SIMULATION OF ALTERNATIVE SCENARIOS FOR THE FURTHER REDUCTION OF LIGHT DUTY VEHICLE CO2 EMISSIONS IN THE EUROPEAN UNION : AN APPLICATION OF THE EUROPEAN TREMOVE 2 MODEL

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1 BACKGROUND

This paper presents TREMOVE 2 model simulations by Transport & Mobility Leuven for the European Commission, Directorate-General Environment. This research work was performed under the service contract for the further development and application of the TREMOVE transport model.

TREMOVE 2 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 transport demand, modal split, vehicle fleets, emissions of air pollutants and welfare level under different policy scenarios. All relevant transport modes are modelled. The TREMOVE 2 version used for the presented simulation covers the 1995-2020 period for 21 countries. The model is described in detail by Proost, S., De Ceuster, G., Van Herbruggen, B., Logghe, S., Ivanova, O., Carlier, K. (2006/1).

As explained in the Communication "*Community strategy to reduce CO_2 emissions from passenger cars and to improve fuel economy*" (COM(95) 689 final) the European Community aims at reducing CO_2 emission from passenger cars. The European Council and the European Parliament specified that the objective of the strategy should be to achieve an average test-cycle CO_2 emission figure for new passenger cars of 120 gram CO_2 per kilometre. The Community strategy was based on three pillars : a) agreements with the car industry on fuel economy improvements; b) fuel-economy labelling of cars; c) fiscal measures. With regard to a), the European, Japanese and Korean Automobile Manufacturer Associations entered into commitments to achieve new passenger car fleet average CO_2 emissions of 140 gram per kilometre by 2008/9 (measured according to Directive 93/110/EC).

In addition to the three pillars of the strategy, several other options are feasible that could contribute to achieving CO_2 emission reductions beyond the current Commitments by the manufacturers. Therefore the Commission has carried out a joint evaluation, involving the Commission, the stakeholders, selected national experts and consultants in order to adress two key issues :

A. The costs and reduction potential of technologies and other measures to reduce CO_2 emissions;
B. An extended impact assessment of policy scenarios to reduce CO_2 emissions from passenger cars in the EU.

Results of Task A are reported by Smokers, R., Vermeulen, R., van Mieghem, R., Gense, R., Skinner, I., Fergusson, M., MacKay, E., ten Brink, P., Fontaras, G., Samaras, Z., (2006). This report is further referred to as 'Task A report'.

One of the tools used for Task B was the TREMOVE 2 model. This paper presents scenario simulations performed by Transport & Mobility Leuven in this context.

Based on the Task A and Task B results, on 7 February 2007, the Commission adopted the Communication (COM(2007) 19) outlining a comprehensive new strategy to reduce CO_2 emissions from new cars and vans sold in the European Union.

The remainder of this paper is composed of 4 sections. In section 2 an overview of the scenario simulations performed is provided. Section 3 then refers to the input data and assumptions used in the scenario modelling. In Section 4 the simulation results are presented. Finally, section 5 provides suggestions and caveats for further research work.

2 OVERVIEW OF SCENARIOS

Table 1 lists the scenarios presented in this paper.

Scenario D23 can be interpreted as an extension of the current 140 g. voluntary agreement with the car industry towards 120 g. in 2012. An average CO_2 test-cycle emission level of 120 gram per kilometre is reached, through technical measures at the car vehicle level only. Note however that it is assumed that an equal percentage reduction objective would be set for each individual manufacturer, rather than for the manufacturer associations (European, Japanese, Korean) 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 greenhouse gas 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;
- TPMS: Tyre Pressure Monitoring Systems;
- LRRT: Low Rolling Resistance Tyres;
- LVL: Low Viscosity Lubricants;
- MAC: Accelerating the introduction of more fuel efficient airco systems;

- N1: Measures for the N1 vehicle class (light duty trucks and vans), 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 the Task A report.

Table 1: Overview of CO2CAR scenarios

Code	Scenario
D20	135g
D21	130g
D22	125g
D23	120g
D24	125g + GSI
D25	125g + GSI + TPMS
D26	125g + GSI + TPMS +N1 -15g
D27	125g + GSI + TPMS +N1 -15g + LRRT
D28	130g + GSI + TPMS +N1 -15g + LRRT + MAC
D29	130g + GSI + TPMS +N1 -30g + LRRT + MAC
D30	130g + GSI + TPMS +N1 -30g + LRRT + MAC + LVL
D31	130g + GSI + TPMS +N1 -45g + LRRT + MAC + LVL
D32	130g + GSI + TPMS +N1 -60g + LRRT + MAC + LVL

3 SCENARIO INPUT DATA AND ASSUMPTIONS

3.1 Baseline for car and N1 greenhouse gas emissions

Before the simulations were performed, the TREMOVE business-as-usual scenario (further referred to as 'baseline') has been brought in line with the baseline in the Task A report.

