# Impact Assessment Institute

The Institute for Impact Assessment and Scientific Evaluation of Policy and Legislation

"Impartial Analysis for Policy Making"

## Final report on the
## Impact Assessment accompanying the
## Strategy for Reducing Heavy-Duty Vehicles Fuel Consumption and $CO_2$ Emissions – SWD (2014) 160 final

18th January 2016

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**Accompanying statement**

This report has been written according to the guiding principles of the Impact Assessment Institute (IAI): objectivity, transparency, 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 essential step laid down in the procedures of the Impact Assessment Institute and this is manifested in the openness to further review and to new data. Even at publication of the final version, the report explicitly requests additional data where the readily available data was not sufficient to complete all intended analysis.

# Executive Summary

**Main findings**

The IAI scrutinised the Impact Assessment accompanying the European Commission Strategy for Reducing Heavy-Duty Vehicle Fuel Consumption and $CO_2$ Emissions, and assessed the quality of the presented assumptions, data, analysis and conclusions.

The Impact Assessment concludes that the average cost-effective $CO_2$ reduction potential per vehicle is 35.1%. However, this IAI report identifies verifiable evidence for only a 20% cost-effective reduction potential, due to the following main factors:

- A 7.4% reduction in the overall potential when applying well-documented methodologies for combining individual technology effects
- A further 7.7% reduction in the potential due to revised estimates for the cost-effective potential of individual technologies, especially hybrid technology

The resulting 20% $CO_2$ reduction potential is only 5% above the expected “natural” $CO_2$ reduction between 2015 and 2030 quoted in the Impact Assessment. The adjusted numerical evidence therefore calls into question the conclusion of the Impact Assessment regarding the effectiveness of proposed future policy options.

The Impact Assessment expresses the expectation that $CO_2$ reduction measures will be significantly less expensive in practice than its own projections, citing studies in related policy areas. To establish a comprehensive assessment of the viable $CO_2$ reduction potential, an in-depth analysis is required to provide prima facie evidence for whether and to what extent such effect exists for the case of heavy duty vehicles.

In conclusion, in future policy work in this area, the significant revisions and the need for additional analysis identified in this IAI study should to be taken into account.

This report has scrutinised in-depth the content of the Impact Assessment accompanying the Strategy for Reducing Heavy-Duty Vehicle Fuel Consumption and $CO_2$ Emissions, 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 likelihood of a significant change in the state of the art should be considered. The time (2009-2014) represents at least half a development life cycle for heavy duty vehicles, during which technologies have been further matured and additional knowledge has been gained on the viability of advanced $CO_2$ reduction measures.

Presentational aspects somewhat undermine the positive impression of the Impact Assessment. 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. Examples are provided in Annex I.

This observation in itself 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 content is the detailed analysis of impacts in terms of the costs and benefits of measures for reducing the $CO_2$ emissions of heavy duty vehicles. The key parameter resulting from the calculations is the cost effective potential for $CO_2$ reduction, since this indicates the feasible level of ambition of future policies including regulation.

The Impact Assessment quotes a value of 35.1% for the weighted average cost effective $CO_2$ reduction potential across all vehicle types. The following table provides an overview of all the effects identified in the IAI analysis, which act to modify this figure (**+ve** means greater $CO_2$ reduction potential or lower abatement cost, **-ve** means lower $CO_2$ reduction potential or higher abatement cost, compared to the Impact Assessment).

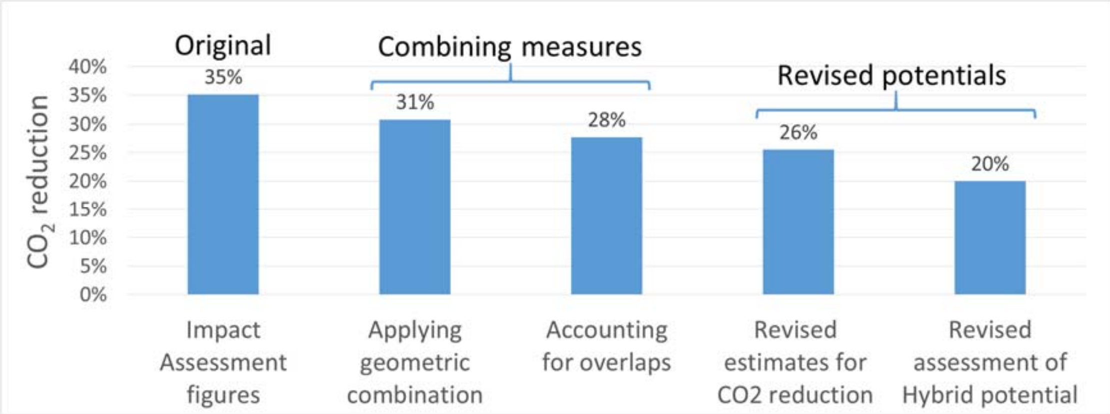
| **Revised element (* indicates inclusion in chart below)** | **Section** | **Numerically assessed** | **Direction of change** |
|---|---|---|---|
| *Using geometric combination methodology from CE Delft 2012 report | 3.1.1 | yes | -ve |
| *Accounting for overlap of technologies reflecting TNO 2006 methodology | 3.1.1 | yes | -ve |
| *Revision of cost and $CO_2$ 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 |
| Accounting for already realised technologies | 3.1.2 | no | -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, economies of scale, new tech. | 3.2.7 | no | +ve |

The main quantifiable effects on the GHG reduction potential are the following:

- Use of the mathematically correct geometric combination of potentials (-4.3%)
- Accounting for overlap of the effect of technologies (-3.1%)
- A revision of the $CO_2$ reduction potential of certain technologies (-2.2%)
- Considering the potential without hybrid technology, due to the use of a 90% subsidised cost figure for one vehicle application casting uncertainty on all figures (-5.5%)

Furthermore, the Impact Assessment expressed the expectation of a significant fall in the costs of $CO_2$ reduction measures compared to those projected. This is substantiated by referring to the experience of passenger car $CO_2$ emissions. However, since the characteristics and operating conditions of heavy duty vehicles and passenger cars differ greatly, further investigation is necessary to determine whether and the extent to which this phenomenon would similarly apply to the analysis of heavy duty vehicles.

