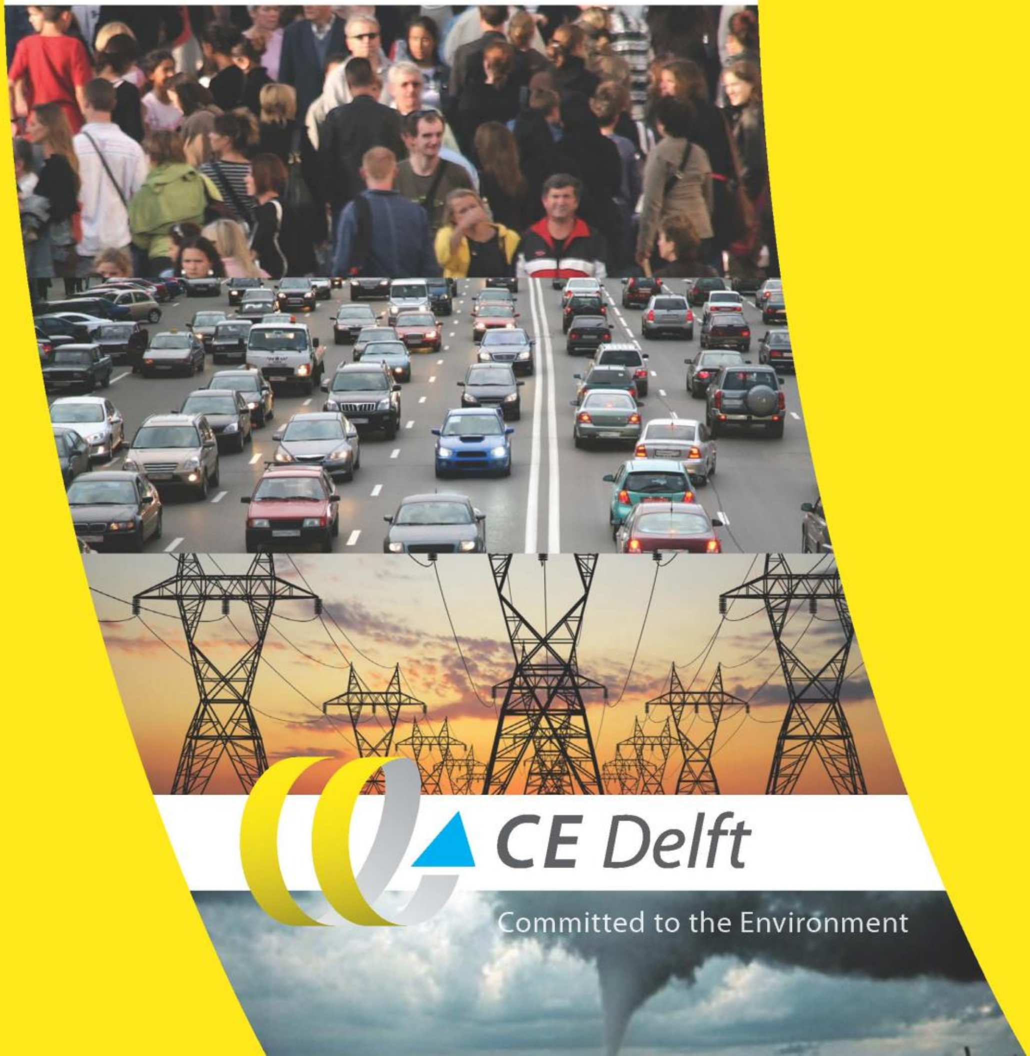
Assessment of the Modalities for LDV CO_2 Regulations beyond 2020



CE Delft

Committed to the Environment

Assessment of the Modalities for LDV CO_2 Regulations beyond 2020

This report is prepared by:

Huib van Essen (CE Delft), Maarten Verbeek (TNO), Sanne Aarnink (CE Delft), Richard Smokers (TNO)
Delft, CE Delft, January 2017

Publication code: 17.4D44.02

Vehicles / Emissions / Reductions / EC / Policy measures / Regulation / Future / Impacts / Evaluation

Client: European Commission, DG CLIMA.

CE publications are available from www.cedelft.eu

Further information on this study can be obtained from the contact person, Huib van Essen.

CE Delft
Committed to the Environment

Through its independent research and consultancy work CE Delft is helping build a sustainable world. In the fields of energy, transport and resources our expertise is leading-edge. With our wealth of know-how on technologies, policies and economic issues we support government agencies, NGOs and industries in pursuit of structural change. For 35 years now, the skills and enthusiasm of CE Delft's staff have been devoted to achieving this mission.

Contents

Summary

Background, scope, objective and approach

The CO_2 regulation for Light Duty Vehicles (LDVs, i.e. cars and vans) is one of the main pillars of the EU climate policy for transport. Binding CO_2 emission targets for newly sold vehicles have been set by Regulations (EC) 443/2009 for passenger cars (EC, 2009) and (EC) 510/2011 for vans (EC, 2011). The target set for passenger cars is 95 g/km to be met in 2021 and for vans 147 g/km to be met in 2020. Both are defined in terms of fleet wide average Tank to wheel CO_2 emissions on the NEDC type approval test.

Both Regulations should contribute to the overall GHG emission reduction goals of the EU, in particular the 60% reduction of transport's GHG emissions in 2050 compared to 1990 and the 30% GHG emissions reduction for the non-ETS sectors in 2030 relative to 2005.

The Regulations require the Commission to review the emission targets and the modalities, including whether a utility parameter is still needed and whether mass or footprint is the more sustainable utility parameter, in order to establish the CO_2 emissions targets for the period beyond 2020, taking into account the long term climate objectives. To explore the design of the post-2020 CO_2 regulations for LDVs, the Commission has tasked a consortium of CE Delft, TNO and Cambridge Econometrics, supported by Transport and Mobility Leuven to carry out this study.

The overall objective of this study is to evaluate and compare the impacts of different possible design options for the cars and vans CO_2 regulations beyond 2020.

More specifically, the objectives of the study are:

1. To assess what level of ambition for the post-2020 regulation would be needed for meeting the overall climate goals.
2. To identify objectives and key design options ('modalities') for the regulation and how they link to each other.
3. To assess the pros and cons of these various modalities.
4. To carry out a detailed assessment of the impacts of combinations of modalities.
5. To evaluate a short list of policy variants on various criteria.
6. To assess stakeholders' views on the post-2020 regulation.

The research questions have been answered by carrying out an extensive literature review, a stakeholder survey, and quantitative assessments by running various models, complemented by qualitative assessments.

Conclusions on the objectives and key design options (modalities)

The main objective of the CO_2 regulations for cars and vans is to contribute to the reduction of GHG emissions in order to mitigate climate change.
The specific objective is to reduce the CO_2 emissions and energy consumption of new light duty vehicles.

For the design of these regulations, the following main design choices (printed bold) and associated modalities have been considered:

A. What is the scope of the Regulation?
- A1 Regulated vehicle categories.
- A2 Regulated entities.
- A3 Metric.
- A4 Embedded emissions.

B. How to measure the parameters needed for determining the overall performance?
- B1 Measuring TTW vehicle parameter(s).
- B2 Determining WTT parameters.
- B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal.

