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TNO report

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Assessment of alternative targets and modalities for the CO_2 regulation for light commercial vehicles

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1 Introduction

Transport is one of the main CO_2 emitting sectors in Europe, and the only one that continues to grow substantially. Since road transport is responsible for the majority of the overall transport emissions, regulations[1] have been adopted for the purpose of reducing CO_2 emissions from passenger cars and light commercial vehicles (LCVs).

Recently studies [TNO 2011] and [TNO 2012a] have been published by a consortium of organisations (amongst others TNO and CE Delft), which review the feasibility of the proposed 2020 targets for passenger cars (95 g CO_2/km) and LCVs (147 g CO_2/km). These reports have provided input to an Impact Assessment carried out by the European Commission in support of setting modalities for these 2020 targets, which was published in July 2012.

Transport & Environment (T&E) has requested TNO to investigate a number of issues in order to enable T&E to take a position in the discussions regarding the 2020 targets for passenger cars and LCVs and their consequences. In the analysis of some issues, CE Delft has been involved.

1.1 Objective

The main objective of this project has been to provide insight in a number of issues that were either already identified in [TNO 2011] or [TNO 2012a] or that were raised by T&E, i.e.:

- possible causes for the prominently lower 2010 average CO_2 emissions of LCVs in comparison to the 2007 average estimated in [TNO 2009];
- the equivalency of proposed and alternative targets for passenger cars and LCVs with respect to the efforts required to meet these targets;
- costs and benefits related to various alternative targets, incl.:
  – the additional manufacturer costs for meeting the CO_2 target;
  – payback periods for the end user: while the additional manufacturer costs are likely to lead to an increase of the purchase price, the improved fuel efficiency leads to fuel cost savings;
  – overall CO_2 savings resulting from various alternative targets;
- evidence for leakage and weakening of the car target including practical examples of the potential impact;
- impacts on the market and rebound effects arising from possible alternative targets and further;

[1] Regulation (EC) No 443/2009 for passenger cars (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:023:0016:0028:EN:PDF)
Regulation (EU) No 510/2011 for LCVs (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2011R0510:20120313:EN:PDF

[2] European Vehicle Market Statistics, December 2011, http://www.theicct.org/european-vehicle-market-statistics

[3] http://www.eutransportghg2050.eu/cms/illustrative-scenarios-tool/

[4] http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-2

[5] Theoretically there may be a fourth behavioural response: a modal shift from a LCV to a passenger car or to heavy duty truck or vice versa. However, due to the specific character of the LCV we assume that this shift is negligible. This is also the conclusion of some TREMOVE runs

Regulation (EU) No 510/2011 for LCVs (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2011R0510:20120313:EN:PDF

- impact of the legislation on innovation, illustrated by examples of which technologies are likely to be deployed depending upon the stringency of the target.

Alternative target levels, as assessed in this report, have been suggested by T&E. Assessment of these targets has been carried out in an objective and fact-based manner using the assessment tools and methodology developed by TNO and its partners in the context of the studies carried out for the European Commission. TNO and its partners do not propose feasible or favourable target levels.

1.2 Report structure

[TNO 2012a] already identified and discussed the significant drop in average LCV CO_2 emissions between the value estimated for 2007, which was derived in [AEA 2009], and the 2010 value estimated in [TNO 2012a]. A further discussion of these figures is given in chapter 2. In chapter 3, equivalent LCV targets are derived for various (alternative) CO_2 emission targets for passenger cars. Fuel cost savings in relation to additional vehicle costs resulting from the various alternative LCV targets are provided in chapter 4. Chapter 5 deals with the possible CO_2 emissions leakage resulting from different limit functions for passenger cars and LCVs. The possible leakage resulting from lower operational costs for LCVs is indicatively analysed in chapter 6. Finally, the technologies that are likely to be applied by manufacturers depending on the stringency of the LCV target are described in chapter 7, providing insight in the extent to which different target levels stimulate innovation. A final summary of all conclusions is given in chapter 8.

2 Discussion of the apparent decrease of average CO_2 emissions of LCVs between 2007 and 2010

2.1 Introduction

One of the more surprising outcomes of the analyses presented in [TNO 2012a] was that the 2010 average CO_2 emission of LCVs in Europe was estimated at 181.5 g/km. This is very close to the 175 g/km target, set for 2017, and much lower than the average of 203 g/km that was estimated for 2007 in [AEA 2009]. Both average results, and the way they are derived from the averages per segment and the sales distributions over these segments, are presented in Table 1.

The 2010 average may be considered to shed a new light on the attainability of the 2017 target as well as the 147 g/km target proposed for 2020. In this chapter some background information is presented on the way in which the 2007 and 2010 averages were estimated, and various origins for the apparent decrease between 2007 and 2010 are discussed.

Table 1 2007 and 2010 sales distributions and CO_2 emissions per LCV class

		Class I	Class II	Class III	Average
2007	sales distribution	18%	25%	57%	-
	CO_2 emissions [g/km]	145	179	231	203
2010	sales distribution	21%	34%	45%	-
	CO_2 emissions [g/km]	123	162	223	181

2.2 The 2007 database

The analysis in [AEA 2009] was based on a Light Commercial Vehicle sales database for 2007, obtained from JATO, containing data on sales and vehicle characteristics of 20 European countries. The report mentions that a problem with the databases was that for a large share of the entries (specific model variants sold in a given country) CO_2 and/or mass and size data were missing. For CO_2 this was largely resulting from the fact that reporting CO_2 emissions for N_1 vehicles, as measured on the Type Approval test, has only become mandatory for new models since the adoption of Directive 2004/3/EC (amending Directive 80/1268/EEC) in 2004. Furthermore by then some heavier N_1 vans as well as many N_2 vans had engines that were type approved under HD legislation, so that no CO_2 data at the vehicle level were available either. The absence of mass data and other vehicle specifications for a number of entries was most likely resulting from omissions in national registration databases. In [AEA 2009], the missing CO_2 data was determined for all vehicle models, on the basis of data on CO_2 and mass as available in the database, the average CO_2 emission, average mass and (if statistically significant) the linear regression of CO_2 as function of mass. This information has been used to fill the gaps in the database for all entries for which CO_2 and/or mass data were missing. If a statistically significant linear regression was available for a given vehicle model, missing CO_2 data were calculated as function of the mass value available in the database entry. If the regression was not sufficiently significant or if mass data were not available, the average CO_2 value, derived from entries for other vehicles of the same model in the database, was used as a proxy. A limited number of vehicles, for which missing data could not be corrected, was excluded from the database.

As CO_2 values were especially lacking for the larger / heavier LCVs (Class III) and for the larger / heavier variants of a given model, the use of linear regression as a means to estimate missing CO_2 values will in many case have been an extrapolation on the basis of available data. As extrapolation involves a higher degree of uncertainty than interpolation, this enhances the uncertainty of the overall 2007 average calculated on the basis of available and estimated CO_2 data.

2.3 The 2010 database

For the analyses in support of defining modalities for the 147 g/km target for 2020 the year 2010 was chosen as reference year for two different reasons. First of all [TNO 2012a] introduced an improved approach for generating cost curves for CO_2 reduction technologies to be applied to LCVs in 2020. This required the use of a more recent reference year for the cost assessment model. Secondly the use of a more recent reference year would strongly reduce the need to correct the database for missing CO_2 data and would thus reduce the impact of estimated CO_2 values on the accuracy of the overall sales average CO_2 value.

Therefore a 2010 LCV sales database was acquired from JATO, including amongst other things, sales, CO_2 emissions, kerb weight, footprint, payload and price for the largest five EU Member States (Germany, France, UK, Italy, Spain). Initially a 2009 sales database was purchased from Polk, containing information for the largest five EU Member States plus Poland and Romania, but this revealed very strong impacts of the economic crisis on total sales as well as the distribution over size classes. In consultation with the European Commission’s DG CLIMA it was decided that 2009 was insufficiently representative to serve as a basis for projections up to 2020. The 2010 database still contains impacts of the crisis, illustrated by the sales distribution shown in Table 1, but these impacts were significantly less pronounced than in 2009.

The small number of countries for which 2010 data we obtained was the result of budget restraints. An analysis of the wider 2009 database revealed that using the data for the five largest EU Member States generates a sufficiently accurate average as well as sufficiently representative sales distributions and CO_2 averages per manufacturer.

As mentioned in section 2.3 of [TNO 2012a], after some database elaboration steps the 2010 database contained CO_2 data for 98% of its entries.

The estimated 2010 average value of 181.5 g/km is very close to what was determined by the ICCT[2], who recently completed a more elaborate database consolidation and evaluation for passenger cars as well as LCVs. As monitoring of CO_2 data for LCV sales in Member States, as obliged by Regulation (EU) No

[2] European Vehicle Market Statistics, December 2011, http://www.theicct.org/european-vehicle-market-statistics

510/2011 (Annex II), has only commenced in 2012, no official 2010 average for LCVs is available.

2.4 Possible causes for the difference between the 2007 and 2010 sales average CO_2 emissions of LCVs

The following possible causes are available to explain the unexpectedly large difference between the sales average CO_2 emissions for LCVs estimated for 2007 and 2010:
- a shift in sales from larger to smaller vans;
- inaccuracy of the 2007 average due to the correction of missing CO_2 data;
- changes in average mass and power-to-weight ratio per segment;
- application of CO_2 reducing technologies or technology improvements, other than weight reduction;
- increased use of flexibilities in the type approval test procedure.

Impacts of the observed sales shift

Table1 and Figure 1 show that between 2007 and 2010 sales of LCVs have significantly shifted towards smaller vehicles, resulting in a reduced share of class III vehicles and increased shares of class I and II vehicles. The impact of this shift can be estimated by calculating the weighted average of the 2010 average CO_2 emission values per segment using the 2007 sales distribution. This yields a value of around 190 g/km, meaning that 8.5 g/km of the observed reduction can be attributed to the shift in LCV sales between segments. This is about 40% of the observed reduction.

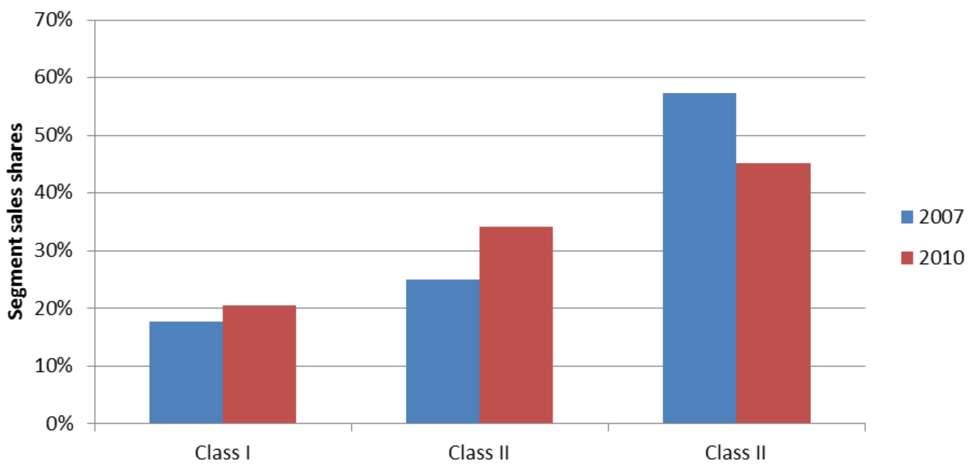


Figure 1 Sales distribution over N1 classes (petrol and diesel) in 2007 and 2010

Potential impacts of the inaccuracy of the 2007 average due to correction of missing data

As mentioned above, the 2007 database lacked CO_2 information for a large share of its entries, which was corrected by using estimates (averages or based on linear fits) derived from CO_2 data available for vehicles from the same model range that were available in the database. This involved a significant degree of uncertainty in the end result. As CO_2 data were especially lacking for larger vans the 2007 average CO_2 emission value for Class III vehicles is considered more uncertain than the values estimated for Class I and II.

[TNO 2012a] revealed that for all assessed utility parameters (including mass and footprint = track width x wheelbase) the CO_2 emissions of LCVs in the database tend to level off at the upper end of the utility range. A major cause for this was found in discontinuities in the type approval test procedure. Various elements of the chassis dynamometer testing procedure, used to determine the CO_2 [g/km] emissions of a vehicle, affect the outcome of the test in such a way that type approval CO_2 emissions become insensitive to increases in vehicle mass (or size) beyond a certain point. The identified elements include the fact that the inertia level set for the test is not increased for vehicles weighing more than 2210 kg, while the resistance factors do not change for vehicles weighing above 2610 kg.

The origins of these discontinuities in the test procedure lie in the limited capabilities of mechanical chassis dynamometers at the time when the test procedure was developed. With modern electromechanical chassis dynamometers these limitations no longer exist. In order to improve the basis of CO_2 legislation for LCVs it would therefore be advisable to update type approval test procedures in such a way that especially for larger vans measured CO_2 values become more realistic.

In view of the above one could conclude that the use of linear regressions derived from available data to estimate missing CO_2 data in the 2007 database may have led to an overestimation of the type approval CO_2 emissions especially for heavier / larger vehicles. As explained above, CO_2 data were especially lacking for larger vehicles so that the use of estimates based on linear regression fits would involve a significant degree of extrapolation.

However, as can be seen in Table 1, the CO_2 emissions have decreased more between 2007 and 2010 in class I and class II than they have in class III, both in relative and in absolute terms. Since the reduction in class III between 2007 and 2010 is fairly limited, the overestimation of the average CO_2 emission in this segment resulting from estimating lacking CO_2 data to fill gaps in the 2007 database, is most likely limited. As a direct comparison between the vehicles in the 2007 and 2010 database is not possible, for a range of reasons, the impact of estimated data in the 2007 database cannot be quantified.

Impact of changes in average mass and power-to-weight ratio per segment

Table 2 2007 and 2010 average mass values per LCV class

		Class I	Class II	Class III
2007	mass [kg]	1185	1554	1975
2010	mass [kg]	1197	1526	2013
ΔCO_2 resulting from mass change [g/km]		0.8	-2.0	2.8

Table 2 shows that the for all segments the average mass has reduced slightly between 2007 and 2010. This reduction can be attributed to shifts in sales to lighter vehicles within each segment and/or the application of weight reduction measures by manufacturers. While the contributions of these causes cannot be quantified separately, the net effect on average CO_2 emissions can be estimated using the relation, derived in [TNO 2006], which is valid under the assumption that engine power is adjusted to maintain performance:

$$\Delta CO_2/CO_2 = 0.65 \cdot \Delta m/m$$

As indicated in Table 2 the effect ranges between -2.0 g/km for Class II vehicles and 2.8 g/km for Class III vehicles. The impact on the overall average CO_2 emission value for 2010 is estimated to be 0.7 g/km, based on the 2010 CO_2 values and sales distribution, equivalent to 3.5% of the observed reduction.

Between 2007 and 2010 also the average power-to-weight ratio may have changed in the different segments, not only due to changes in vehicle weight, but also in the installed engine power. Most likely this ration has increased, which might lead to increased CO_2 emissions resulting from an increased share of part-load operation. For the 2007 database, however, no information is available on power-to-weight ratio, so that this effect cannot be quantified.

Potential impacts of the application of CO_2 reducing technologies

Although the CO_2 regulation for LCVs was only adopted in 2011, it may be expected that between 2007 and 2010 manufacturers applied some technological improvements or new technologies to new LCVs that may have resulted in a reduction of the average CO_2 emissions over that period. Estimating the impact of such innovations, however, would require an assessment of the levels of deployment of different technologies in 2007 and 2010. For 2010 such an estimate is made in [TNO 2012b], but for 2007 such data are not available. It is therefore not possible to quantify the impact of technological improvements over the 2007 – 2010 period. Nevertheless, given the limited pressure on lowering CO_2 emissions due to a lack of legislation as well as of fiscal incentives, the contribution of technological improvements to the apparent decrease of LCV CO_2 emissions between 2007 and 2010 is not expected to be large enough to explain the observed reductions. The effect of technologies is expected to be most noticeable in the segments dominated by car derived vans or in which engine platforms are shared with passenger cars, i.e. class I and class II. This may largely be due to cross-over of technologies that were also being applied in passenger cars, for which a CO_2 regulation was adopted in 2009. This corresponds to the larger reductions of CO_2 emissions for these segments as observed in Table 1.

Potential impact of the increased use of flexibilities in the type approval test procedure

In [TNO 2012b] an assessment is made of the extent to which increased utilisation of flexibilities in the type approval test procedure for light duty vehicles may have contributed to observed reductions in the average CO_2 emissions of these vehicles between 2002 and 2010. Upcoming CO_2 legislation and national fiscal and other incentives is expected to have motivated manufacturers to increase utilisation of test procedure flexibilities to lower CO_2 emissions measured on the type approval test.

One category of flexibilities in the test procedure relates to bandwidths specified in the test procedure for test conditions applied to the emission measurement carried out in the laboratory on a chassis dynamometer as well as the coast down test used for measuring vehicle resistance factors as input for the chassis dynamometer settings. Examples of this are the bandwidth of 20 – 30 ^{o}C for the vehicle soak temperature and the temperature in the test cell, the characteristics of wheels and tyres and the state-of-charge of the battery. Carefully choosing test conditions within the allowable bandwidth is found to lead to significant reductions in the measured CO_2 emissions. [TNO 2012b] has identified a range of flexibilities, assessed their possible impact on measured CO_2 emissions and their level of utilisation. For LCVs [TNO 2012b] estimates that increased utilisation of this type of flexibilities may have resulted in a reduction of reported CO_2 emissions by about 5% between 2002 and 2010. As it is expected that the utilisation of flexibilities has increased more in recent years than in the beginning of this period, the impact of increased utilisation of flexibilities between 2007 and 2010 could amount to 3% or more of the 2010 average CO_2 emission value. This corresponds to 5 to 6 g/km.

Another category of flexibilities relates to test conditions which are not or not clearly specified in the test procedures. Examples of this are the surface and slope of the test track used for the coast down test, and various manipulations of the condition of the test vehicle. Despite strong indications that this type of flexibilities are utilised the extent to which this is the case and the possible impact on measured CO_2 emissions is currently unknown.

2.5 Conclusions

Table 3 summarizes the results derived in the previous section for the potential contributions of various possible causes to the observed reduction in CO_2 emissions of LCVs between 2007 and 2010. It is clear from this overview that the unexpectedly high reduction is not only caused by possible errors in the estimation of missing CO_2 data in the 2007 database, of which the impact could not be quantified. A major and certain contribution is attributed to the shift in sales towards smaller vehicles. The impact of mass change is also quite certain. The quantified potential impact of the increased utilisation of test procedure flexibilities is more uncertain, but a finite contribution of this cause is considered likely based on the evidence gathered in [TNO 2012b]. The gap between the observed reduction and the sum of the quantified causes is 7 g/km. A reduction of this order of magnitude can be considered quite reasonable for the application of technological improvements over a 3 year period, especially as some level of cross-over of CO_2 reducing technologies from passenger cars may be expected in Class I and II vehicles.

Table 3 Potential contributions of various possible causes to the observed reduction in CO_2 emissions of LCVs between 2007 and 2010

2007 CO_2 emissions [g/km]	203
2010 CO_2 emissions [g/km]	181
ΔCO2 2007-2010[g/km]	**22**
Potential impact of possible causes for observed reductions [g/km]	
Estimated impact of sales shift	8.5
Potential impact of estimating missing data in 2007 database	??
Estimated impact mass changes	0.7
Potential impact of change in power-to-weight ratio	??
Potential impact of applying CO_2 reducing technologies	??
Potential impact of increased utilisation of flexibilities	5 - 6
Combined impact of estimated causes of reduction [g/km]	**15**

3 Determination of an LCV average CO_2 emission level equivalent to averages of 95 and 80 gCO_2/km for passenger cars

3.1 Introduction

In [TNO 2012a], an indicative target was determined for LCVs that could be considered equivalent to the 95 g/km target for passenger cars. This equivalent target for LCVs was determined on the basis of equal marginal costs for both vehicle classes and was estimated at 113 g/km. This led to the conclusion that the 147 gCO_2/km target for LCVs is less challenging for the manufacturers than the 95 gCO_2/km target for passenger cars.

However, as the baseline and methodology used for defining the LCV cost curves in [TNO 2012a] differed from the methodology used for defining the passenger car cost curves in [TNO 2011], and as [TNO 2011] provides different scenarios for the cost curves for passenger cars, the equivalent target for LCVs as presented in the impact analysis for the 2020 LCV target, is to be considered only indicative. A more detailed analysis is undertaken in this study by determining the equivalent LCVs targets based on the different passenger car cost curve scenarios as described in annex A and [TNO 2011].

Additionally, equivalent LCV targets are determined for an alternative passenger car target for 2020, i.e. 80 g/km. This is also done for several cost curve scenarios described in [TNO 2011].

3.2 Methodology

Various criteria can be used to determine targets for LCVs that are equally stringent as the CO_2 target for passenger cars, e.g.

- equal additional manufacturer costs,
- equal marginal manufacturer costs,
- equal relative price increase or
- equal payback period.

