0	0.00%	-9	-0.04%	-19	-0.08%
	light duty vehicle	0	0.00%	-239	-0.09%	-532	-0.19%
	heavy duty vehicle	0	0.00%	-17	0.00%	-10	0.00%
	bus	0	0.00%	25	0.06%	48	0.18%
	coach	0	0.00%	8	0.01%	15	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	26	0.04%	69	0.10%
	freight train	0	0.00%	1	0.00%	1	0.00%
	inland ship	0	0.00%	3	0.00%	6	0.01%
	plane (ground level)	0	0.00%	-3	-0.01%	-6	-0.01%
	plane (high altitude)	0	0.00%	-31	-0.01%	-57	-0.02%
Life Cycle emissions	all fuels and electricity	180	0.03%	665	0.10%	932	0.13%
Total emissions		-6659	-0.19%	-39123	-1.30%	-63705	-2.20%
VOC emissions - All Countries							
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	48	0.00%	303	0.02%	557	0.05%
	small car	2	0.00%	153	0.09%	324	0.24%
	medium/big car	47	0.02%	211	0.10%	371	0.21%
	moped	0	0.00%	-38	-0.01%	-75	-0.02%
	motorcycle	0	0.00%	-21	-0.02%	-44	-0.04%
	light duty vehicle	0	0.00%	-6	-0.02%	-31	-0.12%
	heavy duty vehicle	0	0.00%	-5	0.00%	-7	0.00%
	bus	0	0.00%	7	0.13%	13	0.31%
	coach	0	0.00%	1	0.01%	2	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.04%	4	0.10%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-2	-0.01%	-4	-0.02%
Life Cycle emissions	all fuels and electricity	247	0.03%	896	0.09%	1240	0.12%
Total emissions		296	0.01%	1199	0.05%	1797	0.09%
Welfare analysis - All Countries							
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2263		-4568	
(Production costs)		0		-453		-859	
Extra public funds (general)		0		165		292	
Extra public funds (labour)		0		275		486	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		400		2326		3745	
Welfare (general)		400		-225		-1391	
Welfare (labour)		400		-115		-1196	
Welfare NPV (general)	**-1985**						
Welfare NPV (labour)	**-1261**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		-0.1	
Pollution benefit CO2		-3.4		-16.1		-27.7	
Pollution benefit N2O		0.0		0.3		0.8	
Pollution benefit Nox		116.2		679.0		1103.7	
Pollution benefit PM		299.1		1706.4		2730.3	
Pollution benefit SO2		-10.3		-39.0		-56.0	
Pollution benefit VOC		-1.2		-4.4		-6.5	

Table 42: A4 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A4		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2508	-5044
Total welfare effect w/o pollution benefits (labour)	-2399	-4850
Pollution benefits - Set 1	2303	3706
Pollution benefits - Set 2	717	1162
Pollution benefits - Set 3	1112	1803
Pollution benefits - Set 4	1394	2261
Pollution benefits - Set 5	2076	3368
Welfare - Set 1 - General	-205	-1338
Welfare - Set 1 - Labour	-95	-1144
Welfare - Set 2 - General	-1791	-3882
Welfare - Set 2 - Labour	-1682	-3689
Welfare - Set 3 - General	-1396	-3241
Welfare - Set 3 - Labour	-1286	-3047
Welfare - Set 4 - General	-1115	-2783
Welfare - Set 4 - Labour	-1005	-2589
Welfare - Set 5 - General	-433	-1676
Welfare - Set 5 - Labour	-323	-1482

Table 43: Model results for scenario A5

Scenario A5							
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-1921	-1.35%	-11138	-9.58%	-18142	-16.86%
	small car	-170	-1.63%	-1022	-9.04%	-1732	-14.26%
	medium/big car	-1751	-4.25%	-10103	-27.51%	-16376	-45.58%
	moped	0	0.00%	-1	-0.04%	-3	-0.07%
	motorcycle	0	0.00%	-6	-0.05%	-12	-0.10%
	light duty vehicle	0	0.00%	-8	-0.05%	-25	-0.18%
	heavy duty vehicle	0	0.00%	-1	-0.01%	-1	-0.01%
	bus	0	0.00%	0	0.03%	1	0.11%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.00%	1	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-25	-0.07%	-50	-0.13%
Life Cycle emissions	all fuels and electricity	31	0.03%	104	0.10%	140	0.13%
Total emissions		-1891	-0.69%	-11060	-4.36%	-18052	-7.08%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-13280	-0.49%	-76712	-3.64%	-124345	-6.52%
	small car	-1254	-0.49%	-7350	-4.47%	-12286	-9.08%
	medium/big car	-12026	-1.94%	-69096	-14.32%	-111506	-25.05%
	moped	0	0.00%	-9	-0.07%	-17	-0.10%
	motorcycle	0	0.00%	-11	-0.05%	-24	-0.10%
	light duty vehicle	0	0.00%	-299	-0.11%	-665	-0.24%
	heavy duty vehicle	0	0.00%	-22	0.00%	-12	0.00%
	bus	0	0.00%	31	0.08%	60	0.23%
	coach	0	0.00%	10	0.01%	19	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	31	0.05%	85	0.13%
	freight train	0	0.00%	1	0.00%	2	0.01%
	inland ship	0	0.00%	4	0.00%	8	0.01%
	plane (ground level)	0	0.00%	-4	-0.01%	-7	-0.01%
	plane (high altitude)	0	0.00%	-38	-0.02%	-72	-0.03%
Life Cycle emissions	all fuels and electricity	194	0.03%	650	0.10%	874	0.12%
Total emissions		-13086	-0.37%	-76100	-2.53%	-123542	-4.27%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	63	0.00%	406	0.03%	746	0.07%
	small car	2	0.00%	196	0.11%	416	0.31%
	medium/big car	61	0.02%	287	0.14%	506	0.29%
	moped	0	0.00%	-48	-0.01%	-96	-0.03%
	motorcycle	0	0.00%	-27	-0.02%	-56	-0.05%
	light duty vehicle	0	0.00%	-7	-0.02%	-39	-0.14%
	heavy duty vehicle	0	0.00%	-6	0.00%	-8	0.00%
	bus	0	0.00%	8	0.17%	17	0.39%
	coach	0	0.00%	2	0.01%	3	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	0	0.00%	0	0.01%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-3	-0.02%	-6	-0.03%
Life Cycle emissions	all fuels and electricity	261	0.03%	844	0.09%	1106	0.11%
Total emissions		324	0.01%	1250	0.06%	1852	0.09%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2824		-5702	
(Production costs)		0		-566		-1072	
Extra public funds (general)		0		177		314	
Extra public funds (labour)		0		296		523	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		478		2784		4494	
Welfare (general)		478		-429		-1967	
Welfare (labour)		478		-310		-1757	
Welfare NPV (general)	**-3466**						
Welfare NPV (labour)	**-2685**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		-0.1	
Pollution benefit CO2		-3.6		-15.0		-24.2	
Pollution benefit N2O		0.0		0.4		1.0	
Pollution benefit Nox		228.7		1322.3		2142.9	
Pollution benefit PM		265.6		1520.6		2436.5	
Pollution benefit SO2		-11.3		-40.1		-56.2	
Pollution benefit VOC		-1.3		-4.5		-6.4	

