

Impact Assessment Institute

The Institute for Impact Assessment and Scientific Advice on Legislation and Regulation

“Impartial Analysis for Policy Making”

**First draft report on the
Impact Assessment accompanying the
Strategy for Reducing Heavy-Duty Vehicles Fuel
Consumption and CO2 Emissions – SWD (2014) 160 final**

8th July 2015

IAI-HDCO2-150708fd

Accompanying statement

This report has been written according to the guiding principles of the Impact Assessment Institute: transparency, objectivity, legitimacy and credibility. It therefore analyses the subject matter critically from a purely factual and scientific point of view, without any policy orientation.

The analysis is open to review and criticism from all parties, including those whose work is scrutinised. Contacts with all relevant parties are logged (Annex VI) to ensure transparency and to guard against “lobbying” of the results.

By its nature the report has a critical characteristic, since it scrutinises the subject document, with its main findings entailing the identification of errors, discrepancies and inconsistencies, complemented by a revision of the analysis. In performing this work, the intention of the report is to be constructive in assisting the authors of the subject document and its background information, as well as all relevant stakeholders in identifying the most robust evidence base for the policy objective in question.

As well as a critical scrutiny report, it is also to be understood as a scenario analysis, asking and answering the question “what if a different assumption / dataset / understanding is taken into account”. It should be seen as a cooperative contribution to the policy making process, proposing ideas that may not have been considered in the original Impact Assessment.

This report is also to be considered as a call for additional data. Peer review is an important element of the procedures of the Impact Assessment Institute and this is manifested in the openness to further review and to new data. In particular at the draft stage, the report explicitly requests additional data where the readily available data was not sufficient to complete all intended analysis.

Executive Summary

This report has scrutinised in-depth the content of the Impact Assessment, analysing its assumptions, background data, analysis, results and conclusions.

The Impact Assessment is thorough and easy to follow, providing a comprehensive and transparent view of the evidence base presented for policy making in this domain.

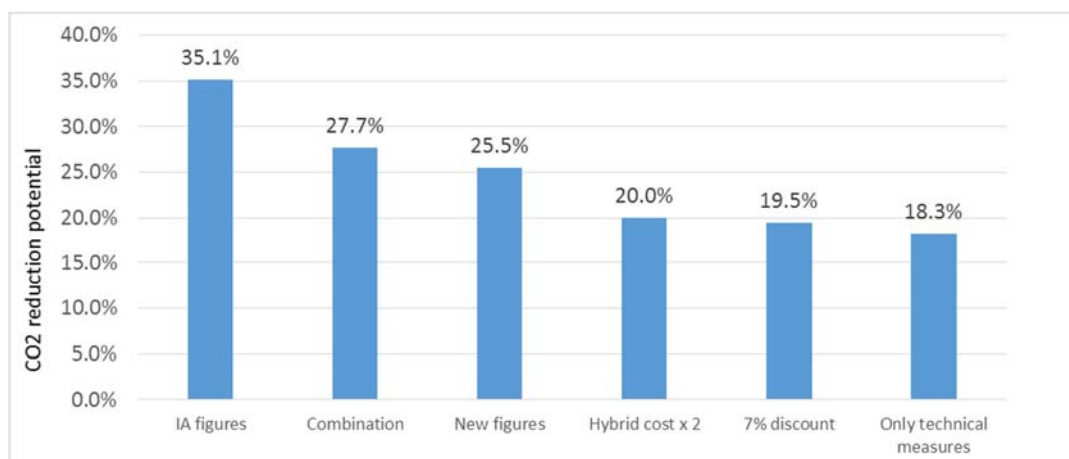
Due to the time elapsed from the compilation of most of the underlying figures used in the report (the 2009 TIAX/NSA study), the possibility of a significant change in the state of the art should be considered. This is addressed further at the end of this Executive Summary.

Some minor aspects somewhat undermine the positive impression. In particular, some of the rhetoric and assumptions stated in the introduction and problem definition appear to presage an expected result, before the corresponding evidence has been presented. The section “Problem definition” reads in certain parts as a summary of the anticipated results.

This observation does not detract from the validity of the content of the Impact Assessment, but brings into question the process employed to compile and present the analysis.

The substantive element is the detailed analysis of impacts in terms of the costs and benefits of measures for reducing the CO₂ emissions of heavy duty vehicles. The key parameter resulting from the calculations is the cost effective potential for CO₂ reduction, since this indicates the feasible level of ambition of future policies including regulation.

The Impact Assessments quotes a value of 35.1% for the weighted average cost effective CO₂ reduction potential across all vehicle types. The following chart shows the recalculated cost effective weighted average CO₂ reduction potential, introducing cumulatively those effects and scenarios which result in a measurable difference:



Two potentially measurable effects have not been included in the chart: €30/t cost effectiveness cut off and using alternative figures for vehicle lifetimes. The concrete effect was calculated to be zero for each case, since no single technology fell below the cost effectiveness threshold due to the recalculation. An additional effect with potentially measurable results would be the accounting for already realised penetration of CO₂ reduction measures. No reliable data has been identified, with additional information being requested from stakeholders.

The following table provides an overview of all the effects identified in the revised analysis, for each indicating whether the influence is positive (greater CO₂ reduction potential or

lower abatement cost compared to the Impact Assessment) or negative (lower CO2 reduction potential or higher abatement cost compared to the Impact Assessment).

Revised element (* indicates inclusion in chart above)	Section	Numerically assessed	Direction of change
*Using geometric combination methodology from CE Delft 2012 report	3.1.1	yes	-ve
*Accounting for overlap of technologies reflecting TNO 2006 methodology	3.1.1	yes	-ve
Accounting for already realised technologies	3.1.2	no (data required)	-ve
*Revision of cost and CO2 reduction potential	3.1.3	yes	+ve/-ve
*Considering uncertainty in cost of hybrids for certain vehicle types	3.2.1	yes	-ve
*7% discount rate	3.2.3	yes	-ve
*Considering only technical measures	3.1	yes	-ve
Non-zero abatement cost as threshold for cost-effectiveness	3.2.2	yes	+ve
Using alternative vehicle lifetime	3.2.3	yes	+ve
Rebound effect	3.2.4	no	-ve
Tightening exhaust emission regulation	3.2.5	no	-ve
Multiple replacements of technology	3.2.6	no	-ve
Learning effects and economies of scale	3.2.7	no	+ve

A superficial review has been performed using data on cost and CO2 reduction potential, obtained from subsequent expert reports. This is presented separately in this report since it is not the objective of this study to use ex-post data to scrutinise the content of the Impact Assessment compiled before that data became available. It does however serve as a feasibility check on some of the recalculations. This new data is expected to provide a more up-to-date basis for future policy analysis.

Conclusion

By applying a reasonable reanalysis to the content of the Impact Assessment and its underlying data, substantial uncertainty in the figures presented has been identified.

Simple application of well documented methodologies for combining CO2 reduction potentials reduces the weighted average cost effective potential from 35% to 28%. Accounting for significant cost uncertainties, in particular in the high-potential but also high-cost hybrid technology, results in a figure of 20% total CO2 reduction potential.

This figure is only 5% above the expected “natural” CO2 reduction between 2015 and 2030. The conclusion of the Impact Assessment, that regulation of vehicle CO2 emissions is the most effective policy option, depends strongly on the high cost-effective potential above the natural improvement, which is therefore called into question by these revised figures.

This report therefore concludes that in ongoing work to assess the potential measures and future actions in this area, the significant effects identified in this report related to background data, methodologies and calculations are to be taken into account.

Additional data requested

The analysis has been performed using readily available data. Parts of the intended analysis require additional data that can only be expected to be provided from expert sources with a direct interest in the content of this report. It is therefore considered appropriate to make an open call for the additional data as part of the peer review process, using this draft report as a platform for further discussion.

The following is a description of the additional data necessary to complement and complete the report:

- The penetration rates of each identified measure in each vehicle type in 2014.
- The calculation method for the trend line to determine the extent of overlap of CO₂ reduction potentials as applied in the 2006 report by TNO et. al. underlying the European Commission impact assessment for CO₂ for passenger cars.
- The underlying calculations behind the NPV and cost effectiveness figures presented on pages 130 to 137 of the Impact Assessment. This information has already been requested through a formal access to document request. It is acknowledged that providing access to such data at the correct level of detail whilst respecting intellectual property may represent a time consuming effort.

Stakeholders are kindly requested to provide fully evidenced data on the above points, in addition to their comments on the content of this draft report. Any new data received will be used as an input to the final report.

Visualisation

The following table provides a visual overview of the results of this report for each element of the evidence presented in the Impact Assessment, using an assessment from 1 to 7 to indicate the level of confidence (1 = highest, 7 = lowest confidence level).

Element	Assessment level & description (1...7)	Notes
Rhetoric	4 Concerns identified with analysis and/or evidence	A number of statements indicate a preconception of certain policy paths, inconsistent with evidence-based policy making
Assumptions	4 Concerns identified with analysis and/or evidence	Consistent with the above, a number of assumptions are made which prejudge the result, but are not substantial in their overall effect
Background data	3 Several questions identified	The data used is well-documented. In some cases, discrepancies between datasets used are apparent. In certain cases a reassessment results in a recalculation of costs and or benefits.
Analysis	5 Substantial concerns identified with analysis and/or evidence	Combination methodologies have not been correctly implemented. Account has not been taken of the already realised penetration of the measures.
Results	5 Substantial concerns identified with analysis and/or evidence	Due to the discrepancies in the analysis and the background data, a significant difference in the cost-effective CO2 reduction potential is identified (weighted average from 35.1% to 18.3%)
Conclusions	5 Substantial concerns identified with analysis and/or evidence	The significantly lower remaining CO2 reduction potential as indicated above seriously undermines the conclusion that regulation is necessary. Further evidence is necessary to demonstrate this need.