As described above, in [TNO 2012a] the average CO_2 emissions target for LCVs is considered equal to the CO_2 emissions target of passenger cars when the marginal costs (costs for reducing the last g/km towards the target) are equal. This criterion is selected because the CO_2 emissions of passenger cars and LCVs would be reduced in such a way that the marginal costs would be equal for passenger cars and LCVs if manufacturers would be able to pool their passenger car and LCV targets or if passenger cars and LCVs would be combined under one regulation.

For the purpose of this analysis average cost curves are constructed for passenger cars and LCVs, using the assessment models developed for [TNO 2011] and [TNO 2012a] and the cost curves for the different market segments. These average cost curves are constructed by determining the average additional manufacturer costs for various CO_2 emission targets and for various slopes of the mass-based limit function (Figure 2).

This is done for three passenger car cost curve scenarios:

- Basic cost curves, as these were used in determining the equivalent LCV target in [TNO 2011];
- Scenario a) curves, as these are assumed to be constructed in a way that is most similar to the methodology used for determining the LCV cost curves;
- Scenario c) cost curves, as these result in the lowest additional manufacturer costs and enable a sensitivity analysis.

A description of these cost curves and the underlying assumptions (as developed in [TNO 2011]) is provided in Annex A. The Scenario b) cost curves are very similar to the Scenario a) cost curves (although derived on the basis of different assumptions), so that the results derived here for Scenario a) can be considered to also apply to Scenario b).

For LCVs only a single set of cost curves is available from [TNO 2012a]. It should be noted, however, that these cost curves were developed using an updated methodology compared to the one used for the Basic cost curves for passenger cars in [TNO 2011]. The LVC costs curves are defined relative to a 2010 reference vehicle rather than a 2002 reference, and are based on a dataset for the potential and costs of CO_2 reducing technologies that was more strongly based on in-house expertise rather than data obtained from industry consultation. As such the LCV cost curves can be considered to be more equivalent to the Scenario a) and b) costs curves for passenger cars than to the Basic cost curves.

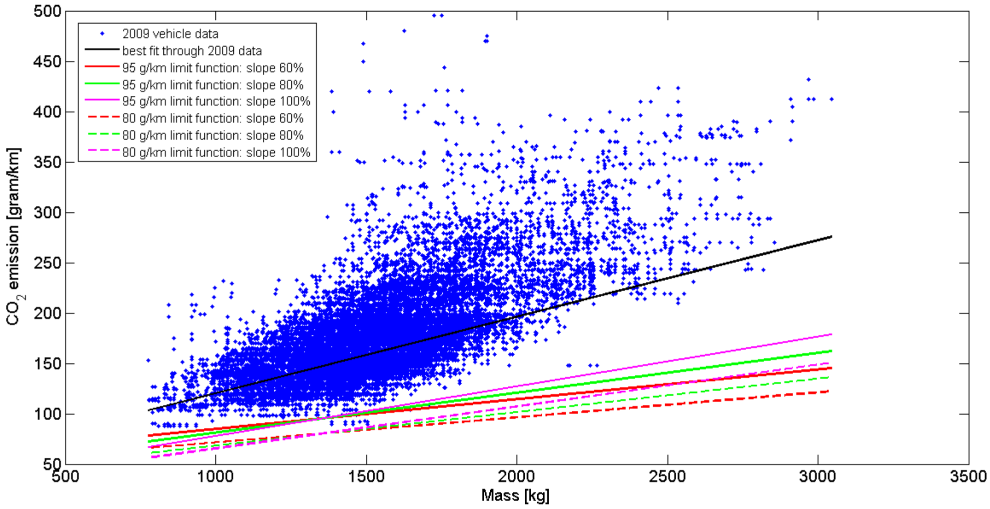


Figure 2 Mass-based limit functions for different passenger car targets (95 g/km and 80 g/km) and for different slope values (60%, 80% and 100%).

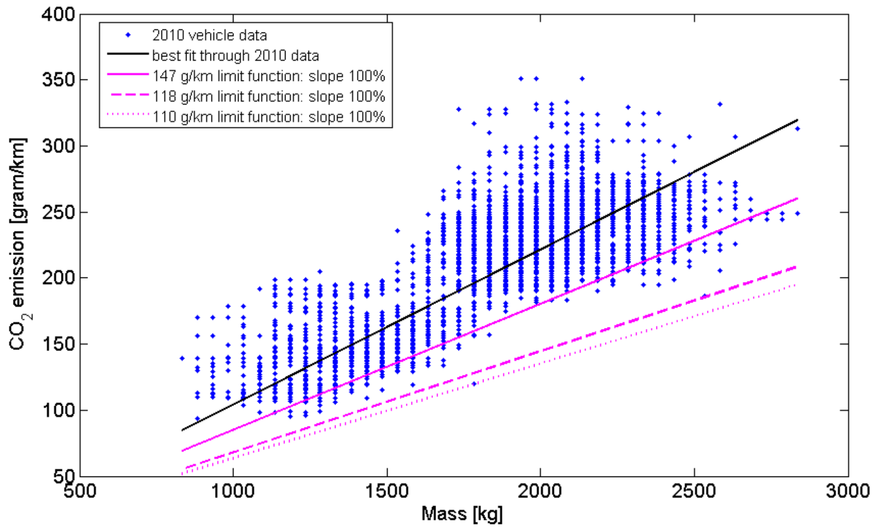


Figure 3 Mass-based limit functions for different LCV targets (147 g/km and 118 g/km and 110 g/km) for 100% slopes.

Hereafter, for three cost curve scenarios the marginal cost levels for passenger cars are determined for two target values, i.e. 95 g/km and 80 g/km (Figure 4). These marginal costs, expressed as €/g/km, are equal to the slope of the average cost curve at the target level. These slopes are indicated by the black lines in the passenger car graph in Figure 4. Two different passenger car targets (with different marginal cost levels), and three alternative sets of passenger car cost curves (that are not parallel), result in six different marginal cost levels to be analysed. .

Finally, for the six different marginal cost levels found in this way the average LCV CO_2 emission levels are determined at which the slope of the average LCV cost curve is equal to the slope of the passenger car cost curves.

As stated above, this analysis is performed for three different cost curve scenarios to indicate the sensitivity of the equivalent LCV target to the cost curves used for the passenger cars. The basic cost curve has the highest slope and the Scenario c) cost curve has the lowest slope of the scenarios defined in [TNO 2011]. Since Scenario a) was selected in the Impact Assessment for the 95 g/km target by the European Commissions and the methodology is closest to the methodology used to define the LCV cost curve, this scenario is also analysed.

The slope value does not significantly affect the average additional manufacturer costs. Since this analysis is not focussed on individual manufacturers, only one limit function slope value is analysed (100%) for the LCVs.

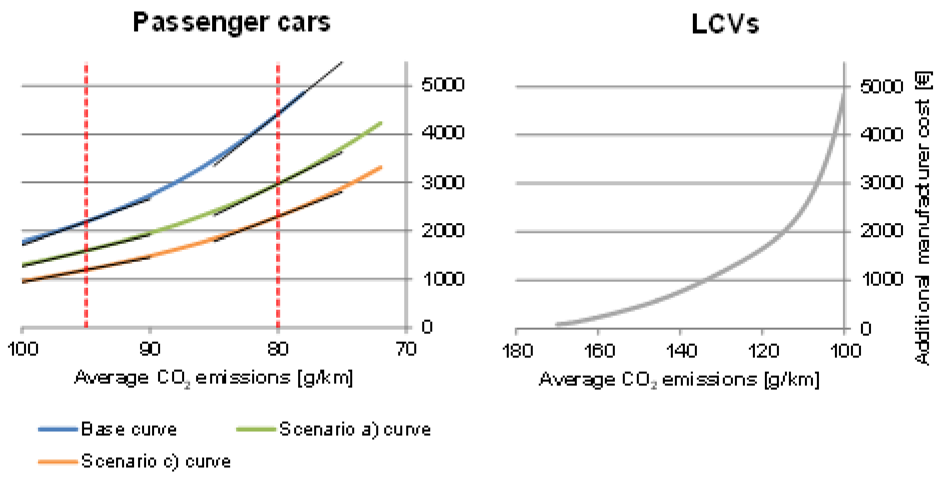


Figure 4 Passenger car average cost curves based on basic 2020 cost curve (blue), Scenario a) cost curve (green) and Scenario c) cost curve (orange). The black lines indicate the slope of the cost curves at the target values (95 g/km and 80 g/km). The right part is the average 2020 LCV cost curve.

3.3 Equivalent cost curves for LCVs and passenger cars

Applying the methodology as described in 3.2 results in Table 4. As can be seen, the average additional manufacturer costs (and also marginal costs) for passenger cars are influenced only very limitedly by the slope of the limit function. As a result the equivalent LCV targets vary only very limitedly for the different limit function slopes.

Obviously, the distribution of the additional manufacturer costs (and marginal costs) over passenger car manufacturers may vary significantly for different limit function slopes. However, that does not influence the overall equivalent LCV target and is therefore outside the scope of this study.

Because of these reasons, the slope of the passenger car limit function is not considered to be an important variable in the remainder of this study.

		Passenger cars			LCVs		
Cost curve type	**Slope**	**2020 CO2 target [g/km]**	**Average additional manufacturer costs [€] Relative to 2009**	**Average additional manufacturer costs [€] Relative to 130 g/km**	**equivalent 2020 CO2 target [g/km]**	**Average additional manufacturer costs [€] Relative to 2010**	**Average additional manufacturer costs [€] Relative to 175 g/km**
Basic	100%	95	2188	1751	113.3	2130	2041
Scenario a)	100%	95	1595	1330	117.6	1801	1712
Scenario a)	80%	95	1593	1329	117.6	1799	1710
Scenario a)	60%	95	1596	1331	117.6	1800	1711
Scenario c)	100%	95	1198	1036	122.5	1525	1436
Scenario c)	80%	95	1199	1037	122.5	1525	1436
Scenario c)	60%	95	1203	1041	122.4	1526	1437
Basic	100%	80	4223	3786	105.4	3251	3162
Scenario a)	100%	80	2971	2706	109.8	2510	2421
Scenario a)	80%	80	2971	2706	109.8	2502	2413
Scenario a)	60%	80	2963	2699	110.0	2487	2398
Scenario c)	100%	80	2295	2133	112.1	2240	2151
Scenario c)	80%	80	2291	2129	112.1	2240	2151
Scenario c)	60%	80	2289	2127	112.3	2223	2134

Table 4 LCV targets equivalent to two different PC targets (95 g/km and 80 g/km), based on three different cost curve scenario types (Basic, Scenario a) and Scenario c)).

The main results of Table 4 are also depicted in Figure 5 and Figure 6.

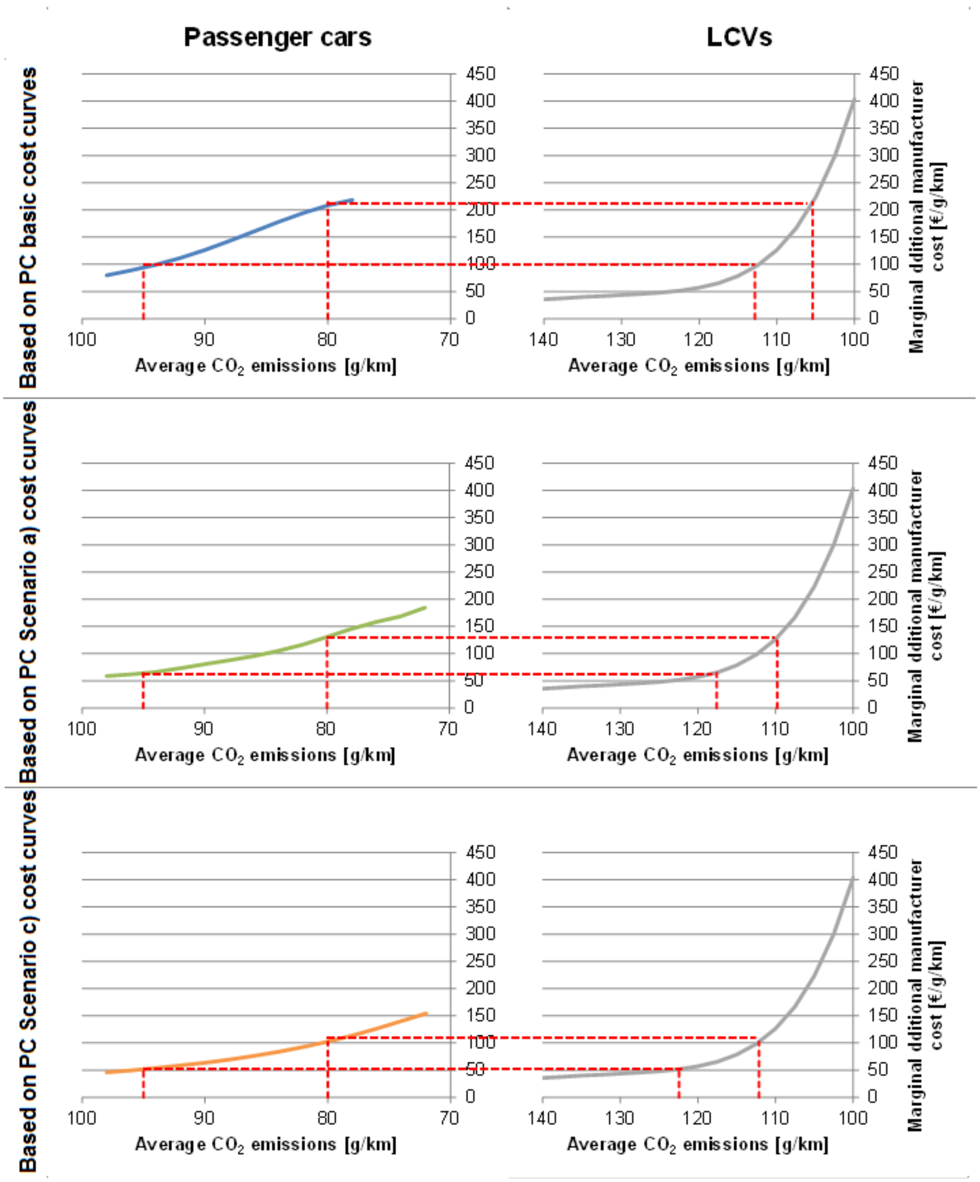


Figure 5 Marginal costs for passenger cars and LCVs in relation to the CO_2 target, allowing to determine an equivalent LCV target based on equal marginal costs. This is done for two target values (95 g/km and 80 g/km) and for three alternative cost curve scenarios.

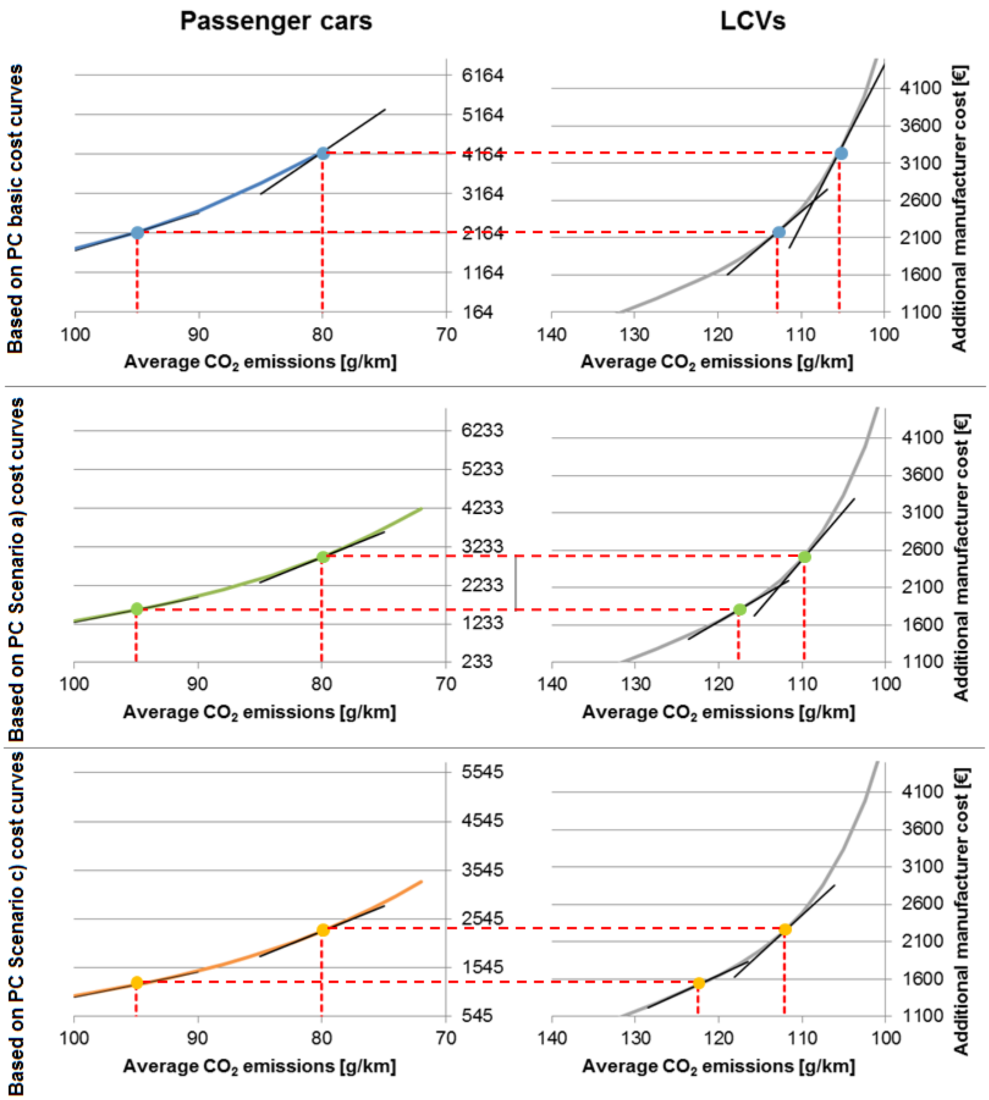


Figure 6 Additional manufacturer costs for passenger cars and LCVs in relation to the CO_2 target, showing the additional manufacturer costs of the equivalent CO_2 emission targets as determined in Figure 5.

3.4 Conclusions

From Table 4 and Figure 6 it can be concluded that the cost curve scenario selected by the European Commission for the Impact Assessment for the 95 g/km target for passenger cars in 2020 (i.e. Scenario a) cost curves with 60% limit function slope) leads to lower additional manufacturer costs (and lower marginal costs at 95 g/km) for passenger cars than application of the Basic cost curves. These Basic cost curves were used in [TNO 2012a] to determine the equivalent LCV target of 113 g/km (as shown in Table 4). Since the marginal costs at 95 g/km are lower when using Scenario a) than when using the Basic cost curves, the average LCV CO_2 emission level with marginal costs equal to that of passenger cars using the Scenario a) cost curves is higher than the value derived using the PC Basic cost curves. Applying Scenario c) cost curves even enlarges this effect.

This means that there is a trade-off between the additional manufacturer costs for meeting the 95 g/km target for passenger cars (depending on the cost curve scenario) and the equivalent target level for LCVs. When the estimated additional manufacturer costs for passenger cars decrease (because of using a cost curve scenario indicating lower costs), the equivalent LCV target increases.

It can also be concluded that even if the cost curve scenario is used for passenger cars that results in the highest equivalent LCV target (Scenario c) cost curve), the equivalent LCV target remains well below 147 g/km. Therefore meeting the 147 g/km target for LCVs is expected to require less effort than achieving the 95 g/km target for passenger cars.

Moreover the additional manufacturer costs for passenger cars to meet the 95 g/km target (based on 60% slope and Scenario a) cost curves (€ 1596)) are quite a bit higher than the additional manufacturer costs for LCVs meeting the 147 g/km target (based on 100% slope (€ 545)), Also the relative price increase for passenger cars (8.6% for a 60% slope and Scenario a) cost curves) is expected to be significantly higher than that for LCVs (3.0%). This confirms the statement above that the 147 g/km target for LCVs seems less challenging than the 95 g/km target for passenger cars.

As was determined in chapter 2, the effect of the segment shift in sales between 2007 and 2010 was approximately 8.5 g/km. Even if the sales distribution of 2007 was to be restored towards 2020, the 147 g/km target for LCVs would still be considerably less challenging than the 95 g/km for passenger cars.

4 Fuel cost savings in relation to additional vehicle costs resulting from various alternative targets for LCVs

4.1 Introduction

Under the CO_2 legislation, based on tailpipe emissions as measured on the type approval test, reducing CO_2 emissions from ICEVs is equivalent to reducing fuel consumption. The latter is achieved by applying technologies that improve the efficiency of the engine and powertrain or reduce the energy required for propelling the vehicle (by lowering the mass or reducing friction and air drag), or by reducing energy consumption by auxiliaries.

