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Authors

Charis Kouridis
Thomas Papageorgiou
Giorgos Mellios

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European Commission
Directorate-General Environment
Directorate C: Climate Change & Air
Unit C3: Clean Air & Transport
1049 Brussels

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Air pollution consequences of postponing the implementation date of EURO VI standards for heavy duty vehicles

EMISIA SA
ANTONI TRITSI 15-17
PO BOX 20640 GR 55104
THESSALONIKI GREECE
tel: +30 2310 473352 fax: + 30 2310 473374
http://www.emisia.com

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Dr. Giorgos Mellios

Author(s)

Charis Kouridis, Thomas Papageorgiou, Giorgos Mellios

Approved by

Summary

This report presents the results of EURO VI scenario runs undertaken by EMISIA SA in the framework of the "Air pollution consequences of postponing the implementation date of EURO VI standards for heavy duty vehicles" scenario runs. The report explains the setup of the scenarios and the mathematical formulation of the emission and cost calculation. In addition it presents the final results of the scenario execution and a sensitivity analysis performed on the date of implementation. The runs have been performed with version 3.1 of the TREMOVE model. This report also compares the results against the run performed in the framework of the "TREMOVE Lot2: Scenario Runs" project with TREMOVE 2.52.

Keywords

TREMOVE, emission projection, cost scenarios, EURO VI, heavy duty vehicles

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64	15	27	5

Contents

1 Executive Summary

Air pollutant emissions decrease over time since EURO V vehicles are being replaced by EURO VI with a 2 years delay. The effect of postponing the implementation year from 2013 to 2015 is mostly significant in the years 2013 and 2014 which are the years when the new technology is not yet implemented. The effect of this 2 year delay is still well visible in 2030 in terms of air pollutant emissions as well as welfare costs. NOx emissions are expected to be 9.2% (40,048 tonnes) higher in 2030 in case the implementation is postponed by 2 years. PM and CH4 emissions are also expected to be higher in 2030, by 5.1% and 3.5% respectively.

NOx emissions show a relatively high increase (9.2%) in 2030 for one main reason. In 2030 pre-EURO VI vehicles that still exist contribute to the total HD NOx emissions by almost 50%. This is due to the fact that EURO VI vehicles, although much higher in numbers, have reduced NOx emissions over EURO V vehicles by 80%. Therefore, the postponement of 2 years increases the number of pre-EURO VI vehicles in such a way that the effect becomes noticeable.

The effects of postponing the implementation of EURO VI on air pollutant emissions in years 2020 and 2030 are summarized in the following tables:

Table 1: Air pollutant emissions of HDV in 2020 (in tonnes):

	CO	VOC	CH4	NMVOC	NOx	PM
Basecase	122,722.7	20,464.2	6,145.9	14,333.9	1,475,553.9	19,787.3
2013 impl.	122,733.4	18,763.7	5,256.4	13,515.5	888,553.6	14,459.5
2015 impl.	122,734.2	19,087.1	5,424.6	13,671.9	998,551.9	15,459.1

Table 2: Air pollutant emissions of HDV in 2030 (in tonnes):

	CO	VOC	CH4	NMVOC	NOx	PM
Basecase	56,344.4	8,174.4	3,240.6	4,952.2	1,409,094.9	16,077.9
2013 impl.	56,273.8	5,324.2	1,758.9	3,571.7	436,655.7	7,227.6
2015 impl.	56,280.1	5,447.5	1,821.3	3,633.0	476,704.5	7,594.0

Table 3: Additional emissions of HDV (in %) due to postponing implementation date by 2 years

	CO	VOC	CH4	NMVOC	NOx	PM
in 2020	0.00%	1.72%	3.20%	1.16%	12.38%	6.91%
in 2030	0.01%	2.32%	3.55%	1.72%	9.17%	5.07%

Table 4: Additional cumulative emissions (in tonnes)

	CO	VOC	CH4	NMVOC	NOx	PM
2015 >> 2020	-62	2,403	1,259	1,155	830,893	7,534
2015 >> 2030	20	4,184	2,171	2,030	1,415,815	12,878

As results of modelled scenarios A1 and A2 are very similar, only results for scenarios A1 are presented in tables above.

2 Introduction

This report presents the results of EURO VI scenario runs undertaken by EMISIA SA in the framework of the "Air pollution consequences of postponing the implementation date of EURO VI standards for heavy duty vehicles" scenario runs. The report explains the setup of the scenarios and the mathematical formulation of the emission and cost calculation. In addition it presents the final results of the scenario execution and a sensitivity analysis performed on the date of implementation. The runs have been performed with version 3.1 of the TREMOVE model. This report also compares the results against the run performed in the framework of the "TREMOVE Lot2: Scenario Runs" project[1] with TREMOVE 2.52.

TREMOVE is a policy assessment model, designed to study the effects of different transport and environment policies on the emissions of the transport sector. It covers economic and technical aspects of transport and it is therefore usable for a complex set of scenario options.

It contains, inter alia, information on the mileage travelled by vehicles in the different transport modes, the vehicle stock and its specific emissions, as well as on the costs of transport and technologies.

In recent years the TREMOVE model has been developed further by TML, Leuven. The model and the different baselines are described in references [2] to [4]; for the runs shown in this report the currently most up-dated version 3.1 has been used.

In total 4 EURO VI scenarios were executed. The first 2 (31_A1_13 and 31_A2_13) were based on the same settings as the scenarios G1/A1 and G5/A2 (here named 252_A1_13 and 252_A2_13) designed in the framework of the "TREMOVE Lot2: Scenario Runs" project with TREMOVE 2.52. They were executed to check the compatibility of the code and the data between the two versions of TREMOVE. (2.52 and 3.1). The last two (31_A1_15 and 31_A2_15) were also based on the same settings with one difference: the implementation date of the new technology, namely a postponement of the introduction by 2 years (from 2013 to 2015). All 4 scenarios were executed using the TREMOVE v.3.1.

The report aims at comparing the results of the above scenarios. There will be a short description of the differences on the results of the runs between the two versions of the model. The focus of the report will be given on the differences between the scenarios and the base case in version 3.1 but also on the differences between the 2013 and 2015 scenarios in economical (welfare) and environmental (emissions) terms.

Runs have been carried out for all countries in TREMOVE v.3.1 (EU 27 plus Croatia, Norway, Switzerland and Turkey) and the totals shown relate to this coverage.

[1] 070501/2005/424660/MAR/C1 TREMOVE Model scenario runs related to the impact assessment of EURO VI emission limit values for Heavy Duty Vehicles

3 Scenario Design

The base case of the TREMOVE version 3.1, displays with regard to the HDV emission standards the situation in 2008, e.g. it includes EURO V as final HDV emission reduction step. This base case has not been modified for the runs included in this report.

The final settings for the EURO VI scenarios were delivered by the Commission at the end of June 2007; the settings for the sensitivity run were delivered in November 2007. Following the proposal made in the Peer Review, limit values for diesel HDV, buses and coaches and for gas engines have been defined. The emission standards considered for those scenarios are given in the following sections.

However, no CNG busses have been modelled in these scenarios. TREMOVE does not include the same level of detail in the description of CNG vehicles, as in the case of diesel buses. TREMOVE only includes Euro III CNG busses, and no other technologies or EEVs. In reality, European urban fleets contain CNG busses of different emission and engine technologies, including both lean-burn (Euro II) and stoichiometric (EEVs) ones. The emission performance of these busses is distinctly different: Lean-burn exhibit high NOx emissions (at an equivalent level of a Euro III diesel bus) while EEVs are at a Euro V level. Similarly, HC emissions are very different, with lean-burn exhibiting high (a few g/km) methane emissions and stoichiometric emitting similarly to gasoline engines (CH_4/THC =5-10%). The fleet description of CNG busses is also quite thin. Greece in 2005 already had 416 CNG busses (one of the largest fleets in Europe) but none appear in TREMOVE. On the other hand, the CNG fleet in EU 25 is in any case, rather small compared to diesel heavy duty vehicles. The European Commission (DG TREN) estimated, in their analysis for the impact assessment of the "Public Procurement" proposal[2], that about 11000 HDV and buses use CNG, compared to about 6 million diesel vehicles. In the light of the rough CNG description in TREMOVE and the relatively small contribution expected from such busses, the study team felt that any conclusions concerning CNG busses with TREMOVE would be highly uncertain, vulnerable to criticism and with low importance compared to diesel vehicles. Therefore the decision was taken not to include them in the analysis.

[2] COM(2005)634 final

3.1 Baseline

The emissions standards considered in the baseline scenario of TREMOVE are presented in the following.

In order to execute the different scenarios, the emission factors for each diesel vehicle category are reduced according to the ratio of the proposed EURO VI emission standard (see following sections) over the emission standards given in Table 5.

Table 5: Emission standards (Operation Cycle: ETC) for diesel engines considered in the baseline scenario

Pollutant	Diesel Emission Standard (=EURO V) g/kWh (ETC)
CO	4.0
THC	0.55
NO_x	2.0
PM	0.03

3.2 Scenarios

The runs were based on the scenario A settings that are described in the following tables.

<u>Scenario A</u>

<table>
<tr>
<td>Short description of scenario/ parameters modified compared to base run</td>
<td>Compared to the baseline emissions are reduced as follows:
Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro
<table>
<tr><th colspan="2">Scenario 5</th><th>Diesel engines</th></tr>
<tr><td rowspan="6">ETC test cycle</td><td>CO</td><td>4.0 g/kWh</td></tr>
<tr><td>THC</td><td>0.16 g/kWh</td></tr>
<tr><td>NOx</td><td>0.4 g/kWh</td></tr>
<tr><td>NH_3 (1)</td><td>10 ppm</td></tr>
<tr><td>PM</td><td>0.01 g/kWh</td></tr>
<tr><td>PM new metric</td><td>review at later date</td></tr>
</table>
Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4
<table>
<tr><th colspan="2">Scenario 5</th><th>Gas engines</th></tr>
<tr><td rowspan="7">ETC test cycle</td><td>CO</td><td>4.0 g/kWh</td></tr>
<tr><td>NMHC</td><td>0.16 g/kWh</td></tr>
<tr><td>CH_4</td><td>0.5 g/kWh</td></tr>
<tr><td>NOx</td><td>0.4 g/kWh</td></tr>
<tr><td>NH_3 (1)</td><td>10 ppm</td></tr>
<tr><td>PM</td><td>0.01 g/kWh</td></tr>
<tr><td>PM new metric</td><td>review at later date</td></tr>
</table>
</td>
</tr>
</table>

The emission reductions due to these scenario settings can be summarised as shown in the next table.

Table 6: Reductions of diesel-powered HDV emissions over EURO V

Pollutant	EURO V Standard (Diesel- ETC) (Excerpt) (g/kWh)	Scenario A Reduction over EURO V (Diesel) (%)
THC	0.55	71
NOx	2.0	80
PM	0.03	67
CO	4.0	0

In addition, the Commission requested from the consortium to take into account the following points:

1. To run defined sets of the "50 % cost allocation" and "100 % cost allocation" scenarios[3]
2. To be coherent with the scope of the proposal on EURO 5 and 6, to include "vehicles with a reference mass above 2610 kg" (instead of "heavy duty vehicles above 3.5 tons").
3. To assume that EURO V fleet consists by 70% of vehicles with SCR and by 30% of vehicles with EGR technology.
4. To formulate the scenarios with the cost of urea (AdBlue) for SCR, taking into account the Urea use of the EURO V fleet.
5. To set in a series of scenarios the CO limit equal to 3 g/kWh.

With regard to point 1, the costs associated with these technology steps are given in the Peer Review. For the 50 % allocation (see later for description) they are displayed in Table 7.

Table 7: Additional technology costs (€/veh.) for diesel-powered HDV in case of 50 % costs allocation

Swept volume	Scenario A
6 litre	2954,-
9 litre	3866,-
13 litre	4866,-

For the 100 % allocation (see later for description) they are displayed in Table 8.

Table 8: Additional technology costs (€/veh.) for diesel-powered HDV of the four scenarios selected by the Commission in case of 100 % costs allocation

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[3] Allocating 50% or 100% of the costs of dual-use technology to EURO VI is based on the qualitative statement in the Peer Review:

> *"As far as the panel is informed the cost data supplied are based on uncertain production volumes of certain typical components in 2012. This leads to the panel's conclusion that cost figures for especially DeNOx and DPF in 2012 and later, could be lower than expressed by the stakeholders now, if large volumes of the total new sold vehicles would be equipped with these components …. Because of this aspect costs data should be seen as worst case."*

and the fact that in a similar situation with regard to EURO V it was decided to reduce the cost by 1/3 in order to account for economies of scale and learning effects.

Swept volume	Scenario A
6 litre	3454,-
9 litre	4466,-
13 litre	5566,-

With regard to point 2, the treatment of LDV with a reference mass above 2610 kg, market studies in Germany showed that this sub-segment corresponds to just about 1% of the LDV fleet. Moreover, TREMOVE does not contain detailed enough information on the LDV segmentation to accurately model this particular vehicle category. Therefore it was decided to neglect this requirement since it would not have any noticeable repercussions on the results.

With regard to point 3, it should be recalled that in the Peer Review the technology costs are based on Euro IV[4]. However, a large number of manufacturers use SCR technology already for complying with EURO V standards. The 30/70-EGR/SCR-share is the result of the market analysis carried out by the current study team in collaboration with the European Commission and has been taken into account for the costs allocation (see cost calculation for exact formulation).

With regard to point 4, the current AdBlue costs have been estimated and attributed to the fleets as proposed under point 3.

With regard to point 5, the requirement to set the CO limit values at levels equivalent to US 2010 standards with a neutral approach (same limit values) for diesel and natural gas powered engines, has been implemented. However, since such a step was not considered in the Peer Review report, the costs remained unchanged.

In summary, the consortium executed the scenarios presented in Table 9, based on requests the Commission, in addition to the information provided by review conducted by the EURO VI expert panel.

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[4] Excerpt from the report on EURO VI: "*Based on the description above, the Euro IV baseline technology scenarios can be described as follows:*

Stoichiometric:

- *Multi point intake manifold fuel injection*
- *Closed loop, close coupled 3-way catalyst*

Lean/stratified:

- *Multi point intake manifold fuel injection*
- *Closed loop, 3 way catalyst for stoichiometric mode working in oxidation mode during lean operation (no NOx aftertreatment needed because of lean combustion)*
- *State of the art sensor technology (linear lambda sondes)*".

Table 9: Executed EURO VI main scenarios, as defined by the Commission

Scenario Category	**A**
	A1
EURO VI with 100% costs allocation	Limit value set&costs as in scenario A; AdBlue costs in accordance with a EURO V split with 70% SCR/30%EGR
	A2
EURO VI with 50% cost allocation	Like A1 plus, but with 50 % cost allocation

It should be mentioned that the EURO VI review report does not provide figures on additional maintenance costs. It is, however, not expected that the additional technologies will last for the whole lifetime of the vehicle without maintenance and replacement. In fact, in the light of the high mileages driven by these vehicles one could expect that the filter and the SCR unit needs to be replaced at least once within the vehicle lifetime. However, due to the lack of data, the maintenance costs were kept equal to zero.

Finally, it should be noted that according to the EURO VI review report, the fuel consumption remains unchanged.

Annex A.1 summarises the scenarios one-by-one.

4 TREMOVE settings

4.1 Emission settings

The software options that TREMOVE 3.1 provides allow modelling the changes in emissions relatively well.

A new HDV vehicle technology was added in the TREMOVE structure and the emissions factors of EURO VI are introduced in this vehicle technology. These emission factors are implemented by making use of a “correction table” which is part of TREMOVE, which is based on the percentage reductions indicated in the given above.

This "correction table" is the REDUC_NEW_TECH dataset of the model which represents the emission reduction percentage for future emissions standards relative to latest existing standard.

4.2 Cost settings

In the 2.52 version of the TREMOVE model the COSTROAD parameter is introduced, which represents the road money components calculated in the vehicle stock module, and it is expressed in Euro per vehicle-kilometre. One of these components is "COSTpurchase" which refers to the vehicle purchase resource cost (in vkm).

With the proper mathematical formulation that is explained in the next paragraph, the parameter COSTROAD is used for modelling the repercussions of HDV price variations and the AdBlue costs.

The estimated additional technology costs - as taken from the review report on EURO VI [1] and shown in Table 7 and Table 8 have to be translated into costs for the HDV and bus/coaches classes as used in TREMOVE. For this purpose, in the first step, a function [swept volume = f(weight)] was derived, based on 2006 market figures. This function shows the following (rounded) relations: 6 litres = 14 tons; 9 litres = 22 tons and 13 litres = 34 tons and buses/coaches.

This spilt, however, does not fit to the weight classes provided by TREMOVE. TREMOVE contains the following classes:

HTD1 = 3,5 – 7,5 tons

HTD2 = 7,5 – 16 tons

HTD3 = 16 – 32 tons

HTD4 = >32 tons

Therefore, in a second step, the following approximation has been applied:

HTD1 = uses costs for 6 litres = 14 tons

HTD2 = uses costs for 6 litres = 14 tons

HTD3 = Uses costs for 9 litres = 22 tons

HTD4 = uses costs for 13 litres = 34 tons

In addition to the cost increases for EURO VI vehicles due to the technology costs, one has to increase the variable costs due to AdBlue consumption. The Peer Review does not contain additional costs due to AdBlue consumption.