Key to assessment levels

1	2	3	4	5	6	7
Correct analysis, fully evidenced	Minor questions identified on analysis and/or evidence	Several questions identified on analysis and/or evidence	Concerns identified with analysis and/or evidence	Substantial concerns identified with analysis and/or evidence	Serious concerns identified with analysis and/or evidence	Incorrect analysis / evidence absent

1 Report on the content of the Impact Assessment

The impact assessment is thorough and well-written, providing a full picture of the subject matter from historical developments through available data, current analysis and conclusions. A few general criticisms are made on the language and structure. In particular, some of the statements and assumptions in the introduction appear to reach conclusions rather than setting the scene objectively. For example in paragraph 26, the conclusion “This remains an area with considerable scope for further action” is reached before the relevant evidence is presented. Additionally, the section “Problem definition” appears to be misnamed, since it includes a summary of the results and conclusions. These issues are summarised section 2 below and detailed in Annex I.

Neither of these criticisms are substantial and they do not affect the quality of the analysis and its conclusions. However for the sake of comprehension and clarity it would be recommended to ensure in future reports that the sections are consistently titled, and written without apparent preconceptions.

The key characteristic in this report is the factual, scientific and economic accuracy of the cost-benefit analysis of the CO₂ reduction measures, dealt with in detail in the subsequent sections.

2 Review of language used in the Impact Assessment

The following comments refer to the language used in the Impact Assessment, identified section by section. A paragraph-by-paragraph review of the specific issues identified is included in Annex I.

Introduction

No substantive comments are made on this section. The only minor criticism is that the assessment and conclusion stated in the last two sentences of paragraph 3 are not referenced, therefore appearing to reach a conclusion before the evidence has been presented.

Chapter 1: Procedural issues and consultation of interested parties

No comments are made on this section.

Chapter 2: Problem definition

The nature of the content of this section does not appear to correspond to the title “Problem definition”. In particular, a number of assumptions and conclusions are made for which the evidence has not been referenced, or are contested by stakeholder bodies and therefore require a reference to put into context. These are listed in Annex I.

Chapter 3: Objectives

The main objectives of effectiveness, efficiency and predictability appear to be well founded. The specific comments, listed in Annex I, relate to the evidence base presented and the quality of the conclusions reached in this section.

Chapter 4: Policy options

No comment on this section, which clearly sets out the policy options available.

Chapter 5: Impact analysis of policy options

This section begins with a profound statement on the unsustainable nature of the baseline scenario for which the evidence has not been presented. As an opening statement it therefore undermines the perceived impartiality of the following analysis in this critical section of the impact assessment. Further comments are include in in Annex I

Chapter 6: Comparing the options

No specific comment is made on this section, which correctly assesses the major effects of each option.

Chapter 7: Monitoring and evaluation

The key elements are fully presented and set out to support the ongoing analysis.

3 Assessment of detailed cost-benefit analysis

The following analyses in detail the figures presented in the impact assessment and its accompanying expert reports, in order to evaluate the viability of the final cost-benefit figures. These calculations and arguments are intended to indicate where a full re-evaluation of the figures may be necessary, not as a definitive reassessment of the results. Where new figures are given, these are indicative to show a direction and general magnitude of the effect.

The assessment is split into the following parts below, analysed using the example of long-haul trucks, being the vehicle category representing the highest aggregate CO₂ emissions:

- 3.1.1 An evaluation of the calculation methodology and recommended recalculations
- 3.1.3 Accounting for potentials already realised by the time of publication of the Impact Assessment, where such information is available
- 3.2 A re-evaluation of the costs and benefits of the individual technologies, where there is clear evidence for using different figures

One particular consideration is the status of the figures used for cost and CO₂ reduction potential. Most of the figures are ultimately derived from the 2009 TIAX/NAS report "Assessment of Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles". The time elapsed between the publication of these figures and the Impact Assessment (4½ years) casts doubt on their efficacy and accuracy. It is acknowledged that the best effort has been made to use the most up-to-date data available and that significant time and effort is required to compile reports on the basis of such raw data. It is also acknowledged that in work subsequent to the publication of the Impact Assessment, updated data is being made available.

This is therefore not a commentary on the quality of the data but an indication that the figures in the Impact Assessment itself are to be considered with a level of uncertainty.

3.1 Methodology by example of long-haul trucks

For each category of vehicle, the figures presented in pages 130-137 of the Impact Assessment are investigated individually, with alternative figures or range and the evidence for them presented. Combining the recalculated figures enables a conclusion on the total reduction potential and cost-benefit. A full set of the results of calculations for all vehicles types is shown in Annex IV.

The following is the table of figures from page 134 of the impact assessment showing the results for long-haul trucks:

Project name	Capital cost (€)	Additional fuel saving percentage (%)	NPV (€)	Marginal abatement cost (€/tCO ₂)	Cumulative carbon savings (%)
Predictive cruise control	81	1,5%	4.217	-336,29	1,5%
Low resistance tires	1.261	10,3%	28.371	-328,16	11,8%
Transmission friction red.	202	1,1%	2.955	-320,83	12,9%
Training and feedback	647	2,2%	5.589	-307,20	15,1%
Automatic tire inflation trailer	283	0,5%	1.176	-276,30	15,6%
Boat tail	1.414	2,5%	5.837	-275,90	18,2%
Full gap fairing	1.011	1,2%	2.507	-244,27	19,4%
Advanced engine	10.953	13,1%	26.578	-242,73	32,5%
Route management	485	0,3%	492	-172,64	32,8%
Full skirts	2.425	1,7%	2.386	-169,99	34,5%
Material substitution	2.401	1,4%	1.727	-143,41	35,9%
Gen II dual hybrid	22.228	6,4%	-3.877	72,41	42,4%

Table 1: Summary results table for long-haul trucks from Impact Assessment p134

The figures presented in the table are analysed below.

3.1.1 Calculation methodology: Combining technology potentials

CE Delft quotes the following formula for geometric combination of the CO₂ reduction effect of individual technologies (report p12):

$$\text{Combined reduction potential (\%)} = 100 \times (1 - (1 - RC_1)/100) \times (1 - RC_2/100) \times \dots \times (1 - RC_i/100)$$

However, it appears that this equation has not been employed in the impact assessment (p134), in which the percentages have simply been added linearly, resulting in a discrepancy of 4.7% in the aggregate cost effective CO₂ reduction potential (31.2% vs. 35.9%).

The impact assessment assumes combination of the technologies without any consideration of overlap – i.e. where two technologies act on reduction of the same energy loss and therefore are (partially) double-counted. This phenomenon is however acknowledged in paragraph 142 of the Impact Assessment, but not followed up in the calculations.

A full analysis of this phenomenon requires an in depth knowledge of the physics on the CO₂ reduction measures and their interactions. Such a level of analysis would appear to be beyond the scope of an ex-ante Impact Assessment and would likely require substantial time and resources, if possible at all.

Using an alternative simpler method, this potential overlap was considered by TNO et. al. in their 2006 report underlying the European Commission impact assessment for CO₂ passenger cars (Contract nr. SI2.408212, pp55-58). Cost curves were plotted with all possible technology combinations and a trend line added with 2/3 of the points to the left of the curve (lower CO₂ reduction) and 1/3 to the right, see example below.

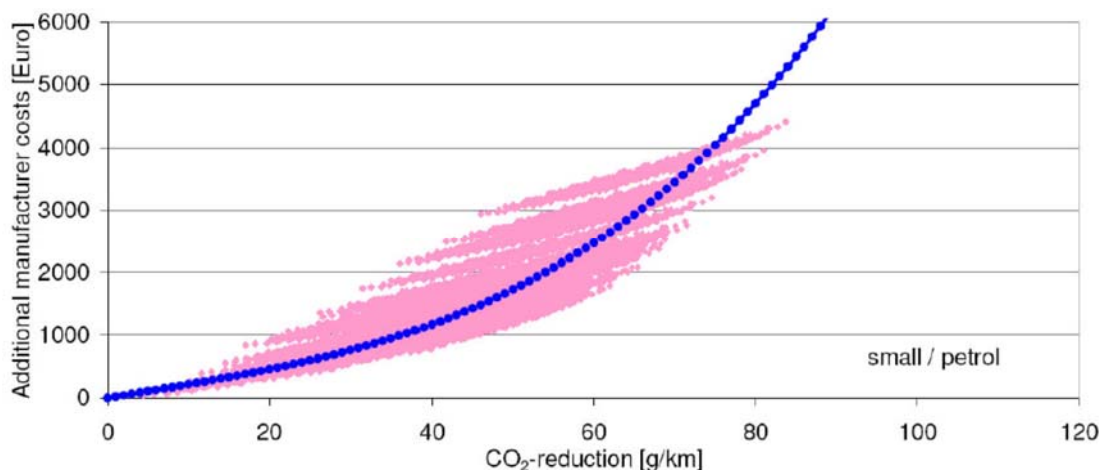
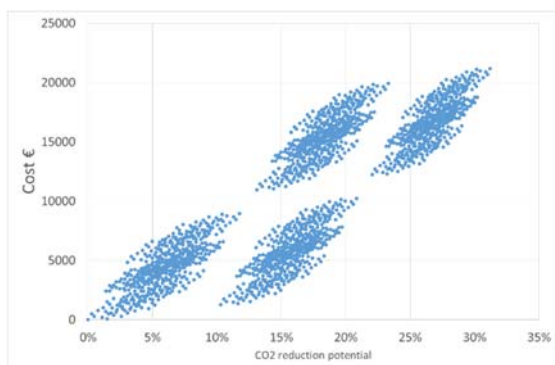


Figure 1: Chart from TNO 2006 report showing technology combination calculation methodology

Analysing the cost curves in the 2006 report, the “discount” created on the CO₂ reduction potential using the above method varied between 7% and 15% depending on vehicle size and fuel type. The methodology for calculation of the trend line is not known.