Table 44: A5 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A5		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-3163	-6354
Total welfare effect w/o pollution benefits (labour)	-3045	-6145
Pollution benefits - Set 1	2756	4446
Pollution benefits - Set 2	896	1454
Pollution benefits - Set 3	1389	2253
Pollution benefits - Set 4	1716	2788
Pollution benefits - Set 5	2550	4141
Welfare - Set 1 - General	-407	-1908
Welfare - Set 1 - Labour	-289	-1699
Welfare - Set 2 - General	-2267	-4899
Welfare - Set 2 - Labour	-2148	-4690
Welfare - Set 3 - General	-1774	-4101
Welfare - Set 3 - Labour	-1656	-3892
Welfare - Set 4 - General	-1447	-3566
Welfare - Set 4 - Labour	-1328	-3357
Welfare - Set 5 - General	-613	-2213
Welfare - Set 5 - Labour	-494	-2004

Table 45: Model results for scenario A6

Scenario A6

PM emissions - All Countries

		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-1928	-1.35%	-11154	-9.60%	-18149	-16.87%
	small car	-171	-1.64%	-1027	-9.08%	-1739	-14.32%
	medium/big car	-1757	-4.27%	-10116	-27.54%	-16383	-45.60%
	moped	0	0.00%	-1	-0.03%	-2	-0.06%
	motorcycle	0	0.00%	-4	-0.04%	-9	-0.08%
	light duty vehicle	0	0.00%	-7	-0.04%	-20	-0.15%
	heavy duty vehicle	0	0.00%	-1	0.00%	-1	-0.01%
	bus	0	0.00%	0	0.02%	1	0.09%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	4	0.10%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-20	-0.06%	-40	-0.10%
Life Cycle emissions	all fuels and electricity	28	0.03%	105	0.10%	148	0.14%
Total emissions		-1899	-0.69%	-11069	-4.36%	-18041	-7.07%

NOx emissions - All Countries

		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-6839	-0.25%	-39757	-1.89%	-64580	-3.39%
	small car	-666	-0.26%	-3842	-2.34%	-6392	-4.73%
	medium/big car	-6173	-1.00%	-35703	-7.40%	-57747	-12.97%
	moped	0	0.00%	-7	-0.05%	-14	-0.08%
	motorcycle	0	0.00%	-9	-0.04%	-19	-0.08%
	light duty vehicle	0	0.00%	-239	-0.09%	-532	-0.19%
	heavy duty vehicle	0	0.00%	-17	0.00%	-10	0.00%
	bus	0	0.00%	25	0.06%	48	0.18%
	coach	0	0.00%	8	0.01%	15	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	26	0.04%	69	0.10%
	freight train	0	0.00%	1	0.00%	1	0.00%
	inland ship	0	0.00%	3	0.00%	6	0.01%
	plane (ground level)	0	0.00%	-3	-0.01%	-6	-0.01%
	plane (high altitude)	0	0.00%	-31	-0.01%	-57	-0.02%
Life Cycle emissions	all fuels and electricity	180	0.03%	665	0.10%	932	0.13%
Total emissions		-6659	-0.19%	-39123	-1.30%	-63705	-2.20%

VOC emissions - All Countries

		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	48	0.00%	303	0.02%	557	0.05%
	small car	2	0.00%	153	0.09%	324	0.24%
	medium/big car	47	0.02%	211	0.10%	371	0.21%
	moped	0	0.00%	-38	-0.01%	-75	-0.02%
	motorcycle	0	0.00%	-21	-0.02%	-44	-0.04%
	light duty vehicle	0	0.00%	-6	-0.02%	-31	-0.12%
	heavy duty vehicle	0	0.00%	-5	0.00%	-7	0.00%
	bus	0	0.00%	7	0.13%	13	0.31%
	coach	0	0.00%	1	0.01%	2	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.04%	4	0.10%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-2	-0.01%	-4	-0.02%
Life Cycle emissions	all fuels and electricity	247	0.03%	896	0.09%	1240	0.12%
Total emissions		296	0.01%	1199	0.05%	1797	0.09%

Welfare analysis - All Countries

	2005	2010	2015	2020
		Difference (euro)	Difference (euro)	Difference (euro)
Utility of households		0	-2263	-4568
(Production costs)		0	-453	-859
Extra public funds (general)		0	165	292
Extra public funds (labour)		0	275	486
Total welfare effect w/o pollution benefits (labour)		0	-2551	-5135
Total welfare effect w/o pollution benefits (general)		0	-2441	-4941
Decomposition external pollution cost - Set 1		367	2139	3447
Welfare (general)		367	-411	-1688
Welfare (labour)		367	-301	-1494
Welfare NPV (general)	**-3241**			
Welfare NPV (labour)	**-2516**			
Decomposition external pollution cost				
Pollution benefit CO		0.0	0.0	-0.1
Pollution benefit CO2		-3.4	-16.1	-27.7
Pollution benefit N2O		0.0	0.3	0.8
Pollution benefit Nox		116.2	679.0	1103.7
Pollution benefit PM		266.0	1519.7	2432.5
Pollution benefit SO2		-10.3	-39.0	-56.0
Pollution benefit VOC		-1.2	-4.4	-6.5

Table 46: A6 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A6		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2508	-5044
Total welfare effect w/o pollution benefits (labour)	-2399	-4850
Pollution benefits - Set 1	2118	3411
Pollution benefits - Set 2	662	1073
Pollution benefits - Set 3	1028	1667
Pollution benefits - Set 4	1285	2086
Pollution benefits - Set 5	1915	3109
Welfare - Set 1 - General	-390	-1633
Welfare - Set 1 - Labour	-280	-1439
Welfare - Set 2 - General	-1846	-3971
Welfare - Set 2 - Labour	-1737	-3777
Welfare - Set 3 - General	-1481	-3377
Welfare - Set 3 - Labour	-1371	-3183
Welfare - Set 4 - General	-1223	-2958
Welfare - Set 4 - Labour	-1113	-2764
Welfare - Set 5 - General	-593	-1935
Welfare - Set 5 - Labour	-484	-1742