For estimating the relevant difference between EURO VI and EURO V, the AdBlue consumed by EURO V vehicles has to be taken into account in order to avoid exaggerating the EURO VI costs. Expert views based on the current HDV EURO V market suggest that about 70 % of the EURO V vehicles will be equipped with SCR and therefore consume AdBlue. This has to be taken into account when allocating the costs.

The consumption of AdBlue for EURO V trucks is currently in the range of 3 - 6% of the diesel fuel consumption (that means already here you have a factor of two), one has also a factor of two for the price of AdBlue (service station 18 litre bottles cost about 0,67 €/litre vs. AdBlue consumption at larger quantities with own storage and pumping system; here the price depends on the quantities one orders. An offer requested by the consortium shows that AdBlue is offered for 0,27 EURO/litre for quantities above 3000 litres if the truck operator has an in-house storage system which costs about 5.000 EURO investments).

Therefore the AdBlue consumption has been modelled as follows: For the class 3,5 - 7,5 t please a net price of 0,6 €/litre, for the class 7,5 - 16 tons a price of 0,50 €/litre, for the class 16-32 tons a price of 0,40 €/litre and for > 32 tons of 0,30 €/litre has been taken.

These findings have been transformed into a cost matrix for AdBlue use.

Table 10: Costs for AdBlue in EURO/litre consumed

AdBlue cost	HTD1	HTD2	HTD3	HTD4	BUS
Scenario A	0.009	0.0075	0.00675	0.006	0.006

It could be argued that a 30% cost allocation of AdBlue to EURO VI should be accompanied by a 30% cost allocation for technology costs as well. However, as explained for the technology costs, the technology costs allocation is based on completely different line of arguments. Therefore the technology costs remained untouched.

4.3 Mathematical formulation of the cost settings

In order to simulate the increase in technology costs in the scenarios due to the use of SCR and DPF the parameter "fixed resource costs" (which is set equal zero in the baseline) was modified by adding a fixed calculated value to the parameter COSTROAD.

The parameter is expressed in €/vkm. In order to obtain the additional costs in €/vehicle one has to attribute these costs to the total mileage driven by the specific vehicle. Additionally, since the above parameters correspond not only to EURO VI vehicles but to the total vehicle type (e.g. HTD1, HTD2 etc), the additional costs were proportionally applied according to the vkm of the EURO VI technology over the vkm of the total vehicle type.

In order to take into account the additional costs for AdBlue a fixed calculated value was added to the parameter COSTROAD. This value was calculated as the product of the additional fuel cost and a percentage of the diesel fuel consumed by the EURO VI vehicles. Both parameters correspond to vehicle type (e.g. HTD1, HTD2 etc) so the additional fuel cost should be proportionally applied (by using the vkm of EURO VI, in relation to the total vkm of the vehicle type). In summary the additional costs have been inserted as follows:

$$Additional\_cost = Technology\_cost + AdBlue\_cost$$

In detail:

$$Additional\_cost = \frac{Cost\_per\_vehicle_i}{Life\_Expectancy_i \cdot Annual\_Mileage_i} \cdot \frac{VehKm_{i,j}}{VehKm_j} + AdBlue\_Alloc \cdot \frac{AdBlue\_Cost_i \cdot Fuel\_Consumed_i}{VehKm_i} \cdot \frac{VehKm_{i,j}}{VehKm_j}$$

Where i is the corresponding technology (EURO VI) and j each heavy duty vehicle type (e.g. 3,5-7,5 ton, >32 ton etc).

For the calculations of each year, input values of the previous year are used (e.g. vkm, annual mileage etc), according to the methodology used in TREMOVE.

5 Scenario results

TREMOVE delivers a large body of data. However, of interest for the EURO VI assessment are mainly the evolution of the emissions of the limited pollutants, and those affected by these limitations and the associated costs. The current version of TREMOVE calculates these parameters up to the year 2030, covering nearly the full effect of EURO VI on emission reductions and costs being deployed.

In addition to the presentation given in the following, the key results are also displayed scenario-by-scenario in Annex A.2.

5.1 Evolution of air pollutant emissions

5.1.1 TREMOVE version comparison

In comparison to the base case, emissions reductions occur mainly for NOx, VOC and PM.

Table 11: Reductions of emissions of HDV in 2030 in % relative to the base case for the two versions (2.52 and 3.1)

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
Reduction relative to 2.52 Basecase						
252_A1_13	0.4	34.6	46.0	25.4	69.2	55.0
252_A2_13	0.4	34.6	46.0	25.4	69.2	55.0
Reduction relative to 3.1 Basecase						
31_A1_13	0.1	34.9	45.7	27.9	69.0	55.0
31_A2_13	0.1	34.9	45.7	27.9	69.0	55.0

Table 12: Total emissions of HDV in 2030 in tons for the two versions (2.52 and 3.1)

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
252_Basecase	52,212	7,047	3,194	3,885	1,394,280	15,174
252_A1_13	51,987	4,609	1,724	2,897	429,658	6,831
252_A2_13	52,014	4,609	1,724	2,897	429,842	6,833
31_Basecase	56,344	8,174	3,241	4,952	1,409,095	16,078
31_A1_13	56,274	5,324	1,759	3,572	436,656	7,228
31_A2_13	56,282	5,324	1,759	3,572	436,704	7,229

Table 13: Reductions of emissions of HDV in 2030 in tons relative to the base case for the two versions (2.52 and 3.1)

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
Reduction relative to 2.52 Basecase						
252_A1_13	225	2,438	1,470	988	964,622	8,343
252_A2_13	198	2,438	1,470	988	964,438	8,341
Reduction relative to 3.1 Basecase						
31_A1_13	70	2,850	1,482	1,380	972,439	8,850
31_A2_13	62	2,850	1,482	1,380	972,391	8,849

It should be noted that the small changes in emissions of pollutants which are actually not reduced due the introduction of new limit values results from small changes in the vehicle fleets. These changes are caused by the additional costs attributed to HDV due to the EURO VI introduction which lead to a small modal shift effect.

The comparison of the two models shows that the differences when using either model are very small. In addition results of scenarios A1 and A2 in both models show that the cost differences between the two scenarios do not affect the reduction or the evolution of the emissions.

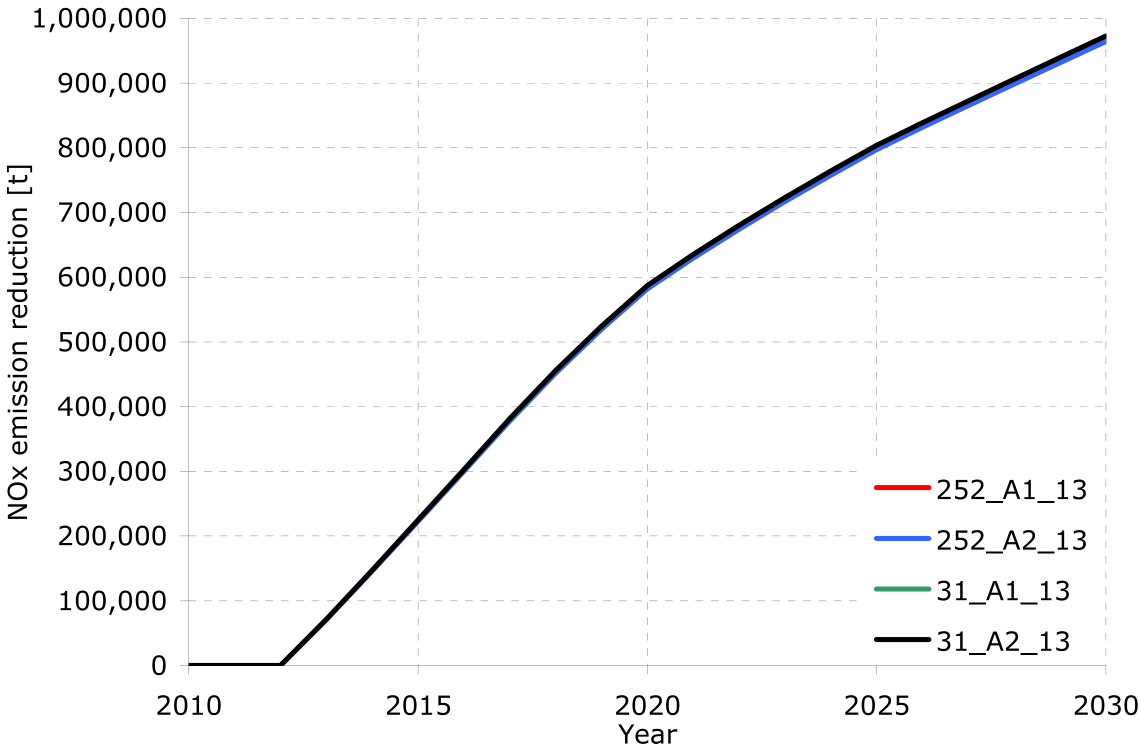

Figure 1: Reductions of NOx emissions of the scenarios in tons (2.52 and 3.1)

Over the years the evolution of emission reductions shows a nearly straight up-wards trend for all pollutants which, however, is not simply linear.

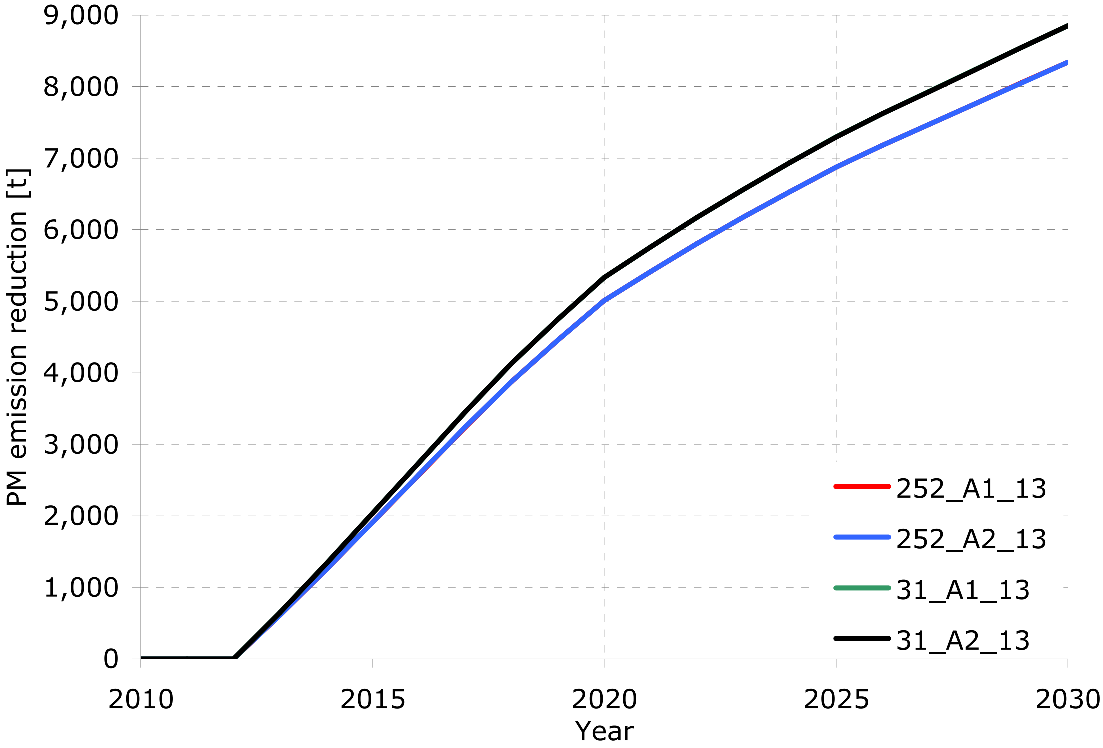

Figure 2: Reductions of PM emissions of the scenarios in tons (2.52 and 3.1)

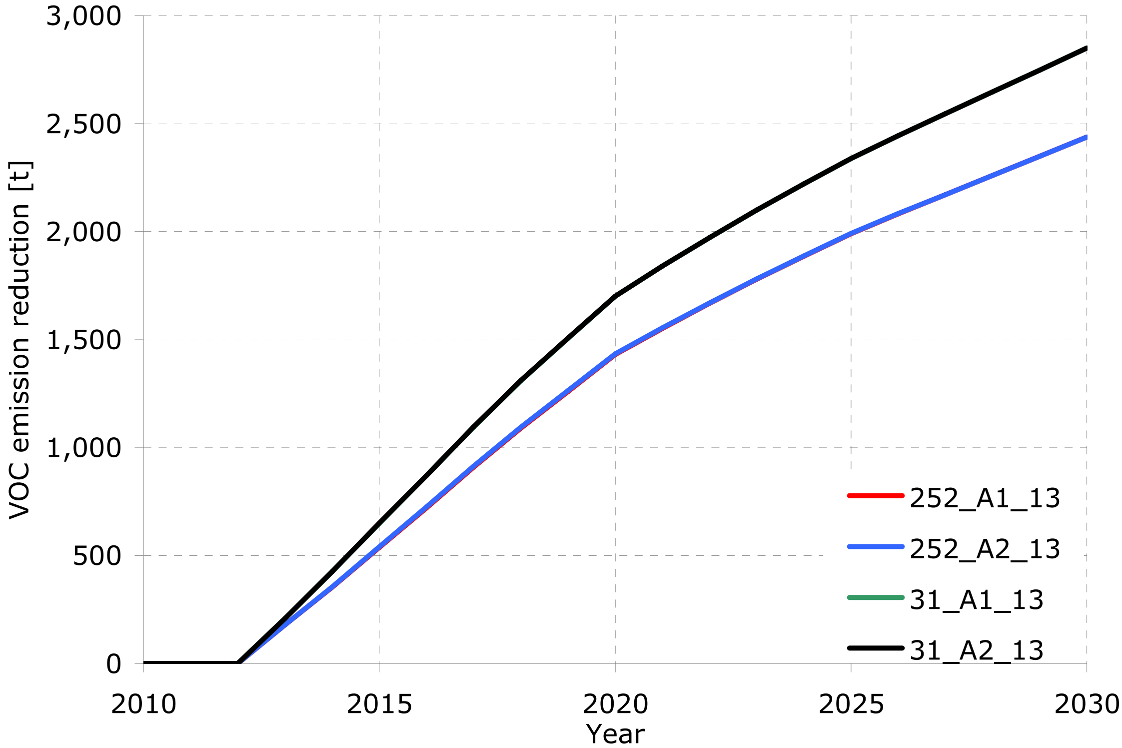

Figure 3: Reductions of VOC emissions of the scenarios in tons (2.52 and 3.1)

5.1.2 Effect of the postponement

From the following tables it is apparent that the impact of the postponement is stronger on NOx emissions, which is expected since NOx emissions are lowered in EURO VI HDV more than PM or VOC. However the overall impact of the postponement of the implementation of the new vehicle technology on the emissions is relatively small when compared to base case. However when comparing in details expected emissions in 2020 and 2030 between the 2013 and 2015 implementation dates, we observe some significant increases in air pollutant emissions.

Table 14: Reductions of emissions of HDV in 2020 in tons relative to the 3.1 base case

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_13	-11	1,701	890	818	587,000	5,328
31_A1_15	-12	1,377	721	662	477,002	4,328
31_A2_13	-10	1,701	890	819	587,009	5,328
31_A2_15	-11	1,378	721	663	477,016	4,328

Table 15: Reductions of emissions of HDV in 2020 in % relative to the 3.1 base case

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_13	0.0	8.3	14.5	5.7	39.8	26.9
31_A1_15	0.0	6.7	11.7	4.6	32.3	21.9
31_A2_13	0.0	8.3	14.5	5.7	39.8	26.9
31_A2_15	0.0	6.7	11.7	4.6	32.3	21.9

Table 16: Reductions of emissions of HDV in 2030 in tons relative to the 3.1 base case

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_13	70	2,850	1,482	1,380	972,439	8,850
31_A1_15	64	2,727	1,420	1,319	932,391	8,484
31_A2_13	62	2,850	1,482	1,380	972,391	8,849
31_A2_15	57	2,726	1,420	1,319	932,349	8,483

Table 17: Reductions of emissions of HDV in 2030 in % relative to the 3.1 base case

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_13	0.1	34.9	45.7	27.9	69.0	55.0
31_A1_15	0.1	33.4	43.8	26.6	66.2	52.8
31_A2_13	0.1	34.9	45.7	27.9	69.0	55.0
31_A2_15	0.1	33.4	43.8	26.6	66.2	52.8

Table 18: Additional emissions of HDV in 2020 in tons relative to the 2013 implementation date

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_15	1	323	168	156	109,998	1,000
31_A2_15	1	324	168	157	109,993	1,000

Table 19: Additional emissions of HDV in 2020 in % relative to the 2013 implementation date

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_15	0.0%	1.7%	3.2%	1.2%	12.4%	6.9%
31_A2_15	0.0%	1.7%	3.2%	1.2%	12.4%	6.9%

Table 20: Additional emissions of HDV in 2030 in tons relative to the 2013 implementation date

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_15	6	123	62	61	40,049	366
31_A2_15	6	123	62	61	40,042	366

Table 21: Additional emissions of HDV in 2030 in % relative to the 2013 implementation date

Scenario/Run	CO	VOC	CH4	NMVOC	NOx	PM
31_A1_15	0.0%	2.3%	3.5%	1.7%	9.2%	5.1%
31_A2_15	0.0%	2.3%	3.5%	1.7%	9.2%	5.1%

Table 22: Additional cumulative emissions in tonnes relative to the 2013 implementation date

31_A1_15	CO	VOC	CH4	NMVOC	NOx	PM
2015 >> 2020	-62	2,403	1,259	1,155	830,893	7,534
2015 >> 2030	20	4,184	2,171	2,030	1,415,815	12,878

Table 23: Additional cumulative emissions in tonnes relative to the 2013 implementation date

31_A2_15	CO	VOC	CH4	NMVOC	NOx	PM
2015 >> 2020	-56	2,405	1,259	1,157	830,922	7,534
2015 >> 2030	17	4,186	2,171	2,031	1,415,754	12,877

The following graphs present, the evolution of the key pollutants for the scenarios over time.