From a societal perspective, the retail price increase of LCVs, resulting from the additional cost that manufacturers make to apply more CO_2 reducing technologies, can therefore be compensated during the lifetime of a vehicle by fuel cost savings. For the end user this means that even if the retail price of LCVs increases because of the CO_2 target set, the total cost of ownership (TCO) may end up lower than without applying the CO_2 reducing technologies to meet a certain CO_2 target.

In Figure 7, the average additional manufacturer costs are depicted as a function of the CO_2 target. This curve is excluding any effects of market shifts and autonomous mass increase. The relation is non-linear because it is assumed that manufacturers are likely to apply the most cost effective reduction technologies at first. It can therefore be expected that lowering the CO_2 emissions average beyond a certain level, will result in a situation in which the additional manufacturer costs (and therefore increased retail price) cannot be compensated by reduced fuel costs.

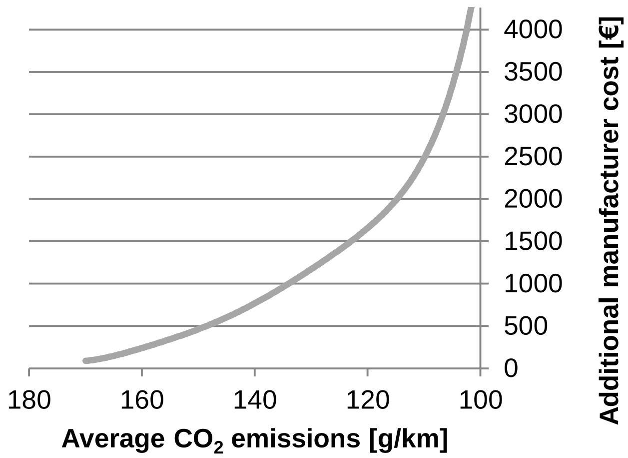


Figure 7 Average additional manufacturer costs of LCVs as a function of the CO_2 target based on the cost curves developed to analyse the impact of the 2020 target of 147 g/km

In this section, the TCO in relation to the additional manufacturer costs (and additional retail price) is determined for different LCV CO_2 target levels. Moreover the break-even period for the end user is determined. All this is determined for various oil price levels.

4.2 Methodology

The methodology and assumptions used in this study is similar to the methodology used in [TNO 2012a]. The most important aspects are described below and summarised in Table 5.

- For the lifetime of the vehicle 13 years is assumed. Moreover the LCV is assumed to have an annual mileage of 23,500 km/year.
- The relations between the oil price and the fuel price are taken from the SULTAN tool that was developed for project: “EU Transport GHG: Routes to 2050[3]” (Figure 8). The oil price is as imported to the EU ($’2008).
- It is assumed that VAT on fuel is returned to the end user, as LCVs are mostly used commercially. Since VAT on fuel is not completely returned in all EU27 countries, this is a conservative assumption. In reality the average fuel costs will be higher, resulting in a greater financial benefit for every g/km CO_2 reduced by the manufacturer. For the average European excise duty on diesel a value of € 0.44/l is assumed (Figure 8). As a result the relations between the oil and fuel prices (excluding all taxes, as well as price excl. VAT but including excise duty) are:

Diesel price (ex tax) [€/l]=	0.0084 * Oil price [€/l] - 0.020
Diesel price (excl. VAT, incl. excise tax) [€/l]=	Diesel price (ex tax) [€/l] + diesel excise tax [€/l]

- An average factor of 1.195 is used to translate the type approval emissions (on which the 2020 CO_2 emission targets are based) into ‘real world’ emissions.
- The relative retail price increase is calculated by multiplying the additional manufacturer costs by a mark-up factor of 1.11.
- Finally a discount rate of 4% is used to amortize cost from a societal perspective. For end users (consumers / companies) a discount rate of 8% is used.

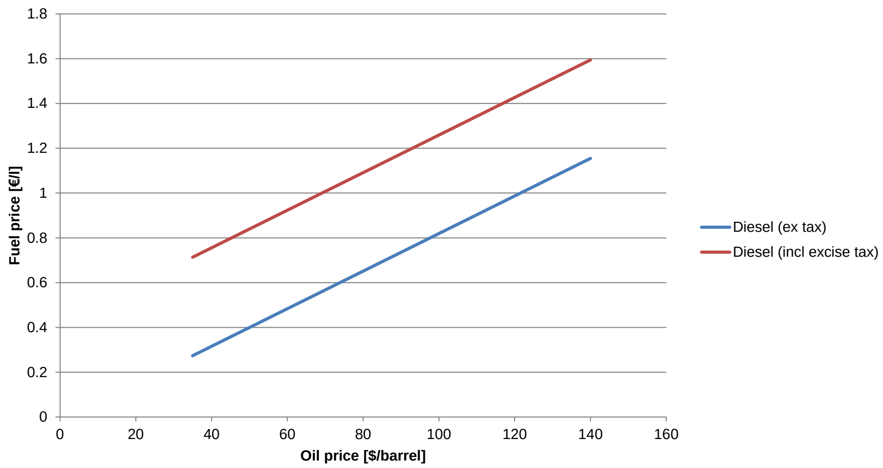


Figure 8 Relation between oil and fuel prices (source: SULTAN tool developed for project: “EU Transport GHG: Routes to 2050”)

[3] http://www.eutransportghg2050.eu/cms/illustrative-scenarios-tool/

Table 5 List of assumptions used to determine the effect of the 147 g/km target on the TCO for the end user.

Assumptions	Value
Vehicle lifetime [years]	13
Average annual mileage [km/year]	23500
CO_2 content [gCO_2/l]	2609
2010 average CO_2 emissions [g/km]	181
2017 average CO_2 emissions [g/km]	175
RW/TA	1.195
Societal discount rate [-]	4%
End user discount rate [-]	8%
Mark-up factor*	1.11

*Retail price increase/manufacturer costs

Finally the reduced CO_2 emissions are determined for the LCV fleet for various alternative targets. For this analysis it is assumed that the emissions of new vehicles between 2017 (175 g/km) and 2020 decrease linearly. The CO_2 emissions of the vehicles acquired between 2010 (181.4 g/km) and 2017 (175 g/km) are also assumed to decrease linearly. This last trend is also used to determine the emissions of new vehicles acquired before 2010. As the assumed vehicle age is 13 years, the CO_2 emissions are backcasted until 2005 to determine the LCV fleet emissions in 2017.

The annual mileage and RW/TA factor are taken from Table 5.

4.3 Results

Lifetime CO_2 reduction

In Figure 9, the average emissions of new vehicles are shown for various alternative 2020 targets (blue lines), assuming that the average emissions of new vehicles decrease linearly between 2017 and 2020. Moreover the overall annual CO_2 emissions of the LCV fleet are shown (red lines). These overall emissions are reduced more than linearly over time, as vehicles from previous years are also taken into account. Figure 10 shows the reduced CO_2 emissions by the LCV fleet in the year 2020 relative to the 147g/km target. It is therefore another way to represent the difference between the LCV fleet CO_2 emissions in 2020 for the targets shown in Figure 9.

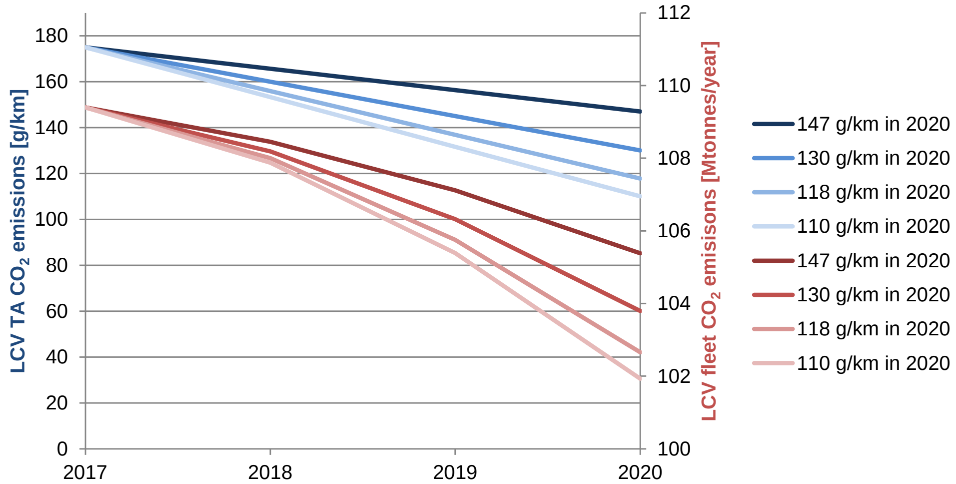


Figure 9 Fleet average CO_2 emissions per km between 2017 and 2020 and the annual LCV fleet CO_2 emissions for various alternative 2020 LCV targets.

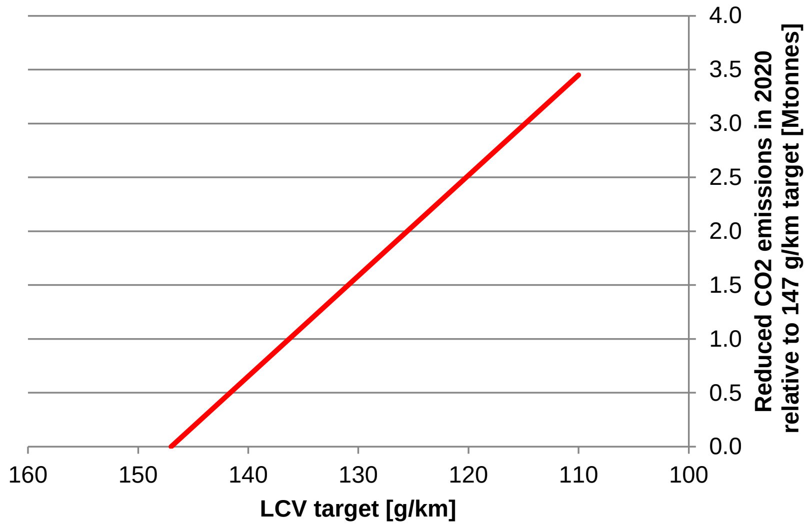


Figure 10 Relation between the 2020 LCV target and the reduced CO_2 in 2020 relative to the proposed 147 g/km target.

<u>End-user perspective</u>
In Figure 11, the end user break-even period in relation to the LCV target are depicted for various oil prices (as imported to the EU ($'2008).), relative to the 2010 situation. More detailed data is presented in Table 23 to Table 38 in Annex B. As can be concluded from Figure 11, the break even period for the end user is just over 3.5 years even for the worst case scenario, i.e. a combination of a low fuel price and a low LCV target of 105 g/km.

For an oil price of 95 $/barrel (close to the current oil price) and a LCV target of 118 g/km, which was determined to be the best equivalent of the 95 g/km target for passenger cars, the break-even period is approximately 2.8 years for end users.

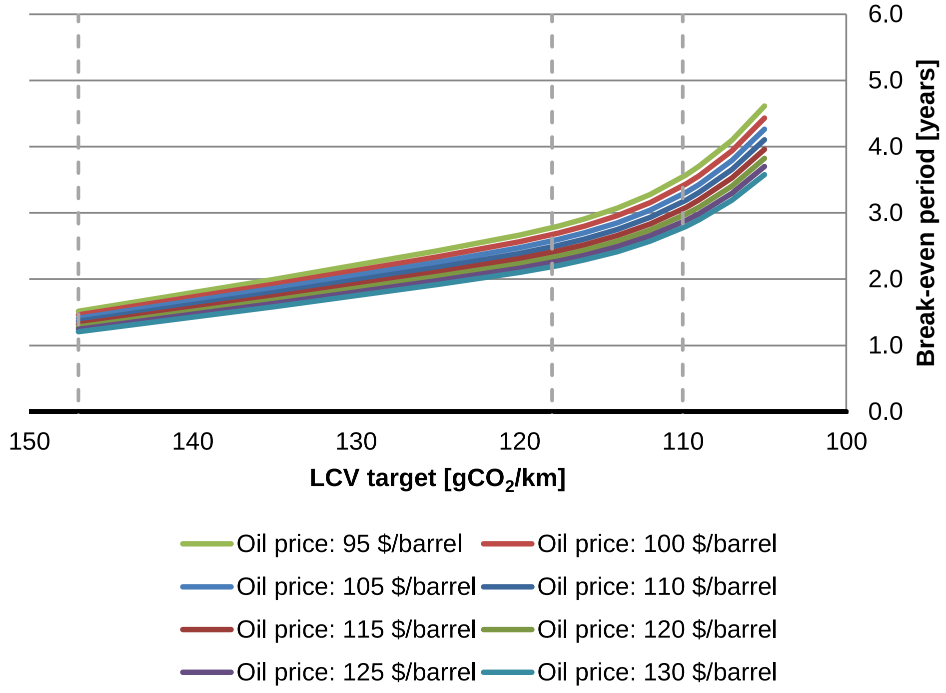


Figure 11 Break-even period for the end user in relation to the LCV target for various oil prices (as imported to the EU ($'2008)) relative to the 2010 situation (average of 181 g/km)

As end users use their acquired new vehicles for an average of approximately five years, , it is likely that the reduced fuel costs will outweigh the increased retail price for the first vehicle owner already.

These break-even periods for the end-user are relative to the 2010 situation in which the average CO_2 emissions were 181 g/km. The break-even periods increase slightly when compared to the existing target for 2017, i.e. 175 g/km. Break-even periods relative to this policy situation are given in Figure 18 in Annex B.

<u>Societal perspective</u>
Also from a societal perspective, the lifetime fuel cost savings (excluding all taxes) outweigh the additional investment resulting from the 2020 target. This is the case for the situation relative to the 2010 situation (Figure 12) and also relative to the 175 g/km target set for 2017 (Figure 19 in Annex B). This results in negative GHG abatement costs for society.

As can be seen, the abatement costs increase slightly with a decreasing LCV target. This results from the additional retail price increasing more than linearly, while the fuel costs reduce only linearly with the reduced target. Dividing these more than linearly increasing costs by a linearly increasing lifetime CO_2 savings, results in increasing abatement costs as the target get stricter.

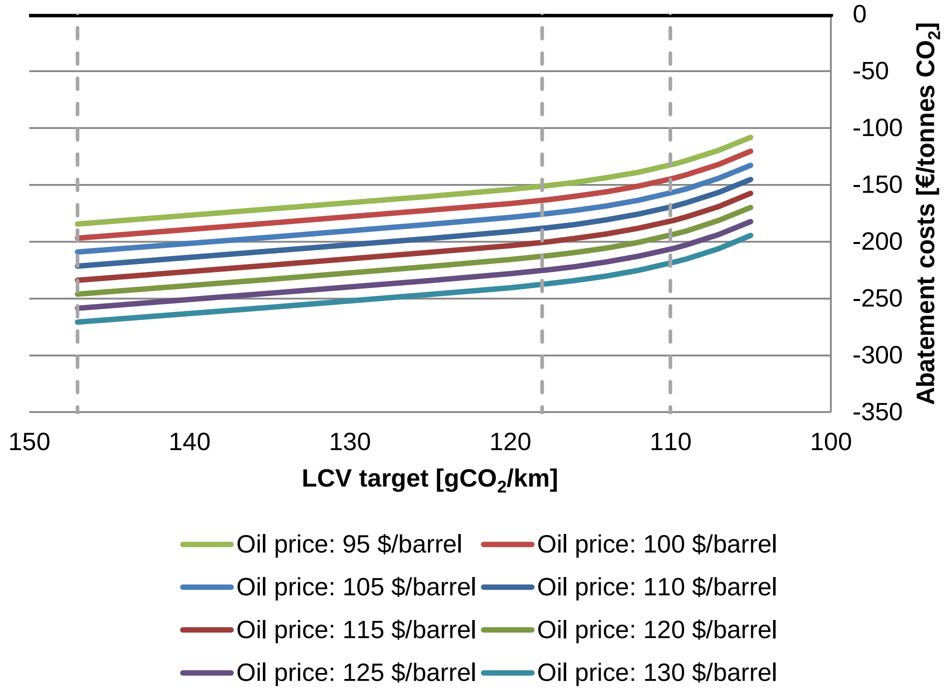


Figure 12 Societal abatement costs in relation to the LCV target for various oil prices (as imported to the EU ($'2008)) relative to the 2010 situation (average of 181 g/km)

These societal abatement costs are relative to the 2010 situation in which the average CO_2 emissions were 181 g/km. The societal abatement costs increase slightly when compared to the active policy for 2017, i.e. 175 g/km. Societal abatement costs periods relative to this policy situation are given in Figure 19 in Annex B.

4.4 Caveats

This analysis is a simplification of reality. A number of factors, that are not taken into account, are expected to have a significant effect on the parameters determined in this section. Some important factors are described below:

- It is assumed that all LCVs users are able to reclaim their fuel related VAT completely. However in some EU countries this is not the case. The assumption made leads to conservative results regarding the break-even period.
- For every oil price value for which the break-even period and the abatement costs are determined, the oil price is assumed not to change over the vehicle lifetime. However, as the break-even periods are relatively short, this assumption is not expected to affect the end result.

In this part of the study, the vehicle mileage is assumed to be independent of the fuel price and independent of vehicle age. The independence of the fuel price translates into a conservative end result as this makes that a larger part of the fuel cost savings comes from future years. Due to the applied discount rate, these savings have a lower value than the short term savings.

5 Possible CO_2 leakage from applying different targets for passenger cars and LCVs

5.1 Introduction

Vehicles are type approved as passenger cars (M1 category) or as LCVs (N1 category. This categorisation determines the manufacturer's average CO_2 emissions for M1 and N1 vehicles. When vehicles are registered by a national registration authority, they may be registered as a passenger car or as a commercial vehicle, resulting in different tax regimes in many European countries. National definitions of passenger cars and vans may deviate from the categorisation used for type approval.

The manufacturer's average CO_2 emissions for M1 and N1 vehicles have to meet certain targets in 2020. The target levels depend on the manufacturer's average mass of M1 and N1 vehicles. For a given average vehicle mass, the target for M1 vehicles is significantly stricter than for N1 vehicles. Selling a certain vehicle (that is available as N1 and as M1) as an N1 vehicle instead of as M1 may reduce the average total additional manufacturer costs for meeting both targets (averaged over both M1 and N1 vehicles). Manufacturers may therefore be willing to financially incentivise end users to acquire the N1 variant independent of how the vehicle is going to be used. This overall cost advantage may even allow manufacturers to promote private consumers to acquire N1 vehicles by means of pricing strategies.

In case national registration authorities allow users to unrestrictedly use N1 type approved, relatively cheap, vehicles for private use, an N1 type approved vehicle may be used as a passenger car, resulting in "CO_2 leakage".

Recently Regulation No 678/2011 amending Directive 2007/46 (Annex I) came into force, which includes some criteria (e.g. regarding loading space characteristics) to more clearly define the vehicle characteristics of the M1 and N1 categories. This should limit the overlap between M1 and N1 and should therefore limit potential CO_2 leakage from vehicles being accounted for in the incorrect (N1 rather than M1) CO_2 regulation scheme.

As a result of this regulation, car derived vans that are currently being sold (e.g. Renault Kangoo or Fiat Doblo) with more than one row of seats, are not likely to be type approved as N1 vehicles because of the requirements of the cargo area. The most likely route for CO_2 leakage is therefore the use of an N1 type approved vehicle as a passenger cars. This would require acceptance of the user to have a limited number of seats, in general only one row.

5.2 Methodology

The possible leakage is determined relative to the share of M1 vehicles shifted to the N1 category, but that are still being used as passenger cars. Using the assumptions in Table 6, the total 2020 TA CO_2 emissions by M1 and N1 vehicles can be determined by adding

- the M1 emissions (number of remaining M1 vehicles after the sales shift with the annual PC mileage and the 2020 PC target) and the

- the N1 emissions, (original number of N1 vehicles with the annual LCV mileage and the 2020 LCV target plus the shifted number of N1 vehicles with the annual PC mileage and the 2020 LCV target).

Multiplying the total 2020 M1 and N1 TA CO2 emissions by the RW/TA ratio provides the total ‘real world emissions. The difference between the situation in which vehicles have shifted from to the original situation, gives an indication for the potential leakage of CO_2 emissions.

Table 6 Assumptions for determining the possible CO_2 leakage resulting from separate limit value curves for M1 and N1 vehicles

	M1	N1
Sales	13.6 mln	1.66 mln
Annual mileage	15000	32500
2020 target	95	147
Vehicle lifetime	13	13
RW/TA ratio	1.195	1.195

In order to determine whether the potential financial benefit for the end user is significant enough to consider acquiring an N1 vehicle (with only one row of seats) rather than an M1 vehicle (with two or more rows of seats), the difference in additional manufacturer costs (and retail price) is determined. This analysis is based on five example vehicles that are sold both as M1 and as N1, i.e. the Citroen Berlingo, Peugeot Partner and the Renault Kangoo, VW Caddy and Fiat Doblo. The characteristics of these vehicle models are determined from a 2009 EU5+2 M1 sales database. The reference mass and CO_2 emissions are the sales weighted average values of the M1 vehicles sold within the EU5+2 in 2009. The sales as shown in Table 6 are taken from the 2011 database for “Monitoring of CO_2 emissions from passenger cars – Regulation 443/20091”[4]. The total sales share of these five analysed vehicles is 1.3% of the total M1 sales.