The chart below shows the recalculated cost effective weighted average $CO_2$ reduction potential, introducing cumulatively the effects and scenarios investigated by the IAI resulting in a quantifiable difference:




Additional scenarios applying using a 7% discount rate, considering only technical measures, using a €30/t cut off and using alternative figures for vehicle lifetimes resulted in small or zero changes in the weighted average cost effective $CO_2$ reduction potential.

An additional review has been performed using data on cost and $CO_2$ reduction potential, obtained from subsequent expert reports. This is presented separately in this report since it is not a primary method 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 are expected to provide a more up-to-date basis for future policy analysis.

In conclusion, in ongoing work to assess the potential measures and future actions in the policy area for heavy duty vehicles, the significant effects identified in this report related to background data, methodologies and calculations need to be taken into account. In addition, it is necessary to investigate in–depth the quoted phenomenon of a significant fall in the costs of $CO_2$ reduction measures over time, in order to generate prima facie evidence to complement this revised analysis.

## 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, in particular stakeholders that hold a direct interest in heavy duty vehicle policy. This IAI study thus serves a dual purpose. It scrutinises the Commission IA and it is a platform for further discussion. As such, it reaches out for additional data as part of its continuous peer review process.

The following is a presentation of additional data which would complement the analysis:

- The penetration rates of each identified measure in each vehicle type in 2014.
- The precise calculation method for the trend line to determine the extent of overlap of $CO_2$ reduction potentials as applied in the 2006 report by TNO et. al. underlying the European Commission Impact Assessment for $CO_2$ 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.

Stakeholders are kindly requested to provide fully evidenced data on the above points, in addition to their comments on the content of this report. Any new data received can be in a future revision of this 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 the principle of 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 $CO_2$ 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 $CO_2$ 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 |

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## Table of Contents

# 1 Report on the content of the Impact Assessment

The Impact Assessment is 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 in 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 Impact Assessments and other policy analysis documents 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 $CO_2$ 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

This section 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 would be appropriate.

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 $CO_2$ 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 $CO_2$ 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 (€/tCO2) | 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*

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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 $CO_2$ reduction effect of individual technologies (report p12):

Combined reduction potential (%) = 100 x (1-(1-RC1)/100) x (1-RC2/100) x … x (1-RCi)/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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ reduction) and 1/3 to the right, see example below.

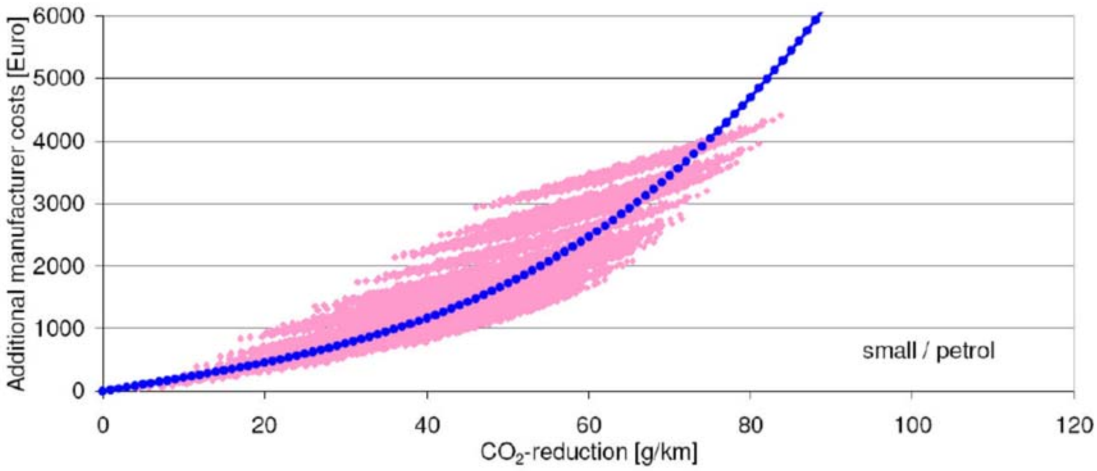
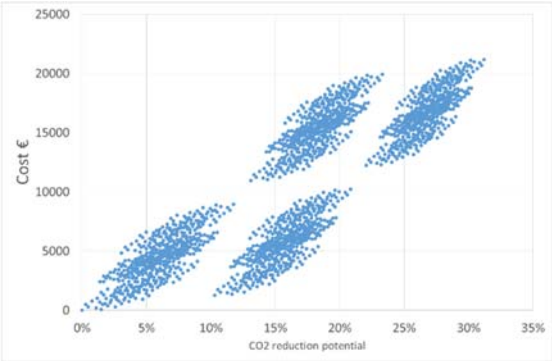



*Figure 1: Chart from TNO 2006 report showing technology combination calculation methodology*

Analysing the cost curves in the 2006 report, the “discount” created on the $CO_2$ reduction potential using the above method varied between 7% and 15% depending on vehicle size and fuel type.

A similar analysis has been attempted using the $CO_2$ reduction and cost figures in the HDV $CO_2$ 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 $CO_2$ 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 $CO_2$ 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

| Measure | $CO_2$ 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 $CO_2$ reduction potential using different calculation methodologies and $CO_2$ potential figures*

The overall effect of application of the combination methodologies as applied by CE DELFT is to reduce the cost-effective $CO_2$ 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 of this study. 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 | $CO_2$ 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 $CO_2$ 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 $CO_2$ 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.

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### *Revised $CO_2$ reduction potentials*

The following table shows where revised figures for the $CO_2$ 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 | $CO_2$ 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 $CO_2$ reduction potentials of technologies for long haul vehicles*

### *Costs of $CO_2$ 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 $CO_2$ reduction potential, due to some widely differing figures in the background studies. An extreme example is the cost ($CO_2$ potential) estimate for predictive cruise control between TIAX and AEA (2011) of €77 (1-2%) and €1400 (5%) respectively. Additionally, such cost figures are sensitive for manufacturers and thereby not freely communicated.

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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ reduction potential. A document request was filed in June 2015 to access the original calculations made using the MACH model, with no response received as of 7th January 2016.