The baseline includes the assumption that the committed 140 g. CO_2/km target will be reached in 2009 by all manufacturer associations. 2002-2009 fuel efficiency improvement paths by car type, as wel as related ex-tax car retail price increases, have been included in the TREMOVE baseline. Note that also in the 2009-2012 period additional technical measures will be needed to keep emissions at 140 g. CO_2/km. These measures are needed to compensate projected increases in vehicle weight in this period.

Also for the N1 vehicle class such fuel efficiency improvement paths have been modelled .

LRRT, TPMS and LVL are included in the baseline for cars. Ex-tax retail prices (for TPMS), extra yearly maintenance costs (for LRRT and LVL) and fuel-efficiency improvements for these technologies are reported in Table 2.

Table 2 : Task A Cost and fuel-efficiency impact LRRT, TPMS, LVL, 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%

Baseline projections for the shares of LRRT and LVL technologies in the fleet are presented in Table 3. The percentages 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 cars and increasing retroffiting over time is assumed for these two technologies. For TPMS no retrofittings are expected. The baseline assumes that, from 2008 onwards, 30% of the new sold cars have the TPMS technology.

Table 3 : Projected basecase shares of LRRT, LVL

Year	LRRT	LVL
2008	50%	5%
2009	52%	6%
2010	54%	8%
2011	55%	9%
2012	57%	11%

2013	59%	13%
2014	61%	16%
2015	62%	16%
2016	64%	18%
2017	66%	20%
2018	68%	22%
2019	69%	23%
2020	71%	25%

Also for GSI, the ex-tax retail price and fuel-efficiency improvement estimates from the Task A study have been implemented in TREMOVE. These input values are reported in Table 2. Note however that no application of GSI equipment is modelled in the baseline.

Well-to-tank emission factors for the greenhouse gases (CO_2 , CH_4 and N_2O) have been updated. The new well-to-tank emission factors result from consultations between EUROPIA and the European Commission. The factors are based on CONCAWE, EUCAR, JRC (2004) and additional assumptions on the mix of fuel production pathways. The assumed pathway mixes and emission factors are reported in Table 4.

Table 4: Mix of fuel production pathways and related 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

3.2 Modelling of the policy scenarios

Technical measures at vehicle level for cars

The Task A report presents technology scenarios for several options to reduce 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, a percentage reduction target per manufacturer is considered.

For each scenario, the Task A report predicts 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). The 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.

CO2 and SO2 emissions follow the same downward trend as the fuel consumption. 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. They are applied also to both hot and cold fuel consumption and emissions.

It is assumed that these technical measures at vehicle level have no impact on maintenance costs.

Technical measures at vehicle level for N1 vehicles

Similarly, the Task A report provides estimates for the least cost solutions to reach targets for the N1-market. The targets considered are reductions of average test-cycle CO_2 emissions by 15 g., 30 g., 45 g. and 60 g. in 2012.

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. These technologies are already present to a limited extent in the baseline. Two possible scenarios for accelerating the introduction of these technologies are considered:

- "Scenario 1" : Compulsory introduction for new cars;
- "Scenario 2" : Purchase incentives for old and new cars.

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

"Scenario 1" is specified as follows :

- For cars sold in 2009 or before : baseline shares of LRRT/TPMS/LVL are kept (see Table 3);
- For cars sold in 2010 : 50% of them are equipped with LRRT/TPMS/LVL (for their full life-time);
- For cars sold in 2011 : 75% of them are equipped with LRRT/TPMS/LVL (for their full life-time);
- For cars sold after 2012 : 100% of them are equipped with LRRT/TPMS/LVL (for their full life-time).

“Scenario 2” targets not only original, but also replacement equipment (retrofit). The projections for the shares of the LRRT and LVL technologies in the whole fleet are presented in Table 5. These market shares are applied for to all cars for all vintages (except cars sold before 1996).

Table 5 : Task A report projected scenario 2 shares of LRRT and LVL

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%

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.

Fuel-efficient airconditioning equipment

The MAC measure in the TREMOVE simulations is a policy 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 the Task A Report and displayed in Table 6.