The manufacturer’s cost benefit from a vehicle shifted from the M1 category is determined by adding the
- saved additional manufacturer costs (for not having to meet the M1 target) and the
- manufacturer costs resulting from the different average that is required for the remaining M1 vehicles (taking into account that the limit value curve will be adapted because of a change of the average mass, which occurs since the shifted vehicles are not taken into account in the average M1 mass anymore).

Moreover the costs for these vehicles shifted to the N1 category are determined by adding the
- additional manufacturer costs (for meeting the N1 target) and the
- manufacturer costs resulting from the different average that is required for the original N1 vehicles (taking into account that the limit value curve will be adapted because of a change of the average mass, which occurs since the shifted vehicles are not taken into account in the average N1 mass anymore).

[4] http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-2

The reduction in retail price is determined by applying the passenger car mark-up factor. Since VAT is not returnable for users that use these N1 vehicles as passenger cars, the mark-up factor for passenger cars is used, i.e. 1.235 (see also [TNO 2011]).

Table 7 Characteristics of M1 vehicle models

Vehicle model	2011 sales (from monitoring mechanism)	2002 reference mass [kg]	2009 reference mass [kg]	2002 CO2 emissions [g/km]	2009 CO2 emissions [g/km]
Citroen Berlingo	45121	1312	1509	162.0	158.9
Peugeot Partner	29593	1265	1518	165.9	156.0
Renault Kangoo	32849	1180	1461	167.7	161.1
VW Caddy	54269	1236	1651	173.5	176.6
Fiat Doblo	12091	1363	1390	187.3	159.2
Average	-	1259	1537	169.1	164.4

5.3 Results

CO_2 leakage may occur when consumers acquire N1 type approved vehicles rather than M1 vehicles to be used as passenger cars (given that the user would accept for example only one row of seats) as explained in section 5.2. This leakage increases linearly with the share of vehicles shifted from the M1 to the N1 category as depicted in Figure 13 and Table 8.

In case all M1 vehicles of the models listed in Table 8 (1.3% of total M1 sales) were to be sold as N1 vehicles and used as passenger cars, a CO_2 leakage of approximately 165 ktonnes of CO_2 would occur.

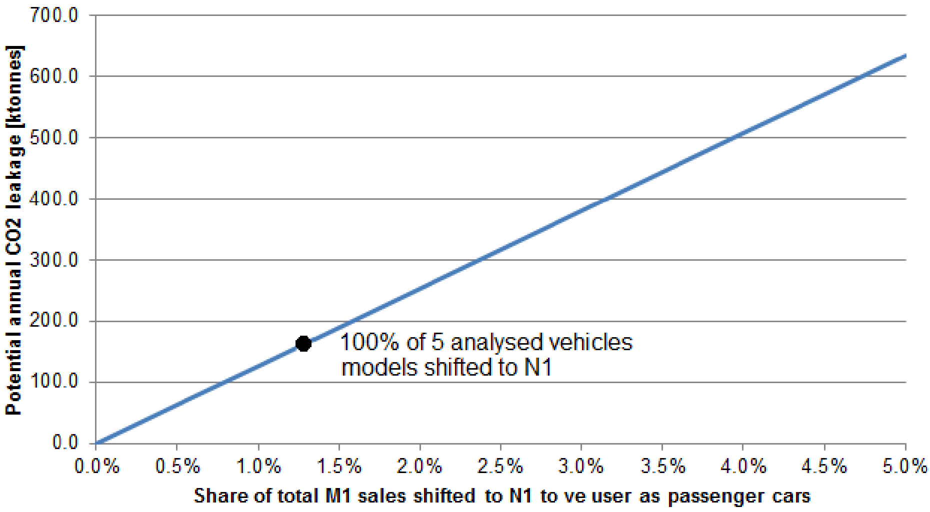


Figure 13 Potential CO_2 leakage in case N1 vehicles are being used as passenger cars

This is equivalent to an increase of the 95 g/km M1 target with the values as listed in Table 8. In case 1.5% of all M1 vehicles were to be sold as N1 vehicles and used as passenger cars, the CO_2 leakage would have an effect equal to an increase of the 2020 M1 target of approximately 0.8 g/km.

Table 8 Assumptions for determining the possible CO_2 leakage resulting from separate limit value curves for M1 and N1 vehicles

M1 - N1 shift	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Emissions based on TA [Mtonnes]	27.3	27.4	27.4	27.5	27.5	27.6	27.6	27.7	27.7	27.8	27.9
Additional emissions compared to no shift	0	63	127	190	254	317	380	444	507	571	634
Equivalent effect on the M1 target [g/km]	0.00	0.26	0.52	0.78	1.04	1.30	1.56	1.82	2.08	2.34	2.60

In Figure 14, five example vehicles are plotted. As can be seen, all five vehicles are well above the 2020 proposed limit value curves. Moreover, the distance to the M1 curve is significantly larger than the distance to the N1 curve. On average this gap is just over 33 g/km for these five vehicles.

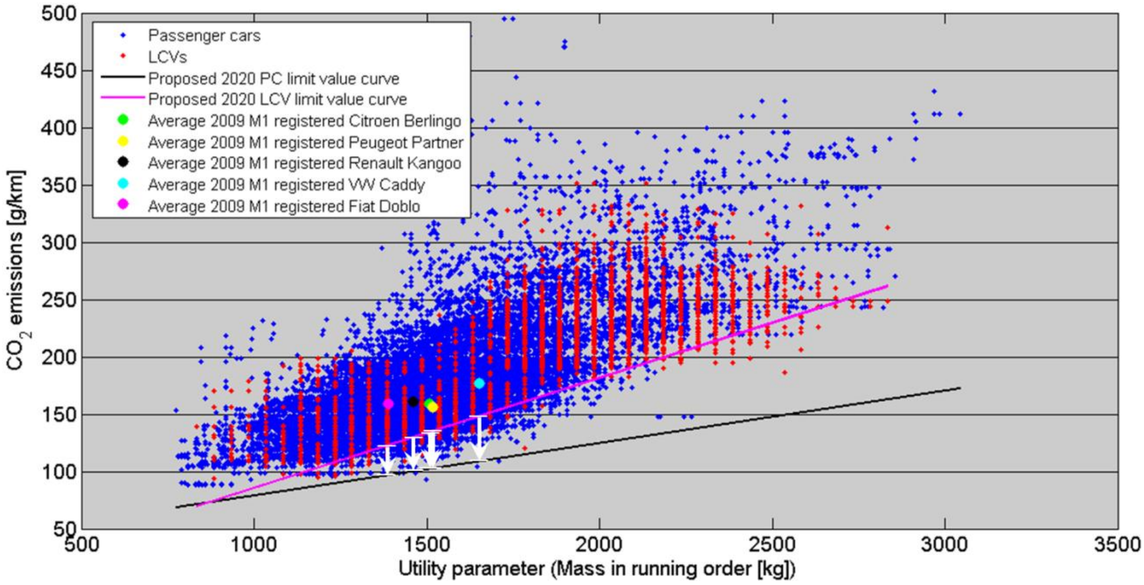


Figure 14 2009 M1 and 2010 N1 vehicle data and the proposed 2020 limit value curves for passenger cars and LCVs. The three example vehicles are indicated by coloured dots.

Table 9 Potential leakage resulting from different limit value curves for M1 and N1 vehicles

Vehicle model	required 2002 - 2020 reduction for M1 (corrected for mass increase)	2002 - 2009 reduction for M1 (corrected for mass increase)	required 2009 - 2020 reduction for M1 (corrected for mass increase)	required 2009 - 2020 reduction for N1 (corrected for mass increase)
Citroen Berlingo	75.6	19.0	56.7	25.2
Peugeot Partner	84.8	31.4	53.4	21.4
Renault Kangoo	93.6	32.6	61.1	32.0
VW Caddy	102.6	34.7	67.9	29.4
Fiat Doblo	93.0	30.5	62.4	36.9
Average	90.2	29.4	60.9	27.9
Relative CO2 reduction	53%	17%	37%	17%

As shown in Table 9, these five vehicles would on average have to reduce 37% between 2009 and 2020 to meet their equivalent of the 95 g/km target, while they would only have to reduce 17% to meet their equivalents of the 147 g/km target.

As shown in Table 10, the manufacturer's cost benefit per vehicle shifted from the M1 category is

- € 3940 saved additional manufacturer costs (for not having to meet the M1 target) and
- approximately € 1000 benefit resulting from the fact that the average CO_2 emissions of the remaining M1 vehicles is allowed to increase, since the equivalent of the 95 g/km target of the five vehicles analysed is higher than 95 g/km and therefore compensated by other vehicles.

The costs for these vehicles shifted to the N1 category are determined by adding the

- € 476 additional manufacturer costs (for meeting the N1 target) and
- approximately € 200 benefit resulting from the fact that the average CO_2 emissions of the original N1 vehicles is allowed to increase, because the equivalent of the 147 g/km target of the five vehicles analysed is lower than 147 g/km and therefore compensated by other vehicles.

As a result, the total benefit for the manufacturer is approximately € 5150 per vehicle sold as N1 instead of N1. Part of this benefit could be used to incentivise passenger car users to acquire an N1 instead of an M1 type approved vehicle.

Given a mark-up factor of 1.235, the effect on the retail price could be as much as € 6360. This amount could be sufficient for some consumers to switch from M1 to N1 vehicles and use it as a passenger car. The consumer would then have to except the characteristics that make it possible for manufacturers to have vehicles type approved as N1, for instance only one row of seats. Moreover national registration authorities would have to allow the usage of such an N1 vehicle to be used as a passenger car.

5.4 Caveats

Before Regulation No 678/2011 amending Directive 2007/46 (Annex I) was introduced, the difference between M1 and N1 vehicles was less clearly defined. As a result, vehicles (also with two rows of seats) may have been type approved as N1 vehicles. As these types of users may require (for example) more than one row of seats, their next vehicle may be an M1 rather than an N1 type approved vehicle. Since the equivalent M1 target is lower than the equivalent N1 target, this may result in a reduction of CO_2 emissions. This effect can only be analysed correctly a couple of years after the introduction of the regulation, because only then it can be determined whether this is the case.

Table 10 Effect of selling an N1 rather than an M1 vehicle on the additional manufacturer costs and retail price

	Share of analysed vehicles shifted from M1 to N1	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Shift from M1	Share of total sales shifted relative to total M1 sales	0.1%	0.3%	0.4%	0.5%	0.6%	0.8%	0.9%	1.0%	1.2%	1.3%
	Additional reduction required for remaining M1 vehicles	0.10	0.09	0.08	0.07	0.05	0.04	0.03	0.02	0.01	0.00
	Additional cost per remaining M1 vehicle	-1.3	-2.6	-3.9	-5.2	-6.5	-7.8	-9.1	-10.4	-11.7	-13.0
	Additional costs for reductions in remaining M1 vehicles per vehicle shifted from M1 to N1	-1015	-1018	-1017	-1015	-1013	-1011	-1008	-1006	-1004	-1001
	Additional manufacturer costs per vehicle shifted form M1 to N1	-3940	-3940	-3940	-3940	-3940	-3940	-3940	-3940	-3940	-3940
	Change in total additional manufacturer costs for meeting 95 g/km per vehice shifted from M1 to N1	-4956	-4958	-4957	-4955	-4953	-4951	-4949	-4946	-4944	-4941
Shift to N1	Share of total sales shifted relative to total N1 sales	1.0%	2.1%	3.1%	4.2%	5.2%	6.3%	7.3%	8.4%	9.4%	10.5%
	Additional reduction required for initial N1 vehicles	-0.11	-0.23	-0.34	-0.46	-0.58	-0.71	-0.84	-0.97	-1.10	-1.24
	Additional cost per initial N1 vehicle	-7	-14	-22	-30	-37	-45	-54	-62	-71	-79
	Additional costs for reductions in initial N1 vehicles per vehicle shifted from M1 to N1	-673	-676	-677	-678	-678	-678	-678	-679	-679	-679
	Additional manufacturer costs per vehicle shifted form M1 to N1	476	476	476	476	476	476	476	476	476	476
	Change in total additional manufacturer costs for meeting 147 g/km per vehice shifted from M1 to N1	-197	-200	-201	-202	-202	-202	-203	-203	-203	-203
Total	Net change in manufacturer costs per vehicle shifted from M1 to N1	-5152	-5158	-5158	-5157	-5156	-5153	-5151	-5149	-5147	-5144
	Net change in retail price per vehicle shifted from M1 to N1	-6363	-6370	-6371	-6369	-6367	-6365	-6362	-6359	-6356	-6353

6 Indicative quantitative assessment of rebound effects

6.1 Introduction

The first order impacts on costs of the CO_2 targets for LCVs are an increase in the purchase costs, due to the application of additional CO_2 reducing technologies, and a reduction in the fuel costs per kilometre as a result of the reduced fuel consumption per kilometre. The currently proposed LCV target for 2020 leads to a net decrease of the total costs of ownership per kilometre driven. Reduction of costs may result in various behavioural responses from LCV drivers, such as increased use of their vehicles. Due to this kind of rebound effects the net CO_2 reduction impact of LCV targets will be reduced relative to the direct impact estimated without taking account of indirect effects. In this section an indicative quantitative assessment of these rebound effects and their impact on the CO_2 reduction potential of LCV targets is presented.

In section 6.2 the various behavioural responses will be discussed that LCV drivers could apply if LCV targets are introduced. Next, the input variables and parameters will be described that are used in the indicative calculations of the rebound effects (section 6.3). The results of these calculations will be presented in section 6.4. To test the sensitivity of the calculations for the values chosen for some of the input variables/parameters the results of some sensitivity analyses will be discussed in section 6.5. Finally, in section 6.6 the overall conclusions of the assessment will be presented.

6.2 Behavioural responses

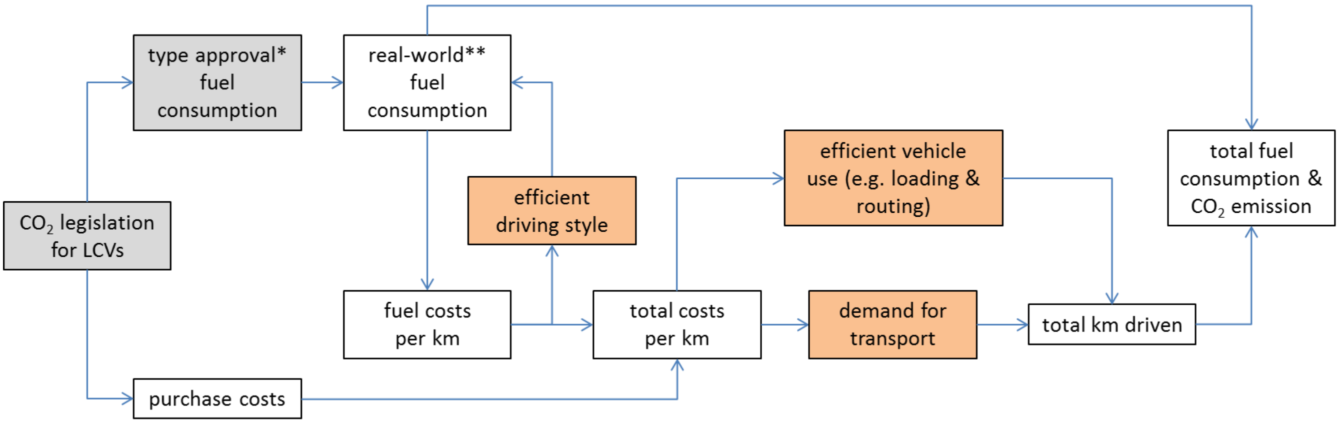
The lower costs per kilometre that result from the introduction of LCV targets may result in three potential behavioural responses of LCV drivers[5]:

- Due to the lower fuel costs drivers will have a smaller incentive to apply a **fuel-efficient driving style**. Therefore some of them may change their driving style which will result in higher (real world) fuel consumption figures per kilometre.
- Due to lower costs per vehicle kilometre (net result of lower variable costs and higher fixed costs[6]) LCV users will have less incentive to **use their vehicle in an efficient manner**. Less efficient routing may be applied as well as lower load factors. As a result the number of vehicle kilometres driven by LCVs may increase.
- Due to lower costs per vehicle kilometre and hence per tonne kilometre the **demand for transport** in general and specifically transport by LCVs may increase. Again this may result in an increase of the number of vehicle kilometres driven by LCVs.

[5] Theoretically there may be a fourth behavioural response: a modal shift from a LCV to a passenger car or a heavy duty truck or vice versa. However, due to the specific character of the LCV we assume that this shift is negligible. This is also the conclusion of some TREMOVE runs carried out by TNO et al. (2012).

[6] It is assumed that van owners act rationally and hence take both variable and fixed costs into account when deciding in which way they will use their vehicle and/or which tariffs they will charge their customers.

These various behavioural responses and their impacts on fuel consumption, costs and CO_2 emissions are graphically shown in Figure 15. The increased fuel efficiency of LCVs (due to the introduction of LCV targets) results in lower fuel costs. Part of this reduction in fuel costs is undone by a less fuel efficient driving style applied by LCV drivers, resulting in an increase in total (real-world) fuel consumption (relative to the case that these rebound effects are not considered). The remaining fuel cost reduction results in lower vehicle kilometre costs. To estimate the net impact on the vehicle kilometre costs not only the lower fuel cost should be considered but also the increased purchase costs of LCVs (due to the application of CO_2 abatement technologies). The resulting change in vehicle kilometre costs results in a change in the number of vehicle kilometres driven, partly due to changes in the efficiency of vehicle usage, partly due to changes in transport demand. The total rebound effect with respect to fuel consumption can be found by combining the impacts on fuel efficiency and vehicle kilometres. Finally, to estimate the total impact of the LCV targets on CO_2 emissions these rebound effects should be combined with the direct impacts of the targets.



*) as measured on the standardised type approval test
**) fuel consumption in daily use of the vehicle, influenced by e.g. travel patterns (urban vs. highway driving) and driving style

Figure 15 Overview of rebound effects (indicated by the orange boxes) affecting the net impact of LCV targets

6.3 Input variables and parameters

<u>Elasticity values</u>
To estimate the size of the various behavioural responses we will make use of an elasticity approach. Two types of elasticities are needed for this approach:

- Fuel cost elasticities with respect to fuel efficiency. These elasticities show the relative change in the fuel efficiency of the vehicle usage as a result of an increase (or decrease) of the fuel costs by 1%. In other words, a fuel cost elasticity of 0.1 implies that an increase of the fuel costs by 10% results in 1% higher fuel efficiency.
- Vehicle kilometre cost elasticities with respect to vehicle kilometres. These elasticities represent the relative change in the number of vehicle kilometres driven by LCVs as a result of an increase (or decrease) of the vehicle kilometre costs by 1%. These elasticities consist of two components: 1) the impacts of the vkm costs on the efficiency of LCV usage, and 2) the impacts of the vkm costs on the demand for LCV transport.

The empirical evidence on elasticities for LCVs is rather scarce. Therefore, most studies applying an elasticity approach to estimate the behavioural impacts of cost changes for LCVs use elasticity values derived from elasticities for Heavy Duty Trucks (e.g. CE Delft, 2009; Ecorys, 2007). In this study we have applied the same approach by using Significance and CE Delft (2010) as starting point for the derivation of elasticity values. In Significance and CE Delft (2010) a state-of-the-art overview of empirical evidence on different kinds of (price) elasticities with respect to heavy duty vehicles is given, including a recommendation of best-guess elasticity values. By adapting the elasticity values from Significance and CE Delft (2010) to the specific requirements of this study we derived the elasticity values presented in Table 11.

Table 11 Elasticities used in this study

Elasticities	**Main analysis**	**Sensitivity analysis**
Fuel cost elasticity w.r.t. fuel efficiency (l/km)	0.05	0.025 – 0.075
Vehicle cost elasticity w.r.t. vehicle kilometres	- 0.45	- 0.25

In Significance and CE Delft (2010) a long term fuel price elasticity with respect to fuel efficiency of 0.1 is presented for heavy duty trucks. This elasticity represents a combined effect, consisting of two behavioural responses: 1) a change in the driving style applied, and 2) a shift to more/less fuel-efficient vehicles. For estimating the rebound effect of applying LCV targets only the first behavioural response should be considered[7]. Therefore, we have to correct the elasticity value presented by Significance and CE Delft et al. (2010). Based on PBL and CE Delft (2010) we assume that the short term fuel price elasticity with respect to fuel efficiency is ca. 50% of the long term elasticity. Assuming that the short term impact of a change in fuel prices/costs on fuel efficiency is mainly related to changes in driving style applied, we find an elasticity value of 0.05 that should be applied in this study. Since the uncertainty in this elasticity value is rather large, we will also apply two sensitivity analyses, based on two alternative values of this elasticity, 0.025 and 0.075 respectively.