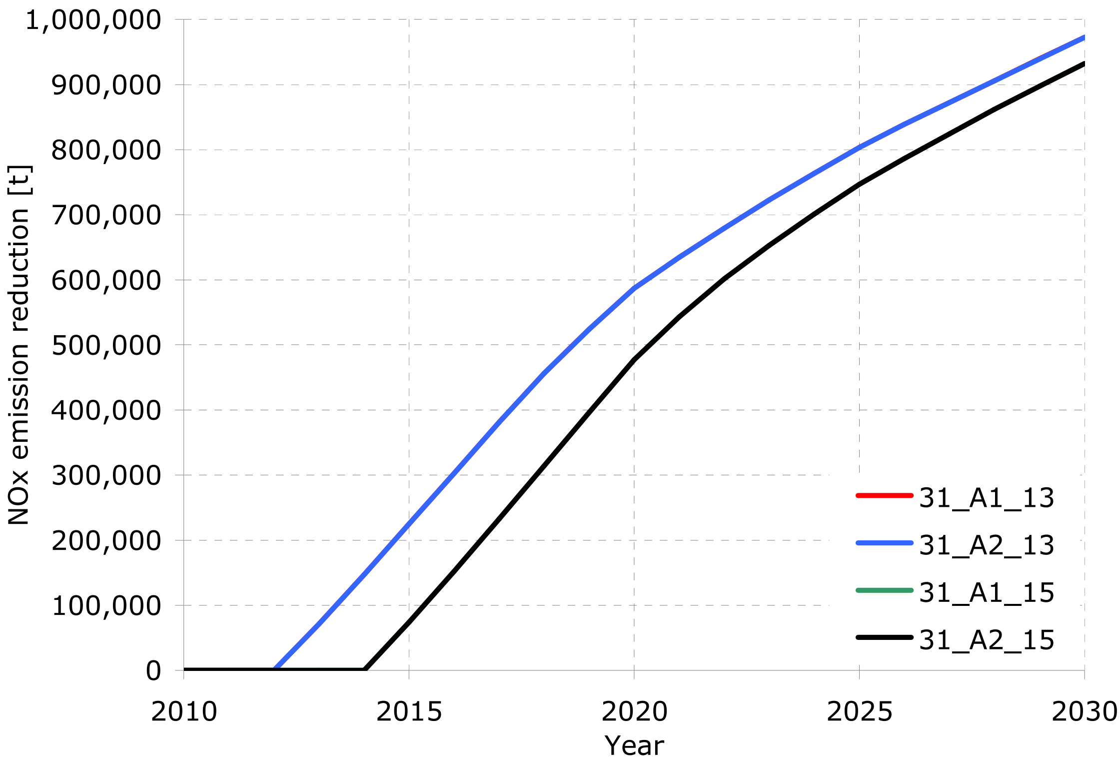

Figure 4: Reduction of NOx emissions of the scenarios in tons relative to the base case

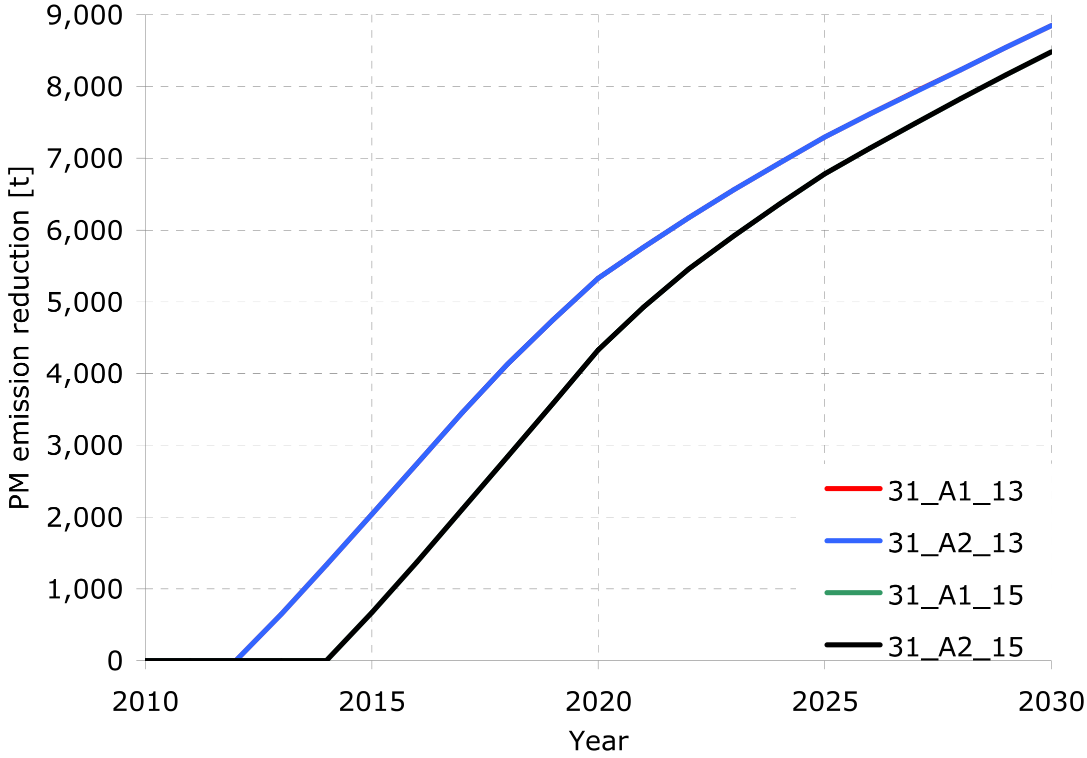

Figure 5: Reduction of PM emissions of the scenarios in tons relative to the base case

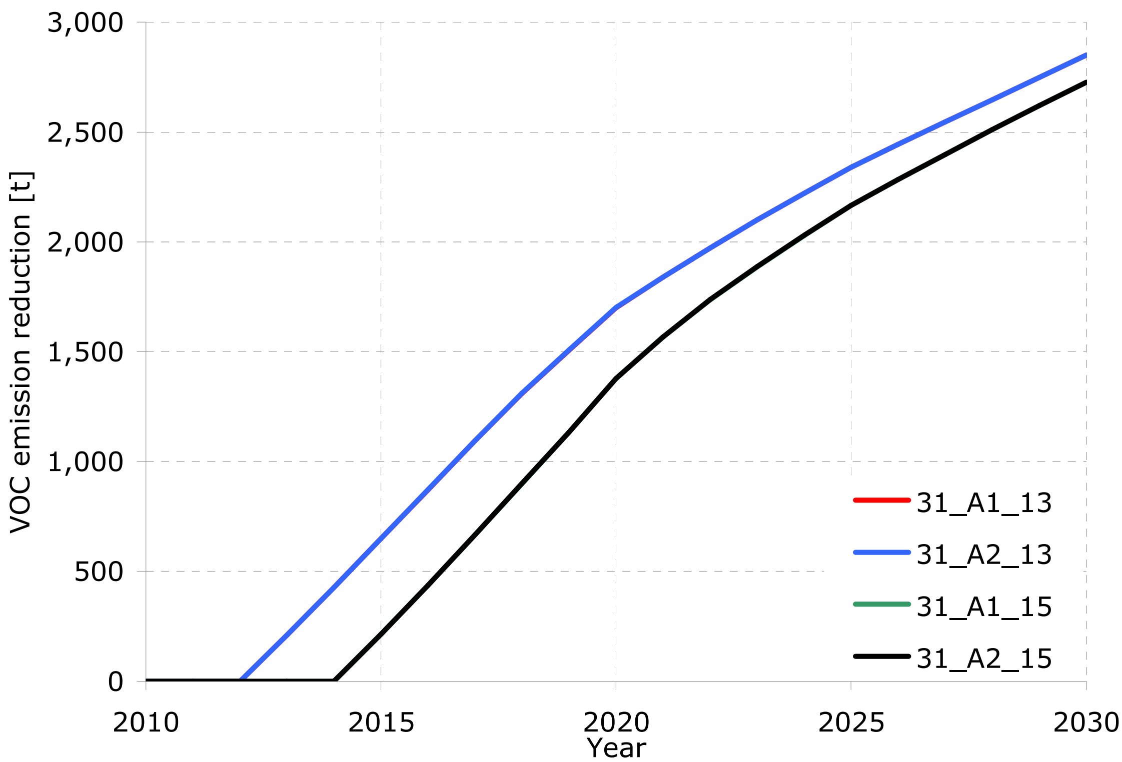

Figure 6: Reduction of VOC emissions of the scenarios in tons relative to the base case

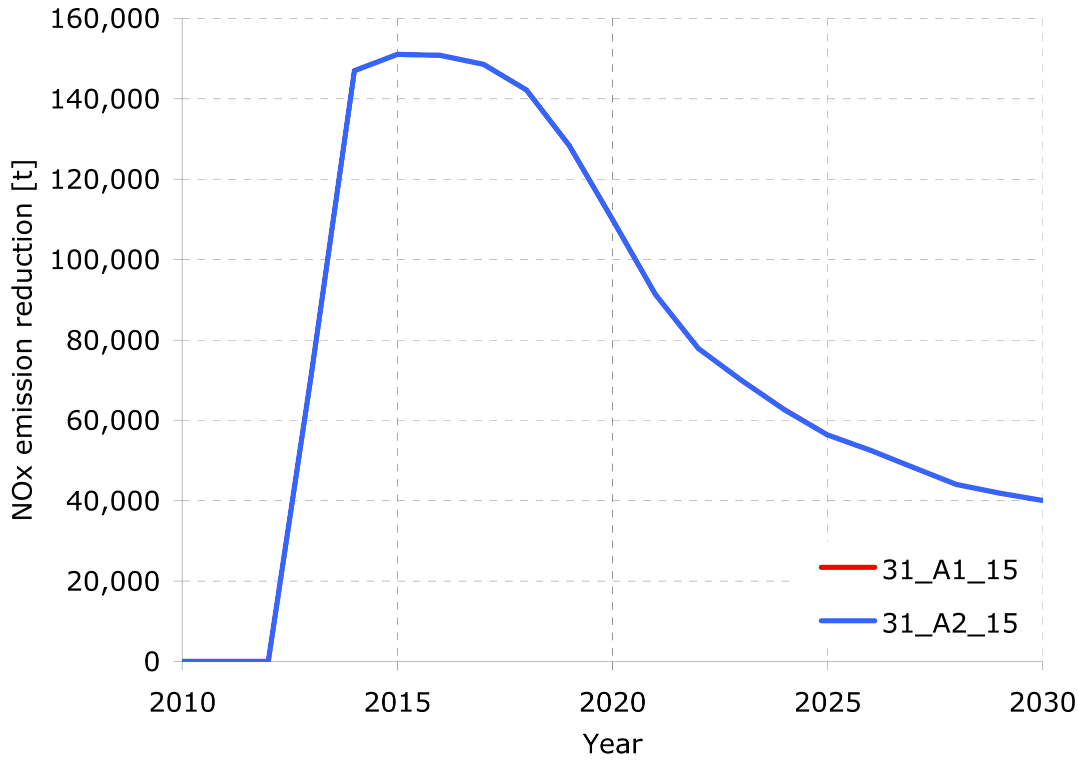

Figure 7: Difference in NOx emissions of the scenarios in tons relative to the 2013 implementation date

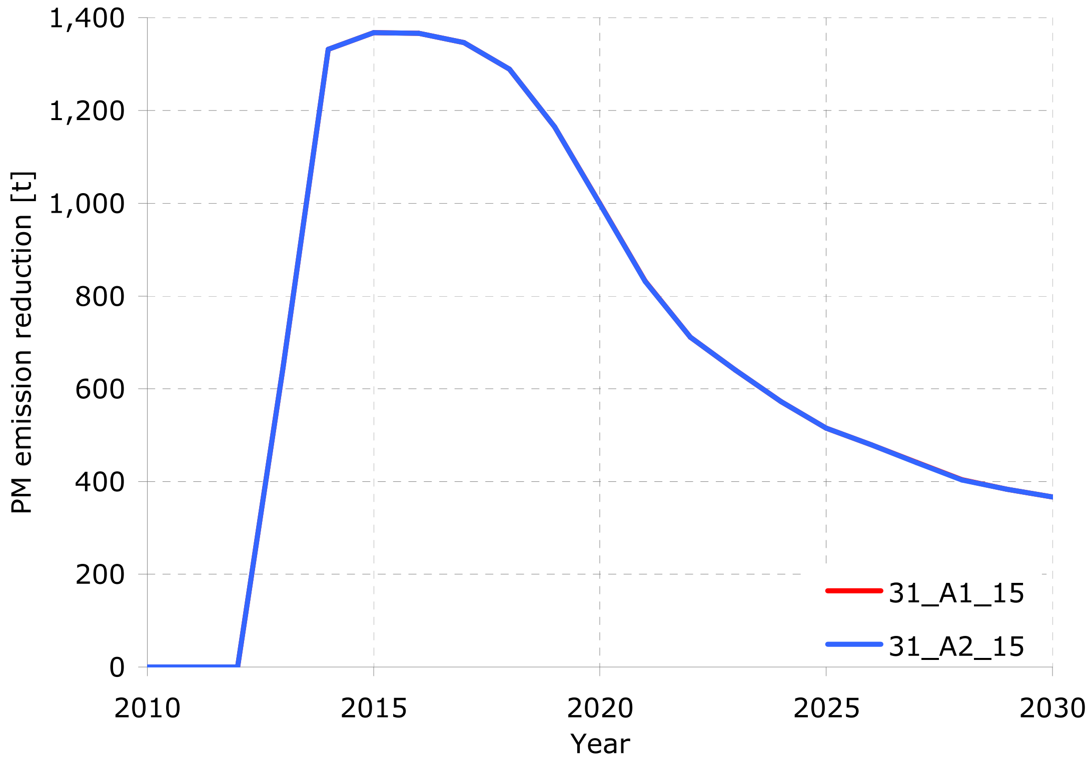

Figure 8: Difference in PM emissions of the scenarios in tons relative to the 2013 implementation date

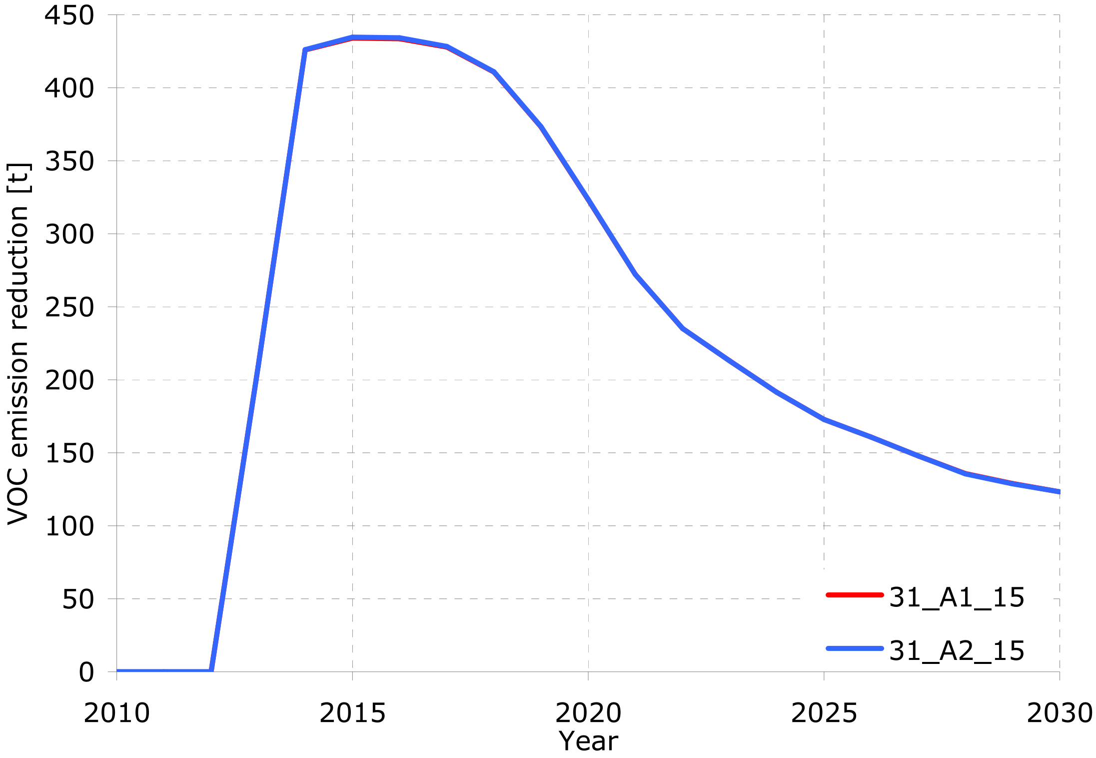

Figure 9: Difference in VOC emissions of the scenarios in tons relative to the 2013 implementation date

Figure 7, Figure 8 and Figure 9 show that the effect of the postponement is significant in the years 2013 and 2014 which are the years when the new technology is not implemented yet when considering scenarios A1 and A2_15. However the effect on the emissions seems to decrease over time since EURO V vehicles are being replaced by EURO VI.