Table 47: Model results for scenario A7

Scenario A7							
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2160	-1.52%	-12502	-10.76%	-20352	-18.91%
	small car	-191	-1.83%	-1147	-10.15%	-1944	-16.01%
	medium/big car	-1970	-4.78%	-11342	-30.88%	-18375	-51.15%
	moped	0	0.00%	-1	-0.04%	-3	-0.07%
	motorcycle	0	0.00%	-5	-0.05%	-11	-0.10%
	light duty vehicle	0	0.00%	-8	-0.05%	-24	-0.17%
	heavy duty vehicle	0	0.00%	-1	-0.01%	-1	-0.01%
	bus	0	0.00%	0	0.02%	1	0.10%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	5	0.12%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-24	-0.07%	-47	-0.12%
Life Cycle emissions	all fuels and electricity	30	0.03%	104	0.10%	142	0.13%
Total emissions		-2130	-0.78%	-12422	-4.90%	-20257	-7.94%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-13270	-0.49%	-76623	-3.63%	-124183	-6.51%
	small car	-1254	-0.49%	-7355	-4.47%	-12300	-9.09%
	medium/big car	-12017	-1.94%	-69017	-14.31%	-111360	-25.02%
	moped	0	0.00%	-8	-0.07%	-17	-0.10%
	motorcycle	0	0.00%	-10	-0.05%	-23	-0.09%
	light duty vehicle	0	0.00%	-282	-0.10%	-629	-0.22%
	heavy duty vehicle	0	0.00%	-20	0.00%	-12	0.00%
	bus	0	0.00%	29	0.08%	57	0.22%
	coach	0	0.00%	10	0.01%	18	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	29	0.04%	81	0.12%
	freight train	0	0.00%	1	0.00%	2	0.00%
	inland ship	0	0.00%	4	0.00%	7	0.01%
	plane (ground level)	0	0.00%	-4	-0.01%	-7	-0.01%
	plane (high altitude)	0	0.00%	-36	-0.02%	-68	-0.02%
Life Cycle emissions	all fuels and electricity	190	0.03%	655	0.10%	890	0.13%
Total emissions		-13080	-0.37%	-76004	-2.53%	-123360	-4.26%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	61	0.00%	397	0.03%	731	0.07%
	small car	2	0.00%	188	0.11%	400	0.30%
	medium/big car	59	0.02%	282	0.14%	500	0.28%
	moped	0	0.00%	-46	-0.01%	-93	-0.02%
	motorcycle	0	0.00%	-26	-0.02%	-54	-0.04%
	light duty vehicle	0	0.00%	-6	-0.02%	-37	-0.14%
	heavy duty vehicle	0	0.00%	-6	0.00%	-8	0.00%
	bus	0	0.00%	8	0.16%	16	0.37%
	coach	0	0.00%	1	0.01%	3	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	4	0.12%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-3	-0.02%	-5	-0.02%
Life Cycle emissions	all fuels and electricity	257	0.03%	856	0.09%	1136	0.11%
Total emissions		318	0.01%	1253	0.06%	1868	0.09%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2670		-5398	
(Production costs)		0		-534		-1014	
Extra public funds (general)		0		175		310	
Extra public funds (labour)		0		292		517	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		511		2967		4785	
Welfare (general)		511		-62		-1317	
Welfare (labour)		511		55		-1111	
Welfare NPV (general)	**-969**						
Welfare NPV (labour)	**-200**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		-0.1	
Pollution benefit CO2		-3.5		-15.2		-25.0	
Pollution benefit N2O		0.0		0.4		1.0	
Pollution benefit Nox		228.6		1320.5		2139.6	
Pollution benefit PM		298.6		1706.1		2731.9	
Pollution benefit SO2		-11.1		-40.1		-56.5	
Pollution benefit VOC		-1.2		-4.5		-6.5	

Table 48: A7 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A7		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2984	-6006
Total welfare effect w/o pollution benefits (labour)	-2868	-5800
Pollution benefits - Set 1	2937	4734
Pollution benefits - Set 2	950	1540
Pollution benefits - Set 3	1471	2386
Pollution benefits - Set 4	1823	2957
Pollution benefits - Set 5	2708	4394
Welfare - Set 1 - General	-47	-1272
Welfare - Set 1 - Labour	70	-1066
Welfare - Set 2 - General	-2034	-4466
Welfare - Set 2 - Labour	-1918	-4260
Welfare - Set 3 - General	-1513	-3620
Welfare - Set 3 - Labour	-1396	-3414
Welfare - Set 4 - General	-1162	-3049
Welfare - Set 4 - Labour	-1045	-2843
Welfare - Set 5 - General	-276	-1612
Welfare - Set 5 - Labour	-159	-1406

Table 49: Model results for scenario A8

		Scenario A8					
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2165	-1.52%	-12518	-10.77%	-20368	-18.93%
	small car	-191	-1.83%	-1151	-10.19%	-1951	-16.07%
	medium/big car	-1973	-4.79%	-11355	-30.92%	-18388	-51.18%
	moped	0	0.00%	-1	-0.03%	-2	-0.05%
	motorcycle	0	0.00%	-5	-0.04%	-10	-0.08%
	light duty vehicle	0	0.00%	-7	-0.05%	-21	-0.15%
	heavy duty vehicle	0	0.00%	-1	0.00%	-1	-0.01%
	bus	0	0.00%	0	0.02%	1	0.09%
	coach	0	0.00%	0	0.00%	0	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	4	0.11%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-21	-0.06%	-42	-0.11%
Life Cycle emissions	all fuels and electricity	29	0.03%	104	0.10%	145	0.13%
Total emissions		-2136	-0.78%	-12436	-4.90%	-20265	-7.94%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-13235	-0.49%	-76370	-3.62%	-123681	-6.49%
	small car	-1244	-0.48%	-7319	-4.45%	-12239	-9.05%
	medium/big car	-11991	-1.94%	-68833	-14.27%	-110987	-24.93%
	moped	0	0.00%	-7	-0.05%	-13	-0.08%
	motorcycle	0	0.00%	-9	-0.04%	-20	-0.08%
	light duty vehicle	0	0.00%	-250	-0.09%	-551	-0.20%
	heavy duty vehicle	0	0.00%	-18	0.00%	-10	0.00%
	bus	0	0.00%	26	0.07%	50	0.19%
	coach	0	0.00%	9	0.01%	15	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	31	0.05%	73	0.11%
	freight train	0	0.00%	1	0.00%	1	0.00%
	inland ship	0	0.00%	3	0.00%	7	0.01%
	plane (ground level)	0	0.00%	-3	-0.01%	-6	-0.01%
	plane (high altitude)	0	0.00%	-32	-0.01%	-60	-0.02%
Life Cycle emissions	all fuels and electricity	183	0.03%	658	0.10%	912	0.13%
Total emissions		-13052	-0.37%	-75745	-2.52%	-122829	-4.24%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	42	0.00%	278	0.02%	504	0.05%
	small car	1	0.00%	160	0.09%	336	0.25%
	medium/big car	41	0.01%	182	0.09%	311	0.18%
	moped	0	0.00%	-38	-0.01%	-75	-0.02%
	motorcycle	0	0.00%	-22	-0.02%	-46	-0.04%
	light duty vehicle	0	0.00%	-7	-0.02%	-33	-0.12%
	heavy duty vehicle	0	0.00%	-5	0.00%	-7	0.00%
	bus	0	0.00%	7	0.13%	13	0.30%
	coach	0	0.00%	1	0.01%	2	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	4	0.11%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.01%
	plane (ground level)	0	0.00%	0	-0.01%	-1	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-3	-0.01%	-5	-0.02%
Life Cycle emissions	all fuels and electricity	249	0.03%	878	0.09%	1200	0.11%
Total emissions		292	0.01%	1156	0.05%	1705	0.08%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2384		-4800	
(Production costs)		0		-474		-897	
Extra public funds (general)		0		168		297	
Extra public funds (labour)		0		281		496	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		512		2964		4774	
Welfare (general)		512		274		-625	
Welfare (labour)		512		386		-427	
Welfare NPV (general)	**1374**						
Welfare NPV (labour)	**2116**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		-0.1	
Pollution benefit CO2		-3.4		-15.8		-26.8	
Pollution benefit N2O		0.0		0.3		0.8	
Pollution benefit Nox		228.2		1316.3		2131.1	
Pollution benefit PM		298.9		1706.3		2730.8	
Pollution benefit SO2		-10.5		-39.1		-55.7	
Pollution benefit VOC		-1.2		-4.3		-6.2	

Table 50: A8 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A8		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2699	-5426
Total welfare effect w/o pollution benefits (labour)	-2586	-5227
Pollution benefits - Set 1	2934	4724
Pollution benefits - Set 2	949	1536
Pollution benefits - Set 3	1470	2381
Pollution benefits - Set 4	1821	2951
Pollution benefits - Set 5	2706	4386
Welfare - Set 1 - General	235	-702
Welfare - Set 1 - Labour	348	-503
Welfare - Set 2 - General	-1750	-3890
Welfare - Set 2 - Labour	-1637	-3690
Welfare - Set 3 - General	-1229	-3045
Welfare - Set 3 - Labour	-1116	-2846
Welfare - Set 4 - General	-878	-2475
Welfare - Set 4 - Labour	-765	-2275
Welfare - Set 5 - General	7	-1040
Welfare - Set 5 - Labour	120	-841