As mentioned before, the vehicle cost elasticity with respect to vehicle kilometres consists of two components. First of all, changes in vehicle kilometre costs may result in changes in transport efficiency (e.g. changes in routing, changes in load factors). Significance and CE Delft (2010) find a vkm cost elasticity with respect to changes in vehicle kilometres due to changes in transport efficiency of ca. -0.3. According to Ecorys (2007) and CE Delft (2009) there are less possibilities to increase the efficiency of LCV usage than of truck usage, mainly since there are less possibilities to change the size (load capacity) of the vehicle. Therefore, both studies apply an elasticity value of -0.15. We will do the same in this study. Secondly, changes in vehicle kilometre costs may result in changes in transport demand. According to Significance and CE Delft (2010) this effect could be estimated by using a elasticity of -0.3. However, based on Ecorys (2007) and CE Delft (2009) an elasticity value of -0.1should be applied[8]. Based on the value of

[7] A shift to less fuel-efficient vehicles is prevented by the implementation of the LCV targets.
[8] A distinction between ‘freight vans’ and ‘service vans’ (e.g. vans used by plumbers) is made in these studies. For freight vans an elasticity of -0.15 is used, while for service vans an elasticity of -0.05 is used. In this study we use an average value of -0,1.

Significance and CE Delft (2010) we find a vkm cost elasticity of -0.45, which we will apply in the main analysis of this study. Additionally, we will carry out a sensitivity analysis with a vkm cost elasticity of -0.25[9]..

Other input variables

Next to the elasticity values we also made some assumptions to calculate the fuel and vehicle kilometre costs of LCVs. The main assumptions are summarized in Table 12.

In the assessment of the rebound effects we will use the 2017 vehicle as the reference vehicle. For this vehicle an average CO_2 emission level of 175 g/km is already set (see TNO et al., 2012). Additionally, we will apply a sensitivity analysis in which we will use a 2010 vehicle as reference vehicle. Therefore, we also present data for this vehicle in Table 12.
In our assessments we apply a diesel price of 1.44 per litre (excl. VAT). To show the sensitivity of the calculation of rebound effects for different values of fuel prices, we also apply two sensitivity analyses using a fuel price of 1.18 and 1.61 respectively.

Table 12 List of assumptions used to estimate the fuel and vehicle kilometre costs

Assumptions	**Diesel**	**Source**
Vehicle lifetime (years)	13	TNO et al. (2012)
Average annual mileage (km/year)	23500	TNO et al. (2012)
CO_2 content diesel (gCO_2/l)	2609	TNO et al. (2012)
2010 average CO_2 emissions (g/km)	181	TNO et al. (2012)
2017 average CO_2 emissions (g/km)	175	TNO et al. (2012)
2020 average CO_2 emissions (g/km)	147	TNO et al. (2012)
Additional manufacturing costs relative to 2010 (€)	545	TNO et al. (2012)
Additional manufacturing costs relative to 2017 (€)	456	TNO et al. (2012)
Average 2010 sales price (€)	24356	TNO et al. (2012)
Average 2017 sales price (€)	24455	TNO et al. (2012)
Insurance costs (€/vkm)	0.030	TREMOVE 3.3
Repair costs (€/vkm)	0.053	TREMOVE 3.3
Vehicle taxes (ownership taxes, registration taxes, insurance taxes) (€/vkm)	0.016	TREMOVE 3.3
Diesel price (incl. taxes, excl. VAT) (€/l)	1.44 (1.18 – 1.61)	TNO et al. (2012)
RW/TA[a]	1.195	TNO et al. (2012)
End user interest rate	8%	TNO et al. (2012)
Mark-up factor[b]	1.11	TNO et al. (2012)

[a] The real-world (RW) emissions and fuel consumption of vehicles can differ significantly from the values measures on the Type Approval (TA) test. To correct for this we used a correction factor of 1.195 to express all emission and fuel consumption data in terms of real-world values. The same correction factor was used in TNO et al. (2012).

[9] The sum of a vkm elasticity with respect to changes in vehicle kilometres due to changes in transport efficiency of -0.15 and a vkm elasticity with respect to transport demand of -0.10.

[b] The relative increase in the retail price of LCVs due to the CO_2 targets is calculated by multiplying the additional manufacturing costs by a mark-up factor of 1.11 and dividing that by the average retail price for the baseline vehicle. This is in line with TNO et al. (2012).

Based on the assumptions presented in Table 12 the fuel costs and vkm costs of LCVs are calculated (see Table 13).

Table 13 Fuel costs and vkm costs of LCVs

	Diesel price: € 1.18 per litre	**Diesel price: € 1.44 per litre**	**Diesel price: € 1.61 per litre**
Fuel costs 2010 (€/vkm)	0.069	0.084	0.093
Fuel costs 2017 (€/vkm)	0.066	0.081	0.090
Fuel costs 2020 (€/vkm)	0.056	0.068	0.076
Total vehicle kilometre costs 2010 (€/vkm)	0.298	0.313	0.323
Total vehicle kilometre costs 2017 (€/vkm)	0.296	0.310	0.320
Total vehicle kilometre costs 2020 (€/vkm)	0.288	0.300	0.308

6.4 Results

The results of the assessment of rebound effects are shown in Table 14. The lower fuel costs due to the introduction of LCV targets result in an increase of 2% of the number of vehicle kilometres driven by LCVs. Part of this increase in vehicle kilometres is due to lower transport efficiency and another part due to lower transport demand. The relative rebound effect with respect to fuel consumption is equal to 3%. This rebound effect is larger than the one with respect to vehicle kilometres since the total rebound effect is the sum of increased vehicle kilometres and lower fuel efficiency figures (due to a less fuel-efficient driving style). Finally, Table 14 also presents the total effect with respect to fuel consumption (and hence CO_2 emissions), both excluding and including the rebound effects. When the rebound effects are excluded the total relative effect of the targets on fuel consumption is equal to 16.0%[10]. In case the rebound effects are taken into account the reduction potential of this policy instrument is reduced to 14.1%[11].

[10] This is estimated by calculating the relative change in average CO_2 emission figures in the reference scenario (181 g/km) and in the scenario in which the targets are introduced (and where the average CO_2 emission figures are assumed to be equal to the targets, i.e. 147 g/km).

[11] Here the efficiency improvements due to the introduction of the targets should be taken into account, because they lower the absolute size of the rebound effects. This could be explained by the following reasoning. First, let's assume that the initial level of fuel consumption would be 100. If we only consider the rebound effects, the new level would be 102.2. However, the improvement of fuel efficiency (the direct effect) has to be accounted for. Of all the fuel that would be consumed after a cost change, only 100 – 16.0 = 84.0%is actually consumed due to the efficiency improvement. The level of consumption would then be 84.0% * 102.2 = 85.9. As we started from an initial level of 100, the relative improvement that is realised is equal to 100 – 85.9 = 14.1%.

Table 14 Indicative results of assessment of rebound effects associated with a change in the average new LCV CO_2 emissions from 175 g/km to 147 g/km

Effects	**Relative effect**
Rebound effect on vehicle kilometres	1.4%
Rebound effect on fuel consumption	2.2%
Total effect on fuel consumption excluding rebound effects	16.0%
Total effect on fuel consumption including rebound effects	14.1%

6.5 Sensitivity analyses

Baseline vehicle

Next to the case in which a 2017 LCV is used as reference vehicle we also carried out an analysis in which a 2010 LCV is used as reference vehicle. Since the average CO_2 emissions of this vehicle are higher compared to the 2017 vehicle, the reduction effect excluding rebound effects is higher than in the main analysis (18.8% vs. 16.0%). As a consequence also the rebound effects are larger (1.7% vs. 1.4% and 2.6% vs. 2.2%).

Table 15 Results of sensitivity analysis for baseline vehicle. This case is associated with a change in the average new LCV CO2 emissions from 181 g/km to 147 g/km

Effects	**Relative effect**
Rebound effect on vehicle kilometres	1.7%
Rebound effect on fuel consumption	2.6%
Total effect on fuel consumption excluding rebound effects	18.8%
Total effect on fuel consumption including rebound effects	16.6%

Fuel prices

In the main analysis we applied a diesel price of € 1.44 per litre. To check the sensitivity of the analysis for this assumption we also carried out the analysis assuming a diesel price of € 1.18 and € 1.61 per litre. The results of these sensitivity analyses could be found in Table 16. The size of the rebound effects decreases if a lower diesel price is assumed, since the financial incentive for the LCV users to drive more vehicle kilometres or apply a less fuel-efficient driving style reduces (and vice versa). The analyses show that the impact of fuel prices on rebound effects is rather small, ca. 0.1 to 0.3 percentage point.

Table 16 Results of sensitivity analyses for fuel prices. As the base case, this case is associated with a change in the average new LCV CO2 emissions from 175 g/km to 147 g/km

Effects	**Diesel price: € 1.18 per litre**	**Diesel price: € 1.61 per litre**
Rebound effect on vehicle kilometres	1.1%	1.6%
Rebound effect on fuel consumption	1.9%	2.4%
Total effect on fuel consumption excluding rebound effects	16.0%	16.0%
Total effect on fuel consumption including rebound effects	14.4%	14.0%

Elasticity values

As mentioned above we also carried out some sensitivity analyses for the elasticity values applied. For the fuel cost elasticity with respect to fuel efficiency we both applied a higher and lower value (0.075 and 0.025 respectively, instead of 0.05). These alternative elasticity values particularly affects fuel consumption by the rebound effect on fuel efficiency (driving style). The impact on the number of vehicle kilometres is rather small, since this variable is only indirectly affected by this elasticity value. The impact of alternative values for this elasticity on the overall rebound effect is rather small, 0.2 to 0.4 % point. The impact of an alternative vkm cost elasticity with respect to vehicle kilometres (-0.25 instead of -0.45) on the total rebound effect is larger, ca. 0.6 % point. This is mainly due to the rather significant impact on the rebound effect on vehicle kilometres.

Table 17 Results of sensitivity analyses for elasticity values. As the base case, this case is associated with a change in the average new LCV CO_2 emissions from 175 g/km to 147 g/km

Effects	**Fuel cost elasticity w.r.t fuel efficiency of 0.025**	**Fuel cost elasticity w.r.t fuel efficiency of 0.075**	**Vkm cost elasticity w.r.t vehicle kilometres of - 0.25**
Rebound effect on vehicle kilometres	1.4%	1.4%	0.8%
Rebound effect on fuel consumption	1.8%	2.6%	1.6%
Total effect on fuel consumption excluding rebound effects	16.0%	16.0%	16.0%
Total effect on fuel consumption including rebound effects	14.5%	13.9%	14.7%

6.6 Conclusions

Based on the analyses carried out above (main analysis + sensitivity analyses) it can be concluded that the rebound effect of a change in the average new LCV CO_2 emissions from 175 g/km to 147 g/km in terms of vehicle kilometres is roughly 0.8 – 1.6%. In terms of fuel consumption the rebound effect is roughly estimated at 1.6 – 2.6%. The direct CO_2 impact of the change in average new LCV CO_2 emissions from 175 to 147 g/km is 16.0%. However, if we also take these rebound effects into account, the effect of the targets on the fuel consumption is estimated at ca. 13.9% to 14.7%.

These figures should be considered indicative values with relatively high levels of uncertainty. This is mainly due to the static approach applied, based on elasticities. Additionally, the literature does not provide specific elasticity values for LCVs, as a consequence of which we had to derive the elasticities for this issues regarding LCVs from elasticities estimated for heavy duty vehicles.

7 Technologies likely to be applied dependent on the stringency of the LCV target

7.1 Introduction

Depending on the stringency of the overall target, different (types) of technologies are likely to be deployed by manufacturers to reduce their average CO_2 emissions to the target levels. Insights in the expected types of technologies required to meet a certain target, provides awareness of the stringency of the target. For example, a target level that can be met by increased application of technologies that are already rather broadly used, can be considered easily feasible but also as insufficiently promoting innovation. On the other hand a target that would require new technologies that still need a significant amount of development time before they can be deployed, may be perceived as very challenging.

In setting CO_2 reduction targets for the short to medium term, the challenge for policy makers is to strike the right balance between achievability and acceptance on the one hand and promoting innovation in view of longer term sustainability goals on the other hand. In this section the key technologies will be identified they are likely to be applied at different CO_2 target levels for LCVs in 2020, i.e. 147 g/km, 118 g/km and 110 g/km.

7.2 Methodology

For identifying and illustrating the technologies that are likely to be applied by manufacturers to meet their CO_2 targets a partly graphical approach is applied, which is based on the methodology used for defining cost curves as developed and applied in [TNO 2011] for passenger cars and [TNO 2012a] for LCVs.

- Firstly the costs and reduction potentials of all possible technology packages are plotted for all three LCV classes, making so called ‘cost clouds’. The packages including certain key technologies are shaded differently from other packages to be able to identify beyond which reduction level manufacturers are likely to apply certain technologies.
- Next, the cost curves are plotted in these ‘cost clouds’. These curves show the CO_2 reductions that can be realised at certain cost levels. These cost curves are derived from the outer envelope of the cost cloud, which is defined by the most cost effective technology packages. A safety margin is applied to this outer envelope to account for the fact that certain technologies target the same energy loss so that their combined reduction potential is smaller than the direct mathematical combination of their individual potentials. As technology packages higher-up on the outer envelope include more technologies, the safety margin increases with an increasing CO_2 reduction level. It should be noted that the package with which a certain reduction, indicated by the cost curve, is realised, is not positioned on the cost curve itself but rather on the outer envelope of the cost cloud immediately right from that point on the cost curve. In other words, the reduction achievable at a certain cost is indicated by the cost curve, but in the graph the package with which this reduction is realised is not positioned on the cost curve itself but on the outer envelope at the same cost level. This is indicated by the arrows in Figure 16.

- In Figure 17 the average reductions per LCV class that manufacturers have to realise in order to meet a certain overall CO_2 target (147 g/km, 118 g/km or 110 g/km) is indicated by a coloured dot on the cost curve. Additionally also the CO_2 reduction of the manufacturers with the lowest and the highest CO_2 reduction necessary to meet their equivalent of the overall target are indicated by dots on the cost curves. In defining this bandwidth only manufacturers with more than 5% sales share within a LCV class are taken into account. These reduction levels have been determined using the cost assessment model for CO_2 reduction in LCVs as developed for [TNO 2012a].
- Finally, packages of technologies including specific key technologies are plotted in different shades of blue. This way it can be determined visually whether is likely that certain technologies are likely to be applied by manufacturers to achieve a certain target.

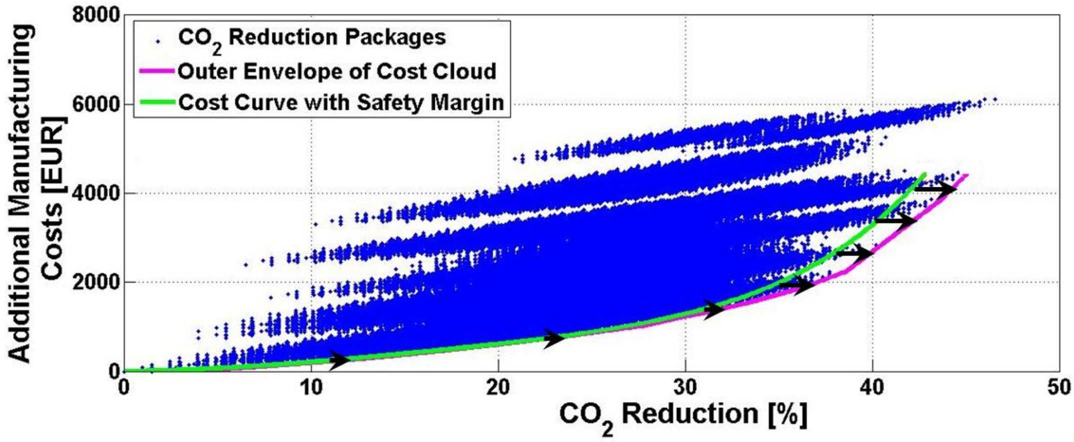


Figure 16 Example of a cost cloud, cost curve and a line indicating the outer envelope of the cost cloud for class I LCVs

7.3 Results

Table 18 shows the average, minimum and maximum reductions of manufacturers with sales shares over 5% within every LCV class for three different overall targets. These reduction percentages are indicated on the cost curves in Figure 17. This figure as well as Figure 20 to Figure 34 in Annex C show the technologies that are included in the technology packages that are likely to be deployed by manufacturers to meet the targets analysed in this study.

The red dot with the lowest CO_2 reduction in Figure 17 (12.8% as shown in Table 18), indicates the reduction required in the Class I segment by the manufacturer (with more than 5% of the sales share in class I) with the lowest reduction required to meet its equivalent of the 147 g/km target. As explained in section 7.2, the technology package that corresponds to this reduction level can be found to the right from the red dot on the outer envelope.

To the right from this first dot the next red dot, at 13.9% (Table 18), indicates the average reduction in the Class I segment that manufacturers have to realise for the 147 g/km target to be met. Again, the technology package corresponding to this reduction level is to the right from this red dot on the outer envelope.

At 15.3% reduction the third red dot indicates the maximum reduction that a manufacturer (with more than 5% of the sales share in class I) has to achieve to meet its equivalent of the 147 g/km target. The technology package that corresponds to this reduction level is again found to the right from the red dot on the outer envelope.

The three black dots indicate the minimum, average and maximum reductions for class I LCVs that have to be realised to meet an overall 118 g/km average, while the three purple dots indicate the minimum, average and maximum reductions for class I LCVs that have to be realised to meet an overall 110 g/km target.

Similar figures, for other LCV classes as well as for other relevant technology types, are depicted in Annex C (Figure 20 to Figure 34).

Table 18 Average, minimum and maximum reductions of manufacturers with sales shares over 5% within every LCV class for three different overall targets

	sales share > 5%	**Class I**	**Class II**	**Class III**
147 g/km	**minimum reduction**	12.8%	11.7%	15.5%
	maximum reduction	15.3%	17.1%	23.6%
	average reduction	13.9%	16.2%	20.8%
117.6 g/km	**minimum reduction**	26.8%	34.5%	32.3%
	maximum reduction	28.2%	35.7%	39.0%
	average reduction	27.4%	34.5%	36.7%
109.8 g/km	**minimum reduction**	32.3%	38.4%	36.9%
	maximum reduction	34.3%	40.0%	42.3%
	average reduction	33.2%	39.1%	40.5%

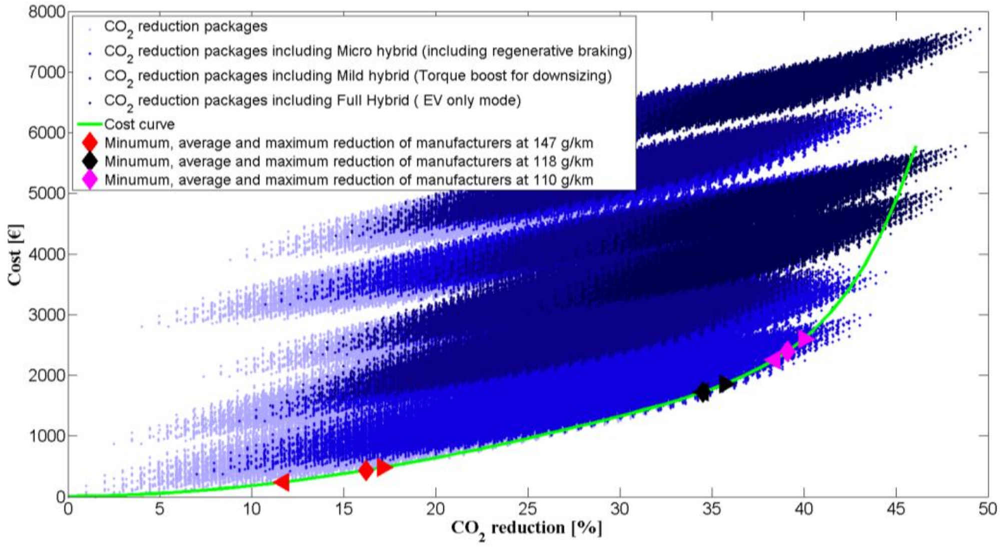


Figure 17 Overview of hybridisation levels for class I LCVs likely to be applied for achieving different CO_2 reduction levels necessary for reaching different overall LCV target levels in 2020. For other key technologies, figures are shown in annex C.

7.4 Conclusions

From Figure 17 it can be concluded that for meeting a target of 147 g/km it is not likely that the technology ‘micro hybrid (including regenerative breaking)’ needs to be applied on a large scale. There are more cost effective options available to realise this reduction. This conclusion can be drawn since all three red dots are situated in a part of the cost cloud with the lightest shade of blue. A technology package with this shade indicates that no hybridisation is included in that package. Therefore this technology is indicated as not likely (- -) to be applied in class I vehicles to meet the 147 g/km target in Table 19. For a 118 g/km target the application of this technology is more likely (+/-) as the dots are in an area very close to packages in which the micro hybrid technology is included. For a 110 g/km target it is very likely that micro hybridisation will be applied (++).