Finally, the effect of the revised figures for $CO_2$ 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 $CO_2$ reduction potential of each measure

| Measure | $CO_2$ potential (IA) | $CO_2$ potential (new estimates) | d) (from above) Accounting for already realised technologies | e) With changes in estimated $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ potential clearly shown in Table 9 and Figure 2 (Section 3.3 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:

- €8 per tonne $CO_2$: the current (January 2016) market price of carbon credits
- €30 per tonne $CO_2$: 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 $CO_2$ above the €30/t level. However, with revised cost and $CO_2$ 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% results in an increase in abatement costs between €92/t$CO_2$ (long haul vehicles) and €172/t$CO_2$ (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 $CO_2$ 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 |

*Table 8: Vehicle lifetimes*

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 results in any change to the cost effective $CO_2$ 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 $CO_2$ 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 $CO_2$ 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, economies of scale and potential overestimation of costs

An expectation is expressed in the Impact Assessment (paragraph 147) of a sharp fall over time 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 $CO_2$ emissions from passenger cars, which concludes that such a fall did indeed occur in that vehicle sector.

In order to determine whether this phenomenon would also apply to the case of heavy duty vehicle $CO_2$ emissions, three main questions are to be addressed. Firstly, the applicability of the phenomenon to heavy duty vehicles requires validation, due to their significant physical and commercial differences to passenger cars. Secondly, it needs to be determined whether this historical phenomenon is a predictor for its reoccurrence in future. Finally, the specific details of the underestimates in $CO_2$ reduction potential require in-depth investigation, to determine whether the same mechanism can be systematically assumed for future predictions.

These questions are as yet unanswered and there is therefore no prima facie evidence for the expected fall in costs of $CO_2$ reduction measures. However, the possibility of costs of $CO_2$ reduction technologies falling over time appears to be a viable consideration needs to be analysed and further investigated.

### 3.2.8 Regional delivery vehicles

The $CO_2$ measures for regional delivery vehicles includes in first position “fuel efficiency improvements” with a $CO_2$ 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.

## 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 $CO_2$ 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 $CO_2$ 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 9: Overview of cost effective $CO_2$ 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):

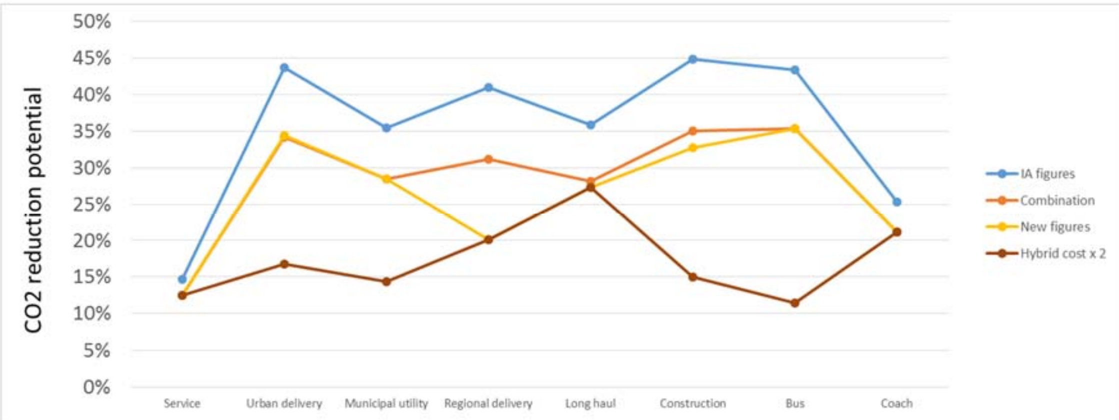


*Figure 2: Chart of cost effective $CO_2$ reductions for all vehicle types under different assumptions*

## 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 $CO_2$ 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 further reduction in the future potential $CO_2$ 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 stakeholders interested in the heavy duty vehicle policy area 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 $CO_2$ 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 $CO_2$ 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 10: 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 11: 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ reduction potential*

### Potential for tyres

The $CO_2$ 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 12: Energy losses through rolling resistance from TIAX/NAS 2009 report*

It is unclear how the $CO_2$ 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 $CO_2$ 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 form 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% x 38% = 0.75% fuel consumption and $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ reduction potential. For those vehicle types, specifically urban delivery, municipal utility, construction and bus, the $CO_2$ 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 $CO_2$ reduction potential for those vehicles significantly, shown in Annex IV and summarised in Table 9 above.

## *Annex III: Amended figures for $CO_2$ reduction potential and cost of measures*

| Measure | $CO_2$ 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; light blue = IAI revised; dark blue = individual revised figure

Service

| | CO2 potential | | | Revised cost & CO2 potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual CO2 potential (IA)** | **Cumulative CO2 potential (IA)** | **Cumulative (revised)** | **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% | 10 | 10 | 1.5% | 699 | -317 | 830 | -372.87 | 1.5% |
| Improved controls | **2.0%** | 3.5% | 3.1% | 48 | 48 | **2.0%** | 882 | -305 | 1,072 | -361.19 | 3.1% |
| Drag reduction | 2.4% | 5.9% | 5.2% | 81 | 81 | 2.4% | 1,059 | -298 | 1,263 | -354.62 | 5.2% |
| 8-speed gear | 3.2% | 9.1% | 7.9% | 869 | 869 | 3.2% | 643 | -137 | 923 | -194.36 | 7.9% |
| Improved diesel engine | 4.1% | 13.2% | 11.3% | 1,213 | 1,213 | 4.1% | 721 | -120 | 1,083 | -178.00 | 11.3% |
| Transmission friction red | 0.4% | 13.6% | 11.6% | 202 | 202 | 0.4% | 5 | -8 | 22 | -37.06 | 11.6% |
| Material substitution | 1.1% | 14.7% | 12.5% | 505 | 505 | 1.1% | 5 | -3 | 111 | -68.00 | 12.5% |
| Dual-mode hybrid electric | 21.3% | 36.0% | 29.0% | 23,441 | 23,441 | 21.3% | -13,364 | 426 | -11,513 | 364.23 | 29.0% |