C. How to determine the overall performance?
- C1 Rewarding off-cycle reductions.
- C2 Rewarding or penalising technologies.
- C3 Aggregation & weighting.

D. Approach for target setting[1]
- D1 Approach for target setting.

E. How to fairly distribute the burden across regulated entities?
- E1 Utility parameter.
- E2 Shape and slope of target function.

F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?
- F1 Pooling.
- F2 Trading CO_2 credits.
- F3 Banking/borrowing.
- F4 Excess emission premiums.
- F5 Derogations.
- F6 Correction for autonomous utility change.

The pros and cons of all modalities were evaluated qualitatively including considerations on feasibility, contribution to the overall objectives of the regulation and inter-dependencies with other modalities.

Furthermore, many modalities were assessed quantitatively on their impacts for 2025 and 2030 on WTW CO_2 emissions (as a measure of the effectiveness), cost for manufacturers, end-users and society as a whole and competitiveness of EU automotive industry. This quantitative assessment was done by running TNO's cost assessment model. using the cost curves obtained from (Ricardo-AEA, 2016) and the Commission's DG JRC. The model calculates for each policy variant the lowest cost for each manufacturer to meet the target. The model was run for three different target levels that are based on 3, 4 and 6% annual emission reduction between 2020 (vans) or 2021 (cars) and 2025/2030. This was done (for both cars and vans) for all combinations of the modalities listed in Table 1, and for five different technology scenarios. All together 9,600 policy variants were assessed. The five technology scenarios each have fixed shares of the various alternative powertrain technologies (BEV, PHEV, REEV and FCEV) as described in (Ricardo-AEA, 2016).

In addition to this assessment on a very high number of policy variants, four policy variants have been selected and assessed in more detail on a broader range of impacts. These four variants differ regarding the target level (3 or 6% annual reduction) and the modality values. In two policy variants the modalities are as in the current regulations, while in the other two variants, modalities

[1] Target for one or more fixed years (e.g. 2025 and/or 2030; with/without phase-in) or annually declining targets.

were optimized for societal cost effectiveness (see Table 22 for an overview of the scenarios).

All impacts have been compared to a business as usual (BAU) scenario that assumes unchanged continuation of the existing CO_2 standards beyond 2020/2021as well as the technology scenario with the lowest share of alternative powertrains ('Ultra-efficient-ICEV').

Table 1 Modalities and other variables that were quantitatively assessed with the 'cost assessment model'

Modalities and modality options	
Modality	**Modality options**
A2. Regulated entity	Individual OEM (brand) Manufacturer group
A3. Metric	TTW WTW
C1. Rewarding off-cycle technologies	Excluded Included
C3. Aggregation & weighting	Mileage weighting excluded Mileage weighting included
E1. Utility parameter	Mass Footprint
E2. Limit function slope	5 slopes
Other variables	
Variable	**Variable options**
Target year	2025 2030
Vehicle type	Passenger cars Vans (LCVs)
Target level	3% annual reduction 4% annual reduction 6% annual reduction
Technology scenarios	Mixed xEV Ultra efficient ICEV Extreme BEV Extreme PHEV/REEV Extreme FCEV

Conclusions on effectiveness

The runs with the cost assessment model show that the overall WTW GHG emission reduction achieved (compared to BAU) mainly depends on the emission target level. For the three target levels assessed (based on an annual emission reduction between 2020/2021 and 2030 of 3, 4 and 6%, respectively), the vehicle life-time emission reduction of all new cars sold in 2025 is 25 to 50 Mton, while for all new cars sold in 2030, this is 50 to 100 Mton. For vans, the emission reductions are 5 to 11 Mton for vehicles sold in 2025 and 8 to 17 Mton for vehicles sold in 2030. The reductions for the policy variants with the weakest targets are at the lower-end of these ranges, while reductions in the policy variants with the strictest target levels are at the higher-end.

Apart from the target level, the emission reduction achieved is somewhat affected by the technology scenario (future fleet composition). On average, the scenarios with the highest share of BEVs show the largest emission reduction, but the differences with the other technology scenarios are not so large (less than 10%). Furthermore, changing the utility parameter from mass to footprint

and incentivising the uptake of off-cycle technologies both slightly (less than 10%) increase the effectiveness. Changing the other modalities has no significant impact on the effectiveness.
The MOVEET model runs show that the scenarios considered for passenger cars would reduce the total emissions of passenger transport in the EU in 2030 (compared to BAU) by 7 to 15% (less and most stringent target level, respectively). This modelling takes account of fleet renewal rates and impacts on transport demand and modal split. These reductions will further increase after 2030 when larger shares of the fleet will be affected by the new targets (due to fleet renewal).

Conclusions on cost impacts (for manufacturers, end-users and society)

For the four policy variants assessed in detail, the cost assessment shows net benefits for society - in terms of net societal cost savings over the entire vehicle lifetime, excluding external cost impacts - in all technology scenarios both in 2025 and 2030. As shown in Table 2, the highest societal benefits are found with the most stringent target levels (based on 6% annual emission reduction between 2020/2021 and 2030), both for cars and vans. The societal benefits were found to increase when off-cycle emissions are included and the utility parameter is changed from mass to footprint. The other modalities have relatively small cost impacts.

Table 2 Societal benefits in the four policy variants assessed in detail in 2025 and 2030*

Societal benefits (€/vehicle)		2025	2030
Cars	3% annual reduction	450-600	850-1,100
	6% annual reduction	750-1,000	1,300-1,800
Vans	3% annual reduction	1,000-1,300	1,750-2,050
	6% annual reduction	2,000-2,250	3,250-3,500

* The lower values are for the current design of the regulation, while the higher values are for an alternative design (WTW metric, footprint as utility parameter and with mileage weighting).

With the current choices for modalities of the regulation, the societal benefits of the least stringent target considered (based on 3% annual emission reduction between 2020/2021 and 2030) are almost € 450 for cars sold in 2025 to € 850 for cars sold in 2030. Societal benefits increase to over € 600 in 2025 and € 1,100 in 2030 by choosing an alternative design (a WTW metric, footprint as utility parameter and with mileage weighting). With the most stringent target levels assessed, these benefits are 54 to 77% higher than with the less stringent targets. Also for vans, a more stringent target results in higher net societal benefits, up to € 2,250 in 2025 and almost € 3,500 in 2030 for the policy variants with the alternative design choices.

The societal benefits are the result of the energy cost savings exceeding the increase in manufacturing costs. Table 3 summarizes the additional manufacturing costs for new vehicles sold in 2025 and 2030. The manufacturing costs increase by up to € 1,700 for cars and € 850 for vans (both in 2030 with the most stringent target level and the current design of the regulations).
For each year, the lower cost increases are for the policy variants using alternative choices for modalities; the higher costs for the current design.
For vans a similar pattern was found for the manufacturing costs, but with lower values.

Table 3 **Manufacturing cost increase in the four policy variants assessed in detail in 2025 and 2030***

Additional manufacturing costs (€/vehicle)		2025	2030
Cars	3% annual reduction	250-350	550-750
	6% annual reduction	650-750	1,250-1,700
Vans	3% annual reduction	80-100	200-200
	6% annual reduction	350-450	850-850

* The higher values are for the current design of the regulation, while the lower values are for an alternative design (WTW metric, footprint as utility parameter and with mileage weighting).