Table 51: Model results for scenario A9

Scenario A9							
				PM emissions - All Countries			
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2175	-1.53%	-12548	-10.80%	-20391	-18.95%
	small car	-193	-1.85%	-1160	-10.26%	-1964	-16.17%
	medium/big car	-1982	-4.81%	-11381	-30.99%	-18410	-51.24%
	moped	0	0.00%	-1	-0.02%	-1	-0.04%
	motorcycle	0	0.00%	-3	-0.03%	-6	-0.05%
	light duty vehicle	0	0.00%	-4	-0.03%	-13	-0.09%
	heavy duty vehicle	0	0.00%	-1	0.00%	0	0.00%
	bus	0	0.00%	0	0.01%	0	0.06%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.02%	3	0.07%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.00%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-13	-0.04%	-26	-0.07%
Life Cycle emissions	all fuels and electricity	26	0.03%	108	0.11%	160	0.15%
Total emissions		-2149	-0.78%	-12453	-4.91%	-20257	-7.94%
				NOx emissions - All Countries			
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-13153	-0.49%	-75700	-3.59%	-122448	-6.42%
	small car	-1219	-0.47%	-7229	-4.39%	-12127	-8.97%
	medium/big car	-11934	-1.93%	-68332	-14.17%	-110037	-24.72%
	moped	0	0.00%	-5	-0.04%	-9	-0.05%
	motorcycle	0	0.00%	-6	-0.03%	-13	-0.05%
	light duty vehicle	0	0.00%	-156	-0.06%	-343	-0.12%
	heavy duty vehicle	0	0.00%	-11	0.00%	-6	0.00%
	bus	0	0.00%	17	0.04%	32	0.12%
	coach	0	0.00%	5	0.00%	9	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	16	0.02%	45	0.07%
	freight train	0	0.00%	1	0.00%	1	0.00%
	inland ship	0	0.00%	2	0.00%	4	0.00%
	plane (ground level)	0	0.00%	-2	-0.01%	-4	-0.01%
	plane (high altitude)	0	0.00%	-20	-0.01%	-37	-0.01%
Life Cycle emissions	all fuels and electricity	163	0.03%	690	0.10%	1019	0.15%
Total emissions		-12990	-0.37%	-75030	-2.50%	-121466	-4.20%
				VOC emissions - All Countries			
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	33	0.00%	208	0.02%	387	0.04%
	small car	1	0.00%	102	0.06%	216	0.16%
	medium/big car	32	0.01%	146	0.07%	262	0.15%
	moped	0	0.00%	-25	-0.01%	-50	-0.01%
	motorcycle	0	0.00%	-14	-0.01%	-29	-0.02%
	light duty vehicle	0	0.00%	-4	-0.01%	-20	-0.07%
	heavy duty vehicle	0	0.00%	-3	0.00%	-4	0.00%
	bus	0	0.00%	5	0.09%	9	0.21%
	coach	0	0.00%	1	0.01%	2	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.02%	2	0.07%
	freight train	0	0.00%	0	0.00%	0	0.00%
	inland ship	0	0.00%	0	0.00%	0	0.00%
	plane (ground level)	0	0.00%	0	0.00%	0	-0.01%
High Altitude	plane (high altitude)	0	0.00%	-2	-0.01%	-3	-0.01%
Life Cycle emissions	all fuels and electricity	229	0.02%	966	0.10%	1420	0.14%
Total emissions		262	0.01%	1174	0.05%	1806	0.09%
				Welfare analysis - All Countries			
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-1472		-2944	
(Production costs)		0		-292		-548	
Extra public funds (general)		0		151		268	
Extra public funds (labour)		0		251		443	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		514		2950		4739	
Welfare (general)		514		1338		1516	
Welfare (labour)		514		1438		1691	
Welfare NPV (general)	**8744**						
Welfare NPV (labour)	**9401**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		0.0	
Pollution benefit CO2		-3.2		-17.7		-32.4	
Pollution benefit N2O		0.0		0.2		0.6	
Pollution benefit Nox		227.2		1304.1		2107.8	
Pollution benefit PM		299.8		1706.2		2727.1	
Pollution benefit SO2		-8.9		-38.0		-56.7	
Pollution benefit VOC		-1.0		-4.5		-6.8	

Table 52: A9 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A9		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-1589	-3174
Total welfare effect w/o pollution benefits (labour)	-1490	-2999
Pollution benefits - Set 1	2921	4689
Pollution benefits - Set 2	943	1521
Pollution benefits - Set 3	1462	2360
Pollution benefits - Set 4	1812	2927
Pollution benefits - Set 5	2695	4353
Welfare - Set 1 - General	1331	1515
Welfare - Set 1 - Labour	1431	1690
Welfare - Set 2 - General	-646	-1653
Welfare - Set 2 - Labour	-546	-1479
Welfare - Set 3 - General	-127	-814
Welfare - Set 3 - Labour	-27	-639
Welfare - Set 4 - General	223	-247
Welfare - Set 4 - Labour	323	-72
Welfare - Set 5 - General	1105	1179
Welfare - Set 5 - Labour	1205	1354

Table 53: Model results for scenario A10

Scenario A10							
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2703	-1.90%	-15878	-13.66%	-26061	-24.22%
	small car	-191	-1.83%	-1144	-10.12%	-1938	-15.96%
	medium/big car	-1968	-4.78%	-11342	-30.88%	-18381	-51.16%
	moped	0	0.00%	-2	-0.04%	-3	-0.08%
	motorcycle	0	0.00%	-7	-0.06%	-14	-0.12%
	light duty vehicle	-544	-2.77%	-3388	-21.91%	-5730	-41.65%
	heavy duty vehicle	0	0.00%	-1	-0.01%	-6	-0.05%
	bus	0	0.00%	0	0.03%	1	0.12%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	6	0.14%
	freight train	0	0.00%	1	0.06%	3	0.12%
	inland ship	0	0.00%	1	0.02%	3	0.03%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-38	-0.11%	-78	-0.20%
Life Cycle emissions	all fuels and electricity	49	0.05%	184	0.18%	275	0.25%
Total emissions		-2654	-0.97%	-15732	-6.20%	-25864	-10.14%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-21011	-0.78%	-124111	-5.89%	-204535	-10.73%
	small car	-1254	-0.49%	-7331	-4.46%	-12237	-9.05%
	medium/big car	-12026	-1.94%	-69177	-14.34%	-111702	-25.10%
	moped	0	0.00%	-10	-0.08%	-20	-0.12%
	motorcycle	0	0.00%	-12	-0.06%	-28	-0.11%
	light duty vehicle	-7731	-2.63%	-47566	-17.16%	-80436	-28.53%
	heavy duty vehicle	0	0.00%	-127	-0.02%	-357	-0.06%
	bus	0	0.00%	34	0.09%	66	0.25%
	coach	0	0.00%	9	0.01%	16	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	35	0.05%	95	0.14%
	freight train	0	0.00%	23	0.06%	43	0.12%
	inland ship	0	0.00%	18	0.02%	39	0.03%
	plane (ground level)	0	0.00%	-7	-0.02%	-15	-0.03%
	plane (high altitude)	0	0.00%	-58	-0.02%	-116	-0.04%
Life Cycle emissions	all fuels and electricity	307	0.05%	1153	0.17%	1712	0.24%
Total emissions		-20704	-0.59%	-123016	-4.10%	-202939	-7.01%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	33	0.00%	414	0.03%	857	0.08%
	small car	2	0.00%	219	0.13%	468	0.35%
	medium/big car	61	0.02%	230	0.11%	382	0.22%
	moped	0	0.00%	-55	-0.01%	-111	-0.03%
	motorcycle	0	0.00%	-31	-0.02%	-65	-0.05%
	light duty vehicle	-30	-0.06%	109	0.32%	312	1.16%
	heavy duty vehicle	0	0.00%	-70	-0.04%	-157	-0.09%
	bus	0	0.00%	9	0.18%	18	0.42%
	coach	0	0.00%	1	0.01%	2	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.14%
	freight train	0	0.00%	1	0.06%	2	0.12%
	inland ship	0	0.00%	1	0.02%	2	0.03%
	plane (ground level)	0	0.00%	-1	-0.02%	-2	-0.03%
High Altitude	plane (high altitude)	0	0.00%	-4	-0.03%	-9	-0.04%
Life Cycle emissions	all fuels and electricity	408	0.04%	1467	0.15%	2113	0.20%
Total emissions		442	0.02%	1880	0.08%	2970	0.14%