5.2 Costs

TREMOVE calculates a standard set of welfare costs.

Utility of households: Represents the impact of the increase in transport price for persons. (The change of transport prices for 'goods' is covered in the production costs term). If it is negative, persons have to pay more for transport.

Production costs: Represent the costs for industry and other sectors to provide their products/services increases - as the price of transport increases. If it is negative it means here the production costs of HDV, buses and coaches are higher.

Costs of public funds (general): represents Government income. The Government gets less income, and has to compensate this by increasing general taxes - assuming that the overall government budget has to be kept constant. The taxes covered are

- private passenger transport - in case vkm decreased: all vehicle related taxes and Vat (on fuel, on purchase, on ownership, on registration, on insurance, on repair)
- heavy duty truck freight transport - in case of vkm decrease: decrease in fuel tax only.
- public transport - in case of decreased passenger-kilometres - decreased government expenditures to subsidies.

Costs of public funds (labour): as above, but government compensates by increasing labour taxes

Pollution benefits: represent the external costs as developed in CAFE by AEAT. There are low and high estimates in accordance with the Clean Air For Europe (CAFE)[5] settings. If the pollution benefits are positive, the cost burden is lowered.

Sum of welfare: Yearly welfare differences are calculated as sum of changes in 'utility of households', 'production costs', 'costs of public funds' and 'pollution benefits'. The net present value is the discounted sum over the 2005 to 2030 years in 2005.

As shown in the following tables, the sum of welfare is in all cases positive.

A positive number in the welfare calculations means a welfare gain. That means in these cases that the decrease of the environmental burden is higher than the cost burden added to households, production and public funds.

[5] http://ec.europa.eu/environment/air/cafe/

5.2.1 TREMOVE version comparison

Table 24: Results of welfare calculations for scenarios 252_A1_13, 252_A2_13, 31_A1_13 and 31_A2_13 for year 2030 (low and high values)

Costs are expressed in (mil EURO per Year)	252_A1_13 2030	31_A1_13 2030	252_A2_13 2030	31_A2_13 2030
Sum of utility of households	9.2	-139.3	6.7	-123.1
Sum of production costs	-2,404.3	-2,769.2	-2,120.3	-2,433.8
Sum of cost of public funds (general)	-572.6	-100.4	-502.0	-88.8
Sum of cost of public funds (labour)	-868.6	-157.2	-761.3	-139.1
Total welfare effect w/o pollution benefits (general)	-2,967.7	-2,576.3	-2,615.6	-2,260.0
Total welfare effect w/o pollution benefits (labour)	-3,263.6	-2,633.1	-2,874.8	-2,310.3
Pollution Benefits (low values)	5,703.6	5,703.5	5,689.7	5,700.9
Pollution Benefits (high values)	15,519.3	15,544.8	15,472.0	15,527.4
Sum of Welfare (general/low values)	2,735.9	3,127.2	3,074.1	3,440.9
Sum of Welfare (general/high values))	12,551.6	12,962.1	12,856.5	13,263.0
Sum of Welfare (labour/low values)	2,439.9	3,070.4	2,814.8	3,390.6
Sum of Welfare (labour/high values)	12,255.6	12,905.3	12,597.2	13,212.7

As for emissions the observed positive welfare costs trend holds for the whole period up to 2030, see graphs shown below.

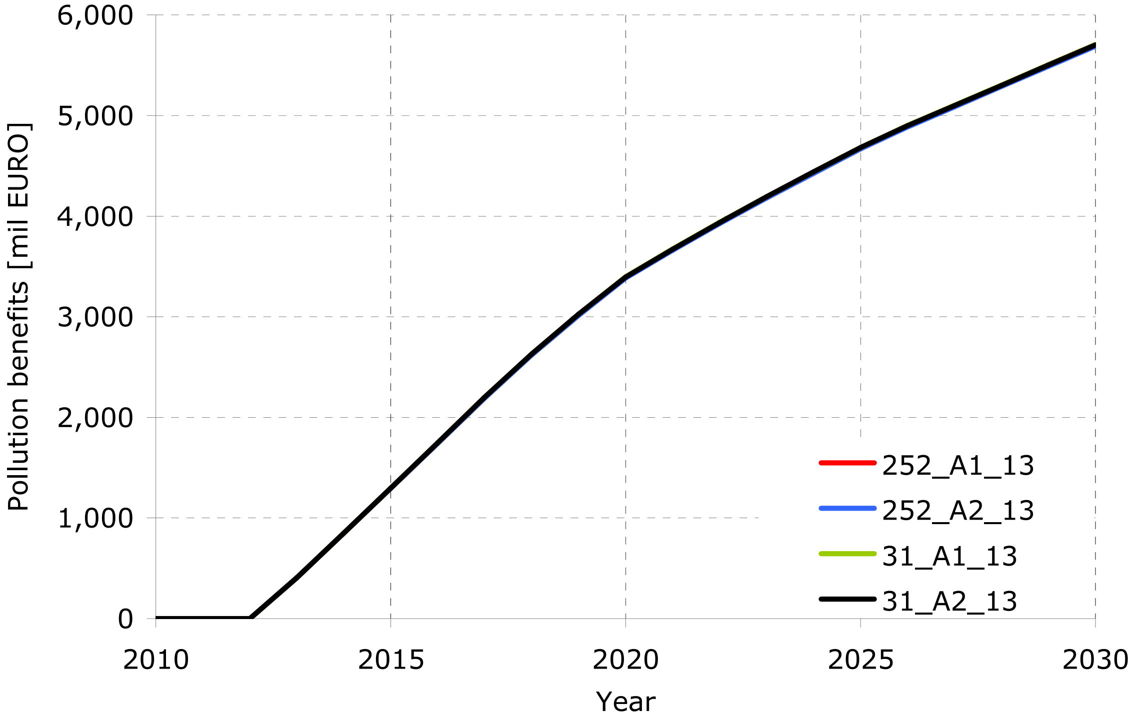

Figure 10: Pollution benefits in million EUROS for scenarios 252_A1_13, 252_A2_13, 31_A1_13 and 31_A2_13 (low values)

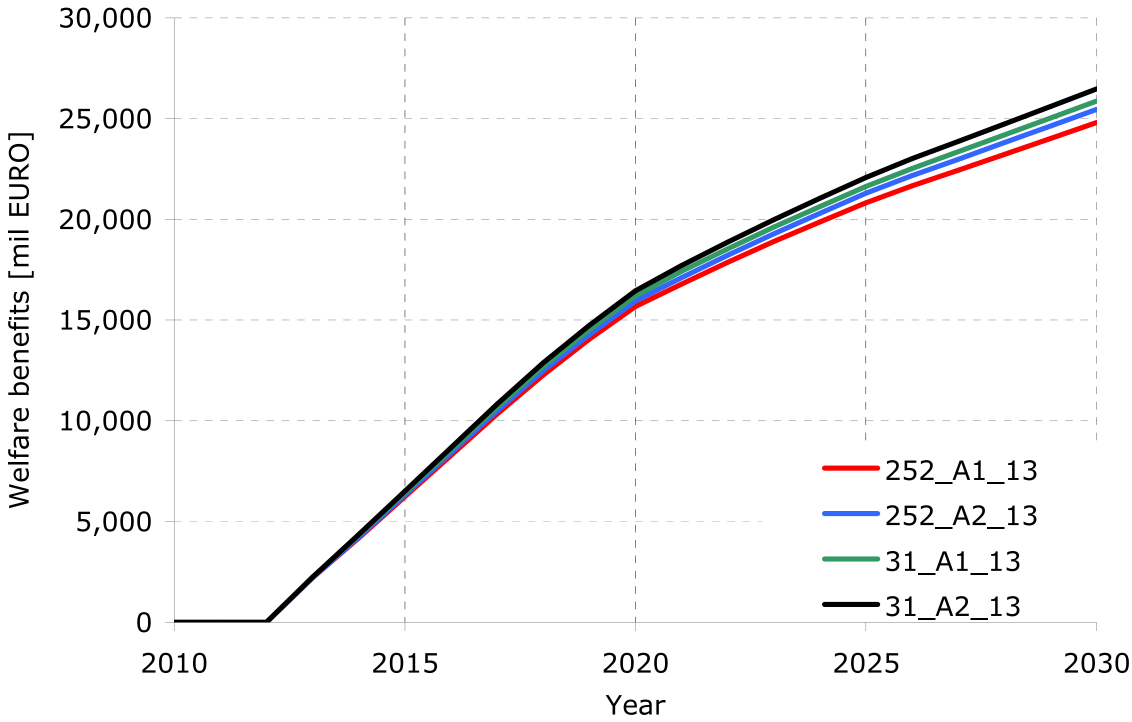

Figure 11: Sum of welfare benefits in million EURO for scenarios 252_A1_13, 252_A2_13, 31_A1_13 and 31_A2_13 (high values)

As mentioned it was not possible to model reductions of CNG vehicles. However, it is obvious that the additional technology costs for these vehicles would not change the picture. Assuming that all vehicles use EURO VI technology in 2030, the technology costs would account for about 1-3% of the technology costs for diesel powered HDV.

As with emissions, welfare values do not show significant differences between the two versions of the model.

5.2.2 Effect of the postponement

The following tables and graphs show the effect of the postponement of the implementation of the technology when using the TREMOVE version 3.1.

Table 25: Results of welfare calculations for scenarios 31_A1_13, 31_A2_13, 31_A1_15 and 31_A2_15 for year 2030 (low and high values)

Costs are expressed in (mil EURO per Year)	31_A1_13 2030	31_A1_15 2030	31_A2_13 2030	31_A2_15 2030
Sum of utility of households	-139.3	-126.0	-123.1	-111.3
Sum of production costs	-2,769.2	-2,547.9	-2,433.8	-2,241.0
Sum of cost of public funds (general)	-100.4	-94.6	-88.8	-83.8
Sum of cost of public funds (labour)	-157.2	-147.4	-139.1	-130.5
Total welfare effect w/o pollution benefits (general)	-2,576.3	-2,371.9	-2,260.0	-2,081.2
Total welfare effect w/o pollution benefits (labour)	-2,633.1	-2,424.7	-2,310.3	-2,127.9
Pollution Benefits (low values)	5,703.5	5,444.3	5,700.9	5,440.9
Pollution Benefits (high values)	15,544.8	14,834.6	15,527.4	14,817.6
Sum of Welfare (general/low values)	3,127.2	3,072.4	3,440.9	3,359.8
Sum of Welfare (general/high values))	12,962.1	12,457.5	13,263.0	12,733.1
Sum of Welfare (labour/low values)	3,070.4	3,019.7	3,390.6	3,313.1
Sum of Welfare (labour/high values)	12,905.3	12,404.8	13,212.7	12,686.5

As for emissions the observed positive welfare costs trend holds for the whole period up to 2030, see graphs shown below.

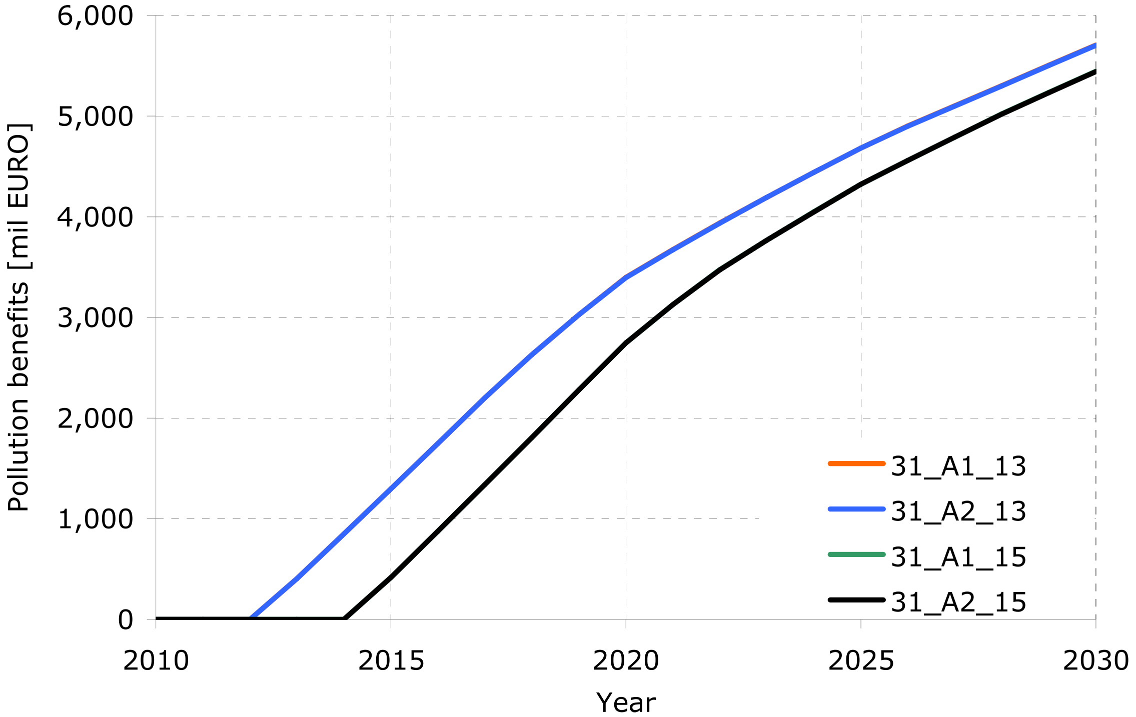

Figure 12: Pollution benefits in million EUROS for scenarios 31_A1_13, 31_A2_13, 31_A1_15 and 31_A2_15 (low values)

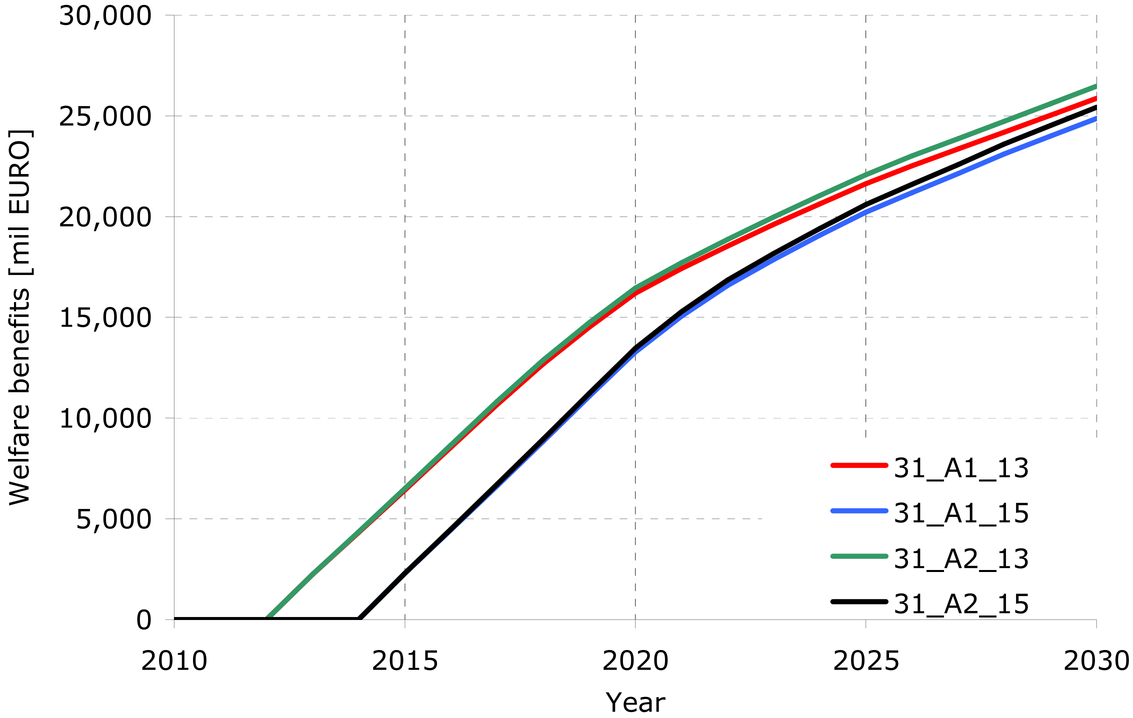

Figure 13: Sum of welfare benefits in million EURO for scenarios 31_A1_13, 31_A2_13, 31_A1_15 and 31_A2_15 (high values)

The results show that there is a welfare loss that is a direct result of the two year postponement. However this loss does not to pear significant even in year 2030 compared to the total welfare gain from the implementation of the technology.