The higher manufacturing costs translate in higher vehicle prices for end-users, but these are more than compensated by fuel cost savings. The net cost savings for end-users (including taxes; accounted over the first five years) for the four scenarios assessed in detail are shown in Table 4. For cars, the cost savings found were € 400 to € 900 per car sold in 2025 and € 800 to € 1,700 per car sold in 2030. The lowest values were found for the current the design and the least stringent targets, while the highest values are for the alternative design and the most stringent targets. Also for vans the higher manufacturing cost are more than compensated by energy cost savings over the entire vehicle lifetime, with overall even higher net cost savings for end-users.

Table 4 **Net cost savings for end-users over the first five years of the vehicle lifetime in the four policy variants assessed in detail in 2025 and 2030***

Total net end-user cost savings over first five years of vehicle lifetime (€/vehicle)		2025	2030
Cars	3% annual reduction	400-550	800-1,000
	6% annual reduction	750-900	1,300-1,700
Vans	3% annual reduction	950-1,250	1,600-1,950
	6% annual reduction	1,850-2,100	3,100-3,300

* The lower values are for the current design of the regulation, while the higher values are for an alternative design (WTW metric, footprint as utility parameter and with mileage weighting).

It needs to be emphasized that all cost estimates depend on a broad range of assumptions, and further sensitivity analyses would be useful to test the robustness of the conclusions for different assumptions.

Conclusions on the competitive position of ACEA-members

The competitiveness of ACEA-members (used as a proxy for the European automotive sector, i.e. manufacturers having their R&D and production facilities established within the EU) is affected by the legislation if the average cost impacts for compliance with the legislation are different for them than for other manufacturers.

It was found that the competitive position of the EU automotive sector may be affected to some extent by the choice of some modalities. This is the case for introducing mileage weighting (slightly negative impact in most policy variants), including off-cycle technologies, keeping mass as utility parameter, regulating manufacturer groups instead of brands, a steep target function and a less stringent target (all slightly improving competitive position). However, the differences are generally not large.

Conclusions on the quantitative assessment of selected policy variants

The four selected policy variants for passenger cars have been assessed on various other impacts using four different models. Besides the CO_2 emissions reduction and cost impacts (using TNO's cost assessment model), also the wider impacts on the transport system (using MOVEET), economic impacts (using E3ME) and social equity impacts (using EDIP) were assessed.

The model runs made with MOVEET show that the lower end-user cost due to the regulation results in an increase in passenger car transport vehicle-kilometres of 0.2 to 0.9%. This is partly the result of some modal shift: the total demand for rail, tram and bus transport decreases by 0.5 to 1.3% in 2025 and 1.1 to 2.7% in 2030. The net impact on the total passenger transport demand is small (less than 0.15% increase). The largest impacts were found in the scenarios with the most stringent target level (6% annual reduction).

The E3ME model runs show that in almost all scenarios there is an increase in GDP of up to 0.2%, relative to the BAU in the same year. The highest increase is found in the scenarios with the most stringent target level. In these scenarios, employment increases by up to 0.15%, consumption by up to 0.25% and investments by up to 0.15%.

Impacts on income levels were modelled by EDIP. In all scenarios, the income levels increase in all income groups by 0.25 to 1.3% in 2025 and 0.4 to 1.4% in 2030. In most scenarios, the relative increase is highest in the highest income groups.

To show the impacts on income distribution, also the impact on the Gini coefficient has been modelled. The results show small impacts: the income inequality slightly increases: in all scenarios the Gini coefficient increases by less than 0.2%.

Conclusions on modalities that have been evaluated qualitatively

Regulated entity, pooling and trading

Regulating manufacturer groups has the advantage of providing more options for cost optimization. However, regulating brands in combination with pooling offers manufacturers even a larger degree of flexibility in this respect.
The theoretical maximum reduction in manufacturing costs that can be achieved by pooling are about 1 to 3% for cars and 3 to 8% for vans. However in practice, cost reductions will be lower.

Trading could be an effective alternative, allowing manufacturers to decrease compliance costs without becoming dependent of each other, but has the drawback that it significantly increases the administrative burden of the policy. Furthermore, previous studies showed that the additional cost benefits of trading compared to pooling are very small.

Embedded emissions

Before considering to include embedded emissions in the scope of the Regulations, a first step could be to incentivise the harmonised reporting of those emissions.

A drawback for such reporting is that the administrative burden and complexity is expected to be relatively high, both for OEMs and authorities, as it requires gathering and verification of large amounts of detailed data and defining a specific methodology.

Type approval and real world emissions
The increasing gap between type approval (NEDC) and real world emissions significantly reduces the effectiveness of the current CO_2 regulations and requires attention for the post 2020 regulations. While the switch from NEDC to WLTP is likely to yield more representative type approval CO_2 emission figures, it is not expected to completely close the gap with real-world CO_2 emissions.

As until now manufacturers have optimized their vehicles and vehicle testing to NEDC, they may be expected to do the same in the future under WLTP.
Thus, the conversion factors from NEDC to WLTP could change over time and the gap between WLTP TA values and real world emission levels may increase again. Options for dealing with this issue include additional approaches for determining CO_2 emissions, based either on road tests (e.g. using PEMS) or ECU data of on road vehicles.

Large scale fuel consumption data of in-use vehicles might be used to derive real-world emission values for specific models. In order for such a system to work, a number of procedures and arrangements would need to be developed and agreed upon, which can be complex.

An alternative that could be investigated is to use real-world measurements (e.g. PEMS or monitoring of ECU data) additional to the Type Approval test. However, also this approach, provided feasible, would add complication and have a higher administrative burden.

Eco-innovations and rewarding off-cycle emission reductions
The current approach of eco-innovation credits improves the cost-effectiveness of the Regulations as it allows to reward some off-cycle technologies (auxiliaries or devices that are not switched on during the test or for which the impacts are not or not accurately measured on the test) which reduce emissions at low cost. However, to keep the eco-innovation credits in line with the type approval test, the implications of the change to the WLTP need to be investigated and taken into account.

The main drawback of the current approach is its high administrative burden. The burden for OEMs could be reduced by establishing a pre-defined list of eligible technologies and the ‘default’ credits OEMs can receive for each option. Additionally, OEMs could still apply for credits for new technologies not previously listed if they provide sufficient evidence.

Enlarging the scope of eligible technologies would benefit the cost effectiveness if robust measurement or assessment procedures exist. However, the option of granting credits for off-cycle technologies should be taken into account when setting the target levels in order to avoid the risk of reducing the effectiveness of the regulation.

Rewarding low-emission vehicles
Different types of regulatory tools could be used to reward the uptake of ZEV (zero emission vehicles) or ULEV (ultra-low emission vehicles). ZEV/ULEV mandates may help to ensure reduction of TTW CO_2 emissions and will lead to lower WTW GHG emissions from transport in case the carbon intensity of energy carrier production (electricity and hydrogen) is low. Moreover, they could facilitate the transition towards the long term decarbonisation targets which require a higher share of ZEV.