A similar analysis has been attempted using the CO₂ reduction and cost figures in the HDV CO₂ impact assessment. The chart below shows the distribution of points for long haul vehicles. The distribution is highly heterogeneous in comparison to the above example, making the selection of an equivalent trend line in the same manner very difficult.



The equivalent distribution for the other vehicle types is also highly heterogeneous and all are included in Annex V, showing only the points representing cost effective technologies according to the Impact Assessment and a second version excluding the hybrid technology where applicable.

Due to the clear difficulties to create an equivalent trend line through such an inhomogeneous distribution, even with a defined methodology, an estimated figure the discount in the combined CO2 reduction of 10% is taken for all vehicle types. This figure reflects the outcome of the corresponding 2006 TNO analysis and a visual assessment of the charts in Annex V.

It results in a further 3.1% reduction in the cost effective CO2 reduction potential from the 31.2% quoted above.

The updated calculation methodology above results in the following revised figures:

- a) The figures shown in the impact assessment
- b) The figures calculated from the individual improvements according to the combination methodology indicated by CE Delft.
- c) The figures from b. with a 10% discount reflecting the methodology of TNO in its 2006 report as explained above

The figures are shown in the table below, with the following key valid for all tables in this section:

Impact assessment data	Data from this report	Revised data point	Cost effective limit
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Measure	CO2 potential (impact assessment)	a) Cumulative (impact assessment)	b) Cumulative (CE Delft methodology)	c) Cumulative (CE Delft & TNO methodologies)
Predictive cruise control	1.5%	1.5%	1.5%	n/a
Low resistance tires	10.3%	11.8%	11.6%	10.5%
Transmission friction red.	1.1%	12.9%	12.6%	11.4%
Training and feedback	2.2%	15.1%	14.5%	13.1%
Automatic tire inflation trailer	0.5%	15.6%	15.0%	13.5%
Boat tail	2.5%	18.2%	17.1%	15.4%
Full gap fairing	1.2%	19.4%	18.1%	16.3%
Advanced engine	13.1%	32.5%	28.8%	25.9%
Route management	0.3%	32.8%	29.0%	26.1%
Full skirts	1.7%	34.5%	30.2%	27.2%
Material substitution	1.4%	35.9%	31.2%	28.1%
Gen II dual hybrid	6,4%	42.4%	35.6%	32.1%

Table 2: Combined CO2 reduction potential using different calculation methodologies and CO2 potential figures

The overall effect of application of the combination methodologies as applied by CE DELFT is to reduce the cost-effective CO2 reduction potential from 35.9% to 28.1%.

3.1.2 Taking account of realised and maximum feasible penetration of technologies

A reassessment is required considering the extent of penetration by 2014 of the technologies identified in the Impact Assessment. Additionally the maximum feasible penetration, if not 100%, is to be identified. This enables a calculation of the remaining potential for reduction, which is relevant to determine the potential for regulation or other measures.

Certain technologies (for example low rolling resistance tyres) are already supplied as standard on a certain proportion of new trucks. Some of the engine technologies quoted in the background report have also already been incorporated into new vehicles. Other technologies, for example boat tails for aerodynamic improvements have negligible penetration as of 2014.

Similarly, low rolling resistance tyres may not be feasible for 100% of vehicles for technical or safety reasons. Additionally, technical or safety constraints may limit the maximum fit rate for aerodynamic or other measures.

Data on this item requires expert input from credible sources and is not readily available to the author. The calculation has therefore been performed with a zero realised penetration rate and 100% maximum penetration rate for all identified technologies, pending new information to be provided during the peer review of this study.

The effect of this accounting is shown in the table below (comparing to the final figures in the above table):

- d) The figures from c) above amended by considering the already realised technology penetration by 2014 (zero effect pending expert input)

Measure	CO2 potential (impact assessment)	c) (from above) Cumulative (CE Delft & TNO methodologies)	Penetration rate of technology	d) Accounting for already realised technologies
Predictive cruise control	1.5%	n/a	0	1.50%
Low resistance tires	10.3%	10.5%	0	10.5%
Transmission friction red.	1.1%	11.4%	0	11.4%
Training and feedback	2.2%	13.1%	0	13.1%
Automatic tire inflation trailer	0.5%	13.5%	0	13.5%
Boat tail	2.5%	15.4%	0	15.4%
Full gap fairing	1.2%	16.3%	0	16.3%
Advanced engine	13.1%	25.9%	0	25.9%
Route management	0.3%	26.1%	0	26.1%
Full skirts	1.7%	27.2%	0	27.2%
Material substitution	1.4%	28.1%	0	28.1%
Gen II dual hybrid	6.4%	32.1%	0	32.1%

Table 3: Combined CO2 reduction potential accounting for already realised technologies

Any effect for long haul trucks or other vehicle types is therefore to be determined.

3.1.3 Cost and benefit of individual technologies

The figures for CO2 reduction potential of the identified technologies have been reassessed. In most cases they have been found to be compatible with data provided by other sources. In certain cases overestimates of the reduction potential were identified. In other cases underestimates were found, with the net effect for this vehicle type being approximately neutral.

Revised CO2 reduction potentials

The following table shows where revised figures for the CO2 reduction potential of the technologies have been identified. Only where there is clear and credible evidence for the revised figures have they been included in this analysis and for other vehicle types (see Annex II).

Measure	CO2 potential (IA)	Revised figure (“-“ means not revised)
Predictive cruise control	1.5%	-
Low resistance tires	10.3%	6.68%
Transmission friction red.	1.1%	-
Training and feedback	2.2%	5%
Automatic tire inflation trailer	0.5%	-
Boat tail	2.5%	-
Full gap fairing	1.2%	-
Advanced engine	13.1%	-
Route management	0.3%	-
Full skirts	1.7%	-
Material substitution	1.4%	-
Gen II dual hybrid	6,4%	-

Table 4: Reassessment of CO2 reduction potentials of technologies for long haul vehicles

Costs of CO2 reduction measures

The development of the costs between publication of the underlying study (TIAX/NAS 2009) and of the impact assessment (2014) may result in significant changes. The largest potential differences are in the costs of advanced engines and hybrid systems, with some recent data addressed in section 3.5.

A reanalysis of the figures presented for the cost of the measures proves significantly more difficult than for the CO2 reduction potential, due to some widely differing figures in the background studies and the sensitivity of costs for manufacturers.

In this report therefore, the cost figures have not been revised, except for a specific analysis for hybrid technology (section 3.2.1).

Net present value and CO2 abatement costs

For vehicle types with high mileage (in particular long-haul and regional delivery), the cost effectiveness calculation has a low sensitivity to the cost of technology, since the fuel savings are significantly higher. These are also the types with the highest aggregate consumption.

For long haul trucks, only the hybrid technology is calculated as not cost effective using the original figures. Using the new estimates for CO2 potential from Table 4, the material substitution technology becomes (marginally) non-cost-effective (resulting in a 0.65% reduction in total cost effective potential).

For low-mileage vehicle types (e.g. construction, municipal), there is a higher sensitivity to the cost of the CO2 reduction measures.

Using the new figures enables a revision of the net present value and abatement costs, shown in the following table:

Measure	Impact Assessment		Revised figures	
	NPV	Abatement cost	NPV	Abatement cost
Predictive cruise control	4,217	-336,29	4,693	-370.96
Low resistance tires	28,371	-328,16	31,518	-362.84
Transmission friction red.	2,955	-320,83	3,299	-355.58
Training and feedback	5,589	-307,20	6,354	-342.49
Automatic tire inflation trailer	1,176	-276,30	1,308	-310.24
Boat tail	5,837	-275,90	6,542	-310.29
Full gap fairing	2,507	-244,27	2,808	-277.46
Advanced engine	26,578	-242,73	30,736	-278.22
Route management	492	-172,64	470	-185.66
Full skirts	2,386	-169,99	2,985	-208.21
Material substitution	1,727	-143,41	-14	-174.00
Gen II dual hybrid	-3,877	72,41	-1,861	34.47

Table 5: revised figures for net present value and CO2 abatement cost of technologies for long haul vehicles

It is noted that the figures for NPV and abatement cost quoted in the Impact Assessment could not be reproduced exactly when using the same base figures. More detailed information on the original parameters and calculations is necessary to ensure 100% agreement. However, the differences were not found to be significant and are not large enough to affect the key calculation of the cost effective CO2 reduction potential. A document request has been filed to access the original calculations made using the MACH model, to enable a revision in a later draft.