Table 26: Difference in welfare costs when comparing the different implementation date runs for year 2030 (low and high values)

Costs are expressed in (mil EURO per Year)	31_A1_13 2030	31_A1_15 2030	31_A2_13 2030	31_A2_15 2030
Sum of utility of households	0	13.3	0	11.8
Sum of production costs	0	221.3	0	192.8
Sum of cost of public funds (general)	0	5.7	0	5.0
Sum of cost of public funds (labour)	0	9.8	0	8.6
Total welfare effect w/o pollution benefits (general)	0	204.4	0	178.8
Total welfare effect w/o pollution benefits (labour)	0	208.5	0	182.4
	0		0	
Pollution Benefits (low values)	0	-259.2	0	-259.9
Pollution Benefits (high values)	0	-710.2	0	-709.7
	0		0	
Sum of Welfare (general/low values)	0	-54.8	0	-81.1
Sum of Welfare (general/high values))	0	-504.6	0	-529.8
Sum of Welfare (labour/low values)	0	-50.7	0	-77.5
Sum of Welfare (labour/high values)	0	-500.5	0	-526.3

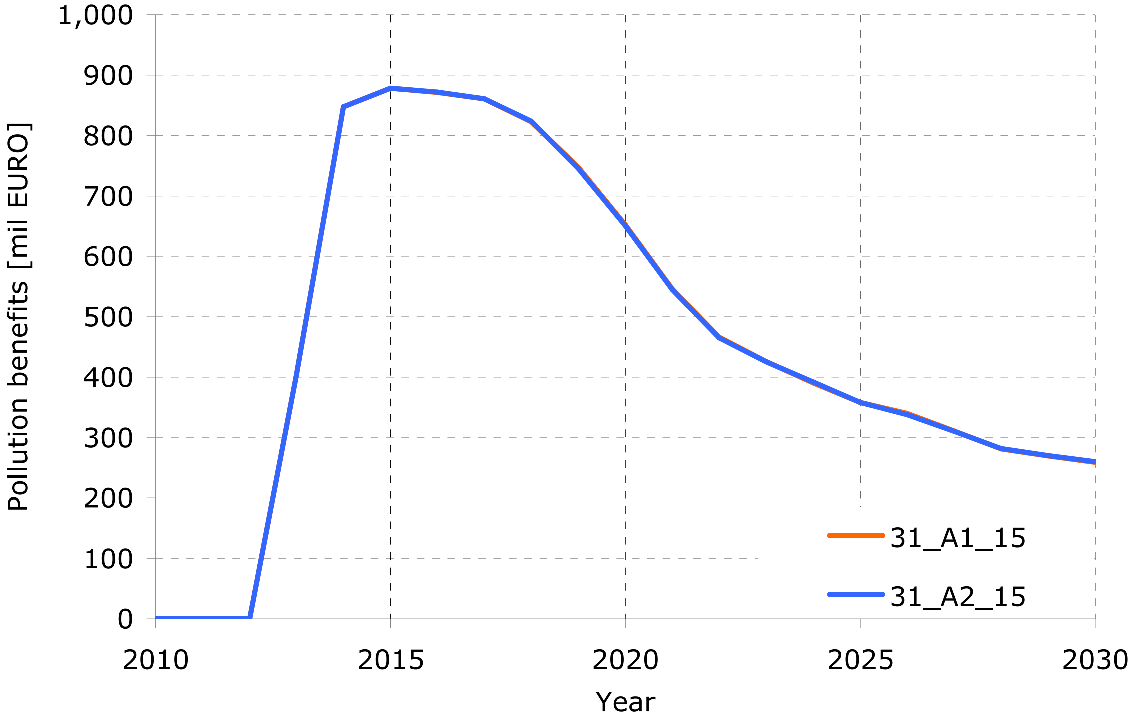

Figure 14: Pollution benefits in million EUROS for scenarios 31_A1_15, 31_A2_15 compared to 31_A1_13 and 31_A2_13 (low values)

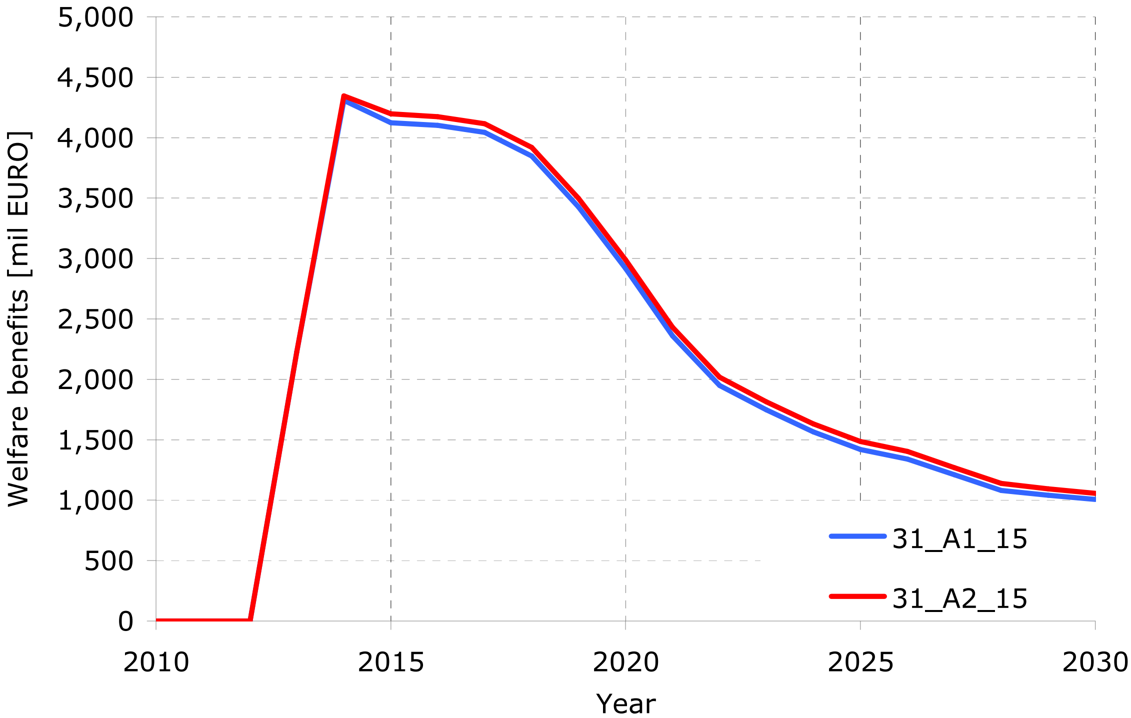

Figure 15: Sum of welfare benefits in million EURO for scenarios 31_A1_15, 31_A2_15 compared to 31_A1_13 and 31_A2_13 (high values)

Comparing scenarios A1 and A2 for the two different implementation dates we can clearly see that the effect is significant in years 2013 and 2014 but less important as the EURO VI vehicles are introduced in the fleet.

6 Conclusions

The repercussions of EURO VI emission limit values for Heavy Duty Vehicles (HDV) on emissions and costs have been investigated using the TREMOVE model, version 3.1, on the basis of instructions of the European Commission, DG Environment.

The sets of emission limit values, related to EURO V, are as follows:

Table 27: Reductions of diesel-powered HDV emissions over EURO V of the four scenarios selected by the Commission

Pollutant	**EURO V** Standard (Diesel- ETC) (Excerpt) (g/kWh)	**Scenario A** Reduction over EURO V (Diesel) (%)
THC	0,55	70
NOx	2,0	80
PM	0,03	66
CO	4,0	0

The TREMOVE model produces year by year output up to the year 2030.

Comparing the two versions of the model we can see that they (v2.52 and v3.1) produce very similar results for both emissions and welfare in both scenarios A1 and A2.

Looking into the effect of the introduction of EURO VI vehicles against the TREMOVE baseline it could be shown that

i. The application of the of limit values would result in significant NOx and visible PM and VOC emission reductions;

ii. The application of the limit values would in all cases results in positive overall welfare costs with the tendency of higher overall welfare costs in case of more stringent emission limits. The impact of a 50% or 100% technology cost (scenarios A1 and A2) allocation on the welfare results is very small;

iii. The costs associated with the different technologies required for meeting the different sets of emission limit values do not influence the transport demand, e.g. the application of even the most stringent set of limits would have no impact on road transport demand.

Looking into the effect of the postponement it can be shown that

i. The effect is significant in years 2013 and 2014, when the technology in scenarios 31_A1_15 and 31_A1_15 is not yet introduced;

ii. The effect becomes less significant as the time progresses due to the increase in the percentage of the population of EURO VI vehicles in the fleet.

7 References

[1] N.L.J. Gense (TNO), Riemersma (TNO), C Such (Ricardo), L Ntziachristos (LAT): EURO VI technologies and costs for Heavy Duty vehicles - The expert panel's summary of stakeholders' responses. Final Report of 12.09.2006

[2] Bart van Herbruggen, Griet De Ceuster, Kristof Carlier, Steven Logghe, Bruno Vanzeebroeck, Olga Ivanova (all TML): TREMOVE: Further development and application of the TREMOVE transport model - Lot 3 - Simulation of policy packages. Draft Final Report of 05.09.2006

[3] Bart van Herbruggen, Griet De Ceuster, Kristof Carlier (all TML): Further development and application of the TREMOVE transport model - Lot 3 - Policy runs. Draft Final Report of 05.11.2006

[4] Bart van Herbruggen, Griet De Ceuster, Kristof Carlier, Olga Ivanova (all TML), Angelo Martino, Davide Fiorello (all TRT): TREMOVE: Service contract for the further development and application of the transport and environmental TREMOVE model LOT 1- Improvement of the data and model structure. Final Report of 09.07.2007

[5] Karl-Heinz Zierock, Leon Ntziachristos, Chariton Kouridis, Dimitrios Gkatzoflias, Zissis Samaras: TREMOVE Model scenario runs related to the impact assessment of EURO VI emission limit values for Heavy Duty Vehicles. Draft Final Report of 03 March 2007.

8 ANNEXES

A.1: “Documentation Sheets” of scenarios executed

A.2: “Results Sheets” of scenarios executed

A.3: Emission results for all 31 countries of scenarios executed

NOx, PM, VOC, SO_2 - Year 2030

A.1: "Documentation Sheets" of scenarios executed

<table>
<tr><th colspan="2">TREMOVE Scenario - Documentation sheet of individual measures</th></tr>
<tr><td>Measure number (TREMOVE-sector code.number)</td><td>EURO VI - scenario 252_A1_13, 100% cost allocation</td></tr>
<tr><td>Other codes (e.g. Scenes; RAINS)</td><td>EEA Handbook: SNAP 07 03; UNFCCC NFR 1A3b; 2002 NFR 1A3biii</td></tr>
<tr><td>Title of measure</td><td>EURO VI limit values for HDV</td></tr>
<tr><td>Short description</td><td>Introduction of revised emission limit values for NOx, PM, THC (NMHC for CNG), CO and CH4 (limits in g/kWh):
<table><tr><th></th><th>NOx</th><th>PM</th><th>THC/NMHC</th><th>CO</th><th>CH4</th></tr><tr><td>Diesel</td><td>0,4</td><td>0,01</td><td>0,16</td><td>4,0</td><td>none</td></tr><tr><td>CNG</td><td>0,4</td><td>0,01</td><td>0,16</td><td>4,0</td><td>0,50</td></tr></table>NH3 < = 10 ppm for SCR + urea solutions</td></tr>
<tr><td>Target(s)
(e.g. mode or means of transport, types of vehicles, fuels…)</td><td>➢ Freight transport,
➢ Vehicles with a reference weight above 2610 kg,
➢ Diesel and CNG fuel</td></tr>
<tr><td>Regulatory background
1 Approach
2 Responsibility
3 State-of-play</td><td>1 Regulation
2 EU
3 In preparation, proposal expected in 2007</td></tr>
<tr><td>Implementation schedule
1 Start of measure
2 End of measure</td><td>1 1.1.2013 for all new type approvals; potential availability of EURO VI vehicles before that date is not taken into account
2 -</td></tr>
<tr><td>Geographical coverage
1 All EU MS
2 Selected EU MS
3 Selected parts of EU MS</td><td>1 all 27 EU MS + CH, NOR, HR, TR
2 -
3 -</td></tr>
<tr><td>Vehicles coverage
1 All vehicles
2 Only new vehicles
3 Fraction of vehicle market</td><td>1 -
2 All new vehicles with a reference weight above 2610 kg,
3 -</td></tr>
<tr><td>References and data sources</td><td>Directive 2005/55/EC as last amended</td></tr>
<tr><td>Comments on scenario design
1 general comments
2 technical aspects
3 cost aspects
4 political aspects
5 possible synergies
6 other aspects</td><td>1 Based on Peer review of September 2006: Diesel 5/CNG 5
2 Diesel: To achieve this Scenario NOx limit will require both cooled EGR and SCR. Together with an advanced development of the combustion system, fuel injection and turbocharging technology, it seems feasible to meet the PM limit with either an open-flow DPF or a wall-flow DPF. Fuel consumption is likely to increase compared to the Euro IV baseline, especially in the case of a wall-flow DPF; CNG (stoichiometric): optimised multipoint injection, improved catalytic converter, inlet manifold optimisation, CNG (lean burn): pre-cat UEGO, lean-burn lambda control, inlet manifold optimisation, SCR system, improved SCR control system
3 Average costs. Diesel: Swept volume 6 litre = 3454 EURO; 9 l = 4466 EURO; 13 l = 5566 EURO; cost increase due to urea consumption included; no additional maintenance costs.
4 Might include revised EEV standards + PM review clause
5 Fuel consumption kept stable; NO/NO2 ratio of NOx emissions might change
6 Transformation from swept volume to weight classes according to 2006 market investigation</td></tr>
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(TREMOVE-sector code. number)</td><td>EURO VI - scenario 252_A2_13, 50% cost allocation</td></tr>
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8 Diesel: To achieve this Scenario NOx limit will require both cooled EGR and SCR. Together with an advanced development of the combustion system, fuel injection and turbocharging technology, it seems feasible to meet the PM limit with either an open-flow DPF or a wall-flow DPF. Fuel consumption is likely to increase compared to the Euro IV baseline, especially in the case of a wall-flow DPF; CNG (stoichiometric): optimised multipoint injection, improved catalytic converter, inlet manifold optimisation, CNG (lean burn): pre-cat UEGO, lean-burn lambda control, inlet manifold optimisation, SCR system, improved SCR control system
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A.2: “Results Sheets” of scenarios executed

Title of Scenario

EURO VI

Scenario

252_A1_13, 100 % cost allocation

Based on Peer review of September 2006: Diesel 5/CNG 5.

Baseline: TREMOVE 2.52

Links to other models

Short description of scenario/ parameters modified compared to base run

Compared to the baseline emissions are reduced as follows:

Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro

Scenario 5		Diesel engines
ETC test cycle	CO	4.0 g/kWh
	THC	0.16 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4

Scenario 5		Gas engines
ETC test cycle	CO	4.0 g/kWh
	NMHC	0.16 g/kWh
	CH_4	0.5 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

In contrast to the "Documentation sheet" the changes for N1, class 3 are not included in this run.