A proper design of the mandate is important to achieve technology neutrality, to prevent market distortion and to stimulate technology development and production within the EU. The minimum share of ZEVs or ULEVs could be combined with a bonus/malus for the average CO_2 value that needs to be met (e.g. less stringent CO_2 target for OEMs selling a high share of ULEVs/ZEVs). Such a 'flexible mandate' has the advantage that it provides more flexibility to OEMs, but should be designed properly to mitigate the risk of reducing the overall effectiveness of the regulation.

Technology specific targets
The current regulations set a single target covering all types of powertrains. An alternative approach would be to have technology specific targets, i.e. a separate target for ICEVs and/or ULEVs and no target (or a separate energy efficiency target) for ZEVs. Technology specific targets may increase the effectiveness of the policy by reducing the possibility of leakage of GHG emissions due to certain (drivetrain) technologies with higher WTT emissions. To limit the uncertainty of the overall effectiveness of the policy, technology specific targets could be combined with a ZEV or ULEV mandate. However, this modality is likely to go at the cost of higher vehicle and societal cost.

Banking and borrowing
Banking and borrowing may reduce additional manufacturer costs significantly, especially if allowed before as well as after the target year. The impact on total CO_2 emissions is likely to be very small. In order to manage the risk of manufacturers not being able to balance out a negative amount of CO_2 credits, a maximum amount of borrowed CO_2 credits could be defined.

Excess premiums
The currently established € 95/g/km level of excess premium provides enough incentive for the vast majority of manufacturers to reduce the CO_2 levels of their vehicle fleet. The only exception are manufacturers with very high baseline CO_2 emissions, for instance because a large share of their sales are sports cars and/or SUVs. The share of such manufacturers in the overall car sales is however limited.

Derogations for small and niche manufacturers
The contribution of small volume OEMs (<10,000 cars or <22,000 vans) to total CO_2 emissions is very small (below 0.01%). Therefore, the market distortion impact of allowing a derogation for such OEMs to avoid excessive impacts is likely to be limited.

Derogations provided to 'niche' car manufacturers (currently defined as producing 10,000–300,000 cars/year) have drawbacks in terms of competitive neutrality and may reduce the effectiveness of the regulation. Negative consequences could be prevented by lowering the upper threshold or by eliminating this derogation possibility. However, a more extensive quantitative assessment of the impacts of such options was not foreseen within the context of this study.

Stakeholder views
Different stakeholder groups have expressed very different preferences regarding future modalities:
– A majority of the vehicle OEMs are in favour of broadening eco-innovations, extending super credits, adding flexibilities, allowing banking and borrowing and lower excess premiums.
– A majority of the component OEMs and the steel industry are in favour of including embedded emissions and WTT emissions and the broadening of eco-innovations.
– Environmental NGOs are in favour of real world emission measurements, elimination of super credits, a flexible ZEV/ULEV mandate, mileage

weighting, switching to footprint as utility parameter and allowing to bank & borrow emissions between years.

Considerations regarding target levels

The stringency of the regulation depends strongly on the target levels. The assessment of target levels that are consistent with meeting the overall 2050 GHG reduction goals for transport or the 2030 reduction goal for the non-ETS sectors showed that these levels strongly depend on a broad range of assumptions, such as development of transport demand, CO_2 reduction in other transport modes and the contribution from biofuels.

Under a 'mid'-scenario that includes 25% biofuels, the (NEDC-based) target values allowing to meet the 2050 reduction goals would be 70 g/km (2025) and 55 g/km (2030) for cars and 116 g/km (2025) and 89 g/km (2030) for vans. Target levels needed to meet the 2030 objectives for non-ETS sectors would be lower: 65 g/km (2025) and 44 g/km (2030) for cars and 100 g/km (2025) and 66 g/km (2030) for vans.

Target levels that are fully robust for expected developments up to 2030 and also ensure that the long term goals are met in case of higher transport growth rates, lower or no shares of biofuels for LDVs or less GHG reduction in HDVs and other transport modes are (close to) 0 g/km in 2030 for both cars and vans.

Considerations regarding the future development of ZEV

In case of a quicker shift towards zero emissions vehicles beyond the technology scenarios assessed in this study, the impacts of the targets and modalities would have to be reconsidered. Such a shift might be triggered for example by fast developments in battery or fuel cell technology. This would allow CO_2 target levels to be much lower than what has been considered in this study, and would render many modalities irrelevant (e.g. utility parameter, mileage weighting), while others could become increasingly important (metric, embedded emissions).

Recommendations for further research

Some modalities and options that are not further analysed in this study, are recommended for further quantitative analysis. These are in particular:
- TTW CO_2 emission targets for ICEs with exclusion of Zero Emission Vehicles;
- a (flexible) minimum share of low-emission vehicles in vehicle sales (mandates);
- technology specific targets;

Also approaches for determining the TTW emissions deserve further research, as they are highly important for the effectiveness of the regulation.

Furthermore, to complement the assessments in this study, it is recommended to carry out additional sensitivity analyses on:
- other target levels, particularly more stringent targets (or even estimating optimal target levels;
- combinations of cost curves and technology scenarios (e.g. higher or lower cost scenarios for AFVs as well as for ICEVs);
- technology scenario (particularly in relation to quantifying the impacts a (flexible) ZEV or ULEV mandate);
- deviation between RW-WLTP-NEDC, differentiated to fuel type and size class;
- energy prices;
- WTT emission factors.

Glossary

Abbreviation	
AFV	Alternative Fuel Vehicle (includes biofuel vehicles, PHEVs, REEVs and ZEVs)
BAU	Business as Usual
BEV	Battery Electric Vehicle (full electric, so no PHEV or REEV)
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
CPT	Clean Power for Transport
ECU	Engine Control Unit
ETS	Emission Trading System
EV	Electric vehicle (includes BEVs/FCEVs)
FCEV	Fuel Cell Electric Vehicle (running on hydrogen)
FQD	Fuel Quality Directive
GHG	Greenhouse Gas
GVW	Gross Vehicle Weight
H_2	Hydrogen
HDV	Heavy Duty Vehicle (HGV, buses and coaches)
HGV	Heavy Goods Vehicle (lorries)
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
kWh	kilo-Watt-Hour
LCV	Light Commercial Vehicle
LDV	Light Duty Vehicle (LCV/car)
LNG	Liquefied Natural Gas
MJ	Mega-Joule
MS	Member State
Mt	Mega ton
NEDC	New European Driving Cycle
NGO	Non-Governmental Organisation
NOx	Nitrogen Oxides (includes nitrogen monoxide and nitrogen dioxide)
OEM	Original equipment manufacturer
PC	Passenger car
PEMS	Portable Emissions Measurement System
PHEV	Plug-in Hybrid Electric Vehicle
RE	Renewable Energy
REEV	Range Extended Electric Vehicle
RW	Real world
TA	Type Approval
TCO	Total Cost of Ownership
TTW	Tank-to-wheel
ULEV	Ultra-Low Emission Vehicles(includes ZEVs, PHEVs, REEVs)
VAT	Value Added Taxes
VRT	Vehicle Registration Taxes
WLTP	Worldwide harmonized Light vehicles Test Procedures
WTT	Well-to-tank
WTW	Well-to-wheel
ZEV	Zero Emission Vehicle (includes BEVs/FCEVs)

1 Introduction

1.1 Background

The European Commission has set a very ambitious objective for reducing its domestic greenhouse gas (GHG) emissions by 2050 to a level that is 80-95% lower than the 1990 emission level. This is in line with the need to limit global climate change to a temperature increase of well below 2°C with respect to pre-industrial levels. The Commission's 'Roadmap for moving to a competitive low carbon economy in 2050' outlines a pathway to how the EU can meet this 2050 target in the most cost-effective way. The Roadmap considers the pathways for each of the sectors, identifying the magnitude of reductions required in each sector in 2030 and 2050.