As can also be concluded from Figure 17, the large scale deployment of mild and full hybrid technology is unlikely for any of the analysed targets.

Other technologies and LCV classes are analysed in Annex C (Figure 20 to Figure 34). The conclusions drawn from these figures are summarised in Table 19. This table indicates how likely it is that various technologies are deployed on a fairly large scale for meeting different target levels. The technologies that are most likely needed for meeting the 147 g/km, 118 g/km and 110 g/km targets are summarized in Table 20, Table 21 and Table 22 respectively.

Table 19 Likeliness for certain key technologies to be applied within the different LCV classes for various LCV alternative targets

	147 g/km			118 g/km			110 g/km		
	Class I	Class II	Class III	Class I	Class II	Class III	Class I	Class II	Class III
Mild downsizing	++	+	++	++	++	++	++	++	++
Medium downsizing	-	-	++	+/-	++	++	++	++	++
Micro hybrid	- -	-	+/-	+/-	++	++	++	++	++
Mild hybrid	- -	- -	- -	- -	- -	- -	- -	- -	- -
Full hybrid	- -	- -	- -	- -	- -	- -	- -	- -	- -
BIW lightweighting (mild)	- -	- -	- -	-	-	-	+	+	+
BIW lightweighting (medium)	- -	- -	- -	- -	- -	- -	- -	- -	- -
BIW lightweighting (strong)	- -	- -	- -	- -	- -	- -	- -	- -	- -
Aerodynamics improvement (minor)	++	+	++	++	++	++	++	++	++
Aerodynamics improvement (major)	++	+	+	++	++	++	++	++	++
Reduced driveline friction (mild)	+/-	++	++	+/-	++	++	++	++	++
Reduced driveline friction (high)	-	+	+	+	++	++	++	++	++

Table 20 Key technologies likely to be applied on a fairly large scale in case of a 147 g/km target (the technologies in grey are less likely to be deployed than the ones in black)

Technologies likely to be applied at a target of 147 g/km		
Class I	Class II	Class III
Mild downsizing	Mild downsizing	Medium downsizing
Aerodynamics improvement (major)	Aerodynamics improvement (major)	Aerodynamics improvement (major)
Reduced driveline friction (mild)	Reduced driveline friction (mild)	Reduced driveline friction (high)
	Reduced driveline friction (high)	Micro hybrid

Table 21 Key technologies likely to be applied on a fairly large scale in case of a 118 g/km target (the technologies in grey are less likely to be deployed than the ones in black)

Technologies likely to be applied at a target of 118 g/km		
Class I	Class II	Class III
Mild downsizing	Medium downsizing	Medium downsizing
Aerodynamics improvement (major)	Micro hybrid	Micro hybrid
Reduced driveline friction (high)	Aerodynamics improvement (major)	BIW lightweighting (mild)
Medium downsizing	Reduced driveline friction (high)	Aerodynamics improvement (major)
Micro hybrid		Reduced driveline friction (high)

Table 22 Key technologies likely to be applied on a fairly large scale in case of a 110 g/km target (the technologies in grey are less likely to be deployed than the ones in black)

Technologies likely to be applied at a target of 110 g/km		
Class I	Class II	Class III
Medium downsizing	Medium downsizing	Medium downsizing
Micro hybrid	Micro hybrid	Micro hybrid
BIW lightweighting (mild)	BIW lightweighting (mild)	BIW lightweighting (mild)
Aerodynamics improvement (major)	Aerodynamics improvement (major)	Aerodynamics improvement (major)
Reduced driveline friction (high)	Reduced driveline friction (high)	Reduced driveline friction (high)

From Table 19 to Table 22 it can be concluded that the technologies likely to be applied by manufacturers to meet their equivalents of the 147 g/km, 118 g/km and 110 g/km targets do not include technologies that are still in the early development stage. Most of the technologies identified in Table 20 to Table 22 are currently already being applied in passenger cars. Since Class I and II LCVs are mostly car derived vans, have an equivalent in the M1 category, or make use of powertrain technologies shared with passenger car models, many manufacturers already have experience with applying these technologies.

For the 118 g/km and 110 g/km targets, the additional key technologies expected to be applied compared to the 147 g/km target are micro hybridisation (start-stop systems) and mild BIW light-weighting. The latter technology seems the most challenging technology that is likely to be applied. Also for the passenger cars, this technology is expected to contribute significantly to achieve the 95 g/km target.

7.5 Caveats

The likeliness for technologies to be applied by manufacturers to meet different target levels can only be assessed indicatively, as the types of technologies that manufacturer apply to reduce their CO_2 emissions depend on more than only the cost effectiveness. The types of technologies to be applied can for instance be a strategic decision, aiming at positioning specific brands in different ways, or can be based on the need to create return on investments made by a company in specific technological developments. One should also keep in mind that targets can be met in different ways with respect to technology deployment strategies. A target for the sales average CO_2 emissions can be met by applying CO_2 reducing technologies to a similar level on all vehicle models in all segments, leading to large production volumes for these vehicles, or by applying more advanced CO_2 reduction technologies to a limited share of the sales spectrum to compensate for below average reductions achieved in other vehicles.

7.6 Conclusions

For meeting the 147 g/km target for LCVs in 2020, manufacturers are likely to apply only technologies that are currently already being applied in passenger cars on a significant scale, i.e. mild downsizing, (major) aerodynamics improvements and significant reduction of the driveline friction. This 147 g/km target is therefore not likely to stimulate innovation.

For the analysed 118 g/km and 110 g/km targets, the additional key technologies expected to be applied compared to the 147 g/km target are micro hybridisation (start-stop systems) and mild BIW light-weighting. The former technology is currently already being applied in passenger cars on a relatively large scale and is also being applied in a range of van models. The BIW light-weighting therefore seems to be most innovative or challenging technology for which application is stimulated. At the same time a range of other technologies is available to manufacturers for achieving similar average levels of CO_2 emission reduction as achieved by the combination of micro hybridisation and mild BIW light-weighting. The alternative targets therefore can be considered to provide a significantly stronger stimulus for innovation in the LCV market, compared to the current 147 g/km target, without demanding application of very advanced technologies.

8 Conclusions

8.1 LCV CO_2 reduction between 2007 and 2010

In [TNO 2012a] a significant decrease was identified between the 2007 and 2010 average type approval CO_2 emissions of LCVs, i.e. from 203 g/km to 181 g/km. Part of this unexpectedly high reduction is caused by possible errors in the estimation of missing CO_2 data in the 2007 database. However, this factor (of which the impact could not be quantified) is not the only contributor to the decrease. Based on assessment of other causes, it is also found not to be dominant factor. A major and certain contribution comes from the shift in sales towards smaller vehicles (approximately 8.5 g/km). The impact of mass change within segments is also quite certain (2.0 g/km). The quantified potential impact of the increased utilisation of test procedure flexibilities is more uncertain, but a finite contribution of this cause is considered likely based on the evidence gathered in [TNO 2012b]. The gap between the observed reduction and the sum of the quantified causes is 4 g/km. A reduction of this order of magnitude can be considered quite reasonable for the application of technological improvements over a 3 year period, especially as some level of cross-over of CO_2 reducing technologies from passenger cars may be expected in Class I and II vehicles.

8.2 Equivalent targets for passenger cars and LCVs in 2020

In [TNO 2012a] the importance was stressed for equivalent targets for passenger cars and LCVs. Equivalency of targets was defined as equal marginal costs to achieve the passenger car and LCV targets. It was concluded that a 113 g/km target for LCVs would be equivalent to the 95 g/km target for passenger cars, based on the Basic cost curves (explained in Annex A).

For the impact assessment of the 95 g/km target for passenger cars, the European Commissions applied Scenario a) cost curves, rather than these Basic cost curves. Applying these Scenario a) cost curves for passenger cars, that are methodologically closest to the LCV cost curves, the equivalent LCV target would become 118 g/km rather than 113 g/km. In other words, the lower the (marginal) additional manufacturer costs for passenger cars, the higher the equivalent LCV target. Besides the marginal costs, also the absolute additional manufacturer costs for achieving the 95 g/km target as well as the resulting relative price increases are significantly higher than for the 147 g/km LCV target. Assuming the Scenario a) cost curves to the applicable, it can be concluded that the 147 g/km for LCVs is less challenging than the 95 g/km target for passenger cars in 2020.

8.3 Effects of alternative 2020 LCV targets on the end user and society

Reducing CO_2 emissions of LCVs leads to increased purchase costs and reduced fuel costs per km. For an oil price of 95 $/barrel (close to the current oil price) and a LCV target of 118 g/km, the break-even period is approximately 2.8 years for end users. Even in a scenario, with an oil price that will not increase from now on (95 $/barrel) and a low LCV target of 105 g/km, the break even period for the end user is expected to be just over 3.5 years. This is expected to be well within the period of the first owner.

Also from a societal perspective, the lifetime fuel cost savings (excluding all taxes) outweigh the additional investment resulting from a 2020 target of 118 or 110 g/km. This results in negative GHG abatement costs for society.

The CO_2 emissions reduced in the lifetime of the average LCV are linearly related to the stringency of the target. The annually reduced amount of CO_2 is approximately 2.7 megatonnes and 3.5 megatonnes for respectively a 118 g/km target and a 110 g/km target (equivalent to a 80 g/km target for passenger cars), relative to a 147 g/km target in 2020.

8.4 Potential leakage resulting from different limit functions for passenger cars and LCVs

Vehicles are type approved as passenger cars (M1 category) or as LCVs (N1 category. This categorisation is leading for determining the manufacturer's average CO_2 emissions for M1 and N1 vehicles. Various vehicle models are produced in M1 and N1 variants. When an N1 vehicle is registered by a national registration authority, it may be registered as a passenger car or as a commercial vehicle, resulting in different tax regimes in many European countries. Because of restrictions in the recently introduced Directive 2007/46 (Annex I), it is not likely that vehicles designed as passenger cars will be type approved as N1 vehicles.

The manufacturer's average CO_2 emissions for M1 and N1 vehicles have to meet certain targets in 2020. The target levels depend on the manufacturer's average mass of M1 and N1 vehicles. For a given average vehicle mass, the target for M1 vehicles is significantly stricter than for N1 vehicles. It could therefore be beneficial for manufacturers to sell a vehicle type approved as N1 for use as passenger car. The additional manufacturer costs are approximately € 5150 lower if an N1 type approved vehicle is sold as passenger car rather than an M1 equivalent. The retail price benefit for the end user is even higher (€ 6360).

If national registration authorities would allow the use of N1 type approved vehicles as passenger cars (with buyers accepting a limited number of seats), "CO_2 leakage" may occur. Per pro cent of M1 vehicles shifted to N1 this could be approximately 125 ktonnes of CO_2.

8.5 Potential rebound effects resulting from the LCV CO_2 target

The expected rebound effect of the reduction of the fuel costs as a result of reducing average LCV CO_2 emissions from 175 g/km to the 147 g/km target is roughly 1 - 2% on the total vehicle kilometres driven. In terms of fuel consumption per kilometre the rebound effect is roughly estimated at 1.7 - 3%. If these rebound effects are taken into account, the impact of the targets on the fuel consumption is estimated at ca. 13.6% to 14.6% (assuming a 2017 baseline vehicle) instead of 16% (= 1-147/175).

8.6 Technologies likely to be applied for achieving various alternative LCV CO_2 targets

For meeting the 147 g/km target for LCVs in 2020, manufacturers are likely to apply only technologies that are currently already being applied in passenger cars on a significant scale, i.e. mild downsizing, (major) aerodynamics improvements and significant reduction of the driveline friction. This 147 g/km target is therefore not likely to stimulate innovation in LCVs.

For the analysed 118 g/km and 110 g/km targets, the additional key technologies expected to be applied compared to the 147 g/km target are micro hybridisation (start-stop systems) and mild BIW light-weighting. The former technology is currently already being applied in passenger cars on a relatively large scale.

The alternative targets therefore can be considered to provide a significantly stronger stimulus for innovation in the LCV market, compared to the current 147 g/km target, without demanding application of very advanced technologies.

9 Literature

[AEA 2009]	Assessment of options for the legislation of CO_2 emissions from light commercial vehicles, carried out by CE Delft, TNO, Öko-Institut and AEA on behalf of the European Commission (DG ENV, framework contract nr. ENV C.5/FRA/2006/0071, Service Request no.: ENV C5/GK/ak/D(2007)17850, Contract no.: 070307/2007/485408/FRA/C3) in 2008-09 http://ec.europa.eu/clima/events/0019/final_report_lcv_co2_250209_en.pdf
[CE Delft 2009]	Milieudifferentiatie van de kilometerprijs voor vrachtauto's, bestelauto's en autobussen, Delft, 2009
[Ecorys 2007]	Effecten vormgeving kilometer-prijs bij variabilisatie van BPM, MRB en Eurovignet, Rotterdam, 2007
[PBL and CE Delft, 2010]	Effecten van prijsbeleid in verkeer en vervoer, Bilthoven/Delft, 2010
[Significance and Delft, 2010]	Price sensitivity of European road freight CE transport - Towards a better understanding of existing results, Den Haag/Delft, 2010
[TNO 2006]	Service Contract to review and analyse the reduction potential and costs of technological and other measures to reduce CO_2 emissions from passenger cars, carried out by TNO, IEEP and LAT on behalf of the European Commission (DG Enterprise, contract nr. SI2.408212) in 2006. http://ec.europa.eu/clima/policies/transport/vehicles/docs/report_co2_reduction_en.pdf
[TNO 2011]	Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars, Service request #1 for Framework Contract on Vehicle Emissions, Final Report, Framework Contract No ENV.C.3./FRA/2009/0043, Delft, November 25, 2011 http://ec.europa.eu/clima/policies/transport/vehicles/cars/docs/study_car_2011_en.pdf
[TNO 2012a]	Support for the revision of regulation on CO2 emissions from light commercial vehicles, Service request #3 for Framework Contract on Vehicle Emissions, Final Report, Framework Contract No ENV.C.3./FRA/2009/0043, Delft, April 26, 2012 http://ec.europa.eu/clima/policies/transport/vehicles/vans/docs/report_co2_lcv_en.pdf

[TNO 2012b]	Supporting Analysis regarding Test Procedure Flexibilities and Technology Deployment for Review of the Light Duty Vehicle CO_2 Regulations, Service request #6 for Framework Contract on Vehicle Emissions, Final Report, Framework Contract No ENV.C.3./FRA/2009/0043, To be published in 2012

10 Signature

Delft, 4 October 2012

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A Alternative cost curves for passengers cars

The information in this annex is taken from [TNO 2012a] for clarification.

Creation of cost curves for passenger cars in 2020

Starting point for the creation of cost curves, describing the additional manufacturer costs for achieving increasing levels of CO_2 reduction in different vehicle segments, was the collection of information on cost and reduction potentials of individual CO_2 reducing technologies. These technologies include various measures to improve engine efficiency, such as reduced friction, direct injection, various levels of engine downsizing and variable valve timing and actuation. In addition options for more efficient transmissions are included, as well as engine start-stop and various degrees of hybridisation, weight reduction, improved aerodynamics, low rolling resistance tyres, and improvements in ancillary systems and auxiliaries. Costs and reduction potentials are defined relative to 2002 baseline vehicles. The year 2002 was selected as baseline year because none of these technologies were applied at any significant scale yet in that year. The cost assessment model contains 2002 data for all manufacturers included in the analysis.

Data were collected from literature, in-house expertise and through questionnaires sent out to manufacturers and component suppliers as well as their European associations. Based on an evaluation of the different inputs, technology tables were constructed with selected values for costs and reduction potentials of different technologies, specified separately for six vehicle segments (small, medium-size and large vehicles on petrol resp. diesel).

Subsequently, by combining options that are technically compatible into packages of measures, a large number of possible technology packages were identified, each with a different overall CO_2 reduction potential and different overall costs. Cost curves can then be created by consecutively selecting the most cost-effective packages that enable increasing levels of CO_2 reduction. In drawing the cost curves a “safety margin” is taken into account to correct for the fact that simply combining the CO_2 reduction potentials of individual measures will often lead to overestimation of the overall CO_2 reduction potential of the complete package. This is because some measures partly overlap in their impact as they have an effect on the same source of energy loss.

Scenario variants for the cost curves

In the course of the study two issues arose that justified critical evaluation of the cost curves as generated using the methodology described above. These issues are:

- Observed progress in CO_2 reduction in European new passenger car fleet in the 2002-2009 period
    - In the last decade CO_2 emissions of new passenger cars have decreased significantly. At the same time vehicle prices have not increased. This could be interpreted as an indication that part of the observed reductions in type approval CO_2 emissions over the last years may need to be attributed to other causes than application of technologies that are included in the cost curves used to assess the costs of meeting the targets for 2015 and 2020.
    - These other causes may include CO_2 reduction due to small technical improvements that are not mentioned in technical specifications of vehicles and are not included in the cost curves developed in this project and previous studies, effects of optimising the powertrain

calibration by improving trade-offs against other parameters, and the possible utilization of flexibilities in the test procedure.

- Technical data becoming available from EPA studies in support of the US legislation on CO_2 emissions from light duty vehicles
  - These data seem to suggest that the costs of reducing CO_2 emissions in passenger cars could be lower than estimated in this study.

In the context of this study, and given the limited availability of necessary information, both issues could not be dealt with in detail. In order to obtain an indicative insight in the possible implication of these issues, however, it has been considered useful to develop indicative cost curves for three different scenario variants that can be used to perform a sensitivity analysis with the cost assessment model. The scenario variants are:

a) Alternative accounting for progress observed in the 2002-2009 period

- A variant including an additional reduction step based on the assumption that a given share of the reductions achieved in the 2002-2009 period cannot be attributed to application of technologies that are included in the technology tables underlying the cost curves.
- The assessment model used in this study is based on cost curves defined relative to 2002 baseline vehicles and attributes reductions in CO_2 emissions observed between 2002 and 2009 (most recent database used to describe the current situation) to the use of a part of the reduction potential described by the cost curves. Due to the strong non-linearity of the cost curves the possibility that other causes may be responsible for the observed reductions between 2002 and 2009 could have a significant impact on the assessment of cost for moving from the 2009 values to the 2020 target values.
- For the size of the additional reduction step 10% was assumed for petrol vehicles and 9% for diesels. These values were estimated on the basis of a detailed comparison of 12 vehicle models sold in 2002 and 2010 and identification of the headline CO_2-reducing technologies used in the 2010 vehicles.

b) Alternative cost curves based on a modified technology table

- An evaluation of available results from the EPA studies in support of the US CO_2 target for passenger cars provided strong indications that the costs for meeting the European 95 g/km target for 2020 could be lower than the estimates based on the cost curves from this study. Due to large differences in technology definitions, baseline vehicles and drive cycles, however, the direct use of EPA data for the European assessment was considered not appropriate.
- To test the possible impact of the most striking differences between US data and cost and reduction figures used in this study a selection of data on cost and reduction potential derived from the EPA studies, specifically for full hybrids and the various levels of weight reduction, has been used to construct a modified technology table. Alternative cost curves have been constructed on the basis of this table.
- This variant is created to allow an indicative assessment of the possible implications that information from EPA studies underlying the US CO_2 legislation for cars might have for assessment of the costs of meeting the European target for 2020.

c) Combination of a) and b

B Resulting tables for determining societal abatement costs and break-even period

The tables in this annex show the characteristics of the calculations regarding the abatement costs and break even period. Tables are provided for various oil prices (95, 100, 105, 110, 115, 120, 125 and 130 $/barrel) relative to the situation in 2010 (181 g/km) and relative to the situation in 2017 (175 g/km). The resulting figures are presented in section 4.3.

Finally, this annex also includes a visual representation of the break-even period and societal abatement costs relative to 175 g/km.