Table 6 : Cost and fuel-efficiency impacts of fuel-efficient airconditioning

	MAC fuel consumption litre/100 km	Increase in car ex-tax retail price - EURO
2008 Basecase (absolute value)	0.256	
2010 Scenario (diff. scenario vs basecase)	-0.034	24
2011 Scenario (diff. scenario vs basecase)	-0.048	35
2012-2020 Scenario (diff. scenario vs basecase)	-0.021	19

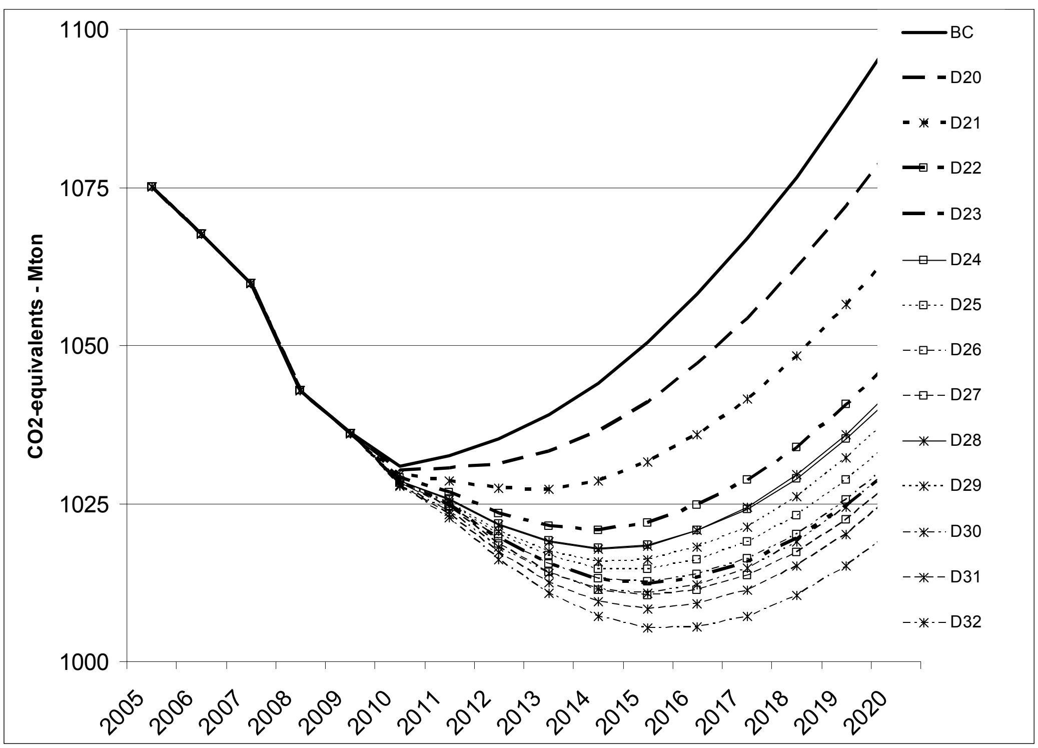
4 SCENARIO RESULTS

This section is composed of four subsections. The effect of the simulated policies on total transport greenhouse gas emissions is presented in section 4.1. Section 4.2 discusses the cost-effectiveness of the simulated emission abatement scenarios. The welfare effects calculated by TREMOVE are shown in section 4.3. Finally, in section 4.4 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.

4.1 Effects on overall transport greenhouse gas emissions

Figure 1 shows the evolution of total greenhouse gas emissions in the baseline 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 the EU15 countries, Czech Republic, Hungary, Poland and Slovenia.

Figure 1: D20-D32 Evolution of well-to-tank GHG emissions



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, 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 for transport.

In scenarios D24 to D32, technical measures at the vehicle level are combined with supplementary measures (see Table 1). Scenarios D24 to D27 (thin lines with squares) combine a 125 g. target with supplementary measures. Scenarios D27 to D32 (thin lines with stars) combine a 130 g. target with supplementary measures. Figure 1 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. It is 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 4.4.