The transport sector is responsible for almost a quarter of the EU GHG emissions and therefore it has an important role in reaching the EU's 2050 target. The reduction targets in the Roadmap for the transport sector (including emissions from aviation but excluding marine shipping) are between -20 and 9% for 2030, and the 2050 reduction targets are 54 to 67%. While GHG emissions from the other sectors have decreased by almost a quarter between 1990 and 2009, those from transport have increased by almost a third during this same period (AEA; CE Delft ; TEPR ; TNO, 2012). It will require significant effort to alter this rising trend and to start moving towards the target that has been set for the sector.

As road transport causes roughly 80% of the EU's transport emissions, it is important to reduce the emissions from this transport mode drastically. For Light Duty Vehicles (LDVs) binding CO_2 emission targets for newly sold vehicles have already been set with Regulations (EC) 443/2009 for passenger cars and (EC) 510/2011 for vans (EC, 2009) and (EC, 2011). Both regulations are contributing substantially to meeting the 60% target set in the 2011 White Paper on transport. However, additional policies to meet these GHG emission reduction targets are necessary and setting new binding emission targets for LDVs for the period beyond 2020 is one of the likely candidates. However, as the situation beyond 2020 is likely to be different from now (e.g. more alternative fuel vehicles (AFVs)), new designs of these Regulations may be necessary.

The European Commission has requested a study on possible design options for modalities of the LDV CO_2 Regulations beyond 2020. A consortium led by CE Delft (together with TNO, Cambridge Econometrics, and TML) has been selected to perform this study.

1.2 Objectives, overall approach and outline of the study

The overall objective of the study is to evaluate the possible design options for car and light commercial vehicle CO_2 regulations beyond 2020, including the impacts that can be expected from the different options and the pros and cons of the design options.

More specifically, the study answers the research questions which are listed below. With each research question, the approach is indicated as well as in which chapter the results can be found.

1. What **level of ambition** for the post-2020 regulation is expected to be needed for meeting the overall climate objectives? How does this depend on other developments both within the transport sector and other sectors?

This question will be answered by exploring the implications of different levels of ambition in relation to the LDV contribution to meeting the overall EU climate goals and depending on different assumptions and scenarios. The results of this can be found in Annex A (a brief summary of the main results is integrated in Chapter 3, Section 3.3.6).

2. What are the **objectives and key design options ('modalities')** for the regulation and how do they link to each other?
3. What are the **pros and cons of these various modalities**?

These two questions will be answered by:
- considering the objectives of the Regulations and identify how different modalities could contribute to achieving them;
- providing a synthesis of available information on modalities from the existing Regulations from previous studies, other modalities employed elsewhere and other possible alternative modalities;
- exploring the appropriateness and compatibility of both existing modalities and of possible alternative modalities for the CO_2 regulations for the period 2020-2030 and beyond;
- developing a long list of modality options and to assess these against a wide set of criteria, including - but not limited to - previous experiences, results from the synthesis on available information;
- identifying promising, incompatible, and inappropriate combinations of modalities.

The results of this can be found in Chapter 2.

4. What are the **stakeholders' views** on the modalities for the post-2020 regulations?

This question will be answered by analysing the results of the stakeholder survey that has been carried out. The detailed results of this survey can be found in Annex D.4. The main findings are summarised in Chapter 2. Also the methodology for the quantitative and qualitative assessments of selected modalities and modality values that is applied for the analysis is presented in detail in Annex D.4; a brief summary is also integrated in Section 2.4.

5. What are the **impacts of combinations of modalities**?

This question will be answered by:
- assessing the impacts of the long list promising policy variants (i.e. combinations of modalities and target levels) on cost and emissions from cars and vans, for various technology scenarios;
- assessing a short list of four policy variants on all assessment criteria, including the wider impacts on transport, economy and social equity;
- assessing the impacts of other modalities that could not be covered by the quantitative assessments.

The results of this can be found in Chapter 3, 4 and 5, respectively.

6. To make **recommendations** to the Commission on the most promising design options for the car and light commercial vehicle CO_2 regulations beyond 2020, based on a broad range of criteria.

This question will be answered by assessing and combining the answers on the previous research questions. The results of this are presented in Section 5.6.

1.3 Scope of the project

The scope for the project has been defined as follows:
- The project focusses on CO_2 regulations for cars and vans (i.e. Light Commercial Vehicles (LCVs)).
- The project focusses on the period beyond 2020, with a particular focus on 2025 and 2030. Where possible and relevant, the implications for the period beyond 2030 are also taken into account.
- The project builds on available information from the wide range of studies that have been previously executed on the modalities of the Regulations. Additional qualitative and quantitative assessments is carried out to fill any gaps in the available data and insights. Promising combinations of modalities are quantitatively assessed in detail with respect to costs for meeting various target levels, distributional impacts, social equity, competitive neutrality, technological neutrality, international competitiveness, impact on the EU economy, achievability, compatibility with the necessary emissions trajectory and overall cost effectiveness for the options considered.

The study focusses on CO_2 emissions and hence does not contain an assessment of other emissions, e.g. of air pollutants. In case of the well-to-tank (WTT) emissions, e.g. emissions from power generation or fuel production, also other greenhouse gas emissions (e.g. methane, nitrous oxide) are taken into account in the analysis. Everywhere in this report where WTT or WTW (well-to-wheel) CO_2 emissions are mentioned, CO_2 equivalents are meant.

Adopting a greenfield approach

The CO_2 Regulations are an existing policy instrument in which several design choices were already made. However, the situation beyond 2020 may be inherently different from the existing situation. Therefore, a Greenfield perspective has been adopted for this study. This implies that the objectives of the Regulations are taken as a starting point and hereafter the modalities required to reach those objectives are evaluated.

This Greenfield perspective allows considering new, innovative modalities which have not been covered by previous work. In this project, such innovative modalities are proposed and discussed where appropriate and a first broad analysis has been performed. However, more detailed analyses are outside the scope of this research.

The Greenfield perspective also implied that a very broad range of options and a very high number of variants have been considered, which has made it more challenging to present the results of the analysis in a concise manner.

2 Objectives and design options

2.1 Introduction

Chapter overview	
Goal	To identify the main objectives of the Regulation and to assess all possible modalities and design options, including the development of a framework to structure these modalities and options, based on literature and develop an approach for quantitative and qualitative assessments of selected options.
Output	– The key objectives of the future Regulations. – A framework for structuring modalities and design options. – A long list of (relevant) modalities and design options (for 2020-2030). – An overview of the results of the literature assessment of all modalities and design options, including their pros and cons. – A list of most promising modalities to consider for the post-2020 regulation, based on previous studies and experiences. – Summary of the stakeholders' views on the modalities for the post-2020 regulations. – A methodology for quantitative and qualitative assessments of selected options.
Annexes	Annex C, Annex D, Annex D.4, Annex F.