Characteristics relative to 2010

Table 23 End user TCO results and societal abatement costs for various LCV targets at an oil price of 95 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
	Annual fuel savings [€ per g/km]	8	8	8	8	8	8	8	8	8	8	8	8	8
	NPV of lifetime fuel savings [€ per g/km]	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5
	Lifetime fuel cost savings [€]	6315	6148	5981	5914	5730	5563	5396	5262	5062	4644	4227	3809	2807
	Abatement costs [€/tonne CO_2]	-108	-120	-129	-132	-139	-144	-148	-150	-154	-160	-177	-171	-184
End user	Diesel price (ex VAT) [€/l]	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
	Annual fuel savings [€ per g/km]	13	13	13	13	13	13	13	13	13	13	13	13	13
	NPV of lifetime fuel savings [€]	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
	Lifetime fuel cost savings [€]	7825	7618	7411	7328	7100	6893	6686	6521	6272	5755	5237	4720	3478
	End user break even period [years]	4.6	4.1	3.7	3.6	3.3	3.1	2.9	2.8	2.7	2.4	1.8	2.0	1.5

Table 24 End user TCO results and societal abatement costs for various LCV targets at an oil price of 100 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
	Annual fuel savings [€ per g/km]	9	9	9	9	9	9	9	9	9	9	9	9	9
	NPV of lifetime fuel savings [€ per g/km]	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0
	Lifetime fuel cost savings [€]	6656	6480	6304	6233	6039	5863	5687	5546	5335	4895	4455	4015	2958
	Abatement costs [€/tonne CO2]	-120	-132	-141	-144	-151	-156	-160	-163	-166	-172	-189	-184	-197
End user	Diesel price (ex VAT) [€/l]	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	Annual fuel savings [€ per g/km]	14	14	14	14	14	14	14	14	14	14	14	14	14
	NPV of lifetime fuel savings [€]	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1
	Lifetime fuel cost savings [€]	8095	7881	7666	7581	7345	7131	6917	6746	6489	5953	5418	4883	3598
	End user break even period [years]	4.4	3.9	3.6	3.4	3.2	3.0	2.8	2.7	2.6	2.3	1.7	1.9	1.5

Table 25 End user TCO results and societal abatement costs for various LCV targets at an oil price of 105 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
	Annual fuel savings [€ per g/km]	9	9	9	9	9	9	9	9	9	9	9	9	9
	NPV of lifetime fuel savings [€ per g/km]	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5
	Lifetime fuel cost savings [€]	6997	6811	6626	6552	6349	6164	5979	5830	5608	5146	4683	4220	3110
	Abatement costs [€/tonne CO2]	-133	-144	-153	-156	-163	-168	-172	-175	-179	-185	-202	-196	-209
End user	Diesel price (ex VAT) [€/l]	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
	Annual fuel savings [€ per g/km]	14	14	14	14	14	14	14	14	14	14	14	14	14
	NPV of lifetime fuel savings [€]	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6
	Lifetime fuel cost savings [€]	8365	8143	7922	7833	7590	7369	7147	6970	6705	6152	5598	5045	3718
	End user break even period [years]	4.3	3.8	3.4	3.3	3.0	2.9	2.7	2.6	2.5	2.3	1.7	1.9	1.4

Table 26 End user TCO results and societal abatement costs for various LCV targets at an oil price of 110 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Annual fuel savings [€ per g/km]	10	10	10	10	10	10	10	10	10	10	10	10	10
	NPV of lifetime fuel savings [€ per g/km]	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1
	Lifetime fuel cost savings [€]	7337	7143	6949	6872	6658	6464	6270	6115	5882	5396	4911	4426	3261
	Abatement costs [€/tonne CO2]	-145	-157	-166	-169	-176	-181	-185	-188	-191	-197	-214	-208	-221
End user	Diesel price (ex VAT) [€/l]	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
	Annual fuel savings [€ per g/km]	14	14	14	14	14	14	14	14	14	14	14	14	14
	NPV of lifetime fuel savings [€]	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2
	Lifetime fuel cost savings [€]	8634	8406	8177	8086	7835	7606	7378	7195	6921	6350	5779	5208	3837
	End user break even period [years]	4.1	3.7	3.3	3.2	2.9	2.8	2.6	2.5	2.4	2.2	1.6	1.8	1.4

Table 27 End user TCO results and societal abatement costs for various LCV targets at an oil price of 115 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	Annual fuel savings [€ per g/km]	10	10	10	10	10	10	10	10	10	10	10	10	10
	NPV of lifetime fuel savings [€ per g/km]	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6
	Lifetime fuel cost savings [€]	7678	7475	7272	7191	6967	6764	6561	6399	6155	5647	5139	4631	3413
	Abatement costs [€/tonne CO2]	-157	-169	-178	-181	-188	-193	-197	-200	-203	-209	-226	-221	-234
End user	Diesel price (ex VAT) [€/l]	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
	Annual fuel savings [€ per g/km]	15	15	15	15	15	15	15	15	15	15	15	15	15
	NPV of lifetime fuel savings [€]	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8
	Lifetime fuel cost savings [€]	8904	8669	8433	8339	8080	7844	7609	7420	7137	6549	5960	5371	3957
	End user break even period [years]	4.0	3.5	3.2	3.1	2.8	2.7	2.5	2.4	2.3	2.1	1.6	1.7	1.3

Table 28 End user TCO results and societal abatement costs for various LCV targets at an oil price of 120 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
	Annual fuel savings [€ per g/km]	11	11	11	11	11	11	11	11	11	11	11	11	11
	NPV of lifetime fuel savings [€ per g/km]	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1
	Lifetime fuel cost savings [€]	8019	7807	7595	7510	7277	7064	6852	6683	6428	5898	5367	4837	3564
	Abatement costs [€/tonne CO2]	-170	-181	-190	-193	-200	-205	-210	-212	-216	-222	-239	-233	-246
End user	Diesel price (ex VAT) [€/l]	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Annual fuel savings [€ per g/km]	15	15	15	15	15	15	15	15	15	15	15	15	15
	NPV of lifetime fuel savings [€]	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3
	Lifetime fuel cost savings [€]	9174	8931	8688	8591	8324	8082	7839	7645	7354	6747	6140	5533	4077
	End user break even period [years]	3.8	3.4	3.1	3.0	2.7	2.6	2.4	2.3	2.2	2.0	1.5	1.7	1.3

Table 29 End user TCO results and societal abatement costs for various LCV targets at an oil price of 125 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
	Annual fuel savings [€ per g/km]	11	11	11	11	11	11	11	11	11	11	11	11	11
	NPV of lifetime fuel savings [€ per g/km]	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6
	Lifetime fuel cost savings [€]	8360	8139	7918	7829	7586	7365	7144	6967	6701	6148	5595	5043	3716
	Abatement costs [€/tonne CO2]	-182	-194	-203	-206	-213	-218	-222	-225	-228	-234	-251	-245	-258
End user	Diesel price (ex VAT) [€/l]	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	Annual fuel savings [€ per g/km]	16	16	16	16	16	16	16	16	16	16	16	16	16
	NPV of lifetime fuel savings [€]	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9
	Lifetime fuel cost savings [€]	9444	9194	8944	8844	8569	8319	8070	7870	7570	6945	6321	5696	4197
	End user break even period [years]	3.7	3.3	3.0	2.9	2.7	2.5	2.4	2.3	2.2	2.0	1.5	1.6	1.2

Table 30 End user TCO results and societal abatement costs for various LCV targets at an oil price of 130 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3333	2935	2619	2511	2256	2069	1911	1802	1656	1397	958	958	545
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	27.6	26.9	26.1	25.8	25.0	24.3	23.6	23.0	22.1	20.3	18.5	16.6	12.3
Societal	Diesel price (ex all taxes) [€/l]	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
	Annual fuel savings [€ per g/km]	12	12	12	12	12	12	12	12	12	12	12	12	12
	NPV of lifetime fuel savings [€ per g/km]	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1
	Lifetime fuel cost savings [€]	8701	8471	8240	8148	7895	7665	7435	7251	6974	6399	5824	5248	3867
	Abatement costs [€/tonne CO2]	-194	-206	-215	-218	-225	-230	-234	-237	-240	-246	-263	-258	-271
End user	Diesel price (ex VAT) [€/l]	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
	Annual fuel savings [€ per g/km]	16	16	16	16	16	16	16	16	16	16	16	16	16
	NPV of lifetime fuel savings [€]	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5
	Lifetime fuel cost savings [€]	9713	9456	9200	9097	8814	8557	8300	8095	7786	7144	6501	5859	4317
	End user break even period [years]	3.6	3.2	2.9	2.8	2.6	2.4	2.3	2.2	2.1	1.9	1.4	1.6	1.2

Characteristics relative to 175 g/km

Table 31 End user TCO results and societal abatement costs for various LCV targets at an oil price of 95 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
	Annual fuel savings [€ per g/km]	8	8	8	8	8	8	8	8	8	8	8	8	8
	NPV of lifetime fuel savings [€ per g/km]	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5
	Lifetime fuel cost savings [€]	5847	5680	5513	5446	5262	5095	4928	4795	4594	4176	3759	3341	2339
	Abatement costs [€/tonne CO2]	-102	-114	-124	-127	-135	-140	-144	-147	-151	-157	-170	-169	-184
End user	Diesel price (ex VAT) [€/l]	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
	Annual fuel savings [€ per g/km]	13	13	13	13	13	13	13	13	13	13	13	13	13
	NPV of lifetime fuel savings [€]	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5	103.5
	Lifetime fuel cost savings [€]	7245	7038	6831	6748	6521	6314	6107	5941	5693	5175	4658	4140	2898
	End user break even period [years]	5.1	4.5	4.1	3.9	3.6	3.4	3.2	3.1	3.0	2.7	2.0	2.3	1.8

Table 32 End user TCO results and societal abatement costs for various LCV targets at an oil price of 100 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
	Annual fuel savings [€ per g/km]	9	9	9	9	9	9	9	9	9	9	9	9	9
	NPV of lifetime fuel savings [€ per g/km]	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0
	Lifetime fuel cost savings [€]	6163	5987	5811	5740	5546	5370	5194	5053	4842	4402	3962	3522	2465
	Abatement costs [€/tonne CO2]	-114	-127	-136	-139	-147	-152	-157	-159	-163	-169	-183	-182	-197
End user	Diesel price (ex VAT) [€/l]	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	Annual fuel savings [€ per g/km]	14	14	14	14	14	14	14	14	14	14	14	14	14
	NPV of lifetime fuel savings [€]	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1	107.1
	Lifetime fuel cost savings [€]	7495	7281	7067	6981	6746	6531	6317	6146	5889	5354	4818	4283	2998
	End user break even period [years]	4.9	4.3	3.9	3.8	3.5	3.3	3.1	3.0	2.9	2.6	2.0	2.2	1.8

Table 33 End user TCO results and societal abatement costs for various LCV targets at an oil price of 105 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
	Annual fuel savings [€ per g/km]	9	9	9	9	9	9	9	9	9	9	9	9	9
	NPV of lifetime fuel savings [€ per g/km]	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5
	Lifetime fuel cost savings [€]	6478	6293	6108	6034	5830	5645	5460	5312	5090	4627	4165	3702	2591
	Abatement costs [€/tonne CO2]	-127	-139	-149	-152	-159	-165	-169	-172	-175	-182	-195	-194	-209
End user	Diesel price (ex VAT) [€/l]	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
	Annual fuel savings [€ per g/km]	14	14	14	14	14	14	14	14	14	14	14	14	14
	NPV of lifetime fuel savings [€]	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6
	Lifetime fuel cost savings [€]	7745	7524	7302	7214	6970	6749	6528	6351	6085	5532	4979	4426	3098
	End user break even period [years]	4.7	4.2	3.8	3.6	3.3	3.1	3.0	2.9	2.8	2.5	1.9	2.1	1.7

Table 34 End user TCO results and societal abatement costs for various LCV targets at an oil price of 110 $/barrel

	2020 average CO_2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO_2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Annual fuel savings [€ per g/km]	10	10	10	10	10	10	10	10	10	10	10	10	10
	NPV of lifetime fuel savings [€ per g/km]	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1	97.1
	Lifetime fuel cost savings [€]	6794	6600	6406	6328	6115	5920	5726	5571	5338	4853	4368	3882	2718
	Abatement costs [€/tonne CO_2]	-139	-151	-161	-164	-172	-177	-181	-184	-188	-194	-208	-206	-221
End user	Diesel price (ex VAT) [€/l]	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
	Annual fuel savings [€ per g/km]	14	14	14	14	14	14	14	14	14	14	14	14	14
	NPV of lifetime fuel savings [€]	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2	114.2
	Lifetime fuel cost savings [€]	7995	7766	7538	7447	7195	6967	6738	6556	6282	5711	5139	4568	3198
	End user break even period [years]	4.5	4.0	3.6	3.5	3.2	3.0	2.9	2.8	2.7	2.4	1.8	2.1	1.7

Table 35 End user TCO results and societal abatement costs for various LCV targets at an oil price of 115 $/barrel

	2020 average CO_2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO_2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	Annual fuel savings [€ per g/km]	10	10	10	10	10	10	10	10	10	10	10	10	10
	NPV of lifetime fuel savings [€ per g/km]	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6
	Lifetime fuel cost savings [€]	7110	6906	6703	6622	6399	6195	5992	5830	5586	5078	4570	4063	2844
	Abatement costs [€/tonne CO_2]	-151	-164	-173	-176	-184	-189	-194	-196	-200	-207	-220	-219	-234
End user	Diesel price (ex VAT) [€/l]	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
	Annual fuel savings [€ per g/km]	15	15	15	15	15	15	15	15	15	15	15	15	15
	NPV of lifetime fuel savings [€]	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8	117.8
	Lifetime fuel cost savings [€]	8245	8009	7773	7679	7420	7185	6949	6761	6478	5889	5300	4711	3298
	End user break even period [years]	4.3	3.9	3.5	3.4	3.1	2.9	2.8	2.7	2.6	2.4	1.8	2.0	1.6

Table 36 End user TCO results and societal abatement costs for various LCV targets at an oil price of 120 $/barrel

	2020 average CO_2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO_2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
	Annual fuel savings [€ per g/km]	11	11	11	11	11	11	11	11	11	11	11	11	11
	NPV of lifetime fuel savings [€ per g/km]	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1	106.1
	Lifetime fuel cost savings [€]	7425	7213	7001	6916	6683	6470	6258	6089	5834	5304	4773	4243	2970
	Abatement costs [€/tonne CO_2]	-164	-176	-186	-189	-196	-202	-206	-209	-213	-219	-232	-231	-246
End user	Diesel price (ex VAT) [€/l]	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Annual fuel savings [€ per g/km]	15	15	15	15	15	15	15	15	15	15	15	15	15
	NPV of lifetime fuel savings [€]	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3	121.3
	Lifetime fuel cost savings [€]	8494	8252	8009	7912	7645	7402	7160	6965	6674	6067	5461	4854	3398
	End user break even period [years]	4.2	3.7	3.4	3.3	3.0	2.8	2.7	2.6	2.5	2.3	1.7	1.9	1.6

Table 37 End user TCO results and societal abatement costs for various LCV targets at an oil price of 125 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
	Annual fuel savings [€ per g/km]	11	11	11	11	11	11	11	11	11	11	11	11	11
	NPV of lifetime fuel savings [€ per g/km]	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6	110.6
	Lifetime fuel cost savings [€]	7741	7520	7298	7210	6967	6745	6524	6347	6082	5529	4976	4423	3096
	Abatement costs [€/tonne CO2]	-176	-188	-198	-201	-209	-214	-218	-221	-225	-231	-245	-243	-258
End user	Diesel price (ex VAT) [€/l]	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	Annual fuel savings [€ per g/km]	16	16	16	16	16	16	16	16	16	16	16	16	16
	NPV of lifetime fuel savings [€]	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9	124.9
	Lifetime fuel cost savings [€]	8744	8494	8244	8145	7870	7620	7370	7170	6870	6246	5621	4997	3498
	End user break even period [years]	4.0	3.6	3.3	3.2	2.9	2.7	2.6	2.5	2.4	2.2	1.7	1.9	1.5

Table 38 End user TCO results and societal abatement costs for various LCV targets at an oil price of 130 $/barrel

	2020 average CO2 emissions [g/km]	105.0	107.0	109.0	109.8	112.0	114.0	116.0	117.6	120.0	125.0	130.0	135.0	147.0
	Investment [€]	3244	2846	2530	2422	2167	1980	1822	1713	1567	1308	958	869	456
	Average 2020 sales price [€]	23828	23387	23035	22915	22633	22425	22250	22128	21967	21679	21192	21192	20734
	Lifetime reduced CO2 [tonnes]	25.6	24.8	24.1	23.8	23.0	22.3	21.5	21.0	20.1	18.3	16.4	14.6	10.2
Societal	Diesel price (ex all taxes) [€/l]	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
	Annual fuel savings [€ per g/km]	12	12	12	12	12	12	12	12	12	12	12	12	12
	NPV of lifetime fuel savings [€ per g/km]	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1	115.1
	Lifetime fuel cost savings [€]	8056	7826	7596	7504	7251	7021	6790	6606	6330	5755	5179	4604	3223
	Abatement costs [€/tonne CO2]	-188	-201	-210	-214	-221	-226	-231	-234	-237	-244	-257	-256	-271
End user	Diesel price (ex VAT) [€/l]	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
	Annual fuel savings [€ per g/km]	16	16	16	16	16	16	16	16	16	16	16	16	16
	NPV of lifetime fuel savings [€]	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5	128.5
	Lifetime fuel cost savings [€]	8994	8737	8480	8377	8095	7838	7581	7375	7067	6424	5782	5139	3598
	End user break even period [years]	3.9	3.5	3.2	3.1	2.8	2.7	2.5	2.4	2.3	2.2	1.6	1.8	1.5

Visual representation of the break-even period and societal abatement costs relative to 175 g/km

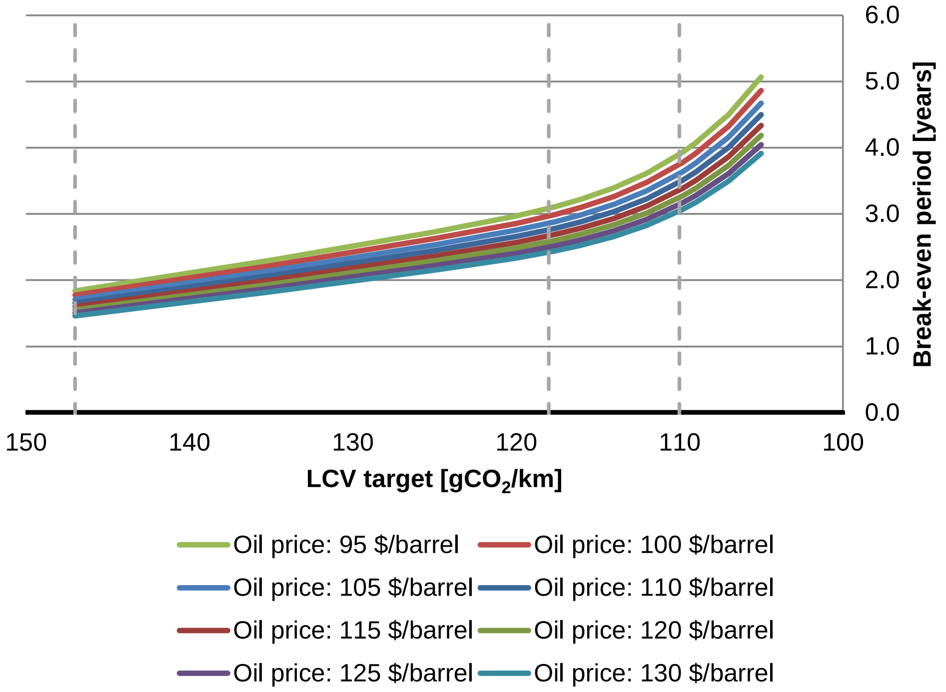

Figure 18 Break-even period for the end user in relation to the LCV target for various oil prices relative to 175 g/km

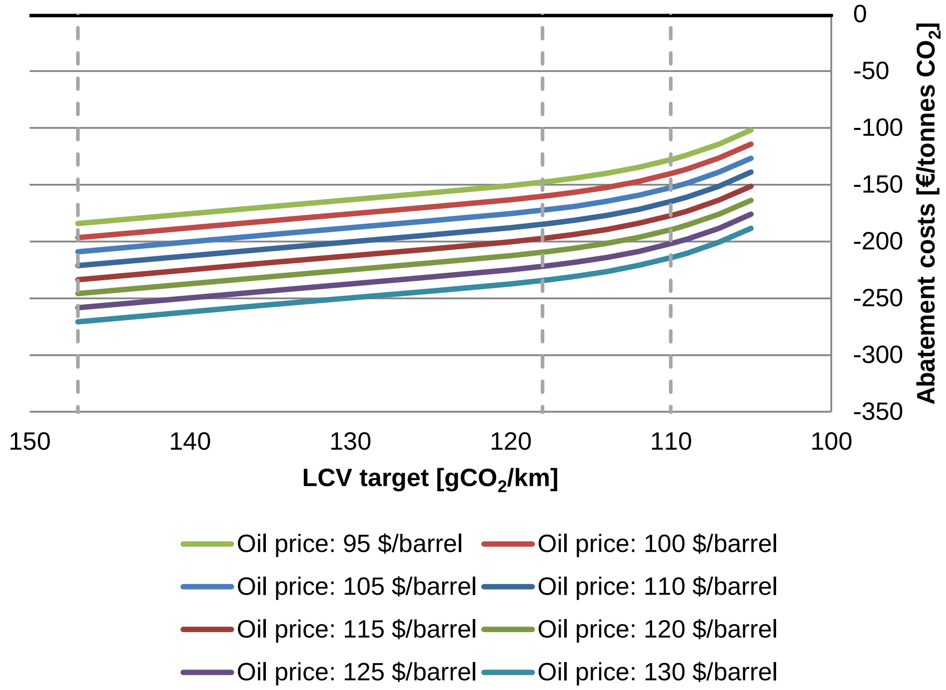

Figure 19 Societal abatement costs in relation to the LCV target for various oil prices relative to 175 g/km