Finally, the effect of the revised figures for CO2 reduction potential are shown, with the cost-effective threshold revised according to the abatement cost figures above

- e) The figures from d) above amended by introducing revised figures for CO2 reduction potential of each measure

Measure	CO2 potential (IA)	CO2 potential (new estimates)	d) (from above) Accounting for already realised technologies	e) With changes in estimated CO2 reduction potential
Predictive cruise control	1.5%	1.5%	1.50%	1.5%
Low resistance tires	10.3%	6.7%	10.5%	7.3%
Transmission friction red.	1.1%	1.1%	11.4%	8.2%
Training and feedback	2.2%	5.0%	13.1%	8.2%
Automatic tire inflation trailer	0.5%	0.5%	13.5%	8.6%
Boat tail	2.5%	2.5%	15.4%	10.6%
Full gap fairing	1.2%	1.2%	16.3%	11.6%
Advanced engine	13.1%	13.1%	25.9%	21.9%
Route management	0.3%	0.3%	26.1%	21.9%
Full skirts	1.7%	1.7%	27.2%	23.0%
Material substitution	1.4%	1.4%	28.1%	23.9%
Gen II dual hybrid	6.4%	6.4%	32.1%	28.2%

Table 6: Final reassessment of CO2 reduction potentials of technologies for long haul vehicles

All the figures in the tables above are shown in comprehensive form for each vehicle type in Annex IV.

Technical vs behavioural measures

In the final analysis of the CO2 reduction potential in the consideration of the most effective policy option, account is to be taken of those measures which are technical and those which are behavioural. Technical measures can in theory be regulated by setting limits for the manufacturer, as proposed by policy option 3. Behavioural measures require action by the owner or driver and do not apply to technologies implemented on the vehicle.

In the case of long haul trucks, two measures are behavioural, “training and feedback” and “Route management”. In determining the potential for technical measures covered by regulation, these behavioural measures should be removed from the analysis (a reduction of 2.7% in the cost effective potential according to the revised figures above). These measures are only included in the list for long haul trucks and do not appear for any of the seven other vehicle types.

3.2 Other effects to be considered and effects specific to other vehicle types

The following commentary reviews the other vehicle types (i.e. apart from long-haul trucks), identifying any specific issues in the evidence presented. In addition it assesses any inconsistencies between the CO2 reduction potential and cost figures presented for the same measure for different types.

3.2.1 Effect of hybrid technology for certain vehicle types

Annex 1 contains an analysis of the cost of hybrid systems and the resulting effect on the cost effectiveness of the hybrid technology for those vehicle types for which it is positively evaluated in the Impact Assessment (urban delivery, municipal utility, construction and bus). A significant uncertainty in the cost figures for hybrid systems is identified, potentially leading to a negative cost effectiveness for this technology for all vehicle types.

A simple sensitivity analysis assuming a doubling of the quoted cost of the technology has been performed, with the resulting effect on the aggregate cost effective CO2 potential clearly shown in Table 8 and Figure 2 below.

3.2.2 Cost effective cut-off point

A consideration which may bring additional technologies into the range of cost effectiveness is the threshold by which cost-effectiveness is determined. In the Impact Assessment, this threshold is set at zero. Alternative options include:

- €6 per tonne CO2: the current (May 2015) market price of carbon credits
- €30 per tonne CO2: the reserve price used in the ETS for calculating exposure to carbon leakage
- €200 per tonne: the equivalent carbon price to the average tax rate on diesel fuel in Europe

The €30/t figure represents a notional carbon cost for the whole economy that has been used formally in EU policy and can be considered a reasonable figure to use for an alternative scenario. The practical effect of this change is calculated to be zero for all vehicle types, since all non-cost effective measures have cost per tonne of CO2 above the €30/t level. However, with revised cost and CO2 benefit figures, it could potentially bring some measures into cost effectiveness.

3.2.3 Lifetime of vehicles and discount rate

The full lifetime of vehicles is used in the Impact Assessment to calculate the net present value and abatement cost of technologies. This therefore takes no account of the time value of money. Since discount rates are habitually used in Impact Assessments (for example the

22nd January 2014 “Policy framework for climate and energy in the period from 2020 to 2030”, it would be prudent to consider them in this analysis.

Employing a moderate discount rate of 7% (e.g. XXXX) results in an increase in abatement costs between €92/tCO₂ (long haul vehicles) and €172/tCO₂ (urban delivery and construction vehicles). The decrease in net present value ranges from a few hundred euros to 28,000 in the case of the most expensive technology.

The practical effect on the cost effective CO₂ reduction potential is however small, as the following table shows:

Vehicle type	Revised cost effective potential using above analysis	Revised cost effective potential using 7% discount rate
Service	12.5%	11.3%
Urban delivery	16.8%	16.5%
Regional delivery	20.1%	17.8%

Table 7: Effect of using 7% discount rate

The vehicle lifetimes used in the Impact Assessment vary significantly according to the following table:

Vehicle type	Service	Urban delivery	Municipal utility	Regional delivery	Long haul	Construction	Bus	Coach
Lifetime (years)	10	19	17	12	8	19	14	12

Slightly different figures are quoted in the AEA-Ricardo study and the Impact Assessment, in particular for long haul trucks (11 years) and buses (15 years). Using these alternative figures for vehicle lifetime does not result in any change to the cost effective CO₂ reduction potential with the current cost and benefits of each measure.

3.2.4 Rebound effect

In paragraph 163 the Impact Assessment acknowledges the material existence of the rebound effect – the increase in fuel usage due to the savings from lower specific consumption and the accompanying increased CO₂ emissions compared to the optimum. Available data does not allow a reasonable evaluation of the effect, but its existence should be made transparent and further investigated.

3.2.5 Criteria emissions regulations

The effect of changing criteria emissions regulations has not been taken into account. A tightening of the standards (from Euro VI to Euro VII) by 2030 is not out of the question. Even in the absence of a new Euro emissions level, secondary legislation and other considerations on exhaust emissions may increase fuel consumption. These include the introduction of in-use standards measures by portable emissions measurement (PEMs) and the ongoing introduction of particle number standards.

3.2.6 Multiple replacements of technology

As acknowledged on page 4-62 of the 2011 TIAX/ICCT study, no account has been taken of the cost of multiple replacement of CO₂ reducing measures during the vehicle lifetime. For example (as in the TIAX study), tyres need to be periodically replaced and the extra cost of low rolling resistance and single wide tyres would therefore be a recurring expense,

especially for long haul vehicles. This may also apply to aerodynamic equipment and advanced engine components. In particular it is likely to apply to batteries for hybrid vehicles, dealt with specifically in section 3.2.1.

Data is not available to evaluate this effect but a consideration should be made in future analyses.

3.2.7 Learning effect and economies of scale on technology costs

An expectation is expressed in the Impact Assessment (paragraph 147) of a sharp fall in the costs to achieve engine improvements. Evidence is presented in paragraph 49 in the form of a 2011 study by TNO et. al. reviewing the regulation on CO2 emissions from passenger cars. This scope of this report does not include scrutiny of the findings of the TNO et. al. report. However, the possibility of costs of CO2 reduction technologies falling over time is a viable consideration and merits further investigation. This has been started with new published estimates (section 3.5) and is to be continued in future analyses.

3.2.8 Regional delivery vehicles

The CO2 measures for regional delivery vehicles includes in first position “fuel efficiency improvements” with a CO2 reduction potential of 6.9% and zero cost. This is extracted directly from the 2011 TIAX study, representing the expected improvement in engine efficiency from 2010 to 2014. However, the equivalent figures for other vehicle types have not been incorporated. This requires clarification.

In addition there appears to be some double counting of potentials in this figure in the 2011 study. For example, according to page XX it states that aerodynamics and tyres have been improved, whereas the potential for these is also included in the main table of new measures. This should be accounted for by the consideration of already realised technologies in the analysis in the previous section.

3.3 Summary for all vehicle types

The calculations have been performed for all eight vehicles types and are shown in detail in Annex IV. The following table shows the maximum cost effective CO2 reduction potential for each vehicle type for the different assumptions and background figures.

Assumption	Maximum cost effective potential (threshold = zero abatement cost)								
	Service	Urban delivery	Municipal utility	Regional delivery	Long haul	Construction	Bus	Coach	Weighted av.
IA figures	14.7%	43.7%	35.5%	41.0%	35.9%	44.8%	43.4%	25.3%	35.1%
IA figures applying full combination methodology	12.5%	34.2%	28.5%	31.1%	28.1%	35.0%	35.4%	21.1%	27.7%
Accounting for realised potential by 2014	12.5%	34.2%	28.5%	31.1%	28.1%	35.0%	35.4%	21.1%	27.7%
Using new CO2 figures	12.5%	34.4%	28.5%	20.1%	27.3%	32.8%	35.4%	21.1%	25.5%
Hybrid cost x2	12.5%	16.8%	14.3%	20.1%	27.3%	15.0%	11.4%	21.1%	20.0%
7% discount rate	11.3%	16.5%	14.3%	17.8%	27.3%	14.8%	11.4%	21.1%	19.5%
30€/t cost-effectiveness cut-off	11.3%	16.5%	14.3%	17.8%	27.3%	14.8%	11.4%	21.1%	19.5%
Subtract behavioural measures	11.3%	16.5%	14.3%	17.8%	23.9%	14.8%	11.4%	21.1%	18.3%

Table 8: Overview of cost effective CO2 reduction potentials for eight vehicle types

These results are also shown graphically below (figures for 7% discount rate, €30/t cost effective cut-off and subtracting behavioural measures are not included since the effects are not large, in order to make the chart readable):