As mentioned in the previous chapter, the objectives of the policy have been taken as the starting point for this study, rather than the current design of the existing Regulations. Therefore, Section 2.2 starts with a definition of the objectives of the Regulations. Hereafter, all modalities which can contribute to these objectives are structured in a framework, which is the topic of Section 2.3. Annex C summarises all design options for each modality included in the framework. Each modality and design option has hereafter been subject to an extensive literature review, the results of which are summarised in Annex D.

A selection of most promising modalities and design options resulting from this literature assessment is presented in Section 2.4. Finally, Section 2.5 describes how these options are further assessed in this study.

2.2 Objectives of the regulations

2.2.1 Main objective

The main objective of the CO_2 regulations for cars and vans is to contribute to the reduction of GHG emissions in order to mitigate climate change. The CO_2 regulations for cars and vans are part of a package of policy measures aimed at reducing the GHG emissions of transport in the EU. Together these transport-related policy measures are intended to contribute to meeting the overall GHG reduction targets set for the EU as a whole.

The overall objective of the regulations is to reduce GHG emissions and fuel consumption of passenger cars and vans on the roads in the EU.

It achieves this objective by setting emission targets for new vehicles. Over time, when these vehicles achieve a larger share in the vehicle fleet, this leads to the desired reduction of GHG emissions at the level of the EU LDV fleet.

As such the objectives of the regulations are connected to overall objectives in the following hierarchical order:
- reducing EU-wide GHG emissions;
- reducing GHG emissions from the EU transport sector;
- reducing CO_2 emissions from LDVs;
- reducing CO_2 emissions of new LDVs.

Defining the overall objectives, to which the regulation is intended to contribute, are necessary to allow evaluation of different options for the targets and modalities of the regulations with respect to their effectiveness. In that context it makes a difference whether the objective against which the effectiveness is assessed is:
- to reduce GHG emission from a global perspective, i.e. including possible impacts on emissions in the energy chain (WTT) or product life-cycle (embedded emissions) that may occur outside the EU; or
- to achieve the EU's GHG emission reduction goals which are defined as reductions of the direct emissions occurring within the EU.

Assessing the effectiveness of targets and modalities against different objectives may lead to different outcomes. This is particularly relevant for the metric chosen for the target (TTW- or WTW-based) and for the options regarding embedded emissions.

If e.g. the objective considered is to reduce direct GHG emissions from the transport sector within the EU, there is a more direct correlation between meeting a TTW target for new vehicles and achieving the objective than when the overall objective is to reduce total GHG emissions (globally). In the latter case the contribution of a TTW target to meeting the objective will depend strongly on the technologies applied to meet the target. The differences are most prominent for imported biofuels and for technologies leading to significant changes in the embedded emissions related to vehicle manufacturing (e.g. battery-electric vehicles (BEVs)) for which a large part of the components or materials may come from outside the EU.

In a similar way it makes a difference whether the effectiveness of options is assessed from the perspective of contributing to reducing direct emissions from the EU transport sector or from the perspective of contributing to overall GHG emission reductions at the EU-level. For the first perspective, battery and fuel cell electric vehicles count as zero-emission, while for the second perspective the emissions produced within the EU for electricity generation and hydrogen production need to be taken into account, which requires considering the broader climate and energy policy instruments.

2.2.2 Other objectives

In addition to climate-related objectives the policy may serve additional objectives of the EU or its Member States. Such objectives may include:
- reducing the dependence on imported oil;
- reducing the dependence on energy imported from unstable regions/countries with unfriendly or unreliable regimes;
- improving the resource efficiency of the European economy;
- improving the competitiveness of the European economy;

– promoting economic growth ('green growth'), either by reducing the costs of transport or by increasing Europe's share in various transport-related value chains;
– promoting the application of innovative technologies (e.g. electric or fuel cell vehicles) that are needed to meet long-term GHG reduction and other sustainability goals.

Such additional objectives may play an important role in the discussion among stakeholders, but can only be taken into account to a limited extent in the design and evaluation of the regulation. Some of the impacts assessed in this study (e.g. costs, competitiveness) relate to the above-mentioned additional objectives, but these aspects are treated as evaluation criteria for comparing options that meet the same climate objectives rather than as goals to which the regulations need to contribute.

2.3 Overview of main choices and modalities

The current CO_2 Regulations contain many different modalities (e.g. the metric, the utility parameter, etc.) and for each modality one design option has been chosen (e.g. TTW CO_2 as a metric, mass as utility parameter, etc.). For the present work a very long list of modalities and design options have been considered. To structure the process of assessing individual modalities and identifying possible packages of modalities and selecting promising policy variants, an overall framework has been developed. This framework categorises the modalities into groups that relate to their primary function in defining the regulation. Figure 1 shows this overall framework.

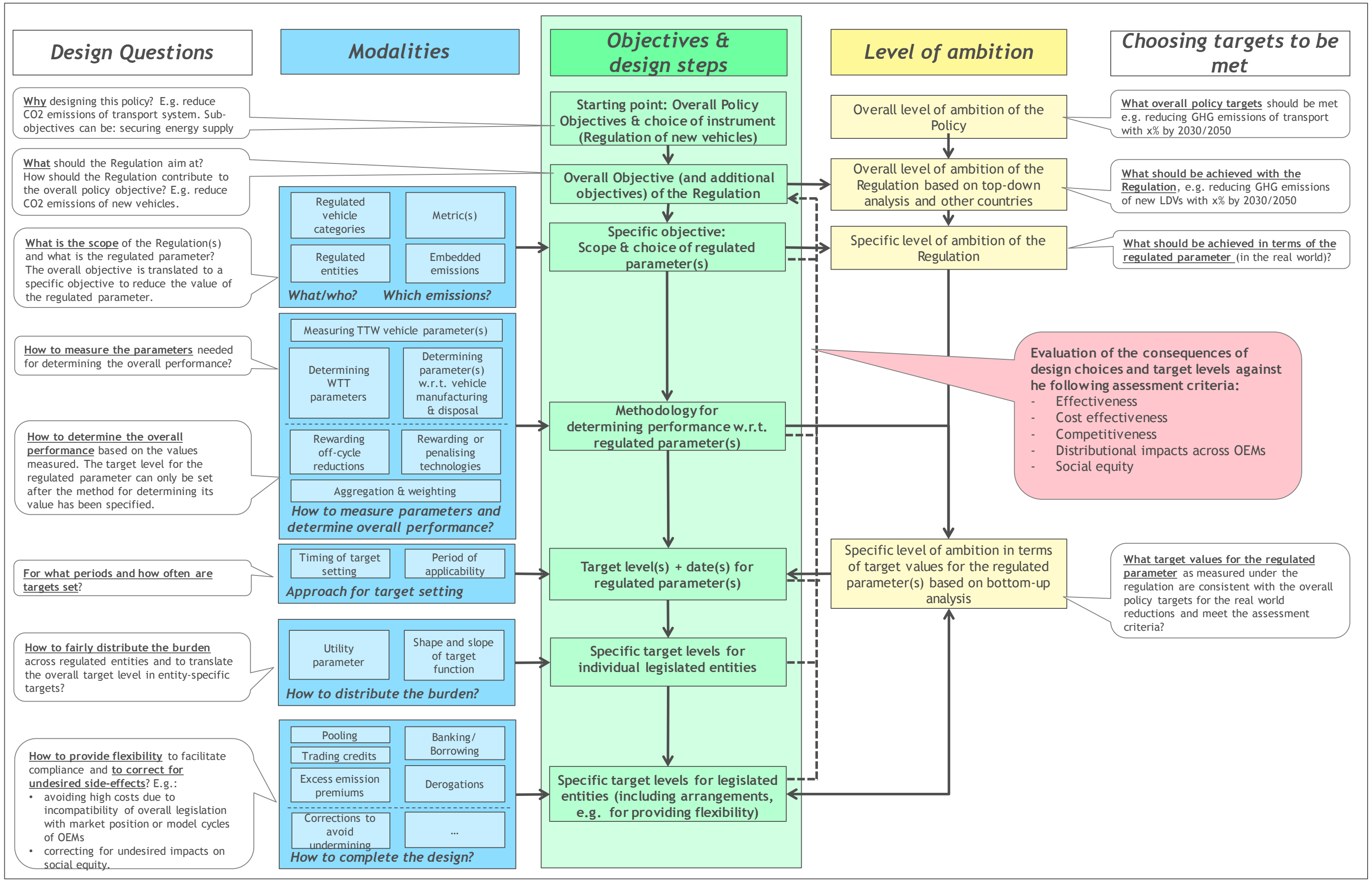
The green column in the middle shows the **main design steps**: from the underlying overall policy objectives (and sub-objectives), to the objective(s) of the regulation, through various steps and choices towards a set of specific targets for the legislated entities. In these design steps two types of choices can be distinguished: design choices (with respect to the modalities) and choices for the target levels (related to the level of ambition).