C Overviews of the technology packages including certain key technologies

Downsizing

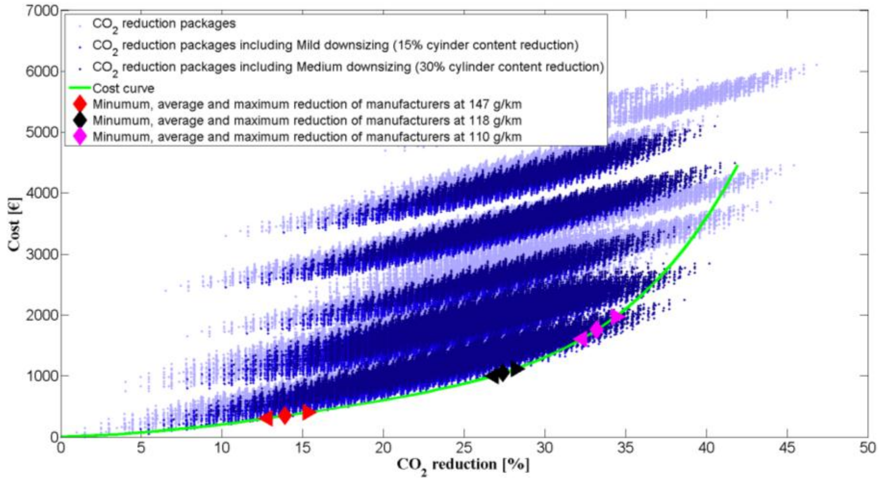

Figure 20 Overview of downsizing levels for class I LCVs likely to be applied at various targets

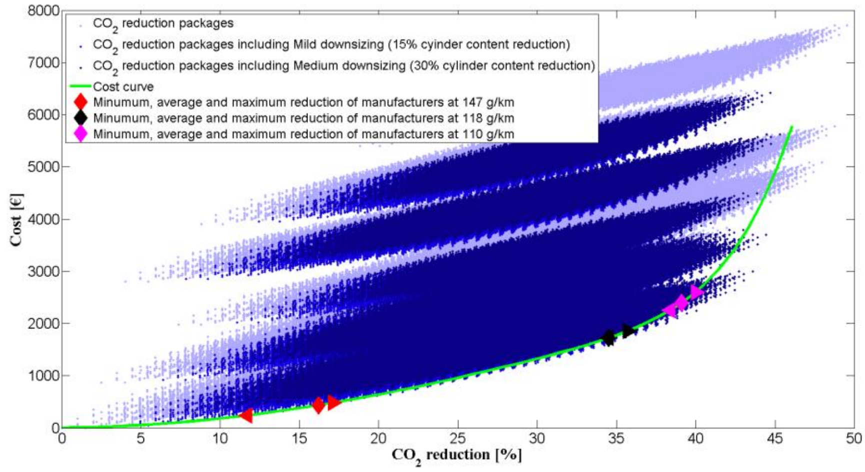

Figure 21 Overview of downsizing levels for class II LCVs likely to be applied at various targets

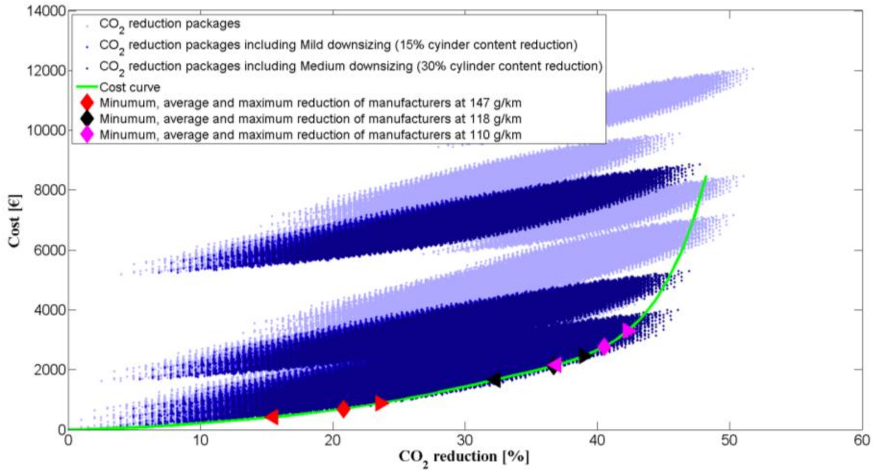

Figure 22 Overview of downsizing levels for class III LCVs likely to be applied at various targets

Hybridisation

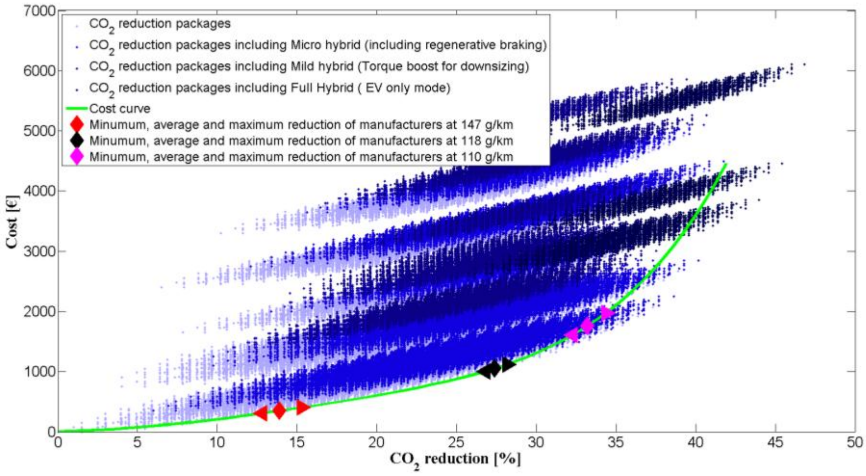

Figure 23 Overview of hybridisation levels for class I LCVs likely to be applied at various targets

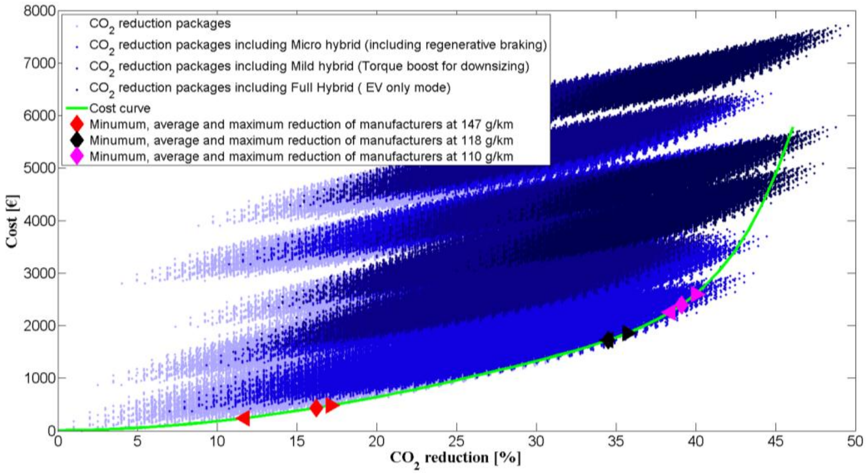

Figure 24 Overview of hybridisation levels for class II LCVs likely to be applied at various targets

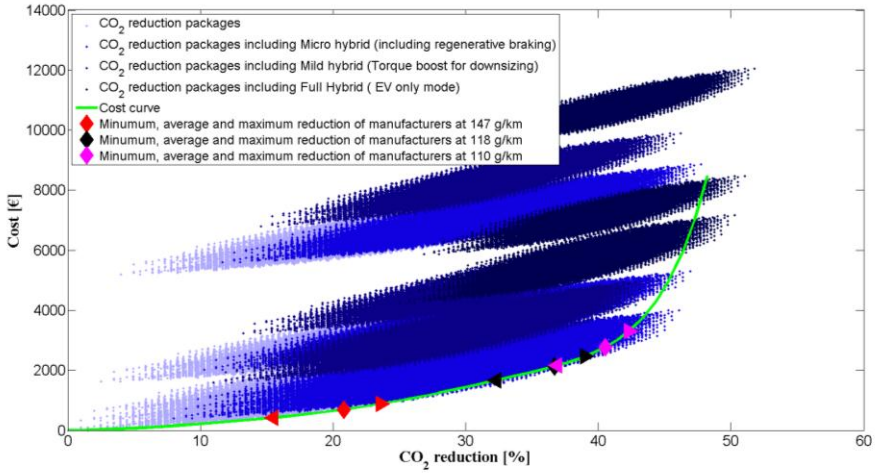

Figure 25 Overview of hybridisation levels for class III LCVs likely to be applied at various targets

Lightweighting

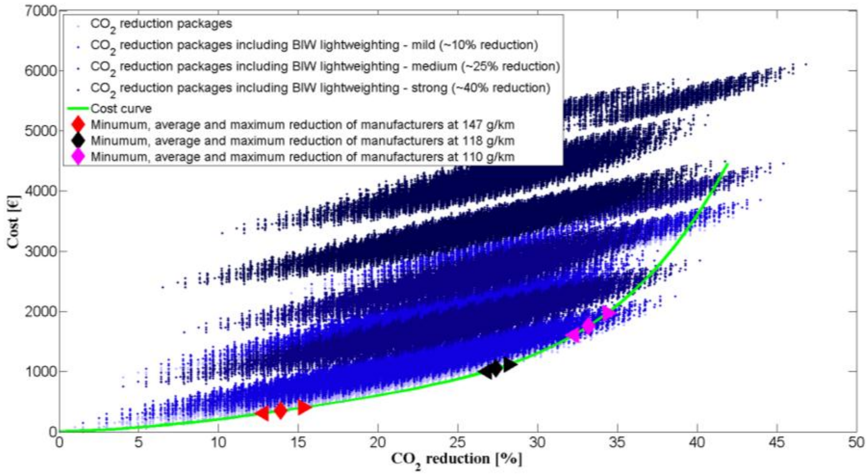

Figure 26 Overview of lightweighting levels for class I LCVs likely to be applied at various targets

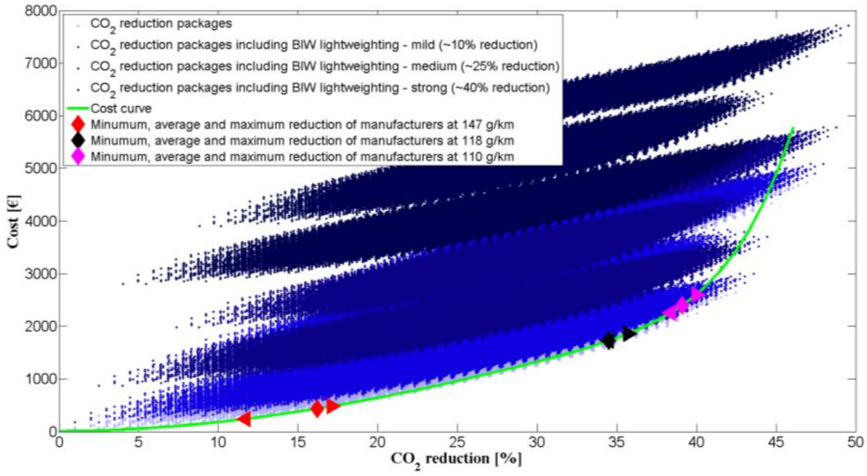

Figure 27 Overview of lightweighting levels for class II LCVs likely to be applied at various targets

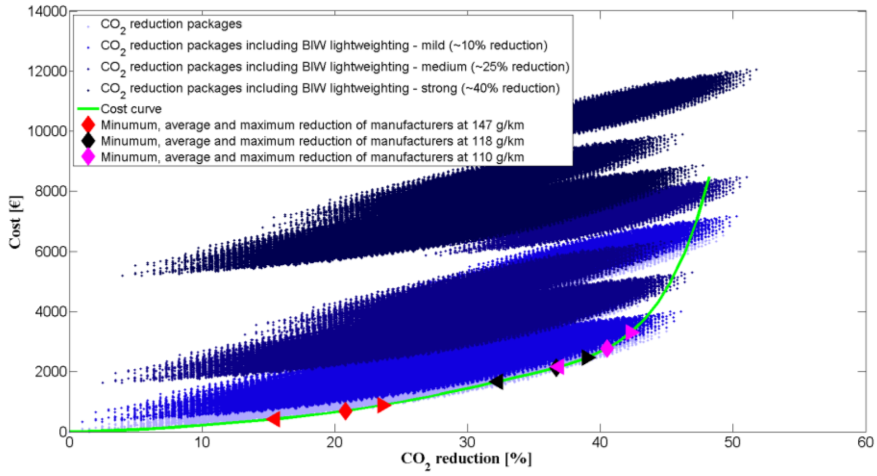

Figure 28 Overview of lightweighting levels for class III LCVs likely to be applied at various targets

Reducing driveline friction

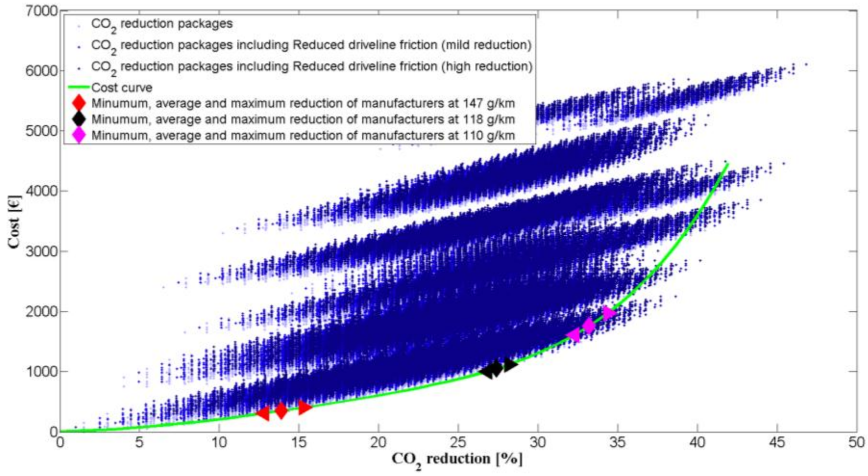

Figure 29 Overview of reducing driveline friction levels for class I LCVs likely to be applied at various targets

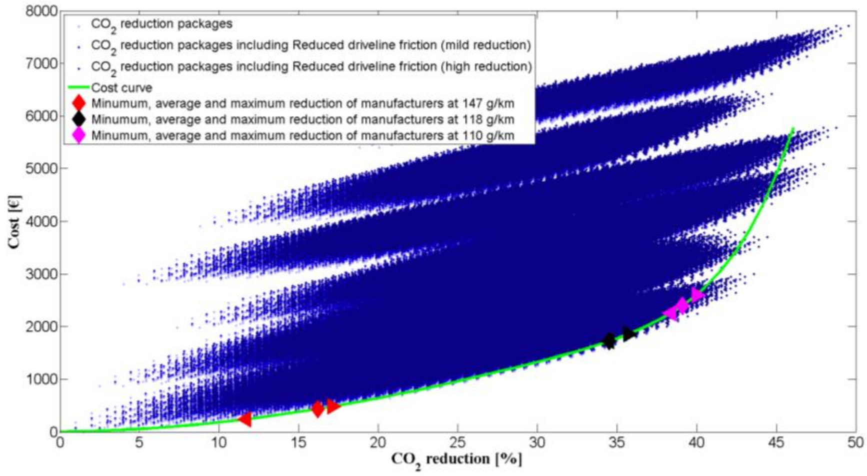

Figure 30 Overview of reducing driveline friction levels for classI I LCVs likely to be applied at various targets

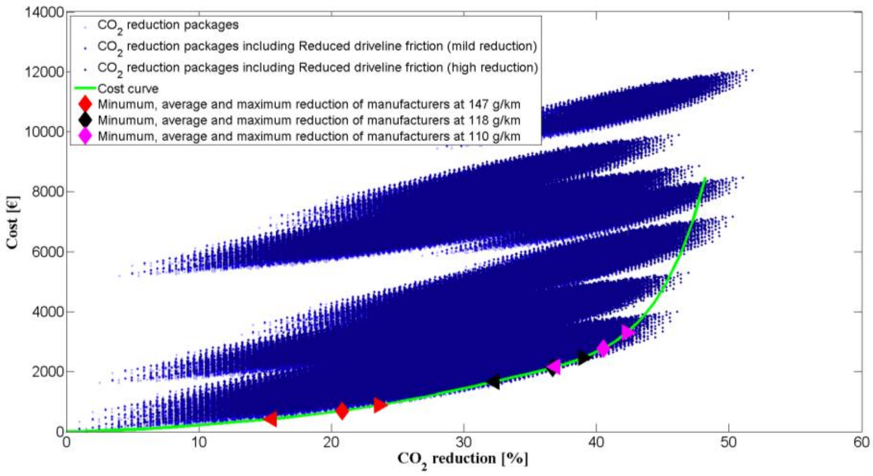

Figure 31 Overview of reducing driveline friction levels for classII I LCVs likely to be applied at various targets

Improving aerodynamics

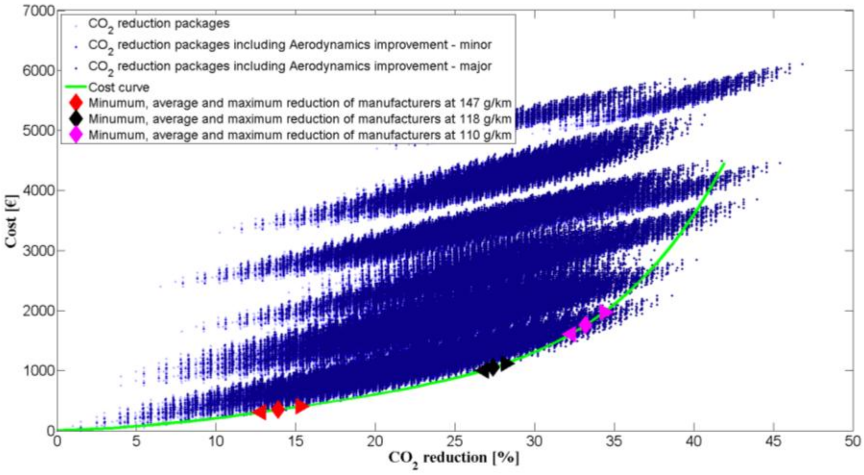

Figure 32 Overview of aerodynamics improvement levels for class I LCVs likely to be applied at various targets

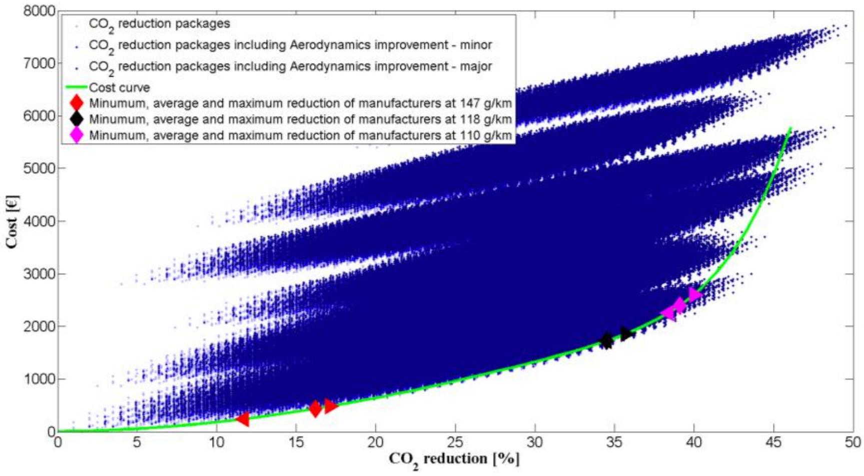

Figure 33 Overview of aerodynamics improvement levels for class II LCVs likely to be applied at various targets

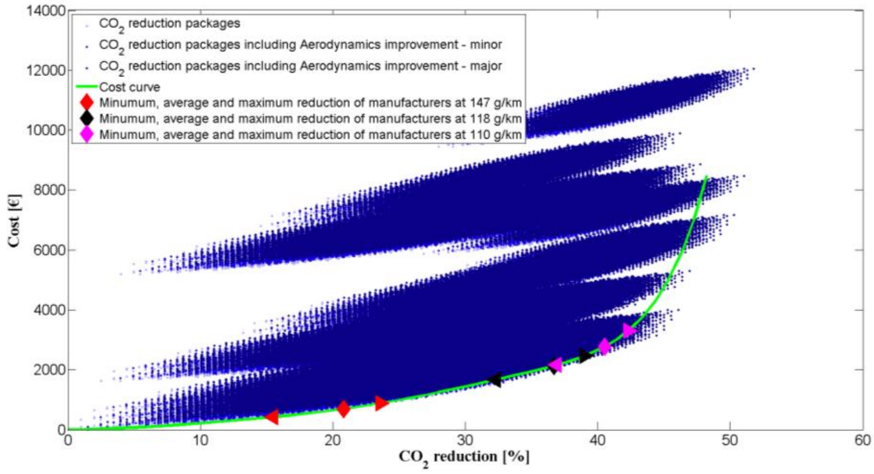

Figure 34 Overview of aerodynamics improvement levels for class III LCVs likely to be applied at various targets