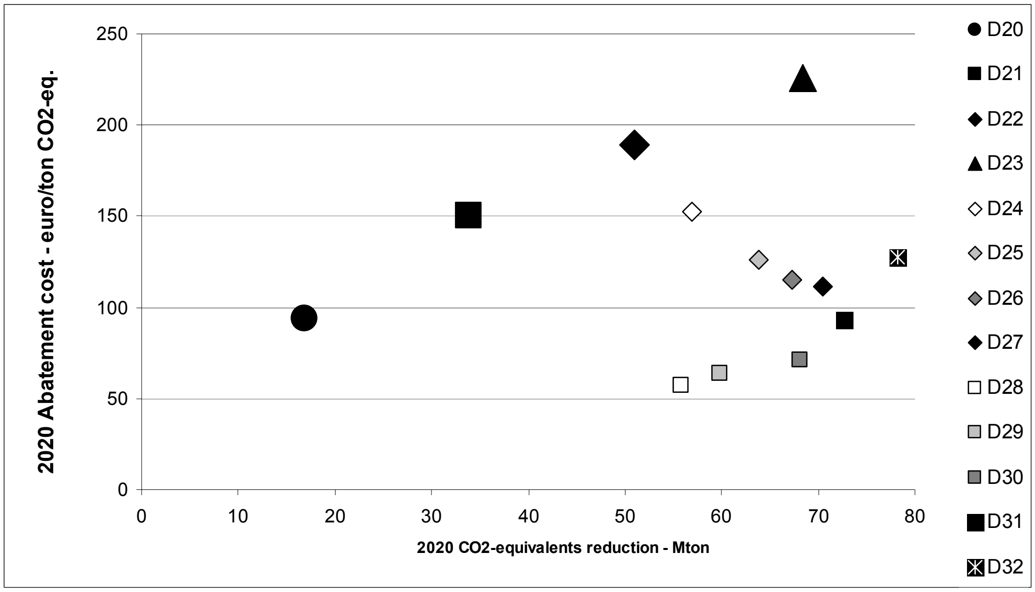
4.2 Cost-effectiveness

Figure 2 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 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 excise taxes will decrease. It is assumed that this loss in government income is compensated by an increase in general taxes, which has a negative impact on overall welfare.

Figure 2: D20-D32 Cost-effectiveness in 2020 – EU15 + 4 NMS



In Figure 2 the scenarios have been grouped in 'clusters'. The larger dots (D20-D23) represent 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 cluster of diamons-shaped dots (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, but at a significantly lower abatement cost than D23. I.e. a package of technical measures at the vehicle level and supplementary measures is more cost-effective than just technical measures at the vehicle level.

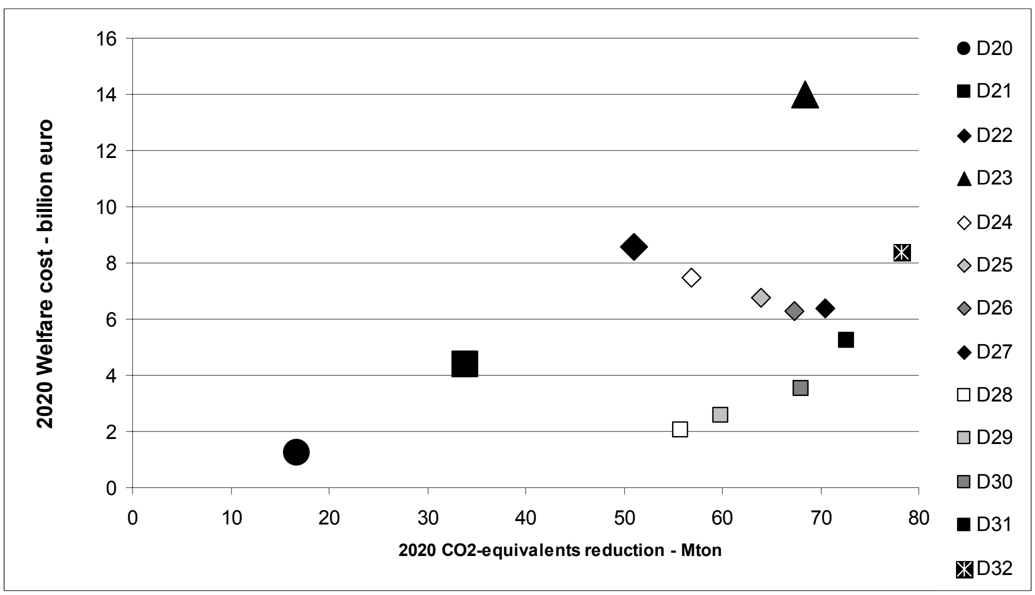
The cluster of square-shaped dots (D28-D32) includes scenarios in which technical measures on the vehicle level for cars up to 130 g./km are combined with supplementary measures. As for the gray cluster, these packages can lead to emission reduction similar to D23, and this at an even lower abatement 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.). 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.