The **design questions and possible modalities** are at the left side of the figure. The design choices for the regulation concern questions such as *what* and *who* is regulated and *how* this is done. For each design choice there are various modalities, which are grouped into a few main categories: the scope, the methodology for determining performance, the approach for target setting, the methodology for distributing the burden to various regulated entities and various choices for completing the design (related to providing flexibility and avoiding unintended side-effects).

The second type of choices to be made are choices related to the **level of ambition and the targets to be met**. These are at the right side of the figure. These choices are related to overall reductions that the regulation should achieve and what targets for the regulated parameters are consistent with these reductions and are acceptable. These choices are more political than the design choices.

The choices made for the modalities and target levels are evaluated on the basis of a set of **assessment criteria** (effectiveness, cost effectiveness, social equity, competitiveness, distributional impacts across manufacturers, social equity). Based on how various options score on these criteria, the overall design can be chosen.

Figure 1 Framework for structuring modalities



2.4 Selection of relevant design options of modalities for 2020-2030

For each modality shown in Figure 1, multiple design options are possible. For the metric for example, a CO_2 (g/km) or energy-based (MJ/km) metric can be defined, which in turn can be TTW, WTW, TTW covering ICEVs only or TTW with notional GHG intensity for ZEVs. In total, 19 modalities and 73 design options have been identified.
A complete overview can be found in Annex A.

For each modality and design option defined on the long list, an extensive qualitative assessment has been made with available literature. The results have been summarised in short fact sheets per modality. Each fact sheet contains the possible design options for a modality, the pros and cons of each design options, recommendations from previous work, interactions with other modalities and design options and the main conclusions for selecting relevant design options for the period beyond 2020.
These fact sheets can be found in Annex D.

Following this qualitative assessment for each modality, it was determined which design options are appropriate for further consideration as an option and which are not further considered. This resulted in a shortened long list, which is summarised in Table 5. A more detailed explanation and assessment of the design options for the various modalities can be found in Annex D and in (TNO et al., 2013).

Table 5 Shortened long list with relevant modalities and design options

Modalities	Design options per modality	Explanation
A. What is the scope of the Regulation?		
A1 Regulated vehicle categories	A1.1 Separate targets for M1 and N1 A1.2 Separate targets for M1 with smallest N1 on the one hand, and remaining N1 on the other hand	With A1.1 passenger cars (M1) and vans (N1) are regulated separately (as in the current regulations), while with A1.2 the smallest vans (which are very similar to passenger cars) are included in the M1 instead of the N1 regulation.
A2 Regulated entities	A2.1 Manufacturer groups A2.2 Brands	The targets can be set for individual brands (e.g. separately for VW, Audi, Skoda, etc.) or for manufacturer groups that are part of one larger legal entity (e.g. for the entire Volkswagen AG).
A3 Metric(s)	A3.1 TTW CO_2 emissions (as in existing Regulation) A3.2 TTW CO_2 emissions for ICEVs only (with exclusion of Zero Emission Vehicles) A3.4 WTW CO_2 emissions	The emissions that are regulated can be based on vehicle's tailpipe emissions (TTW) (A3.1) or may also include upstream (WTT) emissions from the production of the energy carrier (WTW) (A3.4). When regulating TTW emissions, this might be limited to non-ZEVs (A3.2). The way the TTW and WTT emissions are determined are set by modality B1 and B2, respectively. WTT emissions are determined by multiplying the energy use of the vehicle by the WTT emission per unit of energy (for the energy carrier used).

Modalities	Design options per modality	Explanation
A4 Embedded emissions	A4.1 Embedded emissions excluded in the metric A4.3 Embedded emissions excluded in the metric but included with another approach (e.g. reporting of embedded emissions)	Two options are short-listed, both excluding emissions from vehicle production from the metric (as in the current regulation). However, under option (A4.3) embedded emissions would have to be reported. The way the embedded emissions are determined is set by modality B3.
B. How to measure the parameters needed for determining the overall performance?		
B1 Measuring TTW vehicle parameter(s)	B1.1 Type Approval test result (WLTP) B1.2 Type Approval test result + correction for real-world divergence B1.3 Type Approval test result + OEM to provide ECU data on real world fuel consumption B1.4 Real-world measurements (e.g. PEMS or monitoring of ECU data) B1.5 One of the options B1.1, B1.2 or B1.3 combined with specific test procedures for energy using devices and/or off-cycle energy saving technologies	The TTW emissions can be determined by using the data from the type approval test (as in the current approach, but using the new WLTP) (B1.1). To tackle the increasing gap between real world and type approval emissions, a correction factor could be used (B1.2), or the WLTP data could be complemented (B1.3) or replaced (B1.4) by other data that are more representative for real world emissions. When relying on WLTP data, specific test procedures could be used for energy using devices and/or off-cycle energy saving technologies (which are not covered by the WLTP).
B2 Determining WTT parameters	B2.2 Default values for the entire EU projections differentiated to target year B2.4 Default values per MS projections differentiated to target year	The upstream (WTT) emission values of the various energy carriers (in gram of CO_2 eq. per MJ of fuel or electricity) used for calculating emissions in case of a WTW metric can be set for the entire EU or per Member State for the target year. As the WTT emissions of both fuels and electricity are expected to change over time, the values can differ per target year. The WTT emissions are defined as average WTT values (not marginal)[2].
B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal	B3.3 Harmonised LCA reporting by OEMs (per vehicle or e.g. per kg of vehicle weight)	In case embedded emissions are to be reported on (A4.3), this modality describes the way these emissions should be determined.
C. How to determine the overall performance?		
C1 Rewarding off-cycle reductions	C1.1 Eco-innovations (as in existing Regulation) C1.2 Off-cycle technology credits (as in the US Regulation) C1.3 None	This modality is about giving credits (i.e. less strict target) for technologies that reduce emissions but that are not (well) covered by the type approval test. Off-cycle technology credits (C1.2) only apply for devices that are not switched on during the type approval test. Eco-innovations (C1.1) may be broader and also take into account devices that are switched on in the test, but for which the total real-world reduction potential is not accurately measured.