Main findings:

Break-down of costs in 2030:

Costs in 2030 in million EURO	Year 2030
Sum of utility of households	9.2
Sum of production costs	-2,404.3
Sum of cost of public funds (general)	-572.6
Sum of cost of public funds (labour)	-868.6
Total welfare effect w/o pollution benefits (general)	-2,967.7
Total welfare effect w/o pollution benefits (labour)	-3,263.7
Pollution Benefits (low values)	5,703.6
Pollution Benefits (high values)	15,519.3
Sum of Welfare (general/low values)	2,735.9
Sum of Welfare (general/high values))	12,551.6
Sum of Welfare (labour/low values)	2,439.9
Sum of Welfare (labour/high values)	12,255.6

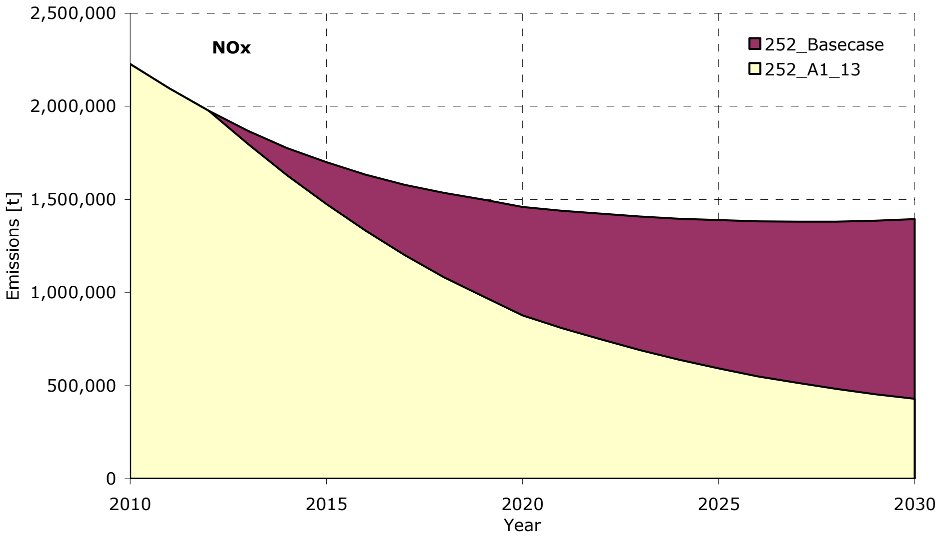
The emissions of HDV, coaches and trucks decrease as shown in the table until 2030.

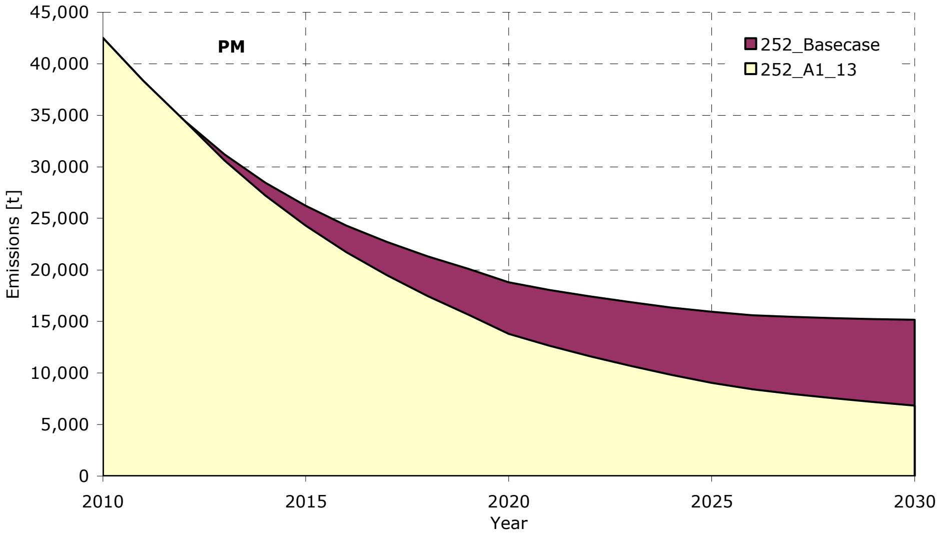
	Difference between base case and scenario in 2030 in percent
Total CO exhaust	0.4
Total CH4 exhaust	46.0
Total NMVOC exhaust	25.4
Total NOx exhaust	69.2
Total PM exhaust	55.0
Total VOC exhaust	34.6

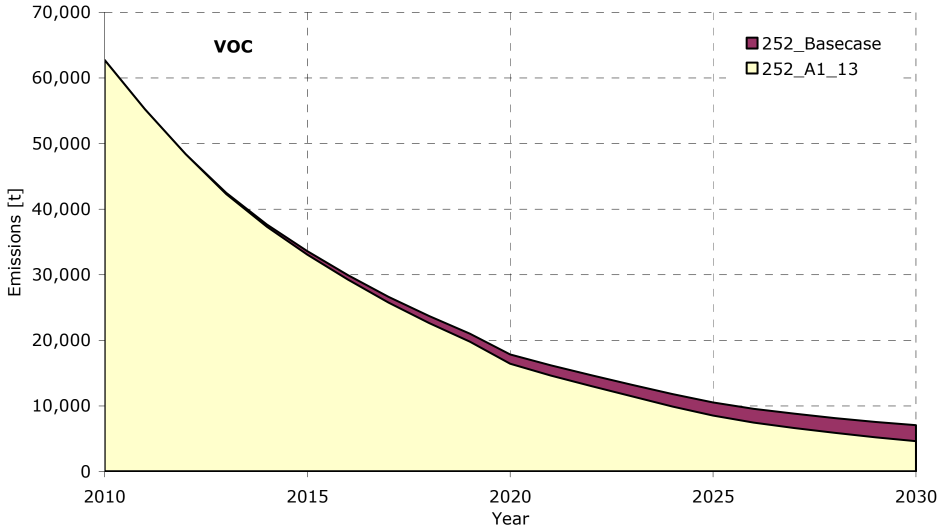
However, the process in not fully completed by that date since the fleet turn-over continues.

Graphs

The graph shows the changes of total transport NOx, PM and VOC emissions, indicating that the VOC reductions are not so significant.





	
Conclusions	Scenario results in reductions of emissions of NOx, VOC/CH4 and PM. Sum of welfare costs is positive.
Follow-up	None
Evaluator/ Date	C. Kouridis – T. Papageorgiou / 19.11.2009

Title of Scenario

EURO VI

Scenario

252_A2_13, 50 % cost allocation

Based on Peer review of September 2006: Diesel 5/CNG 5.

Baseline: TREMOVE 2.52

Links to other models

Short description of scenario/ parameters modified compared to base run

Compared to the baseline emissions are reduced as follows:

Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro

Scenario 5		Diesel engines
ETC test cycle	CO	4.0 g/kWh
	THC	0.16 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4

Scenario 5		Gas engines
ETC test cycle	CO	4.0 g/kWh
	NMHC	0.16 g/kWh
	CH_4	0.5 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

In contrast to the "Documentation sheet" the changes for N1, class 3 are not included in this run.

Main findings:

Break-down of costs in 2030:

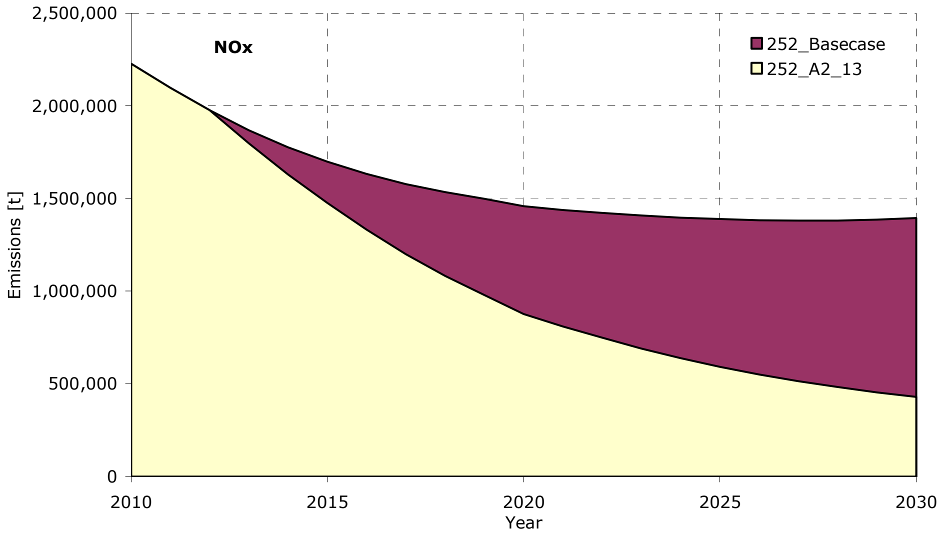
Costs in million EURO	Year 2030
Sum of utility of households	6.7
Sum of production costs	-2,120.3
Sum of cost of public funds (general)	-502.0
Sum of cost of public funds (labour)	-761.3
Total welfare effect w/o pollution benefits (general)	-2,615.6
Total welfare effect w/o pollution benefits (labour)	-2,874.8
Pollution Benefits(low values)	5,689.7
Pollution Benefits (high values)	15,472.0
Sum of Welfare (general/low values)	3,074.1
Sum of Welfare (general/high values))	12,856.5
Sum of Welfare (labour/low values)	2,814.8
Sum of Welfare (labour/high values)	12,597.2

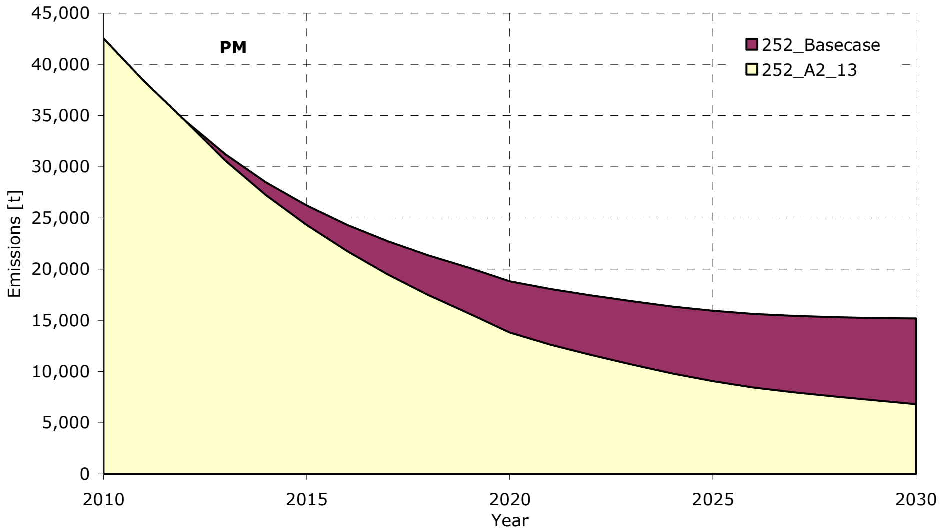
The emissions of HDV, coaches and trucks decrease as shown in the table until 2030. However, the process in not completed by that date since the fleet turn-over continues.

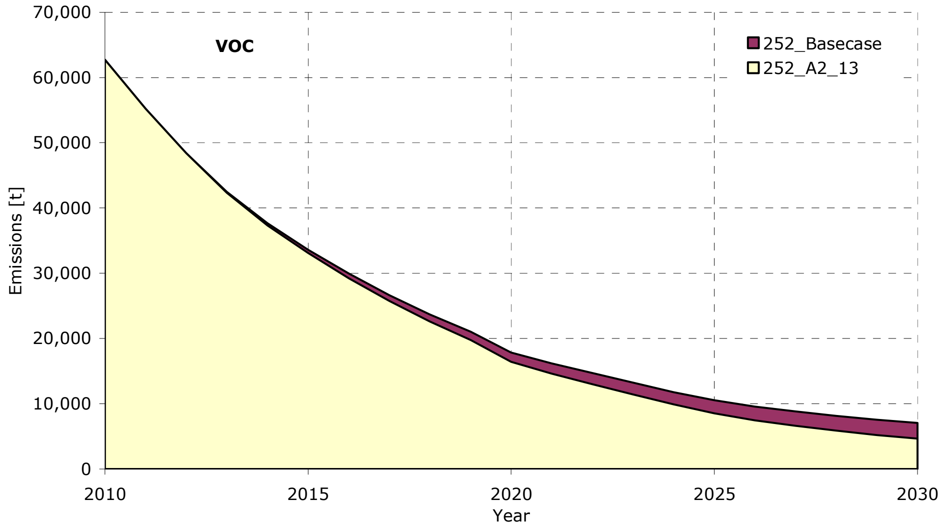
	Difference between base case and scenario in 2030 in percent
Total CO exhaust	0.4
Total CH4 exhaust	46.0
Total NMVOC exhaust	25.4
Total NOx exhaust	69.2
Total PM exhaust	55.0
Total VOC exhaust	34.6

Graphs

The graph shows the changes of total transport NOx, PM and VOC emissions, indicating that the VOC reductions are not so significant.





	
Conclusions	Scenario results in reductions of emissions of NOx, VOC/CH4 and PM. Total of welfare costs is positive.
Follow-up	None
Evaluator/ Date	C. Kouridis – T. Papageorgiou / 19.11.2009

Title of Scenario

EURO VI

Scenario

31_A1_13, 100 % cost allocation

Based on Peer review of September 2006: Diesel 5/CNG 5.

Baseline: TREMOVE 3.1

Links to other models

Short description of scenario/ parameters modified compared to base run

Compared to the baseline emissions are reduced as follows:

Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro

Scenario 5		Diesel engines
ETC test cycle	CO	4.0 g/kWh
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	PM new metric	review at later date

Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4

Scenario 5		Gas engines
ETC test cycle	CO	4.0 g/kWh
	NMHC	0.16 g/kWh
	CH_4	0.5 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

In contrast to the "Documentation sheet" the changes for N1, class 3 are not included in this run.

Main findings:

Break-down of costs in 2030:

Costs in 2030 in million EURO	Year 2030
Sum of utility of households	-139.3
Sum of production costs	-2,769.2
Sum of cost of public funds (general)	-100.4
Sum of cost of public funds (labour)	-157.2
Total welfare effect w/o pollution benefits (general)	-2,576.3
Total welfare effect w/o pollution benefits (labour)	-2,633.1
Pollution Benefits (low values)	5,703.5
Pollution Benefits (high values)	15,544.8
Sum of Welfare (general/low values)	3,127.2
Sum of Welfare (general/high values))	12,962.1
Sum of Welfare (labour/low values)	3,070.4
Sum of Welfare (labour/high values)	12,905.3

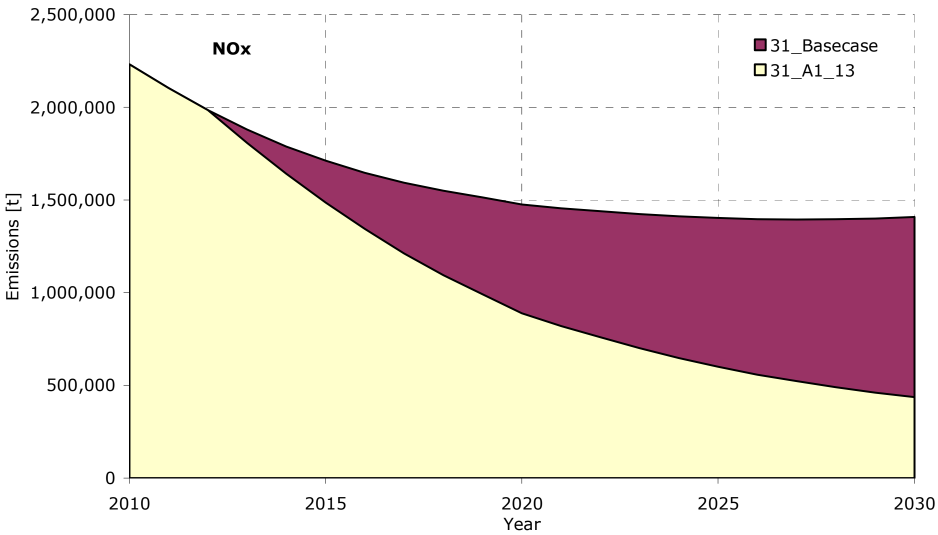
The emissions of HDV, coaches and trucks decrease as shown in the table until 2030.