Urban delivery

| | CO2 potential | | | Revised cost & CO2 potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual CO2 potential (IA)** | **Cumulative CO2 potential (IA)** | **Cumulative (revised)** | **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% | 404 | 404 | 2.3% | 1,913 | -203 | 3,267 | -335.83 | 2.3% |
| Roof deflector | 2.4% | 4.7% | 4.2% | 526 | 526 | 2.4% | 1,991 | -194 | 3,304 | -325.54 | 4.2% |
| Box skirts | 2.4% | 7.1% | 6.2% | 606 | 606 | 2.4% | 1,848 | -185 | 3,224 | -317.66 | 6.2% |
| Low resistance tires | 2.9% | 10.0% | 8.7% | 922 | 922 | 2.9% | 2,092 | -171 | 3,706 | -302.19 | 8.7% |
| Advanced engine | 9.6% | 19.6% | 16.5% | 3,920 | 3,920 | 9.6% | 5,996 | -149 | 11,402 | -280.81 | 16.5% |
| Parallel hybrid electric | 24.1% | 43.7% | 34.2% | 15,358 | 15,358 | 24.1% | 9,470 | -94 | 23,106 | -226.68 | 34.2% |
| Cab side extension | 0.4% | 44.2% | 34.4% | 465 | 465 | 0.4% | -30 | 17 | 173 | -102.50 | 34.4% |
| Material substitution | 2.2% | 46.4% | 35.6% | 3,855 | 3,855 | 2.2% | -1,555 | 166 | -344 | 36.95 | 35.6% |

unchanged

Municipal utility

| | CO2 potential | | | Revised cost & CO2 potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual CO2 potential (IA)** | **Cumulative CO2 potential (IA)** | **Cumulative (revised)** | **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% | 81 | 81 | 0.7% | 1,120 | -242 | 1,561 | -358.75 | 0.7% |
| Low resistance tires | 2.7% | 3.4% | 3.0% | 344 | 344 | 2.7% | 3,947 | -239 | 5,990 | -356.86 | 3.0% |
| Reduced parasitics/friction | 1.0% | 4.4% | 3.9% | 202 | [illegible] | 1.0% | 1,345 | -226 | [illegible] | -344.87 | 3.9% |
| Advanced engine | 10.2% | 14.6% | 12.7% | 3,920 | [illegible] | 10.2% | 12,462 | -198 | 20,009 | -315.54 | 12.7% |
| 8-speed gear | 2.1% | 16.8% | 14.3% | 1,899 | 1,899 | 2.1% | 1,519 | -115 | 3,028 | [illegible]231.90 | 14.3% |
| Parallel hydraulic hybrid | 18.7% | 35.5% | 28.5% | 24,249 | 24,249 | [illegible]8.7% | 5,745 | -50 | 19,621 | [illegible]8.78 | 28.5% |
| Material substitution | 0.6% | 36.1% | 28.8% | 2,425 | 2,425 | 0.6% | -1,444 | 382 | -1,017 | 272.75 | 28.8% |

unchanged unchanged

Regional delivery

| | CO2 potential | | | Revised cost & CO2 potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual CO2 potential (IA)** | **Cumulative CO2 potential (IA)** | **Cumulative (revised)** | **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% | - | - | **0.0%** | 9,959 | -301.64 | **n/a** | **n/a** | 0.0% |
| Predictive cruise control | 1.4% | 8.3% | 7.4% | 81 | 81 | 1.4% | 1,935 | -289.52 | 2,469 | -365.37 | 1.3% |
| Low resistance tires | **9.6%** | 17.9% | 15.3% | 873 | 873 | **6.7%** | 13,024 | -282.68 | **11,295** | **-350.29** | 7.2% |
| Transmission friction red | 1.0% | 19.0% | 16.1% | 202 | 202 | 1.0% | 1,279 | -260.50 | 1,620 | -335.51 | 8.0% |
| Advanced engine | 8.7% | 27.6% | 22.5% | 3,920 | 3,920 | 8.7% | 8,596 | -207.16 | 11,928 | -284.02 | 15.1% |
| Automatic tire inflation trailer | 0.4% | 28.1% | 22.8% | 283 | 283 | 0.4% | 344 | -165.49 | 446 | -230.79 | 15.4% |
| Boat tail | 2.2% | 30.2% | 24.2% | 1,414 | 1,414 | 2.2% | 1,701 | -164.67 | 2,594 | -244.21 | 17.1% |
| Full gap fairing | 1.0% | 31.3% | 24.9% | 1,011 | 1,011 | 1.0% | 500 | -99.86 | 811 | -167.92 | 17.8% |
| Full skirts | 1.7% | 33.0% | 26.0% | 2,425 | 2,425 | 1.7% | 55 | -6.70 | 672 | -81.85 | 19.0% |
| Material substitution | 1.5% | 34.5% | 27.0% | 2,401 | 2,401 | 1.5% | -273 | 38.68 | 331 | -45.77 | 20.1% |
| Gen II dual hybrid | 6.6% | 41.0% | 31.1% | 18,794 | 18,794 | 6.6% | -9,334 | 297.62 | -6,771 | 212.54 | 24.7% |
| Automatic tire inflation tractor | 0.4% | 41.4% | 31.4% | 3,638 | 3,638 | 0.4% | -3,127 | 1,846.28 | -2,909 | 1,506.74 | 25.0% |

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Long-haul

| | $CO_2$ potential | | | Revised cost & $CO_2$ potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual $CO_2$ potential (IA)** | **Cumulative $CO_2$ potential (IA)** | **Cumulative (revised)** | **Cost (IA) €** | **Cost (new) €** | **$CO_2$ potential (new)** | **NPV (IA) €** | **Abatement cost (IA) €/t$CO_2$** | **NPV (revised) €** | **Abatement cost (revised) €/t$CO_2$** | **Cumulative $CO_2$ potential remaining** |
| Predictive cruise control | 1.5% | 1.5% | 1.5% | 81 | 81 | 1.5% | 4,217 | -336 | 4,693 | -370.96 | 1.5% |
| Low resistance tires | **10.3%** | 11.8% | 10.5% | 1,261 | 1,261 | **6.7%** | 28,371 | -328 | **19,997** | **-354.97** | 7.3% |
| Transmission friction red. | 1.1% | 12.9% | 11.4% | 202 | 202 | 1.1% | 2,955 | -321 | 3,299 | -355.58 | 8.2% |
| Training and feedback | **2.2%** | 15.1% | 13.1% | 647 | 647 | **5.0%** | 5,589 | -307 | **15,265** | **-362.01** | 12.3% |
| Automatic tire inflation trailer | 0.5% | 15.6% | 13.5% | 283 | 283 | 0.5% | 1,176 | -276 | 1,308 | -310.24 | 12.7% |
| Boat tail | 2.5% | 18.2% | 15.4% | 1,414 | 1,414 | 2.5% | 5,837 | -276 | 6,542 | -310.29 | 14.6% |
| Full gap fairing | 1.2% | 19.4% | 16.3% | 1,011 | 1,011 | 1.2% | 2,507 | -244 | 2,808 | -277.46 | 15.5% |
| Advanced engine | 13.1% | 32.5% | 25.9% | 10,953 | 10,953 | 13.1% | 26,578 | -243 | 30,736 | -278.22 | 25.3% |
| Route management | 0.3% | 32.8% | 26.1% | 485 | 485 | 0.3% | 492 | -173 | 470 | -185.66 | 25.5% |
| Full skirts | 1.7% | 34.5% | 27.2% | 2,425 | 2,425 | 1.7% | 2,386 | -170 | 2,985 | -208.21 | 26.6% |
| Material substitution | 1.4% | 35.9% | 28.1% | 2,401 | 2,401 | 1.4% | 1,727 | -143 | 2,054 | -174.00 | 27.4% |
| Gen II dual hybrid | 6.4% | 42.4% | 32.1% | 22,228 | 22,228 | 6.4% | -3,877 | 72 | -1,861 | 34.47 | 31.4% |