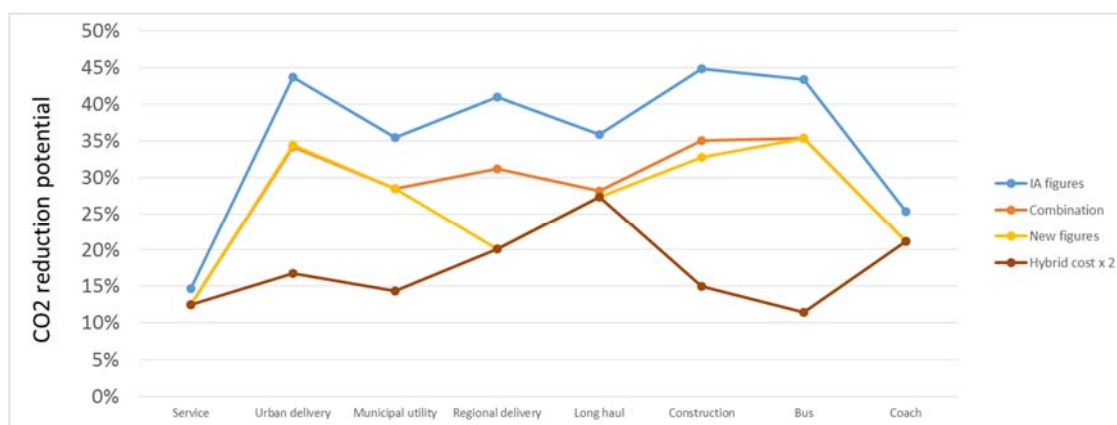


Figure 2: Chart of cost effective CO2 reductions for all vehicle types under different assumptions

3.4 Conclusions

The Impact Assessment reaches the conclusion that option 3(ii), the setting of mandatory emissions limits for newly registered vehicles, is the preferred option, as indicated by the

evaluation in table 6, page 44. This is based on the analysis presented in section 5.3 paragraphs 155 to 181, in which a weighted average cost effective CO2 reduction potential between 2015 and 2030 of 35% is quoted, derived from the calculations. It is stated in paragraph 161 that this represents a 20% improvement over the expected ~1% per year “natural” improvement.

The conclusion is fully dependent on the accuracy of the analysis and calculations. As discussed above, a simple reanalysis of the figures applying correct combination methodology of the potentials results in an alternative figure of 27.7% total cost effective potential. Further sensitivity analysis on the benefits of certain identified technologies and in particular on the cost of hybrid technologies for those vehicle types with the most appropriate duty cycles leads to a worst case cost effective potential of 20%, only 5% above the assumed natural potential.

Further data is to be acquired regarding the penetration of the identified technologies by the time of publication of the Impact Assessment. Such penetration would represent a reduction in the future potential CO2 reductions.

Due to the uncertainties in the figures and the indication that revised results may contradict the conclusions made in the Impact Assessment, it is recommended to reassess the impacts in detail with a full reassessment of the figures taking into account the above analysis.

3.5 Further analysis with subsequently available figures

The European Commission continues to cooperate with the heavy duty vehicle community, in particular the manufacturers, on the development of the future policy regime. Further evidence is therefore being compiled and presented.

In particular new evidence was presented at the 30th January 2015 stakeholder meeting, with the draft final report “Cost-benefit analysis of options for certification, validation, monitoring and reporting of Heavy Duty Vehicles fuel consumption and CO2 emissions”. The full report has subsequently been published by the German Umweltbundesamt (UBA).

ACEA commissioned a report to Transport & Mobility Leuven to assess some of the figures, published in September 2014. This report is not fully comparable to the Impact Assessment since it assesses potential to 2020. However some of the figures could be considered comparable and can be used for a further feasibility check.

The following table shows a comparison between the revised figures for relevant CO2 reduction potential from the above analysis and the corresponding ones from the UBA report.

Measure	Original / Revised figure	UBA report	TML report
Low resistance tires + super singles	6.7%	5.9%	4%
Total for aerodynamics	5.4%	5.8%	4%
Driver training	2.2%	n/a	5%
Advanced engine	13.1%	11%	9%
Material substitution	1.4%	0.7%	0.5%

Table 9: Comparison of Impact Assessment Institute analysis and UBA report for long-haul truck measures

Except for material substitution, there is a maximum difference of 20% between the revised figures in this report and the UBA figures, providing a useful feasibility check for the above analysis. The TML report indicates somewhat lower figures, except for a higher figure for

driver training. The 5% figure for driver training has been used in the main report above since it represents a well evidenced substantial difference from the original figure.

Additionally the following table shows a comparison of the cost of parallel hybrid systems three vehicle types between the Impact Assessment and the UBA report:

Vehicle type	Impact Assessment	UBA report
Long-haul truck (including battery replacement)	€22,228	€60,000
Regional delivery / 12t delivery truck (including battery replacement)	€18,794	€35,000
City bus (including battery replacement)	€17,783	€90,000

Table 10: Comparison of figures for hybrid system cost between Impact Assessment and UBA report for three vehicle types

In each case the estimated cost is significantly higher than that of the Impact Assessment, being at a minimum double and for buses substantially higher, supporting the detail of the analysis in section 3.2.1 with the conclusion that there is a high upward uncertainty in the cost. The conclusions reached of the UBA study itself indicate a question mark on the cost effectiveness of the hybrid technology. This is therefore a strong indicator of the need to take into account this high uncertainty in future policy making.

Annex I: Detailed comments on language used in Impact Assessment

Introduction

No substantive comments are made on this section.

Chapter 1: Procedural issues and consultation of interested parties

No comments are made on this section.

Chapter 2: Problem definition

The following comments look into each instance individually by relevant paragraph:

Paragraph 21: the characterisation of the lack of measurement and recording of HDV CO₂ emissions as a “bottleneck that needs to be addressed” appears to reach a conclusion without evidence being presented. Even though the sentence refers to a later subsection, a justification of the conclusion of the sentence has not been presented.

In the last sentence, the use of the word “neutralise” to describe the effect of exhaust standards on energy efficiency is an absolute term describing a phenomenon of degree. In fact, depending on their stringency and frequency of introduction as well as on the extent of efficiency improvements, exhaust standards may cause the energy efficiency improvements to be partly, fully or more than fully reversed.

Paragraph 26: referring to HDV fuel consumption and CO₂ performance, the text states “This remains an area with considerable scope for further action.” This statement therefore appears to prejudge the result of the impact assessment and does not therefore correspond to the problem definition.

Paragraph 29: the text assesses the prospects for improved fuel consumption and CO₂ performance “in the assumed absence of new and more stringent exhaust gas pollutant standards”. Since deviation from this assumption is feasible by 2030 (in particular introduction of particle number standards, potentially Euro VII standards), the possibility of new standards and their effect on CO₂ emissions should be considered in the full analysis.

Paragraph 37: the text states that “**The main conclusion of this modelling exercise is that the baseline scenario cannot be considered sustainable** in view of EU policies to curb GHG emissions” (bold copied from text). This is a conclusion that requires evidence and justification before being stated. Arithmetically, with 5% of EU GHG emissions from HDVs, sustainable policy objectives can be reached with no improvement in this area, even though that may not be compatible with the objective to create a holistic climate policy.

Paragraph 40: the statement that “European manufacturers could benefit from considerable economies of scale and first mover advantage” due to EU standards having a worldwide impact is not accompanied by specific evidence.

Paragraph 41: similarly, this paragraph makes a statement reaching a profound conclusion on the need for EU action but without the evidence being presented.

Paragraph 59: the comment about past undertakings from manufacturers is not accompanied by evidence or justification. The use of the word “hazardous” to describe reliance on such undertakings is somewhat emotive and dismissive. A more neutral description would be more appropriate.

Paragraph 62: the influence of reduction in CO2 emissions from heavy duty vehicles on the climate would on its own be very small (even if achieved globally), therefore the direct influence on the population (from CO2 alone) would also be small. This of course does not negate such reductions being part of a comprehensive package of measures whose overall effect would indeed be of material degree.

Paragraph 62: the assumption that component suppliers would benefit from increasing demand for technologies is a hypothesis which has not been proven, is contested by some stakeholders and would benefit from an in-depth investigation.

Paragraphs 69, 70, 72: the provisions on the legal basis, subsidiarity and proportionality for such regulation appear to be fully correct and consistent.

Chapter 3: Objectives

Paragraph 77: this paragraph states that post 2020 a quantitative constraint on HDV CO2 emissions is an operational objective. This should however be a conclusion to be reached on the basis of the evidence presented in the impact assessment, not stated as an assumption in advance.

Paragraph 79: the conclusion that the strategy will “shift added value to the manufacturing sector and contribute to growth in the EU” can only be based on the results of the cost-benefit analysis, whose results are required in order to test this conclusion.

Chapter 4: Policy options

No comment on this section.

Chapter 5: Impact analysis of policy options

Paragraph 98: it is stated that the baseline scenario is considered unsustainable according to section 2.3. However, the relevant references in that section are statements and assumptions stated before presentation of the evidence. Furthermore section 2 is named “Problem definition” and by its nature should therefore not include any usable conclusions.

Paragraph 109: even though it is reasonably stated that precise quantification of the effect of option 1 is not possible, the conclusions of this paragraph “not expected to be considerable” and “Emissions may only be reduced by a maximum of a few percentage points” require the evidence to be presented through, at the very least, a rough calculation.

Paragraph 128: the statement on predictability in CO2 emissions with the ETS is an important element of the analysis of this option.

Paragraph 129: evidence and analysis is required to support the statement that effects on modal shift and fuel switch are likely impacts of the ETS option.

Paragraph 142: the statement on the unfeasibility of strict addition of the percentage gains from individual technologies is an important one and this concept should be consistently taken into account in the analysis (see section 3.1.1 below). The OEMs’ statement regarding the challenging nature of approaching the engine thermal efficiency limit is also to be taken into account through robust scientific analysis.

Paragraph 145: the statement that OEMs would recover extra costs through HDV price and that HDV operators would recover additional purchase price with fuel savings is fully dependent on the accuracy of the subsequent cost-benefit analysis.