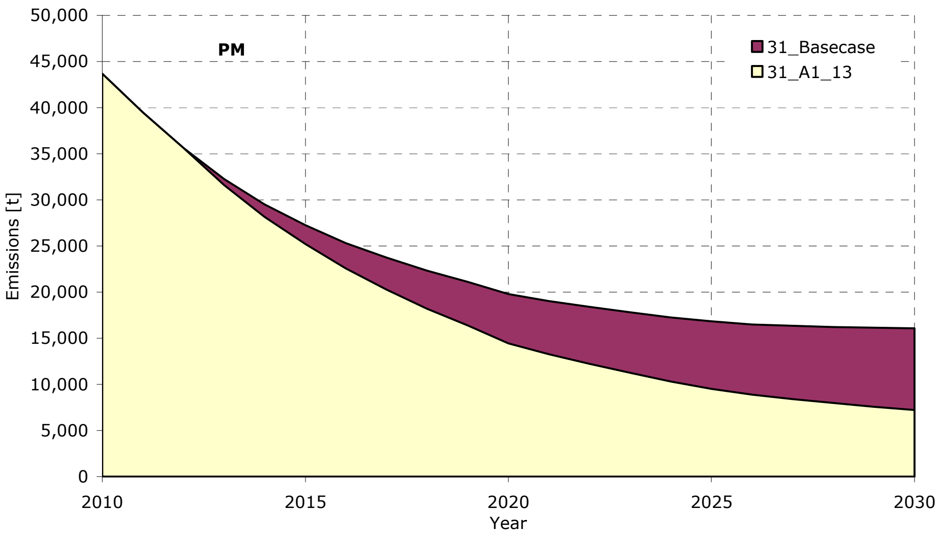
	Difference between base case and scenario in 2030 in percent
Total CO exhaust	0.1
Total CH4 exhaust	45.7
Total NMVOC exhaust	27.9
Total NOx exhaust	69.0
Total PM exhaust	55.0
Total VOC exhaust	34.9

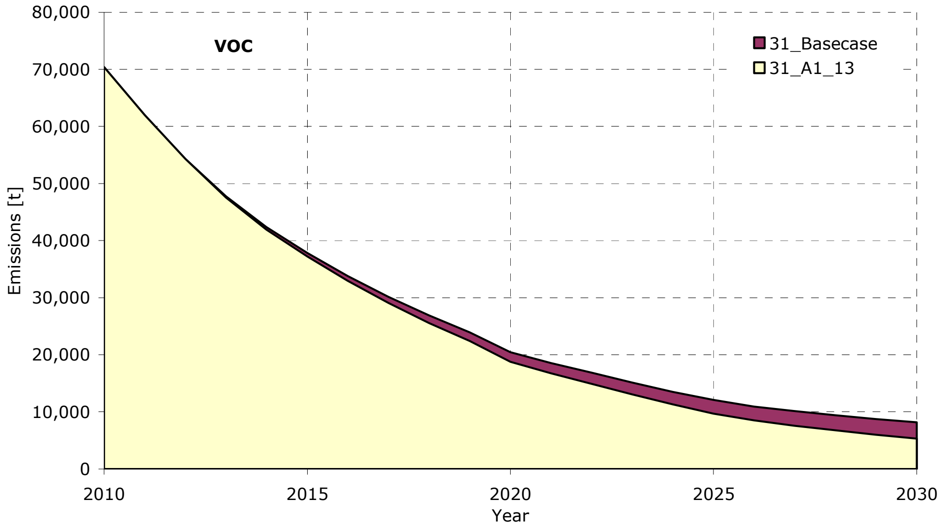
However, the process in not fully completed by that date since the fleet turn-over continues.

Graphs

The graph shows the changes of total transport NOx, PM and VOC emissions, indicating that the VOC reductions are not so significant.





	
Conclusions	Scenario results in reductions of emissions of NOx, VOC/CH4 and PM. Sum of welfare costs is positive.
Follow-up	None
Evaluator/ Date	C. Kouridis – T. Papageorgiou / 19.11.2009

Title of Scenario

EURO VI

Scenario

31_A2_13, 50 % cost allocation

Based on Peer review of September 2006: Diesel 5/CNG 5.

Baseline: TREMOVE 3.1

Links to other models

Short description of scenario/ parameters modified compared to base run

Compared to the baseline emissions are reduced as follows:

Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro

Scenario 5		Diesel engines
ETC test cycle	CO	4.0 g/kWh
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	NH_3 (1)	10 ppm
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	PM new metric	review at later date

Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4

Scenario 5		Gas engines
ETC test cycle	CO	4.0 g/kWh
	NMHC	0.16 g/kWh
	CH_4	0.5 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

In contrast to the “Documentation sheet” the changes for N1, class 3 are not included in this run.

Main findings:

Break-down of costs in 2030:

Costs in million EURO	Year 2030
Sum of utility of households	-123.1
Sum of production costs	-2,433.8
Sum of cost of public funds (general)	-88.8
Sum of cost of public funds (labour)	-139.1
Total welfare effect w/o pollution benefits (general)	-2,260.0
Total welfare effect w/o pollution benefits (labour)	-2,310.3
Pollution Benefits(low values)	5,700.9
Pollution Benefits (high values)	15,527.4
Sum of Welfare (general/low values)	3,440.9
Sum of Welfare (general/high values))	13,263.0
Sum of Welfare (labour/low values)	3,390.6
Sum of Welfare (labour/high values)	13,212.7

The emissions of HDV, coaches and trucks decrease as shown in the table until 2030. However, the process in not completed by that date since the fleet turn-over continues.

	Difference between base case and scenario in 2030 in percent
Total CO exhaust	0.1
Total CH4 exhaust	45.7
Total NMVOC exhaust	27.9
Total NOx exhaust	69.0
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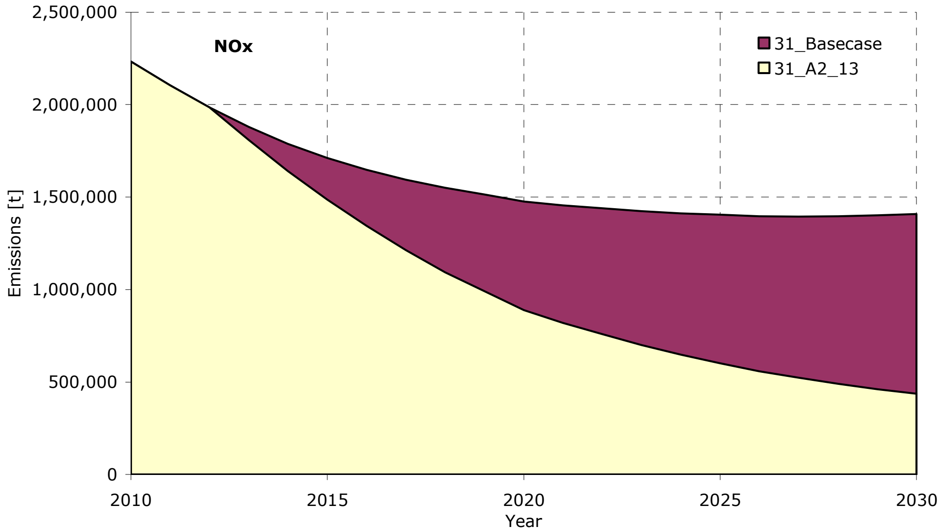
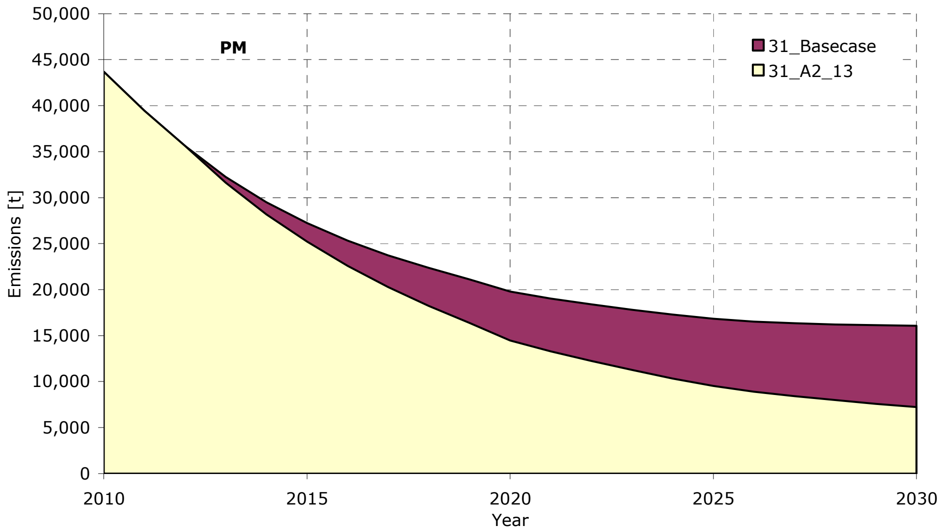
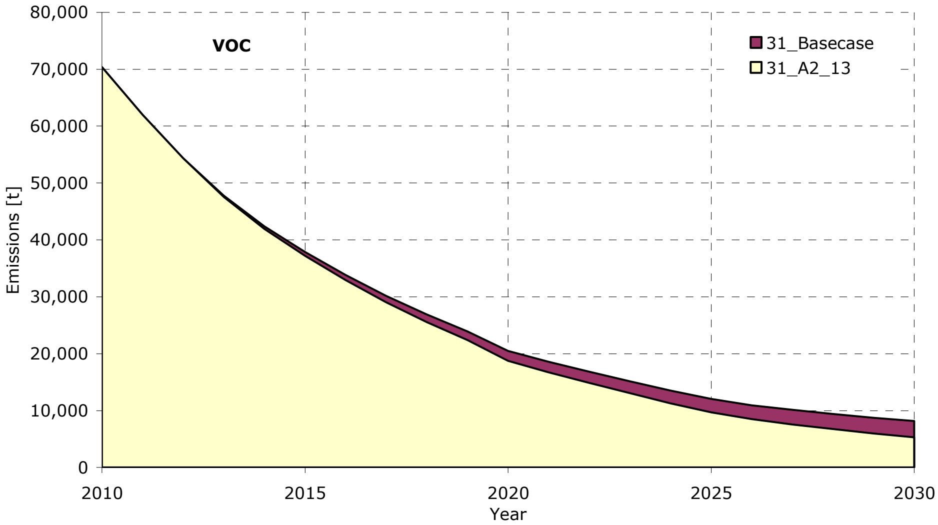
Graphs

The graph shows the changes of total transport NOx, PM and VOC emissions, indicating that the VOC reductions are not so significant.





	
Conclusions	Scenario results in reductions of emissions of NOx, VOC/CH4 and PM. Total of welfare costs is positive.
Follow-up	None
Evaluator/ Date	C. Kouridis – T. Papageorgiou / 19.11.2009

Title of Scenario

EURO VI

Scenario

31_A1_15, 100 % cost allocation

Based on Peer review of September 2006: Diesel 5/CNG 5.

Baseline: TREMOVE 3.1

Links to other models

Short description of scenario/ parameters modified compared to base run

Compared to the baseline emissions are reduced as follows:

Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro

Scenario 5		Diesel engines
ETC test cycle	CO	4.0 g/kWh
	THC	0.16 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4

Scenario 5		Gas engines
ETC test cycle	CO	4.0 g/kWh
	NMHC	0.16 g/kWh
	CH_4	0.5 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

In contrast to the "Documentation sheet" the changes for N1, class 3 are not included in this run.

Main findings:

Break-down of costs in 2030:

Costs in 2030 in million EURO	Year 2030
Sum of utility of households	-126.0
Sum of production costs	-2,547.9
Sum of cost of public funds (general)	-94.6
Sum of cost of public funds (labour)	-147.4
Total welfare effect w/o pollution benefits (general)	-2,371.9
Total welfare effect w/o pollution benefits (labour)	-2,424.7
Pollution Benefits (low values)	5,444.3
Pollution Benefits (high values)	14,834.6
Sum of Welfare (general/low values)	3,072.4
Sum of Welfare (general/high values))	12,457.5
Sum of Welfare (labour/low values)	3,019.7
Sum of Welfare (labour/high values)	12,404.8

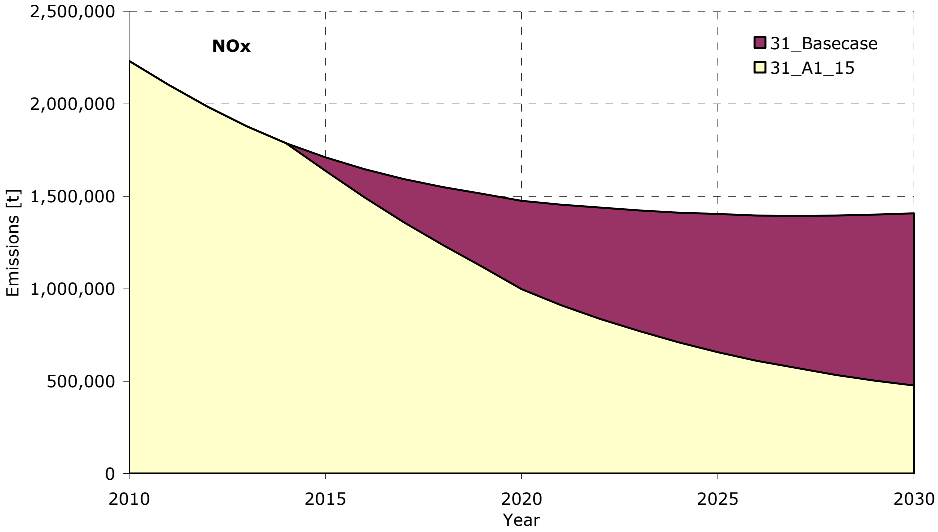
The emissions of HDV, coaches and trucks decrease as shown in the table until 2030.

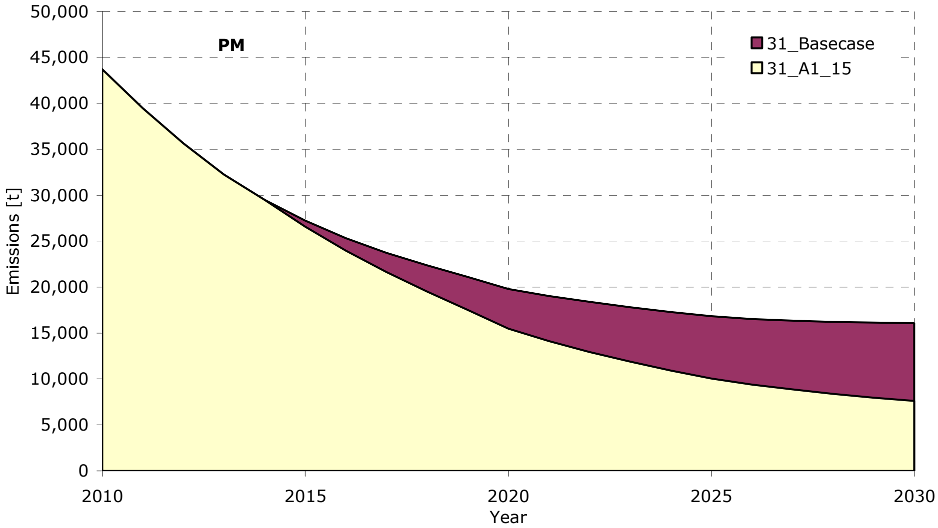
	Difference between base case and scenario in 2030 in percent
Total CO exhaust	0.1
Total CH4 exhaust	43.8
Total NMVOC exhaust	26.6
Total NOx exhaust	66.2
Total PM exhaust	52.8
Total VOC exhaust	33.4

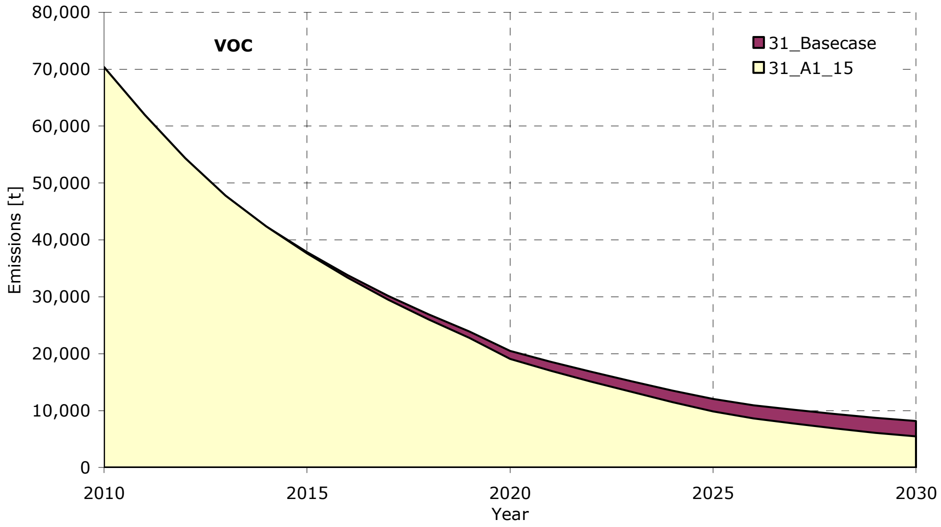
However, the process in not fully completed by that date since the fleet turn-over continues.

Graphs

The graph shows the changes of total transport NOx, PM and VOC emissions, indicating that the VOC reductions are not so significant.





	
Conclusions	Scenario results in reductions of emissions of NOx, VOC/CH4 and PM. Sum of welfare costs is positive.
Follow-up	None
Evaluator/ Date	C. Kouridis – T. Papageorgiou / 19.11.2009

Title of Scenario

EURO VI

Scenario

31_A2_15, 50 % cost allocation

Based on Peer review of September 2006: Diesel 5/CNG 5.

Baseline: TREMOVE 3.1

Links to other models

Short description of scenario/ parameters modified compared to base run

Compared to the baseline emissions are reduced as follows:

Scenario 5 :
Diesel: -80% NOx, -66% PM and -70% THC over Euro

Scenario 5		Diesel engines
ETC test cycle	CO	4.0 g/kWh
	THC	0.16 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

Scenario 5 :
Gas: -80% NOx, -50% PM, -70% NMHC & -25% CH_4

Scenario 5		Gas engines
ETC test cycle	CO	4.0 g/kWh
	NMHC	0.16 g/kWh
	CH_4	0.5 g/kWh
	NOx	0.4 g/kWh
	NH_3 (1)	10 ppm
	PM	0.01 g/kWh
	PM new metric	review at later date

In contrast to the "Documentation sheet" the changes for N1, class 3 are not included in this run.