Construction

| | $CO_2$ potential | | | Revised cost & $CO_2$ potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual $CO_2$ potential (IA)** | **Cumulative $CO_2$ potential (IA)** | **Cumulative (revised)** | **Cost (IA) €** | **Cost (new) €** | **$CO_2$ potential (new)** | **NPV (IA) €** | **Abatement cost (IA) €/t$CO_2$** | **NPV (revised) €** | **Abatement cost (revised) €/t$CO_2$** | **Cumulative $CO_2$ potential remaining** |
| Low resistance tires | **10.5%** | 10.5% | 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% | 202 | 202 | 1.1% | 1,636 | -219 | 2,599 | -350.14 | 7.0% |
| Advanced engine | 9.5% | 21.1% | 17.9% | 3,920 | 3,920 | 9.5% | 11,615 | -184 | 20,267 | -316.20 | 14.8% |
| Parallel hybrid electric | 23.7% | 44.8% | 35.0% | 15,358 | 15,358 | 23.7% | 23,538 | -149 | 44,982 | -281.31 | 32.7% |
| Material substitution | 0.2% | 44.9% | 35.1% | 364 | 364 | 0.2% | -92 | 83 | 145 | -107.60 | 32.8% |
| Automatic tire inflation | 0.3% | 45.2% | 35.3% | 3,638 | 3,638 | 0.3% | -3,095 | 1,400 | -2,874 | 1,420.01 | 32.9% |

Bus

| | CO2 potential | | | Revised cost & CO2 potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual CO2 potential (IA)** | **Cumulative CO2 potential (IA)** | **Cumulative (revised)** | **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% | 202 | 202 | 1.0% | 1,677 | -253 | 2,318 | -347.11 | 1.0% |
| Advanced engine | 10.6% | 11.6% | 10.3% | 3,920 | [illegible] | 10.6% | 15,978 | -228 | [illegible] | -321.98 | 10.3% |
| Low resistance tires | 1.3% | 12.9% | 11.4% | 567 | [illegible] | 1.3% | 1,924 | -219 | [illegible] | -312.05 | 11.4% |
| Series hybrid electric | 30.5% | 43.4% | 35.4% | 17,783 | 17,783 | 30.5% | 39,470 | -196 | 59,077 | -290.05 | 35.4% |
| Material substitution | 3.5% | 46.9% | 37.3% | 12,367 | 12,367 | [illegible] | -5,722 | 244 | -3,547 | [illegible] | 37.3% |

Coach

| | CO2 potential | | | Revised cost & CO2 potential | | | NPV & abatements costs | | | | Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Individual CO2 potential (IA)** | **Cumulative CO2 potential (IA)** | **Cumulative (revised)** | **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% | 81 | 81 | 1.5% | 1,973 | -290 | 2,512 | -365.57 | 1.5% |
| Transmission friction red | 1.2% | 2.7% | 2.4% | 202 | 202 | 1.2% | 1,484 | -266 | 1,872 | -340.61 | 2.4% |
| Low resistance tires | 1.5% | 4.2% | 3.7% | 402 | [illegible] | 1.5% | 1,596 | -241 | [illegible] | -318.85 | 3.7% |
| Streamlining | 6.2% | 10.4% | 9.1% | 2,223 | [illegible] | 6.2% | 6,306 | -223 | [illegible] | -299.08 | 9.1% |
| Advanced engine | 14.6% | 25.0% | 20.9% | 10,953 | 10,953 | 14.6% | 8,983 | -136 | 14,283 | -213.58 | 20.9% |
| Automatic tire inflation | 0.3% | 25.3% | 21.1% | 283 | 283 | [illegible] | 128 | -94 | 236 | [illegible] | 21.1% |
| Gen II parallel hybrid | 8.2% | 33.5% | 26.7% | 28,291 | 28,291 | 8.2% | -17,034 | 456 | -14,117 | 375.87 | 26.7% |
| Material substitution | 0.7% | 34.2% | 27.2% | 4,850 | 4,850 | 0.7% | -3,848 | 1,159 | -3,640 | 1,135.27 | 27.2% |

## *Annex V: Scatter plots for methodology accounting for technology overlap*

Scatter plots have been created for each vehicle type showing all combinations of $CO_2$ 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.

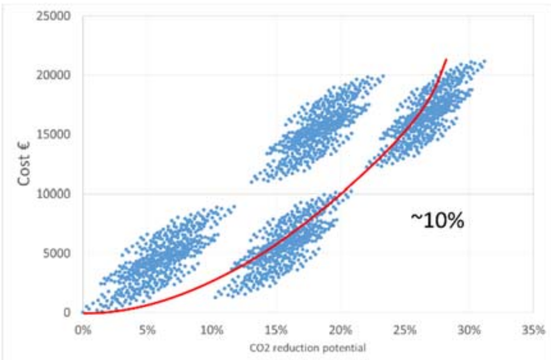
Only those measures determined as cost effective by the Impact Assessment have been included in the scatter plots. To reflect the analysis in this report (section 3.2.1), an additional plot has been created excluding the hybrid technology in cases where the Impact Assessment found this technology to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

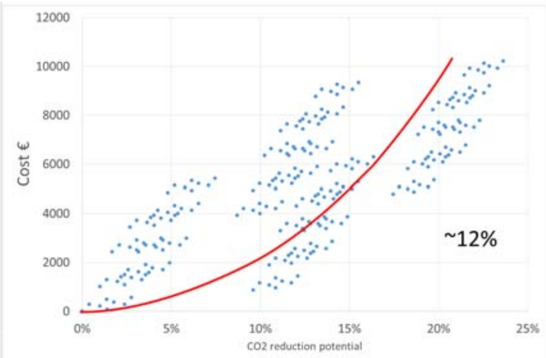
Lacking a more robust methodology, the 10% discount factor is therefore selected for all vehicle types.