		Welfare analysis - All Countries		
	2005	2010	2015	2020
		Difference (euro)	Difference (euro)	Difference (euro)
Utility of households		0	-3017	-6115
(Production costs)		0	-1114	-2262
Extra public funds (general)		0	290	533
Extra public funds (labour)		0	460	840
Total welfare effect w/o pollution benefits (labour)		0	-2551	-5135
Total welfare effect w/o pollution benefits (general)		0	-2441	-4941
Pollution benefits - Set 1		678	4005	6538
Welfare (general)		678	164	-1306
Welfare (labour)		678	333	-999
Welfare NPV (general)	**306**			
Welfare NPV (labour)	**1431**			
Decomposition external pollution cost - Set 1				
Pollution benefit CO		0.0	-0.1	-0.2
Pollution benefit CO2		-5.6	-26.0	-46.4
Pollution benefit N2O		0.0	0.3	0.7
Pollution benefit Nox		341.7	2012.7	3311.6
Pollution benefit PM		360.6	2092.8	3387.5
Pollution benefit SO2		-17.2	-68.2	-105.0
Pollution benefit VOC		-1.7	-6.7	-10.2

Table 54: A10 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A10		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-3781	-7718
Total welfare effect w/o pollution benefits (labour)	-3612	-7412
Pollution benefits - Set 1	3971	6482
Pollution benefits - Set 2	1301	2130
Pollution benefits - Set 3	2017	3305
Pollution benefits - Set 4	2490	4082
Pollution benefits - Set 5	3699	6066
Welfare - Set 1 - General	190	-1236
Welfare - Set 1 - Labour	359	-930
Welfare - Set 2 - General	-2480	-5589
Welfare - Set 2 - Labour	-2311	-5283
Welfare - Set 3 - General	-1764	-4414
Welfare - Set 3 - Labour	-1595	-4108
Welfare - Set 4 - General	-1291	-3636
Welfare - Set 4 - Labour	-1123	-3330
Welfare - Set 5 - General	-82	-1652
Welfare - Set 5 - Labour	87	-1346

Table 55: Model results for scenario A11

		Scenario A11					
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2704	-1.90%	-15882	-13.66%	-26064	-24.22%
	small car	-191	-1.83%	-1145	-10.13%	-1940	-15.98%
	medium/big car	-1970	-4.78%	-11345	-30.89%	-18383	-51.17%
	moped	0	0.00%	-2	-0.04%	-3	-0.08%
	motorcycle	0	0.00%	-6	-0.06%	-13	-0.11%
	light duty vehicle	-544	-2.77%	-3388	-21.92%	-5730	-41.65%
	heavy duty vehicle	0	0.00%	-1	0.00%	-6	-0.04%
	bus	0	0.00%	0	0.03%	1	0.11%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	1	0.06%	3	0.12%
	inland ship	0	0.00%	1	0.02%	3	0.03%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-37	-0.10%	-75	-0.19%
Life Cycle emissions	all fuels and electricity	48	0.05%	185	0.18%	277	0.26%
Total emissions		-2656	-0.97%	-15734	-6.20%	-25862	-10.14%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-21001	-0.78%	-124032	-5.88%	-204390	-10.72%
	small car	-1254	-0.49%	-7336	-4.46%	-12250	-9.06%
	medium/big car	-12017	-1.94%	-69097	-14.32%	-111556	-25.06%
	moped	0	0.00%	-10	-0.08%	-20	-0.12%
	motorcycle	0	0.00%	-12	-0.05%	-27	-0.11%
	light duty vehicle	-7731	-2.63%	-47559	-17.16%	-80417	-28.52%
	heavy duty vehicle	0	0.00%	-126	-0.02%	-356	-0.06%
	bus	0	0.00%	32	0.08%	63	0.24%
	coach	0	0.00%	9	0.01%	15	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	33	0.05%	91	0.13%
	freight train	0	0.00%	23	0.06%	43	0.12%
	inland ship	0	0.00%	18	0.02%	39	0.03%
	plane (ground level)	0	0.00%	-7	-0.02%	-15	-0.03%
	plane (high altitude)	0	0.00%	-60	-0.03%	-120	-0.04%
Life Cycle emissions	all fuels and electricity	303	0.05%	1157	0.17%	1727	0.25%
Total emissions		-20698	-0.59%	-122935	-4.09%	-202783	-7.01%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	31	0.00%	404	0.03%	842	0.08%
	small car	2	0.00%	211	0.12%	452	0.34%
	medium/big car	59	0.02%	225	0.11%	375	0.21%
	moped	0	0.00%	-54	-0.01%	-107	-0.03%
	motorcycle	0	0.00%	-30	-0.02%	-63	-0.05%
	light duty vehicle	-30	-0.06%	110	0.32%	315	1.17%
	heavy duty vehicle	0	0.00%	-70	-0.04%	-156	-0.09%
	bus	0	0.00%	9	0.17%	17	0.41%
	coach	0	0.00%	1	0.01%	2	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.05%	5	0.13%
	freight train	0	0.00%	1	0.06%	2	0.12%
	inland ship	0	0.00%	1	0.02%	2	0.03%
	plane (ground level)	0	0.00%	-1	-0.02%	-2	-0.03%
High Altitude	plane (high altitude)	0	0.00%	-5	-0.03%	-9	-0.04%
Life Cycle emissions	all fuels and electricity	405	0.04%	1478	0.15%	2142	0.20%
Total emissions		436	0.02%	1882	0.08%	2984	0.14%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2864		-5812	
(Production costs)		0		-1082		-2204	
Extra public funds (general)		0		288		529	
Extra public funds (labour)		0		456		833	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		678		4003		6534	
Welfare (general)		678		345		-953	
Welfare (labour)		678		513		-649	
Welfare NPV (general)	**1554**						
Welfare NPV (labour)	**2667**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		-0.1		-0.2	
Pollution benefit CO2		-5.5		-26.3		-47.2	
Pollution benefit N2O		0.0		0.3		0.7	
Pollution benefit Nox		341.6		2011.2		3308.8	
Pollution benefit PM		360.7		2092.8		3387.1	
Pollution benefit SO2		-16.9		-68.1		-105.2	
Pollution benefit VOC		-1.7		-6.7		-10.3	