Main findings:

Break-down of costs in 2030:

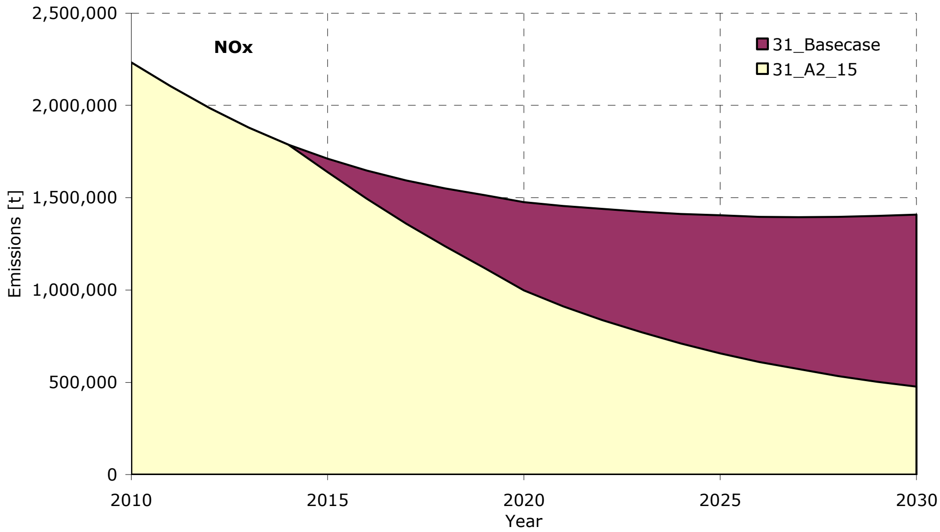
Costs in million EURO	Year 2030
Sum of utility of households	-111.3
Sum of production costs	-2,241.0
Sum of cost of public funds (general)	-83.8
Sum of cost of public funds (labour)	-130.5
Total welfare effect w/o pollution benefits (general)	-2,081.2
Total welfare effect w/o pollution benefits (labour)	-2,127.9
Pollution Benefits(low values)	5,440.9
Pollution Benefits (high values)	14,817.6
Sum of Welfare (general/low values)	3,359.8
Sum of Welfare (general/high values))	12,733.1
Sum of Welfare (labour/low values)	3,313.1
Sum of Welfare (labour/high values)	12,686.5

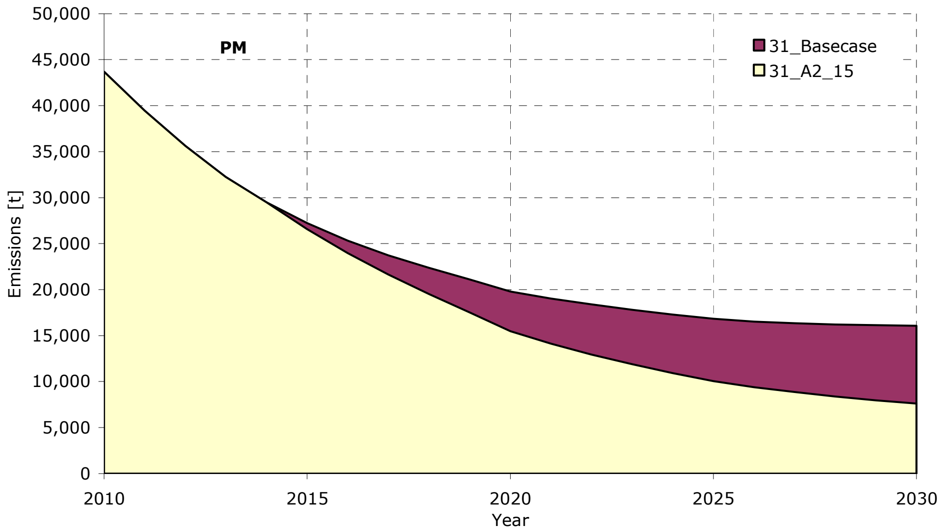
The emissions of HDV, coaches and trucks decrease as shown in the table until 2030. However, the process in not completed by that date since the fleet turn-over continues.

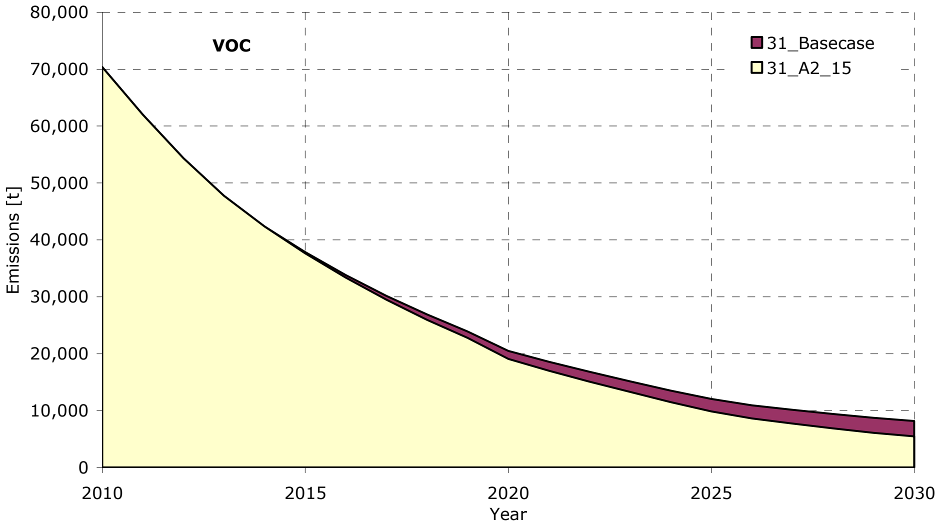
	Difference between base case and scenario in 2030 in percent
Total CO exhaust	0.1
Total CH4 exhaust	43.8
Total NMVOC exhaust	26.6
Total NOx exhaust	66.2
Total PM exhaust	52.8
Total VOC exhaust	33.4

Graphs

The graph shows the changes of total transport NOx, PM and VOC emissions, indicating that the VOC reductions are not so significant.







Conclusions	Scenario results in reductions of emissions of NOx, VOC/CH4 and PM. Total of welfare costs is positive.
Follow-up	None
Evaluator/ Date	C. Kouridis – T. Papageorgiou / 19.11.2009

A.3: Emission results for all countries of scenarios executed

NOx, PM, VOC

Year 2030

First table: NOx

Second table: PM

Third table: VOC

Fourth table: Totals

All figures in tonnes

Abbreviations used:

België/Belgique	BE
България	BG
Danmark	DK
Deutschland	DE
Eesti	EE
Suomi	FI
France	FR
Ελλάδα, Ελλάς	GR
Éire	IE
Italia	IT
Latvija	LV
Lietuva	LT
Luxembourg	LU
Malta	MT
Nederland	NL
Österreich	AT
Polska	PL
Portugal	PT
România	RO
Sverige	SE
Slovensko	SK
Slovenija	SI
España	ES
Česko	CZ
Magyarország	HU
Kypros / Kıbrıs	CY
United Kingdom	UK
Hrvatska	HR
Türkiye	TR
Norge	NO
Schweiz/Suisse/Svizzera	CH

NOx

Country	252_Basecase	252_A1_13	252_A2_13	31_Basecase	31_A1_13	31_A2_13	31_A1_15	31_A2_15
AT	16,930.2	4,963.2	4,967.6	16,990.4	5,000.1	5,000.9	5,585.6	5,586.2
BE	29,319.4	6,067.8	6,071.2	29,791.4	6,119.5	6,121.4	6,227.9	6,229.8
BG	17,859.9	6,871.2	6,873.7	17,623.8	6,741.8	6,742.3	7,175.1	7,175.5
CH	13,052.5	2,726.6	2,730.1	13,147.9	2,768.7	2,769.3	2,905.6	2,906.1
CY	2,103.7	940.1	940.1	2,053.6	919.0	919.1	935.9	935.9
CZ	41,628.4	15,581.8	15,584.3	41,087.8	15,356.2	15,356.9	16,598.5	16,599.0
DE	201,619.3	70,299.4	70,322.7	204,770.7	71,394.5	71,400.2	81,729.2	81,733.9
DK	10,034.8	2,011.4	2,014.6	10,061.6	2,035.8	2,036.5	2,192.1	2,192.7
EE	6,638.6	2,313.0	2,314.1	6,484.3	2,257.5	2,257.8	2,418.1	2,418.3
ES	204,998.8	54,709.9	54,725.0	204,094.6	54,630.6	54,634.4	60,295.1	60,298.3
FI	13,325.7	3,595.7	3,596.8	13,071.1	3,495.8	3,496.0	3,941.6	3,941.8
FR	158,479.1	36,439.5	36,459.6	159,633.3	36,817.3	36,822.4	41,148.2	41,152.7
GR	21,590.9	10,099.4	10,101.0	21,594.9	10,107.8	10,108.2	10,704.8	10,705.1
HR	7,509.2	3,316.9	3,316.9	7,417.7	3,269.7	3,269.7	3,420.8	3,420.8
HU	20,318.2	8,351.0	8,352.7	19,957.6	8,097.2	8,097.7	8,567.3	8,567.6
IE	10,759.8	4,853.9	4,854.2	10,446.6	4,674.8	4,674.8	4,928.2	4,928.2
IT	96,264.8	28,081.8	28,094.8	97,084.7	28,170.2	28,174.3	31,821.8	31,825.1
LT	11,077.8	3,905.4	3,906.9	10,843.2	3,823.3	3,823.6	4,136.1	4,136.3
LU	1,837.1	451.7	452.1	1,791.4	442.7	442.8	480.2	480.2
LV	8,219.6	2,582.4	2,584.6	8,033.6	2,530.9	2,531.2	2,686.4	2,686.8
MT	235.0	65.9	66.1	219.1	62.9	63.0	71.8	71.8
NL	24,887.6	4,903.0	4,917.5	25,053.7	5,034.6	5,037.3	5,272.4	5,274.9
NO	16,005.3	3,787.6	3,790.5	15,926.2	3,779.6	3,780.1	4,199.0	4,199.4
PL	93,037.1	35,975.2	35,984.7	91,018.6	35,116.6	35,118.6	37,739.7	37,741.1
PT	11,306.5	5,060.1	5,062.3	11,311.5	5,067.0	5,067.4	5,322.9	5,323.3
RO	57,384.4	20,498.9	20,511.4	56,728.5	20,252.5	20,254.8	21,554.4	21,556.1
SE	19,714.3	5,049.7	5,051.9	19,609.1	5,016.4	5,016.8	5,672.9	5,673.3
SI	4,982.9	1,945.3	1,945.5	4,909.8	1,907.6	1,907.6	2,016.2	2,016.3
SK	8,219.6	2,582.4	2,584.6	26,778.3	11,866.1	11,866.6	12,433.7	12,434.1
TR	178,092.7	64,437.9	64,452.7	175,209.0	62,709.9	62,713.9	67,327.4	67,330.6
UK	86,846.2	17,189.5	17,211.9	86,351.0	17,189.0	17,198.5	17,195.7	17,205.2

PM

Country	252_Basecase	252_A1_13	252_A2_13	31_Basecase	31_A1_13	31_A2_13	31_A1_15	31_A2_15
AT	185.9	77.0	77.0	195.1	80.7	80.7	86.5	86.5
BE	298.0	100.3	100.3	303.2	101.4	101.4	102.4	102.4
BG	208.1	112.9	113.0	216.1	115.4	115.4	119.5	119.5
CH	135.6	45.7	45.7	143.4	48.6	48.6	49.9	49.9
CY	30.6	18.5	18.5	30.8	18.4	18.4	18.6	18.6
CZ	481.1	259.7	259.7	504.3	269.9	269.9	281.4	281.4
DE	1,970.5	908.8	909.1	2,066.2	952.9	953.0	1,039.2	1,039.3
DK	110.3	36.4	36.4	115.7	38.4	38.4	39.9	39.9
EE	72.3	36.2	36.3	74.0	36.7	36.7	38.1	38.1
ES	2,242.0	879.1	879.3	2,375.7	929.2	929.3	984.6	984.7
FI	155.0	61.1	61.2	161.5	62.8	62.8	67.4	67.4
FR	1,539.6	543.0	543.3	1,613.5	570.3	570.4	607.4	607.5
GR	283.8	176.8	176.9	294.1	181.1	181.1	187.2	187.2
HR	103.6	61.6	61.6	107.7	63.0	63.0	64.7	64.7
HU	253.0	149.2	149.3	260.4	150.6	150.6	154.9	154.9
IE	149.5	92.8	92.8	152.7	92.8	92.8	95.5	95.5
IT	1,038.9	429.7	429.9	1,080.0	443.5	443.6	478.7	478.8
LT	115.7	58.0	58.0	119.8	59.4	59.4	62.1	62.1
LU	19.5	7.3	7.3	20.4	7.7	7.7	8.0	8.0
LV	86.9	39.8	39.8	89.3	40.7	40.7	42.0	42.1
MT	1.9	0.8	0.8	2.2	0.9	0.9	1.0	1.0
NL	275.3	89.5	89.7	292.2	96.5	96.5	98.9	98.9
NO	170.7	61.1	61.1	180.0	64.5	64.6	68.5	68.6
PL	1,065.0	585.5	585.6	1,106.4	599.8	599.8	623.7	623.7
PT	147.1	91.4	91.4	152.7	93.7	93.7	96.1	96.1
RO	657.2	335.8	335.9	684.7	345.8	345.8	358.0	358.1
SE	213.8	80.2	80.3	224.5	84.0	84.0	90.4	90.4
SI	70.0	39.7	39.7	72.9	40.6	40.6	41.8	41.8
SK	86.9	39.8	39.8	320.4	191.0	191.0	195.9	196.0
TR	2,108.2	1,119.8	1,120.0	2,186.1	1,141.7	1,141.7	1,186.0	1,186.0
UK	897.8	293.4	293.7	931.7	305.8	306.0	305.8	306.0

VOC

Country	252_Basecase	252_A1_13	252_A2_13	31_Basecase	31_A1_13	31_A2_13	31_A1_15	31_A2_15
AT	70.8	38.4	38.4	78.6	41.3	41.3	43.4	43.4
BE	76.6	24.7	24.8	77.4	24.3	24.3	24.7	24.7
BG	141.5	115.3	115.3	157.7	126.4	126.5	127.7	127.7
CH	36.8	11.6	11.7	42.8	13.6	13.6	14.0	14.0
CY	24.3	21.1	21.1	26.5	22.4	22.4	22.5	22.5
CZ	292.5	230.6	230.6	330.8	257.4	257.4	261.2	261.2
DE	871.5	547.6	547.7	943.8	584.4	584.4	612.4	612.4
DK	34.0	9.9	9.9	38.2	11.2	11.2	11.8	11.8
EE	45.0	33.8	33.8	50.1	37.4	37.4	37.9	37.9
ES	729.0	371.4	371.5	867.3	432.4	432.5	449.8	449.8
FI	52.2	26.5	26.5	59.2	28.4	28.4	29.8	29.8
FR	451.7	146.8	146.9	505.0	164.1	164.1	176.6	176.6
GR	253.4	223.6	223.5	273.7	238.3	238.3	240.4	240.4
HR	71.2	61.2	61.2	85.4	72.6	72.6	73.1	73.1
HU	179.5	150.9	150.8	194.8	160.7	160.7	162.0	162.0
IE	118.3	102.7	102.7	131.9	112.9	112.9	113.8	113.8
IT	406.6	210.6	210.7	433.0	216.5	216.5	229.4	229.4
LT	66.5	48.6	48.7	74.5	54.3	54.3	55.2	55.2
LU	6.9	3.3	3.3	7.9	3.7	3.7	3.8	3.8
LV	45.2	30.7	30.7	50.3	33.7	33.7	34.2	34.2
MT	1.0	0.5	0.5	1.0	0.5	0.5	0.5	0.5
NL	67.3	19.1	19.2	81.1	23.5	23.6	24.3	24.3
NO	45.0	15.6	15.6	53.2	18.3	18.3	19.5	19.5
PL	662.5	524.4	524.3	751.0	588.0	588.0	596.0	595.9
PT	110.4	95.4	95.3	120.6	102.5	102.5	103.3	103.3
RO	400.9	310.4	310.3	456.5	349.5	349.5	353.6	353.6
SE	62.8	25.0	25.0	72.0	27.7	27.7	29.8	29.8
SI	44.4	37.3	37.3	54.2	45.0	45.0	45.4	45.4
SK	45.2	30.7	30.7	335.7	276.6	276.6	279.0	279.0
TR	1,333.8	1,055.4	1,055.4	1,490.6	1,161.5	1,161.5	1,177.5	1,177.5
UK	300.3	85.9	86.1	329.5	94.8	94.9	94.8	94.9

Country	252_Basecase	252_A1_13	252_A2_13	31_Basecase	31_A1_13	31_A2_13	31_A1_15	31_A2_15
Total NOx	1,394,279.7	429,657.8	429,842.0	1,409,094.9	436,655.7	436,704.3	476,704.5	476,746.4
Total PM	15,174.0	6,830.7	6,833.3	16,077.9	7,227.6	7,228.6	7,594.0	7,594.9
Total VOC	7,047.0	4,608.9	4,609.3	8,174.4	5,324.2	5,324.4	5,447.5	5,447.6