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

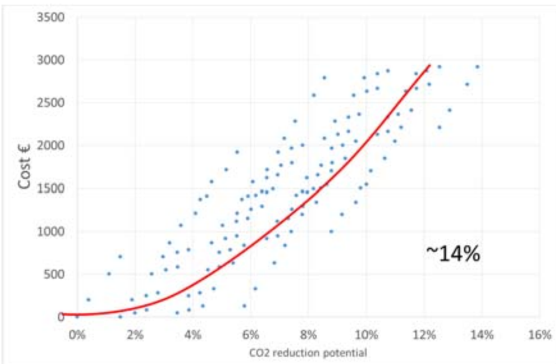
Long haul



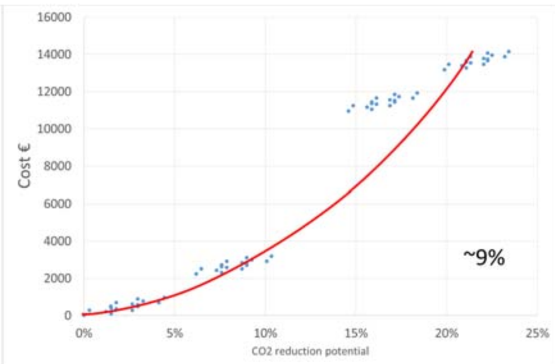

Regional




Service

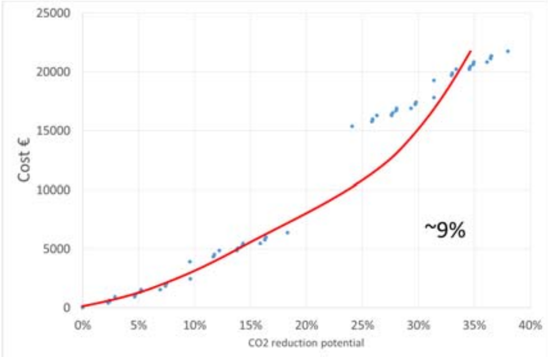



Coach

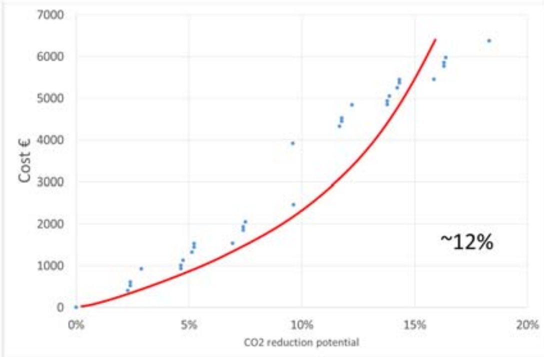


## Vehicle types for which Impact Assessment evaluated hybrid as cost-effective

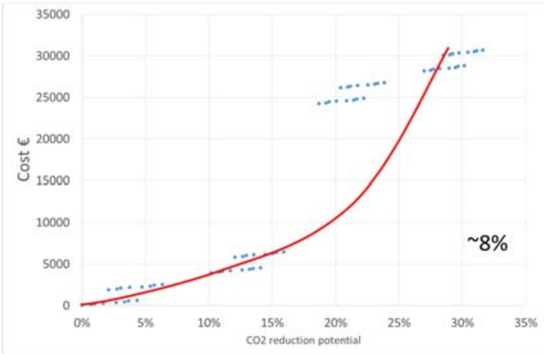
Urban delivery



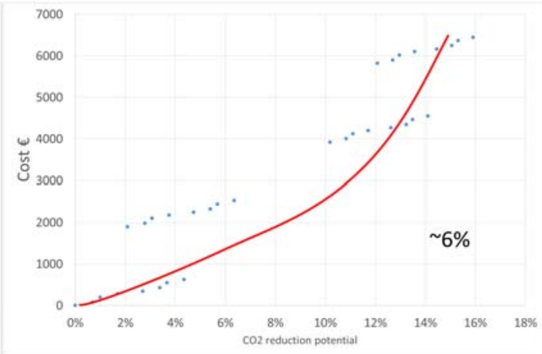

Urban delivery excl. hybrid



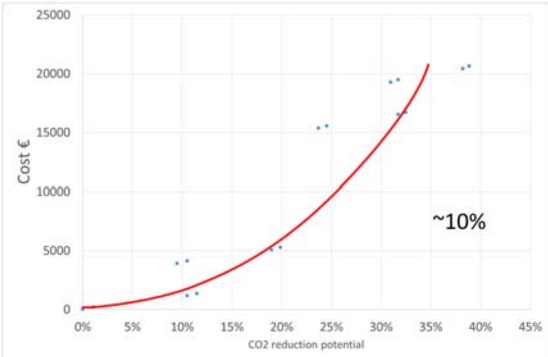

Municipal utility



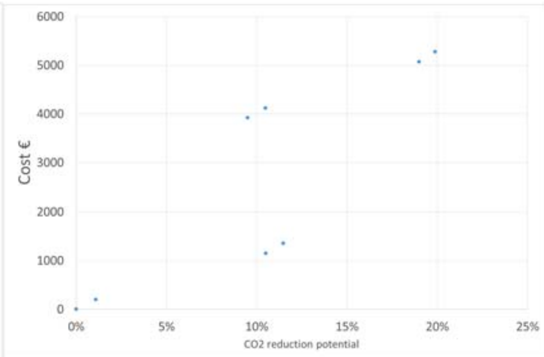

Municipal utility excl. hybrid



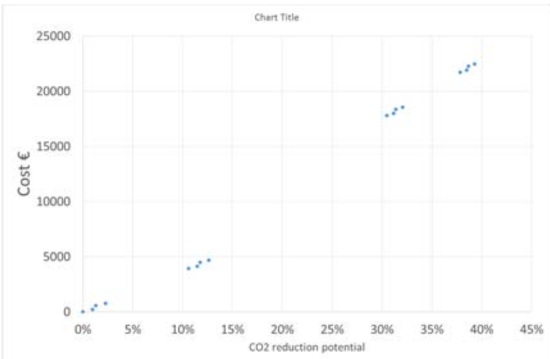

Construction



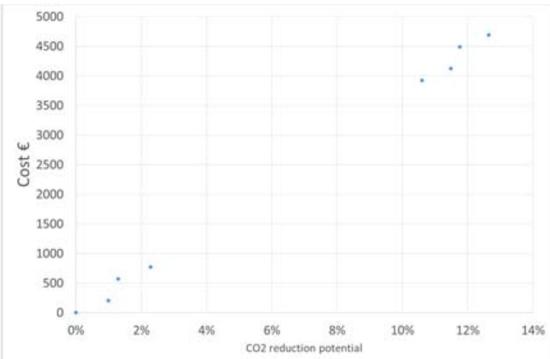

Construction excl. hybrid




Bus




Bus excl. hybrid



## *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. |

*Annex VII: Responses to comments received from stakeholders on draft report*

All comments received from stakeholders to the draft report provided on 8th July 2015 have been recorded, investigated and themselves commented by the IAI below, with action taken where new evidence or analysis has thus been highlighted.

The report and its content was acknowledged by ACEA, the European Association of Automobile Manufacturers, with no specific comments made.

No response to the content of the report has been received as of 7th January 2016 from the main NGO working in the transport domain.

| Organisation: European Commission DG CLIMA Unit C1<br>Date: 8th September 2015 | | |
|---|---|---|
| **Comment** | **Changes made to report** | **Response of Impact Assessment Institute** |
| 1. Time elapsed leads to some of the data being out of date<br><br>This is true. The Commission was not able to revisit in early 2014 the underlying analysis and studies that were carried out in 2010-2012. However, it is not believed that the absence of an update has led to any material change in the conclusions of the Impact Assessment. The assessment carried out in particular looked at long term trends and the abatement potential for HDVs for the horizon 2030. There were, in 2014, no grounds for reconsidering the main conclusions reached by the underlying studies for such long term horizons. Conversely, a major recent development in 2015 is the drop in oil prices: this would now suggest revised long term scenarios and hence cost curves that are less favourable to the uptake of a number of new technologies. | No | Agreed. The comment in the draft report was an acknowledgement of the time necessary to make such analysis and the need for timely updates. |
| 2. The "problem definition" allegedly presaged expected results<br><br>This assertion is not clearly supported in the IAI report text. | No | The explanation for this assertion is given in Section 2, with the detailed listing of each individual case recorded in Annex 1. In the Annex 1 section referring to Chapter 2, a number of instances are highlighted in which conclusions have been stated apparently in advance of the description of the analysis. |



Impact Assessment Institute

| | | |
|---|---|---|
| 3. Recalculation of the $CO_2$ reduction potential of HDV emissions leading to a lower potential<br><br>The focus of the IAI report is on the cost-benefit analysis of $CO_2$ reduction measures. The recalculation produced in the IAI report includes a number of suggestions, e.g. taking into consideration a different lifetime/amortisation period of vehicles, different hybrid vehicle costs, a different discount rate (7% instead of the usual 4% rate used in Commission Impact Assessments), and possible different break-even assumptions.<br><br>Main issues are: | | See below |