4.3 Welfare effects

Figure 3 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 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 3: D20-D32 Welfare cost in 2020 – EU15 + 4 NMS



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

It is not the purpose of this paper 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 8 and

Table 9 provide summaries of the results of scenarios D23 and D30.

Summary tables for all scenarios are reported by Proost, S., De Ceuster, G., Van Herbruggen, B., Logghe, S., Ivanova, O., Carlier, K. (2006/2). Full D20-D32 scenario input and output files are available at the TREMOVE webpage (www.tremove.org).

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.

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 baseline scenario. Table 8 and provide similar tables for the D23 and D30 scenarios.

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 Task A outcome that fuel efficiency improvements for petrol cars are less costly than for diesel cars (see Task A report, figure 3.3).

Table 7: Baseline car sale market shares and CO2 emissions

	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

pcgs : small petrol car; pcgm : medium petrol car; pcgb : big petrol car; pcds : small diesel car; pcdm : medium diesel car; pcdb : big diesel car; pcl : LPG car; pcgs_cng : small CNG car, pcgm_cng : medium CNG car; pcgb_cng : big CNG car

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.

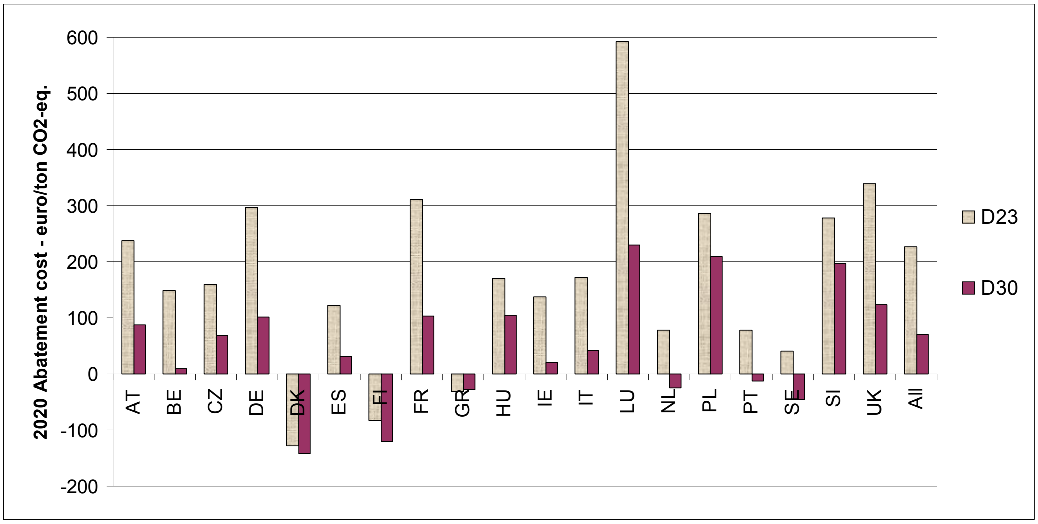
Effects on transport demand

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 earlier, 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 (Table 8) the opposite is true. This scenario leads to a decrease in car kilometres in the long term.

Differences between countries

Figure 4 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 120 g. D30 is a scenario that reaches a similar emission decrease at a lower cost, by combining 130 g. technology with supplementary measures.

Figure 4: 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 shares 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.

5 SUGGESTIONS FOR FURTHER RESEARCH

In this section we make some suggestions for further research that might improve the insight in the cost-effectiveness of CO_2 abatement in the European car sector.

Note that a more extensive interpretation of results, caveats and suggestions is given by Proost, S., De Ceuster, G., Van Herbruggen, B., Logghe, S., Ivanova, O., Carlier, K. (2006/2).

Firstly, the assumed future fuel ressource costs (and taxes) can have a significant impact on the cost-effectiveness results of the scenario simulations. The crude oil price forecast in TREMOVE has been taken from the EU Energy Outlook 2030. As future crude oil prices are uncertain, sensitivity analysis 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 transport forecast model is needed to assess such impacts. An application of TREMOVE in combination with a transport forecast model is described by De Ceuster, G., Logghe, S., Van Herbruggen, B. (2006).

Secondly, for the emission reduction potential of technical measures at the vehicle level, the Task A study has focussed mainly on effects on test-cycle emissions. Further research on the impacts of improved technologies on real-world emissions would be interesting.

Thirdly, there are still uncertainties with respect to the technology costs to reach test-cycle emission reductions. E.g. public knowledge on the effects of improved technogies on repair/maintenance costs is limited.

Finally, 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 and car parameters 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 to the modellers.

APPENDIX

Table 8: 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 9: 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

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