Paragraph 152: the correctly stated lack of a linear relationship between CO2 emissions and pollutant emissions is a relevant factor. However, this analysis appears to be undermined by the clause “while the environmental impact of this option can only be positive due to lower engine fuel consumption”.

Paragraph 159: this paragraph states the assumption that actual costs for hybrid technologies are expected to be lower than the estimates. As indicated in section 3.2.1 below, the opposite possibility also needs to be taken into account.

Paragraph 179: again the correlation is made between fuel consumption and emissions, where in fact no systematic correlation exists, since manufacturers optimise emissions performance to fulfil emissions standards and maximise fuel efficiency.

Chapter 6: Comparing the options

Paragraph 183: this paragraph correctly assesses the major effects of each option.

Chapter 7: Monitoring and evaluation

No comments are made on this section.

Annex II: technology cost and CO2 reduction potential

Potential for tyres

The CO2 reduction potential through introduction of low resistance tyres varies significantly for the different vehicles types. For regional delivery, long haul and construction vehicles they are quoted as approximately 10%. For lower mileage and speed vehicles, i.e. service, urban delivery, municipal utility, buses and coaches it ranges from 1.3% to 2.9%. The figures are extracted from the 2011 TIAX/ICCT study, which are in turn derived from the 2009 TIAX/NAS study.

The reason for the large discrepancy between these two sets of figures is not fully clear from the quoted literature, although reasoning has been provided for certain cases such as coaches. Reasoning does not appear to have been given for construction vehicles, whose potential could be expected to be closer to that of municipal utility or service vehicles due to similar low speed duty cycles.

In the 2009 study the following table estimates the total contribution of rolling resistance to energy losses for different vehicle types.

Vehicle Class	Estimated contribution of Rolling Resistance to energy losses	Rel. Efficacy of Rolling Resistance
Tractor trailer (65K lbs)	13%	1.0
Motor Coach	9%	0.7
Box and Bucket	9%	0.7
Transit Bus	5%	0.4
Refuse	8%	0.8

Table 11: Energy losses through rolling resistance from TIAX/NAS 2009 report

It is unclear how the CO2 reduction potential from low resistance tyres can be as much as 10% for long-haul trucks (tractor trailers), when the maximum energy needed to overcome rolling resistance is only 13%. Indeed the TIAX/NAS report quotes one tyre technology (next generation wide based single tyres) with a potential of up to 14%, higher than the total energy loss from rolling resistance. However, other studies and sources quote between 25 and 60% for the contribution of rolling resistance to fuel consumption.

In order to provide an indication of the magnitude of any correction to the figures, the following sources have been identified:

Low rolling resistance tyres: Continental (2010) up to 3.68% (long haul trucks).

Single wide tyres: Oak Ridge National Laboratory (2006) 3%
Truckingefficiency.org (2015) 3-6%

Taking a conservative line, the total figure of 6.68% is used for the aggregate potential for low rolling resistance tyres and single wide tyres for long-haul and regional delivery vehicles. Even this conservative figure is significantly higher than the figure quoted in the 2014 T&M Leuven study of 4%. The figure for construction vehicles set to the highest value of the range of the low mileage vehicles, i.e. 2.9%.

These figures are integrated into the tables in Annex IV.

Potential for material substitution

The CO₂ reduction potential through material substitution varies in the Impact Assessment between 0.2% for construction vehicles and 3.5% for buses. The source of these figures is not fully clear, since they do not correspond precisely to the figures in the 2012 CE DELFT study nor its sources, the 2011 ICCT/TIAX study and the 2009 NAS/TIAX study. In fact in almost all cases the Impact Assessment figures are lower than the CE DELFT and the NAS/TIAX figures.

Due to the uncertainties in the figures for light weighting (see analysis below), the corresponding calculations in this report have not been amended pending additional information from expert stakeholders during the peer review process.

A short analysis to frame the issue is however performed below:

Long haul truck

For a 450kg (1,000 lbs) reduction, the 2009 TIAX/NAS study calculates the potential for a weight constrained truck (i.e. weight limit fully utilised), assuming that this 2.2% weight reduction of the truck results in a 2.2% increase in the load and therefore a 2.2% reduction in ton-miles(km) travelled. This 2.2% figure is then quoted by the 2011 ICCT/TIAX study and the 2012 CE DELFT study. It is assumed that the 1.4% quoted in the impact assessment is somehow derived conservatively from this 2.2% figure, but no explanation was identified.

Since most truck cargos are volume rather than weight constrained, the 2.2% figure and its derivatives may not give an accurate picture. Additionally, the assumption that the weight saving is fully converted into fuel saving by avoiding journey of additional trucks depends on a number of assumptions that are not proven.

It would therefore be more appropriate to use the volume constrained figure. The 2009 NAS/TIAX study quotes figures from 0.17% to 1.25% saving for a 450kg weight reduction, stating that the range of 0.4% to 0.6% is a "reasonable" one. A figure of 0.5% is therefore used in the revised analysis.

A feasibility check can be performed. The figure in the 2009 TIAX/NAS study (p 4-62) for the proportion of the road load that is weight dependent for a truck at a steady 55mph (80kmh), 38%. The 450kg weight reduction represents 1.95% of the volume-constrained vehicle weight (23,000kg). Assuming a linear relationship, this weight reduction results in a $1.95\% \times 38\% = 0.75\%$ fuel consumption and CO₂ reduction.

Regional delivery and coach (highway driving)

It is assumed that long-haul, coach and regional delivery vehicles have similar duty cycle characteristics and therefore the same 38% of weight dependent road load. This would lead to the conclusion that a similar CO₂ reduction potential through light weighting would be expected for each type. Indeed the Impact Assessment quotes a 0.7% reduction using this measure. The corresponding figure for regional delivery vehicles is 1.5%. This figure in particular would be expected to be similar to that for long haul trucks, due to the similarity in vehicle characteristics.

The following table shows the figures quoted in the Impact Assessment for CO₂ reduction potential using light weighting for the three high mileage vehicle types:

Regional delivery	Long haul	Coach
1.5%	2.2%	0.7%

Local and urban vehicle types

The following table shows the figures quoted in the Impact Assessment for CO2 reduction potential using light weighting for the four local and urban vehicle types:

Service	Urban delivery	Municipal utility	Construction
1.1%	2.2%	0.6%	0.3%

The reasons for the wide spread of figures is not clear, in particular why for construction vehicles it is so low and for urban delivery so high.

Bus

The CO2 reduction potential through light weighting for buses is quoted in the Impact Assessment as 3.5%. This high figures is explained by a high potential to reduce weight (up to 3,500 lbs) through a substantial re-engineering of the vehicle structure using new materials, presented by an aluminium manufacturer. In order to verify this potential to validate it for the analysis, further input is required from automotive suppliers and OEMs.

Hybrid cost for relevant vehicle types

For certain vehicle types, those that spend much of their operation in stop-start cycles, the hybrid technology has been assessed with a high CO2 reduction potential. For those vehicle types, specifically urban delivery, municipal utility, construction and bus, the CO2 reduction potential is significant, ranging from 18% for municipal delivery up to 30% for buses, aligning well to figures produced by OEMs.

With lower confidence levels are the cost figures for the technology. In particular, the TIAX 2011 report indicates that the cost used for hybrid buses is the subsidised cost, assuming a 90% government subsidy. This implies that the actual cost is not €17,783 but €177,830 (or \$220,000 according to the 2009 NAS study from which the data is derived). Using this figure would change the NPV results for hybrid technology for buses from positive €39,470 to negative €139,360.

In the 2009 TIAX/NAS study, all cost figures for hybrid systems are estimated, except those above for buses, which are derived from actual systems on the market (although at low volume). It is unclear from the study why there is such a discrepancy between the cost of hybrid systems for buses (\$220,000) and for other vehicle types (from \$18,000 for class 6 box trucks to \$55,000 for class 8 long-haul trucks). One explanation may be that the figure for buses is more robust and the estimated figures for other vehicle types, gained from site visits are overoptimistic. An alternative explanation is that the figures for the bus, representing low market volumes, could be expected to drop for higher volumes towards the estimated figures of the other vehicle types.

In either case, there is a significant uncertainty in the cost figures for hybrid systems. The positive NPV calculation for those vehicles for which hybrid systems are considered viable in the Impact Assessment (excluding buses dealt with above) range from +€5,745 for municipal utility to +€23,538 for construction vehicles. These figures appear to be within the range of uncertainty of the hybrid system cost figures as discussed above and therefore it would be

prudent to take into account the possibility that in one or more cases the hybrid system would not be cost effective.

An additional factor is the potential cost for battery replacement. As acknowledged in the 2009 TIAX/NAS study, “system reliability over the life of the vehicle has not yet been demonstrated”. It is also acknowledged in the 2015 UBA report, which explicitly includes a provision in the cost estimates for battery replacement for hybrid technology.

The overall effect of this possibility is to reduce the cost-effective CO2 reduction potential for those vehicles significantly, shown in Annex IV and summarised in Table 8 above.