| (i) ex-ante abatement costs are usually underestimated and turn out, over time, to be lower than initially estimated.<br><br>A critical assessment of what happened in the case of ex-ante assessment of emissions abatement costs for cars led to the conclusion that costs turned out to be lower than initially foreseen for a number of reasons (see notably "Support for the revision of Regulation (EC) No 443/2009 on $CO_2$ emissions from cars"<br><br>http://ec.europa.eu/clima/policies/transport/vehicles/cars/docs/study_car_2011_en.pdf);<br><br>A fair review of abatement costs and cost curves produced in the Commission Impact Assessment on HDVs on the basis of abatement costs should have:<br>- taken this into consideration and noted that instead of "downside risks" of under-estimation of the costs (see in particular below point (v) on hybrids), the main risks to this assessment were actually rather "upside risks" of over-estimation of the costs,<br>- and possibly built alternative projections on this basis. This is however not the approach taken in the IAI report which ignores such risks of over-estimated costs. | Yes | Indeed potential overestimation of costs is a material factor to be considered in assessing the potential for policy making in this area, as acknowledged in Section **Error! Reference source not found.**. In fact an analysis of the evidence for this phenomenon this could be an interesting subject for a future Impact Assessment Institute study.<br><br>The IAI report assesses the evidence presented and incorporates alternative evidence sources where available. It would not be appropriate for the IAI to make an assumption that there is a systematic overestimation in the Impact Assessment's analysis, which was produced after the quoted 2011 study. Prima facie evidence for the overestimation of costs in this case would be needed in order to build relevant projections.<br><br>The main technical issue in this respect revolves around the cost of hybrid systems (see below). |

| | | |
|---|---|---|
| | | Since the only available evidence points to an underestimation of the costs of such systems, this is the basis for the IAI's reassessment.<br><br>It is however considered appropriate to make a more explicit reference to the possibility of costs being revised lower at a later stage and the report has been amended to reflect this (Executive Summary and Section **Error! Reference source not found.**).<br><br>Prima facie evidence from any stakeholder can be taken into consideration if provided. |
| (ii) IAI suggestion to assess cost effectiveness differently, i.e. instead of looking at technologies with a negative marginal abatement cost (i.e. break-even point at zero), to define break-even points at e.g. €6 / tonne $CO_2$, or €30 / tonne $CO_2$: this was indeed not the approach followed in the Impact Assessment, and for good reasons, as it de-facto would have pre-empted one of the policy options, i.e. a possible inclusion of road transport into the ETS. | No | This part of the analysis was intended as a scenario analysis using an additional valid parameter, in order to highlight that other definitions of cost-effectiveness can be considered.<br><br>It is well understood that a pre-emption of the implied policy option was intentionally not considered in the Impact Assessment and this part of the analysis should not necessarily be taken as a suggestion, more as a complement to the work done to illustrate possible alternative considerations. |
| (iii) <u>risk of overlaps of technology</u>: the IAI report rightly notes that technology overlaps are possible, leading to non-linear accumulation of the abatement potential of various technologies:<br>This is clearly a "downside risk" to the IA assessment and was recognised as such in the IA, under paragraph 142, which notes that: | No | There are two elements to this issue:<br><br>1. The linear addition of the percentage $CO_2$ reduction potentials for each technology is mathematically incorrect, with the CE Delft report itself having applied the combination |