Table 56: A11 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A11		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-3603	-7371
Total welfare effect w/o pollution benefits (labour)	-3436	-7068
Pollution benefits - Set 1	3970	6478
Pollution benefits - Set 2	1300	2128
Pollution benefits - Set 3	2016	3302
Pollution benefits - Set 4	2489	4079
Pollution benefits - Set 5	3698	6062
Welfare - Set 1 - General	367	-894
Welfare - Set 1 - Labour	534	-591
Welfare - Set 2 - General	-2303	-5244
Welfare - Set 2 - Labour	-2136	-4941
Welfare - Set 3 - General	-1587	-4069
Welfare - Set 3 - Labour	-1420	-3766
Welfare - Set 4 - General	-1114	-3292
Welfare - Set 4 - Labour	-947	-2989
Welfare - Set 5 - General	95	-1309
Welfare - Set 5 - Labour	262	-1006

Table 57: Model results for scenario A12

Scenario A12							
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2712	-1.91%	-15913	-13.69%	-26098	-24.25%
	small car	-191	-1.83%	-1147	-10.15%	-1944	-16.01%
	medium/big car	-1972	-4.79%	-11352	-30.91%	-18388	-51.18%
	moped	0	0.00%	-1	-0.04%	-3	-0.07%
	motorcycle	0	0.00%	-6	-0.05%	-12	-0.10%
	light duty vehicle	-549	-2.79%	-3410	-22.06%	-5756	-41.84%
	heavy duty vehicle	0	0.00%	-1	0.00%	-5	-0.04%
	bus	0	0.00%	0	0.02%	1	0.10%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	5	0.12%
	freight train	0	0.00%	1	0.06%	2	0.11%
	inland ship	0	0.00%	1	0.02%	2	0.03%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-33	-0.09%	-68	-0.18%
Life Cycle emissions	all fuels and electricity	19	0.02%	29	0.03%	26	0.02%
Total emissions		-2692	-0.98%	-15917	-6.27%	-26141	-10.25%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-20957	-0.78%	-123655	-5.86%	-203571	-10.67%
	small car	-1249	-0.49%	-7323	-4.45%	-12237	-9.05%
	medium/big car	-12003	-1.94%	-68956	-14.29%	-111288	-25.00%
	moped	0	0.00%	-9	-0.07%	-18	-0.11%
	motorcycle	0	0.00%	-11	-0.05%	-24	-0.10%
	light duty vehicle	-7705	-2.62%	-47342	-17.08%	-79899	-28.34%
	heavy duty vehicle	0	0.00%	-110	-0.01%	-317	-0.05%
	bus	0	0.00%	28	0.07%	56	0.21%
	coach	0	0.00%	8	0.01%	14	0.02%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	29	0.04%	80	0.12%
	freight train	0	0.00%	21	0.06%	39	0.11%
	inland ship	0	0.00%	16	0.02%	35	0.03%
	plane (ground level)	0	0.00%	-7	-0.02%	-13	-0.03%
	plane (high altitude)	0	0.00%	-54	-0.02%	-109	-0.04%
Life Cycle emissions	all fuels and electricity	119	0.02%	158	0.02%	109	0.02%
Total emissions		-20838	-0.59%	-123551	-4.11%	-203571	-7.03%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	30	0.00%	382	0.03%	780	0.07%
	small car	2	0.00%	191	0.11%	413	0.31%
	medium/big car	54	0.02%	220	0.11%	363	0.21%
	moped	0	0.00%	-49	-0.01%	-99	-0.03%
	motorcycle	0	0.00%	-27	-0.02%	-58	-0.05%
	light duty vehicle	-26	-0.05%	97	0.28%	278	1.03%
	heavy duty vehicle	0	0.00%	-61	-0.03%	-139	-0.08%
	bus	0	0.00%	8	0.15%	16	0.36%
	coach	0	0.00%	1	0.01%	1	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	4	0.12%
	freight train	0	0.00%	1	0.06%	2	0.11%
	inland ship	0	0.00%	1	0.02%	2	0.03%
	plane (ground level)	0	0.00%	-1	-0.02%	-2	-0.03%
High Altitude	plane (high altitude)	0	0.00%	-4	-0.02%	-8	-0.04%
Life Cycle emissions	all fuels and electricity	134	0.01%	7	0.00%	-233	-0.02%
Total emissions		164	0.01%	389	0.02%	547	0.03%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2563		-5271	
(Production costs)		0		-966		-2001	
Extra public funds (general)		0		105		200	
Extra public funds (labour)		0		163		307	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		697		4110		6713	
Welfare (general)		697		686		-359	
Welfare (labour)		697		744		-252	
Welfare NPV (general)	**3817**						
Welfare NPV (labour)	**4203**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		-0.1		-0.1	
Pollution benefit CO2		-1.7		1.2		8.2	
Pollution benefit N2O		0.0		0.2		0.6	
Pollution benefit Nox		344.0		2022.3		3323.7	
Pollution benefit PM		363.7		2107.3		3408.2	
Pollution benefit SO2		-8.0		-19.8		-27.0	
Pollution benefit VOC		-0.6		-0.8		-0.7	

Table 58: A12 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A12		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-3372	-6961
Total welfare effect w/o pollution benefits (labour)	-3314	-6853
Pollution benefits - Set 1	4076	6655
Pollution benefits - Set 2	1355	2228
Pollution benefits - Set 3	2086	3426
Pollution benefits - Set 4	2572	4224
Pollution benefits - Set 5	3808	6249
Welfare - Set 1 - General	704	-306
Welfare - Set 1 - Labour	762	-198
Welfare - Set 2 - General	-2017	-4733
Welfare - Set 2 - Labour	-1959	-4625
Welfare - Set 3 - General	-1286	-3535
Welfare - Set 3 - Labour	-1228	-3427
Welfare - Set 4 - General	-800	-2737
Welfare - Set 4 - Labour	-742	-2629
Welfare - Set 5 - General	436	-712
Welfare - Set 5 - Labour	494	-604