Annex III: Amended figures for CO2 reduction potential and cost of measures

Measure	CO2 reduction potential		
	IA figure	Revised figure	Source
Predictive cruise control	1.5%	-	
Low resistance tires	10.3%	3% + 3.7%	ORNL (SWBT) Continental (LRRT) (ACEA/TML states 4%)
Transmission friction red.	1.1%	-	
Training and feedback	2.2%	5%	ACEA/TML estimate
Automatic tire inflation trailer	0.5%	-	
Boat tail	2.5%	-	
Full gap fairing	1.2%	-	
Advanced engine	13.1%		
Route management	0.3%	-	
Full skirts	1.7%	-	
Material substitution	1.4%	-	
Gen II dual hybrid	6,4%	-	

Annex IV: Full calculations

Key: green = impact assessment; blue = revised

Service

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Low resistance tires	1.5%	1.5%	1.5%	0	1.5%	10	10	1.5%	699	-317	830	-372.87	1.5%
Improved controls	2.0%	3.5%	3.1%	40%	2.4%	48	48	2.0%	882	-305	1,072	-361.19	2.4%
Drag reduction	2.4%	5.9%	5.2%	30%	3.9%	81	81	2.4%	1,059	-298	1,263	-354.62	3.9%
8-speed gear	3.2%	9.1%	7.9%	30%	5.8%	869	869	3.2%	643	-137	1,126	-194.35	5.8%
Improved diesel engine	4.1%	13.2%	11.3%	0	9.3%	1,213	1,213	4.1%	721	-120	1,081	-178.00	9.3%
Transmission friction red	0.4%	13.6%	11.6%	0	9.6%	202	202	0.4%	5	-8	22	-37.05	9.6%
Material substitution	1.1%	14.7%	12.5%	0.3	10.2%	505	505	1.1%	5	-3	111	-18.00	10.2%
Dual-mode hybrid electric	21.3%	36.0%	29.0%	20%	23.8%	23,441	23,441	21.3%	-13,364	426	-11,513	364.23	23.8%

Urban delivery

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Aft box taper	2.3%	2.3%	2.3%	0	2.3%	404	404	2.3%	1,913	-203	3,267	-335.83	2.3%
Roof deflector	2.4%	4.7%	4.2%	40%	3.3%	526	526	2.4%	1,991	-194	3,304	-325.54	3.3%
Box skirts	2.4%	7.1%	6.2%	30%	4.8%	606	606	2.4%	1,848	-185	3,144	-317.65	4.8%
Low resistance tires	2.9%	10.0%	8.7%	30%	6.5%	922	922	2.9%	2,092	-171	3,021	-302.9	6.5%
Advanced engine	9.6%	19.6%	16.5%	0	14.5%	3,920	3,920	9.6%	5,996	-149	11,402	-280.41	14.5%
Parallel hybrid electric	24.1%	43.7%	34.2%	0	32.7%	15,358	15,358	24.1%	9,470	-94	23,106	-26.63	32.7%
Cab side extension	0.4%	44.2%	34.4%	30%	32.9%	465	465	0.4%	-30	17	173	12.50	32.9%
Material substitution	2.2%	46.4%	35.6%	20%	33.9%	3,855	3,855	2.2%	-1,555	166	-344	36.95	33.9%

Municipal utility

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Aggressive shift logic	0.7%	0.7%	0.7%	0	0.7%	81	81	0.7%	1,120	-242	1,561	-358.75	0.7%
Low resistance tires	2.7%	3.4%	3.0%	40%	2.1%	344	344	2.7%	3,947	-239	5,990	-356.86	2.1%
Reduced parasitics/friction	1.0%	4.4%	3.9%	30%	2.7%	202	202	1.0%	1,345	-226	2,020	-344.87	2.7%
Advanced engine	10.2%	14.6%	12.7%	30%	8.9%	3,920	3,920	10.2%	12,462	-198	20,214	-315.54	8.9%
8-speed gear	2.1%	16.8%	14.3%	0	10.6%	1,899	1,899	2.1%	1,519	-115	3,026	-231.90	10.6%
Parallel hydraulic hybrid	18.7%	35.5%	28.5%	0	25.5%	24,249	24,249	18.7%	5,745	-50	19,621	-268.78	25.5%
Material substitution	0.6%	36.1%	28.8%	30%	25.7%	2,425	2,425	0.6%	-1,444	382	-1,017	272.75	25.7%

Regional delivery

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Fuel efficiency improvements	6.9%	6.9%	6.9%	0	6.9%	-	-	0.0%	9,959	-301.64	n/a	n/a	0.0%
Predictive cruise control	1.4%	8.3%	7.4%	40%	6.9%	81	81	1.4%	1,935	-289.52	2,469	-365.37	0.8%
Low resistance tires	9.6%	17.9%	15.3%	30%	12.5%	873	873	6.7%	13,024	-282.68	11,295	-350.29	4.9%
Transmission friction red	1.0%	19.0%	16.1%	30%	13.0%	202	202	1.0%	1,279	-260.50	1,620	-335.51	5.5%
Advanced engine	8.7%	27.6%	22.5%	0	19.7%	3,920	3,920	8.7%	8,596	-207.16	11,928	-284.02	12.9%
Automatic tire inflation trailer	0.4%	28.1%	22.8%	0	20.0%	283	283	0.4%	344	-165.49	446	-230.79	13.2%
Boat tail	2.2%	30.2%	24.2%	30%	21.1%	1,414	1,414	2.2%	1,701	-164.67	2,594	-244.21	14.4%
Full gap fairing	1.0%	31.3%	24.9%	20%	21.6%	1,011	1,011	1.0%	500	-99.86	811	-167.92	15.0%
Full skirts	1.7%	33.0%	26.0%	20%	22.6%	2,425	2,425	1.7%	55	-6.70	672	-81.85	16.0%
Material substitution	1.5%	34.5%	27.0%	30%	23.3%	2,401	2,401	1.5%	-273	38.68	331	-45.77	16.8%
Gen II dual hybrid	6.6%	41.0%	31.1%	0	27.7%	18,794	18,794	6.6%	-9,334	297.62	-6,771	212.54	21.6%
Automatic tire inflation tractor	0.4%	41.4%	31.4%	0	27.9%	3,638	3,638	0.4%	-3,127	1,846.28	-2,909	1,506.74	21.9%

Long-haul

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Predictive cruise control	1.5%	1.5%	1.5%	0	1.5%	81	81	1.5%	4,217	-336	4,693	-370.96	1.5%
Low resistance tires	10.3%	11.8%	10.5%	40%	6.8%	1,261	1,261	6.7%	28,371	-328	19,997	-354.97	4.9%
Transmission friction red.	1.1%	12.9%	11.4%	30%	7.5%	202	202	1.1%	2,955	-321	3,299	-355.58	5.6%
Training and feedback	2.2%	15.1%	13.1%	30%	8.7%	647	647	5.0%	5,589	-307	15,265	-362.01	8.5%
Automatic tire inflation trailer	0.5%	15.6%	13.5%	0	9.1%	283	283	0.5%	1,176	-276	1,308	-310.24	8.9%
Boat tail	2.5%	18.2%	15.4%	0	11.2%	1,414	1,414	2.5%	5,837	-276	6,542	-310.29	10.9%
Full gap fairing	1.2%	19.4%	16.3%	30%	11.8%	1,011	1,011	1.2%	2,507	-244	2,808	-277.46	11.6%
Advanced engine	13.1%	32.5%	25.9%	20%	20.0%	10,953	10,953	13.1%	26,578	-243	30,736	-278.22	19.8%
Route management	0.3%	32.8%	26.1%	20%	20.2%	485	485	0.3%	492	-173	470	-185.66	20.0%
Full skirts	1.7%	34.5%	27.2%	30%	21.0%	2,425	2,425	1.7%	2,386	-170	2,985	-208.21	20.8%
Material substitution	1.4%	35.9%	28.1%	0	22.0%	2,401	2,401	0.8%	1,727	-143	-14	2.25	21.3%
Gen II dual hybrid	6.4%	42.4%	32.1%	0	26.3%	22,228	22,228	6.4%	-3,877	72	-1,861	34.47	25.7%

Construction

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Low resistance tires	10.5%	10.5%	10.5%	0	10.5%	1,152	1,152	6.7%	16,097	-229	15,906	-351.87	6.7%
Transmission friction red	1.1%	11.6%	10.3%	40%	10.0%	202	202	1.1%	1,636	-219	2,599	-350.14	6.6%
Advanced engine	9.5%	21.1%	17.9%	30%	15.3%	3,920	3,920	9.5%	11,615	-184	20,267	-316.20	12.1%
Parallel hybrid electric	23.7%	44.8%	35.0%	0.3	27.7%	15,358	15,358	23.7%	23,538	-149	44,982	-281.31	25.0%
Material substitution	0.2%	44.9%	35.1%	0	27.8%	364	364	0.2%	-92	83	145	-107.60	25.2%
Automatic tire inflation	0.3%	45.2%	35.3%	0	28.0%	3,638	3,638	0.3%	-3,095	1,400	-2,874	1,420.01	25.4%

Bus

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Reduced parasitics/friction	1.0%	1.0%	1.0%	0	1.0%	202	202	1.0%	1,677	-253	2,318	-347.1	1.0%
Advanced engine	10.6%	11.6%	10.3%	40%	6.6%	3,920	3,920	10.6%	15,978	-228	16,792	-321.93	6.6%
Low resistance tires	1.3%	12.9%	11.4%	30%	7.3%	567	567	1.3%	1,924	-219	2,209	-312.05	7.3%
Series hybrid electric	30.5%	43.4%	35.4%	30%	25.0%	17,783	17,783	30.5%	39,470	-196	59,071	-290.05	25.0%
Material substitution	3.5%	46.9%	37.3%	0	27.3%	12,367	12,367	3.5%	-5,722	244	-3,547	151.75	27.3%