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| *"The CE Delft study on abatement cost curves estimated the potential for reduced engine emissions. This suggests that on average about a third of the technical savings feasible to reduce whole vehicle emissions would be achievable at the level of the engine (see table 1, Annex 8). These estimates may however not fully materialise:*<br>*- while the reported negative marginal cost estimates are averages on technology packages, some single independent components within these packages may have positive marginal abatement costs, which would imply that they would not be included, and hence that the level of economically sustainable increased engine performance and reduced $CO_2$ emissions would be lower than assumed;*<br>*- the combination of several technologies may not allow for a strict addition (through incremental multiplication of percentages gained) of individual abatement rates: interactions in a system such as a full vehicle or an engine may not allow for this.*<br>The Impact Assessment however did not consider as feasible a calculation of such downside risks (the TNO & al. report methodology quoted in the IAI assessment was not deemed easy to apply to HDVs in a straightforward way) and preferred a mere transparent acknowledgment of this limitation. | | using the correct geometrical methodology – this is taken to have been an oversight in good faith in the Impact Assessment.<br>2. The technology overlaps are founded on expert engineering knowledge but indeed very difficult to measure. The calculation in the report uses a methodology employed by CE DELFT in a European Commission report and it is therefore considered valid to include a factor taking into account this analysis. |
| (iv) new technologies: with the benefit of hindsight, new technologies not assessed in the Commission Impact Assessment would also suggest that a full re-assessment of the potential of abatement potential, as suggested by the IAI, would mandate the inclusion of other technologies/packages that were not included in the underpinning studies from Ricardo-AEA and TIAX (e.g. CVT (Continuously Variable Transmission) technologies that have a significant potential leading to further abatements). This is inevitable as technology constantly proposes new options. This ex-post analysis demonstrates that other "upside risks" to the Impact Assessment estimate were actually significant, i.e. "risks" of under-estimation of the potential that lies with technology developments allowing for further emission reductions. Such upside "risks" to the Impact Assessment are also ignored in the IAI report. | Yes | Indeed there is a potential upside in considering newly emerging technologies. This is acknowledged in the report under the term “learning effect and economies of scale”, but this term can be expanded by explicitly mentioning technological advances.<br>Since concrete evidence of this potential phenomenon is (by nature) not available, a numerical assessment has not been generated. |
| (v) hybrids: the analysis suggests that one technology, the hybrid technology, has higher costs than foreseen by TIAX, and that its penetration potential has thus been over-estimated. The Commission was not in a position to speculate and to include an | No | In Annex II in the section on hybrids, it is clearly stated that the figure used in the Impact Assessment for the incremental cost of hybrid |

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| alternative assessment of costs to the one produced by TIAX. Indeed, uncertainties are real on such costs, on the downside and upside (and not unilaterally one-way). The IAI report does not provide (in its annex 1) any clear evidence that would mandate a revised assessment of hybrid technology costs. | | buses is the 90% subsidised cost from the 2009 NAS study, implying that the unsubsidised figure would be 10 times higher. This is again taken to be an oversight in good faith.<br><br>In addition the cost for hybrid systems quoted in the recent UBA study supports a scenario of doubling the assumed costs for such systems.<br><br>With these two clear pieces of evidence available, the consequence is a very high uncertainty on the upside only in the cost of hybrid systems used in the Impact Assessment, supporting the scenario presented in which the hybrid is assumed to sit below the cost effectiveness cut off level. |
| (vi) rebound effects: as noted by the IAI, rebound effects (i.e. possible increased traffic and fuel use due to improved vehicle efficiency) have not been calculated in the Impact Assessment: this was openly recognised in the Impact Assessment (paragraph 163) as a limitation and a risk to the assessment. | No | Agreed |
| (vii) possible new Euro VII standards with a tightening of NOX emission standards: this risk that could lead to a loss in HDV $CO_2$ efficiency is not taken into consideration in the Impact Assessment. Commission Impact Assessments only consider proposed legislation. | No | This is understood. It is however valid to highlight such potentially material factors which may arise in the timeframe in question. |
| (viii) retrofitting ("multiple replacements of technology"): retrofitting is not taken as an assumption in the TIAX study used by the Commission in its Impact Assessment. This is a limitation and the focus has clearly been on new vehicles' emissions. | No | In this context the report does not refer to retrofitting, but rather to necessary replacement of technology, specifically tyres and potential advanced components, especially batteries. These could potentially be material additional costs. |
| (ix) UBA study: this study (2015) indeed assessed to a different cumulative cost-effective uptake of new technologies, but with a clear limitation, i.e. the uptake of those | No | The UBA study was acknowledged in the report |

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| technologies – and only those - that can be simulated with the existing modelling methodology. | | as an updated data source. |
| The outcome of this assessment is that the conclusion, according to which the IAI estimates would, as suggested, allow for "a more up-to-date basis for future policy analysis", is not fully supported. The main reason being that "downside" risks to the Commission's estimates of the abatement potential of HDV $CO_2$ emissions have been considered in isolation rather than together with "upside" risks. To be complete a new assessment would now also require variant oil price scenarios (given currently low oil prices) that imply a lower break-even potential of new technologies. The Commission would reassess these costs in a future if necessary in the future. | No | Both upside and downside risks have been taken into account and presented in the report, whose intention is to comment on the presented evidence, not to recreate the analysis or to speculate on future technological advancement.<br><br>Where alternative evidence and methodologies are available, scenarios have been generated. The main "upside" possibility is the potential for the actual costs to be lower than projected costs, which is an abstract expectation based on previous experience with $CO_2$ emissions for passenger vehicles, with prima facie evidence not available at this time.<br><br>The technology item with the greatest weight in the Impact Assessment's analysis is the hybrid. It has been clearly shown that a significant underestimate of the cost has been used in one of the vehicle applications. This therefore indicates a significant risk of higher costs than estimated.<br><br>Alongside the potential for unquantifiable "upside" risks, such as economies of scale, technical progress and new technologies, there are potentially significant "downside" risks on the future potential that cannot be numerically assessed at this time. These include the |

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| | | possibility that the assessed technologies have already started to penetrate the market, that some technologies do not have a 100% penetration rate for all vehicles in each category and potential tightening of exhaust emission standards. There are potential confounding factors in both directions. |