Table 59: Model results for scenario A13

		Scenario A13					
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-2716	-1.91%	-15927	-13.69%	-26111	-24.24%
	small car	-192	-1.84%	-1152	-10.19%	-1950	-16.06%
	medium/big car	-1976	-4.80%	-11365	-30.94%	-18401	-51.22%
	moped	0	0.00%	-1	-0.03%	-3	-0.06%
	motorcycle	0	0.00%	-5	-0.05%	-11	-0.09%
	light duty vehicle	-548	-2.79%	-3407	-22.04%	-5752	-41.81%
	heavy duty vehicle	0	0.00%	-1	0.00%	-5	-0.04%
	bus	0	0.00%	0	0.02%	1	0.09%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	2	0.04%	4	0.11%
	freight train	0	0.00%	1	0.06%	2	0.11%
	inland ship	0	0.00%	1	0.02%	2	0.03%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-31	-0.09%	-63	-0.16%
Life Cycle emissions	all fuels and electricity	45	0.04%	182	0.18%	278	0.25%
Total emissions		-2671	-0.97%	-15776	-6.20%	-25896	-10.12%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-10966	-0.41%	-65246	-3.09%	-108243	-5.66%
	small car	-666	-0.26%	-3828	-2.33%	-6357	-4.70%
	medium/big car	-6158	-1.00%	-35692	-7.40%	-57780	-12.98%
	moped	0	0.00%	-8	-0.06%	-15	-0.09%
	motorcycle	0	0.00%	-9	-0.04%	-21	-0.09%
	light duty vehicle	-4142	-1.41%	-25688	-9.27%	-43943	-15.59%
	heavy duty vehicle	0	0.00%	-113	-0.02%	-324	-0.05%
	bus	0	0.00%	26	0.07%	51	0.19%
	coach	0	0.00%	7	0.01%	12	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	28	0.04%	74	0.11%
	freight train	0	0.00%	22	0.06%	41	0.11%
	inland ship	0	0.00%	16	0.02%	34	0.03%
	plane (ground level)	0	0.00%	-7	-0.02%	-13	-0.03%
	plane (high altitude)	0	0.00%	-52	-0.02%	-104	-0.03%
Life Cycle emissions	all fuels and electricity	283	0.04%	1148	0.17%	1744	0.25%
Total emissions		-10682	-0.30%	-64150	-2.12%	-106603	-3.65%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	20	0.00%	299	0.02%	641	0.06%
	small car	2	0.00%	166	0.10%	357	0.26%
	medium/big car	45	0.01%	154	0.08%	252	0.14%
	moped	0	0.00%	-43	-0.01%	-85	-0.02%
	motorcycle	0	0.00%	-24	-0.02%	-50	-0.04%
	light duty vehicle	-27	-0.05%	99	0.29%	288	1.07%
	heavy duty vehicle	0	0.00%	-63	-0.04%	-142	-0.08%
	bus	0	0.00%	7	0.14%	14	0.32%
	coach	0	0.00%	1	0.00%	1	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.04%	4	0.11%
	freight train	0	0.00%	1	0.06%	2	0.11%
	inland ship	0	0.00%	1	0.02%	2	0.03%
	plane (ground level)	0	0.00%	-1	-0.01%	-2	-0.02%
High Altitude	plane (high altitude)	0	0.00%	-4	-0.02%	-8	-0.04%
Life Cycle emissions	all fuels and electricity	384	0.04%	1506	0.15%	2238	0.21%
Total emissions		403	0.02%	1805	0.08%	2879	0.14%
		Welfare analysis - All Countries					
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		0		-2298		-4668	
(Production costs)		0		-924		-1889	
Extra public funds (general)		0		270		495	
Extra public funds (labour)		0		426		779	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		515		3040		4954	
Welfare (general)		515		87		-1108	
Welfare (labour)		515		244		-824	
Welfare NPV (general)	**-66**						
Welfare NPV (labour)	**974**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		-0.1		-0.1	
Pollution benefit CO2		-5.3		-27.1		-50.0	
Pollution benefit N2O		0.0		0.2		0.5	
Pollution benefit Nox		175.5		1044.5		1729.6	
Pollution benefit PM		361.7		2094.6		3386.3	
Pollution benefit SO2		-15.5		-65.3		-102.0	
Pollution benefit VOC		-1.5		-6.6		-10.3	

Table 60: A13 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A13		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-2906	-5963
Total welfare effect w/o pollution benefits (labour)	-2750	-5680
Pollution benefits - Set 1	3015	4912
Pollution benefits - Set 2	949	1551
Pollution benefits - Set 3	1475	2415
Pollution benefits - Set 4	1843	3018
Pollution benefits - Set 5	2746	4500
Welfare - Set 1 - General	109	-1051
Welfare - Set 1 - Labour	265	-769
Welfare - Set 2 - General	-1957	-4412
Welfare - Set 2 - Labour	-1801	-4129
Welfare - Set 3 - General	-1431	-3548
Welfare - Set 3 - Labour	-1275	-3265
Welfare - Set 4 - General	-1064	-2945
Welfare - Set 4 - Labour	-908	-2662
Welfare - Set 5 - General	-161	-1463
Welfare - Set 5 - Labour	-5	-1180

Table 61: Model results for scenario A14

Scenario A14							
PM emissions - All Countries							
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	1	0.00%	2	0.00%	10	0.01%
	small car	0	0.00%	-16	-0.14%	-32	-0.26%
	medium/big car	4	0.01%	23	0.06%	42	0.12%
	moped	0	0.00%	-1	-0.02%	-2	-0.04%
	motorcycle	0	0.00%	-2	-0.02%	-6	-0.05%
	light duty vehicle	-3	-0.01%	-4	-0.03%	4	0.03%
	heavy duty vehicle	0	0.00%	0	0.00%	-1	-0.01%
	bus	0	0.00%	0	0.01%	0	0.04%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.03%	3	0.08%
	freight train	0	0.00%	0	0.01%	0	0.02%
	inland ship	0	0.00%	0	0.00%	0	0.00%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-13	-0.04%	-27	-0.07%
Life Cycle emissions	all fuels and electricity	-4	0.00%	-60	-0.06%	-116	-0.11%
Total emissions		-3	0.00%	-71	-0.03%	-132	-0.05%
NOx emissions - All Countries							
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-5736	-0.21%	-44804	-2.12%	-86963	-4.56%
	small car	-2845	-1.11%	-21206	-12.89%	-40986	-30.31%
	medium/big car	-2760	-0.45%	-21947	-4.55%	-42729	-9.60%
	moped	0	0.00%	-5	-0.04%	-11	-0.06%
	motorcycle	0	0.00%	-5	-0.02%	-11	-0.04%
	light duty vehicle	-131	-0.04%	-1666	-0.60%	-3289	-1.17%
	heavy duty vehicle	0	0.00%	-16	0.00%	-32	-0.01%
	bus	0	0.00%	12	0.03%	25	0.09%
	coach	0	0.00%	4	0.00%	8	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	19	0.03%	52	0.08%
	freight train	0	0.00%	4	0.01%	7	0.02%
	inland ship	0	0.00%	2	0.00%	5	0.00%
	plane (ground level)	0	0.00%	-1	0.00%	-2	-0.01%
	plane (high altitude)	0	0.00%	-11	0.00%	-21	-0.01%
Life Cycle emissions	all fuels and electricity	-27	0.00%	-373	-0.06%	-724	-0.10%
Total emissions		-5763	-0.16%	-45189	-1.50%	-87708	-3.03%
VOC emissions - All Countries							
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-7022	-0.42%	-40896	-3.24%	-67412	-6.47%
	small car	-3391	-1.15%	-19250	-11.16%	-31618	-23.45%
	medium/big car	-3351	-1.09%	-19687	-9.77%	-32391	-18.40%
	moped	0	0.00%	-25	0.00%	-55	-0.01%
	motorcycle	0	0.00%	-11	-0.01%	-26	-0.02%
	light duty vehicle	-279	-0.55%	-1922	-5.57%	-3321	-12.32%
	heavy duty vehicle	0	0.00%	-7	0.00%	-15	-0.01%
	bus	0	0.00%	4	0.08%	9	0.20%
	coach	0	0.00%	1	0.00%	1	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.03%	3	0.08%
	freight train	0	0.00%	0	0.01%	0	0.02%
	inland ship	0	0.00%	0	0.00%	0	0.00%
	plane (ground level)	0	0.00%	0	0.00%	0	0.00%
High Altitude	plane (high altitude)	0	0.00%	-1	-0.01%	-2	-0.01%
Life Cycle emissions	all fuels and electricity	-31	0.00%	-471	-0.05%	-915	-0.09%
Total emissions		-7053	-0.27%	-41367	-1.83%	-68327	-3.23%
Welfare analysis - All Countries							
	2005	2010		2015		2020	
		Difference (euro)		Difference (euro)		Difference (euro)	
Utility of households		-3		-1058		-2218	
(Production costs)		0		-276		-556	
Extra public funds (general)		3		-71		-143	
Extra public funds (labour)		4		-103		-205	
Total welfare effect w/o pollution benefits (labour)		0		-2551		-5135	
Total welfare effect w/o pollution benefits (general)		0		-2441		-4941	
Pollution benefits - Set 1		119		885		1667	
Welfare (general)		118		-520		-1250	
Welfare (labour)		119		-552		-1313	
Welfare NPV (general)	**-3638**						
Welfare NPV (labour)	**-3854**						
Decomposition external pollution cost - Set 1							
Pollution benefit CO		0.0		0.0		0.1	
Pollution benefit CO2		0.4		8.6		20.9	
Pollution benefit N2O		0.0		0.3		0.7	
Pollution benefit Nox		92.2		710.8		1369.4	
Pollution benefit PM		-0.7		-3.0		-6.1	
Pollution benefit SO2		1.8		21.9		41.6	
Pollution benefit VOC		25.2		146.5		240.3	