Coach

Measure	CO2 potential			Realised penetration		Revised cost & CO2 potential			NPV & abatements costs				Final
	Individual CO2 potential (IA)	Cumulative CO2 potential (IA)	Cumulative (revised)	Penetration rate 2014	Cumulative CO2 potential remaining	Cost (IA) €	Cost (new) €	CO2 potential (new)	NPV (IA) €	Abatement cost (IA) €/tCO2	NPV (revised) €	Abatement cost (revised) €/tCO2	Cumulative CO2 potential remaining
Predictive cruise control	1.5%	1.5%	1.5%	0	1.5%	81	81	1.5%	1,973	-290	2,512	-365.57	1.5%
Transmission friction red	1.2%	2.7%	2.4%	40%	2.0%	202	202	1.2%	1,484	-266	1,872	-340.61	2.0%
Low resistance tires	1.5%	4.2%	3.7%	30%	2.9%	402	402	1.5%	1,596	-241	1,929	-318.85	2.9%
Streamlining	6.2%	10.4%	9.1%	30%	6.7%	2,223	2,223	6.2%	6,306	-223	8,499	-299.08	6.7%
Advanced engine	14.6%	25.0%	20.9%	0	18.9%	10,953	10,953	14.6%	8,983	-136	14,283	-213.58	18.9%
Automatic tire inflation	0.3%	25.3%	21.1%	0	19.1%	283	283	0.3%	128	-94	236	-141.14	19.1%
Gen II parallel hybrid	8.2%	33.5%	26.7%	30%	23.1%	28,291	28,291	8.2%	-17,034	456	-14,117	375.87	23.1%
Material substitution	0.7%	34.2%	27.2%	20%	23.5%	4,850	4,850	0.7%	-3,848	1,159	-3,640	1,135.27	23.5%

Annex V: Scatter plots for methodology accounting for technology overlap

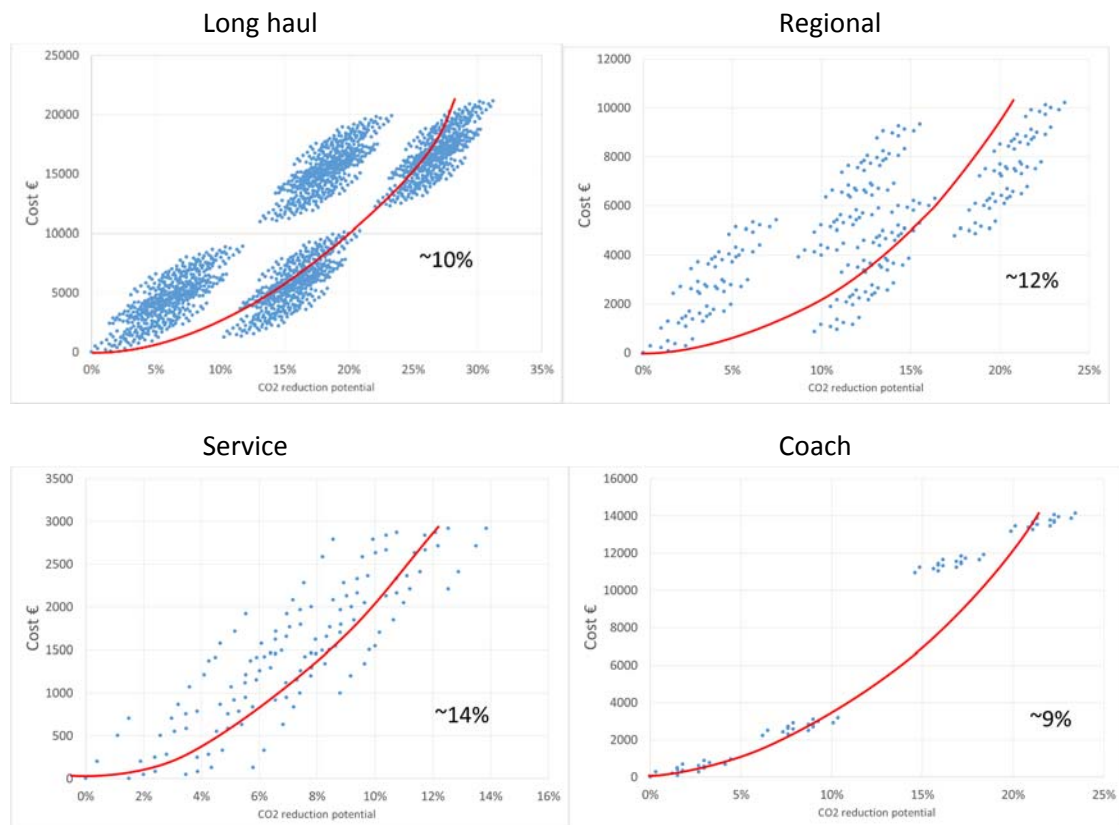
Scatter plots have been created for each vehicle type showing all combinations of CO2 reduction potential and cost of measures. Due to the inhomogeneity of the scatter plots, no mathematical function could be found to create a trend line through the points to reflect the TNO 2006 methodology. Instead, a trend line has been inserted using a visual estimate to create a rough value for each technology.

Only those measures determined as cost effective by the Impact Assessment have been included in the scatter plots. To reflect the analysis in this report (section 3.2.1), an additional plot has been created excluding the hybrid technology in cases where the Impact Assessment found this technology to be cost-effective.

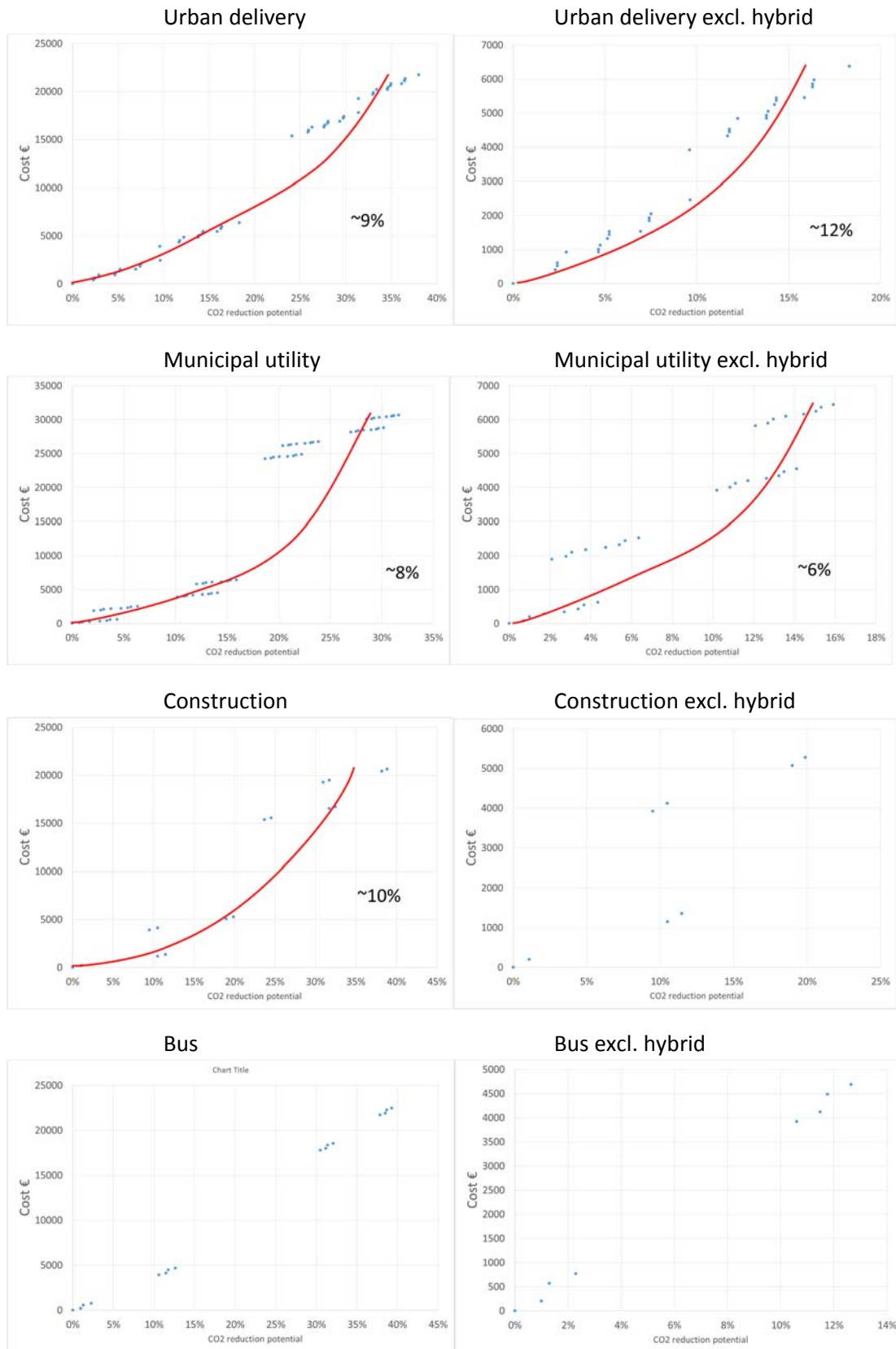
Where sufficient points are available, a visual estimate of the trend line has been made, along with an estimate of the discount also shown. The estimated discount ranges from 6% to 14%, with a weighted average of approximately 10%.

Lacking a more robust methodology, the 10% discount factor is therefore selected for all vehicle types.

Vehicle types for which Impact Assessment evaluated hybrid as non-cost-effective



Vehicle types for which Impact Assessment evaluated hybrid as cost-effective



Annex VI: Log of communications with potentially interested parties

The following communication took place with a potentially interested party, in which the content of this study was explicitly discussed:

2nd July 2015 20 minute phone call with Stefan Larsson, independent consultant and former employee of ACEA regarding cost estimates, providing additional insight on some of the measures. This conversation did not result in any changes to the content of the study.