Table 62: A14 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A14		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-1329	-2757
Total welfare effect w/o pollution benefits (labour)	-1360	-2817
Pollution benefits - Set 1	840	1580
Pollution benefits - Set 2	314	596
Pollution benefits - Set 3	475	898
Pollution benefits - Set 4	593	1115
Pollution benefits - Set 5	849	1599
Welfare - Set 1 - General	-489	-1177
Welfare - Set 1 - Labour	-520	-1237
Welfare - Set 2 - General	-1015	-2161
Welfare - Set 2 - Labour	-1046	-2221
Welfare - Set 3 - General	-855	-1859
Welfare - Set 3 - Labour	-885	-1919
Welfare - Set 4 - General	-737	-1643
Welfare - Set 4 - Labour	-767	-1702
Welfare - Set 5 - General	-480	-1159
Welfare - Set 5 - Labour	-510	-1219

Table 63: Model results for scenario A15

Scenario A15							
		PM emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	1	0.00%	1	0.00%	7	0.01%
	small car	0	0.00%	-13	-0.11%	-26	-0.21%
	medium/big car	3	0.01%	18	0.05%	33	0.09%
	moped	0	0.00%	-1	-0.02%	-1	-0.03%
	motorcycle	0	0.00%	-2	-0.02%	-4	-0.04%
	light duty vehicle	-2	-0.01%	-3	-0.02%	3	0.02%
	heavy duty vehicle	0	0.00%	0	0.00%	-1	0.00%
	bus	0	0.00%	0	0.01%	0	0.03%
	coach	0	0.00%	0	0.00%	0	0.00%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.02%	2	0.06%
	freight train	0	0.00%	0	0.01%	0	0.01%
	inland ship	0	0.00%	0	0.00%	0	0.00%
	plane	-	-	-	-	-	-
Non-Exhaust emissions	road vehicles	0	0.00%	-10	-0.03%	-21	-0.05%
Life Cycle emissions	all fuels and electricity	-3	0.00%	-45	-0.04%	-88	-0.08%
Total emissions		-2	0.00%	-55	-0.02%	-102	-0.04%
		NOx emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-3244	-0.12%	-25453	-1.21%	-49465	-2.59%
	small car	-1626	-0.63%	-12147	-7.38%	-23500	-17.38%
	medium/big car	-1559	-0.25%	-12458	-2.58%	-24292	-5.46%
	moped	0	0.00%	-4	-0.03%	-8	-0.05%
	motorcycle	0	0.00%	-4	-0.02%	-8	-0.03%
	light duty vehicle	-59	-0.02%	-860	-0.31%	-1707	-0.61%
	heavy duty vehicle	0	0.00%	-12	0.00%	-23	0.00%
	bus	0	0.00%	9	0.02%	19	0.07%
	coach	0	0.00%	3	0.00%	6	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	15	0.02%	41	0.06%
	freight train	0	0.00%	3	0.01%	5	0.01%
	inland ship	0	0.00%	2	0.00%	4	0.00%
	plane (ground level)	0	0.00%	-1	0.00%	-2	0.00%
	plane (high altitude)	0	0.00%	-9	0.00%	-16	-0.01%
Life Cycle emissions	all fuels and electricity	-20	0.00%	-284	-0.04%	-550	-0.08%
Total emissions		-3264	-0.09%	-25746	-0.86%	-50032	-1.73%
		VOC emissions - All Countries					
		2010		2015		2020	
		difference (tonne)	difference (%)	difference (tonne)	difference (%)	difference (tonne)	difference (%)
Exhaust emissions	all vehicles total	-3516	-0.21%	-20575	-1.63%	-33973	-3.26%
	small car	-1696	-0.58%	-9672	-5.61%	-15913	-11.80%
	medium/big car	-1681	-0.55%	-9902	-4.91%	-16307	-9.26%
	moped	0	0.00%	-20	0.00%	-43	-0.01%
	motorcycle	0	0.00%	-9	-0.01%	-20	-0.02%
	light duty vehicle	-140	-0.27%	-972	-2.82%	-1689	-6.27%
	heavy duty vehicle	0	0.00%	-5	0.00%	-11	-0.01%
	bus	0	0.00%	3	0.06%	7	0.16%
	coach	0	0.00%	0	0.00%	1	0.01%
	metro/tram	-	-	-	-	-	-
	passenger train	0	0.00%	1	0.02%	2	0.06%
	freight train	0	0.00%	0	0.01%	0	0.01%
	inland ship	0	0.00%	0	0.00%	0	0.00%
	plane (ground level)	0	0.00%	0	0.00%	0	0.00%
High Altitude	plane (high altitude)	0	0.00%	-1	0.00%	-1	-0.01%
Life Cycle emissions	all fuels and electricity	-23	0.00%	-358	-0.04%	-696	-0.07%
Total emissions		-3539	-0.13%	-20932	-0.93%	-34669	-1.64%

Welfare analysis - All Countries				
	2005	2010	2015	2020
		Difference (euro)	Difference (euro)	Difference (euro)
Utility of households		-3	-824	-1727
(Production costs)		0	-212	-426
Extra public funds (general)		2	-53	-106
Extra public funds (labour)		3	-77	-153
Total welfare effect w/o pollution benefits (labour)		0	-2551	-5135
Total welfare effect w/o pollution benefits (general)		0	-2441	-4941
Pollution benefits - Set 1		66	501	947
Welfare (general)		65	-589	-1313
Welfare (labour)		66	-613	-1360
Welfare NPV (general)	**-4114**			
Welfare NPV (labour)	**-4275**			
Decomposition external pollution cost - Set 1				
Pollution benefit CO		0.0	0.0	0.0
Pollution benefit CO2		0.3	6.5	15.9
Pollution benefit N2O		0.0	0.2	0.5
Pollution benefit Nox		52.3	405.2	781.4
Pollution benefit PM		-0.5	-2.2	-4.4
Pollution benefit SO2		1.3	16.6	31.6
Pollution benefit VOC		12.6	74.1	121.9

Table 64: A15 Benefit sensitivity analysis, million EURO – All countries except Switzerland and Norway

Scenario A15		
	2015 (euro)	2020 (euro)
Total welfare effect w/o pollution benefits (general)	-1032	-2139
Total welfare effect w/o pollution benefits (labour)	-1055	-2184
Pollution benefits - Set 1	475	898
Pollution benefits - Set 2	179	343
Pollution benefits - Set 3	271	515
Pollution benefits - Set 4	336	636
Pollution benefits - Set 5	482	912
Welfare - Set 1 - General	-557	-1241
Welfare - Set 1 - Labour	-580	-1286
Welfare - Set 2 - General	-852	-1796
Welfare - Set 2 - Labour	-875	-1841
Welfare - Set 3 - General	-761	-1624
Welfare - Set 3 - Labour	-784	-1669
Welfare - Set 4 - General	-696	-1503
Welfare - Set 4 - Labour	-718	-1548
Welfare - Set 5 - General	-550	-1227
Welfare - Set 5 - Labour	-573	-1272