[2] Marginal emissions are hard to define in a uniform and consistent way. The marginal emissions depend strongly on the country, region and even local situations as they vary with the source of the crude oil, electric power, etc. used (and for electricity this even depends on the time of the day).

Modalities	Design options per modality	Explanation
C2 Rewarding or penalising technologies	C2.1 Super credits C2.2 Minimum share of advanced technologies in vehicle sales C2.3 Flexible minimum share of advanced technologies in vehicle sales C2.6 None	Super credits (C2.1) provide an incentive to increase the share of low or zero emission vehicles, by giving a higher weighting to these vehicles in calculating the average emissions of an OEM. Alternative ways of incentivising ZEV or ULEV sales are a mandatory minimum share of ZEVs or ULEVs, either fixed (C2.2) or with a bonus/malus for the average CO_2 value that needs to be met (less stringent value for OEMs with a relatively high share of ULEVs/ZEVs in their sale) (C2.3).
C3 Aggregation & weighting	C3.2 Limit based on overall sales-weighted average (as in existing Regulation) C3.4 Technology specific targets: limit based on overall sales-weighted average per technology C3.5 Combining C3.2 or C3.4 with mileage weighting	For each OEM, a target value can be set for the sales weighted CO_2 emission of all vehicles (C3.2). Alternatively a target can be set per type of powertrain technology (C3.4). Both options could be combined with mileage weighting. In case of mileage weighting, targets are expressed as lifetime CO_2 emissions (product of assumed mileage and type approval CO_2 emissions) rather than CO_2 emissions per kilometre. The assumed mileage takes account of the fact that some vehicles (e.g. larger or diesel powered vehicles) have a higher average mileage than others.
D. Approach for target setting		
D1 Approach for target setting[3]	D1.1 Targets for fixed date(s) without phase-in D1.2 Targets for fixed date(s) with phase-in (as in existing Regulation) D1.3 Annually declining targets	With D1.1, targets are set for just a few years (e.g. 2025 and 2030) and remain the same in the intermediate/following years. Alternatively, targets could be set for all years (e.g. 2021, 2022, 2023, etc.) (D1.3). Option D1.1 could be combined with a phase-in, which means that already in the year(s) prior to the target year, a certain share of the sales need to meet the target.
E. How to fairly distribute the burden across regulated entities?		
E1 Utility parameter	E1.2 Mass as a utility parameter E1.4 Footprint as a utility parameter	By using a utility parameter, the target values are differentiated according to a chosen utility of the vehicles sold by an OEM. The utility can be either the vehicle weight (mass) (E1.2) or its footprint (E1.4), which is defined as the product of the average track width and wheelbase (approximately the area between the four wheels).
E2 Shape and slope of target function	E2.2 Linear target function with finite slope (including zero slope) E2.3 Truncated linear target function with a floor and/or a ceiling E2.4 Non-linear target function	The target function defines how the target value varies with the value of the utility parameter. The target function can be linear (with different slopes) or non-linear (with different shapes). A truncated function

[3] A target can be defined as the emission value itself or as a percentage reduction against a baseline. However, as a percentage can always be translated into a corresponding emission value, the two are identical.

Modalities	Design options per modality	Explanation
		(E2.3) usually starts flat, then starts going up at a certain value of the utility parameter until another value of the utility parameter from which on the function is flat again.
F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?		
F1 Pooling	F1.1 No pooling F1.2 Pooling between car or van manufacturers (as in existing Regulation)	Pooling (F1.2) allows an OEM to choose for a joint target with another OEM. The target level is then based on the CO_2 performance and utility parameter values of the vehicle sales of both OEMs.
F2 Trading CO_2 credits	F2.1 No trading of credits F2.4 Allowing trading of credits for vans and passenger cars separately For each option a definition of what is traded (grams, grams/km) is required and temporal aspects (banking and borrowing of credits) need to be determined.	Allowing trading (F2.4) means that OEMs that achieve relatively larger CO_2 emission reductions can sell their over-performance as 'credits' to OEMs that reduce less than required for meeting its target.
F3 Banking/borrowing	F3.1 No banking/borrowing F3.2 Allowing only banking (maximum period and maximum banked amount to be specified) F3.3 Allowing banking and borrowing (maximum period and maximum banked/borrowed amounts to be specified)	Banking means that over performance in one year can be compensated by under-performance in a later year. Borrowing is that an under-performance in a certain year is compensated by an over-performance later on.
F4 Excess emission premiums	F4.1 Excess emission premium of €X per excess g/km, possibly with lower premium for the first few g/km exceedance F4.2 No market access when targets are exceeded	OEMs that do not meet their target can either get a fine (excess premium) (F4.1) or be no longer allowed to sell vehicles on the EU market (F4.2).
F5 Derogations	F5.1 For manufacturers with small volume (EU) sales (as in existing Regulation) F5.2 For manufacturers with niche volume (EU) sales (as in existing Regulation) F5.3 For manufacturers with small volume (global) sales F5.4 For manufacturers with niche volume (global) sales F5.5 For certain vehicle types F5.6 Combination of the above	These options represent various possibilities for derogations for small or niche manufacturers.
F6 Correction for autonomous utility change	F6.1 Adjustment of U_0 in target function	The adjustment of the U_0 in the target function means that the utility function is corrected for any autonomous change in the average utility value across all OEMs (either increase or decrease).

Table 6 lists all options that, based on the results of the literature review were excluded for further analysis, including the main arguments. More details on the assessment of these options and the literature used can be found in Annex D.

Table 6 Options that were not selected for further analysis, based on results of the literature review

Modality	Options that were not selected for further analysis and reasons why
A1 Regulated vehicle categories	A1.3 Separate targets for M1 on the one hand, and N1 and (specific segments of) N2 vehicles on the other hand would be overly complicated as there is large share of N2 vehicles are multistage vehicles and adding N2 vehicles makes it more difficult to define a target function that provides reasonable targets over the whole utility spectrum. A.1.4 Merged Regulations (joint target in one regulation) for M1 and N1 could distort competition for those OEMs which only sell one category.
A2 Regulated entity	A2.3 (Importers), A2.4 (Member States), A2.5 (Trade associations) are excluded from further analysis due to their lack to control emissions with direct measures.
A3 Metric(s)	A3.3 (TTW CO_2 emissions with notional GHG intensity for ZEVs[4]) is an inaccurate way of including WTW emissions of ZEVs, so a WTW metric is preferable in this case as all other effects of these metrics are comparable. Thereby, it is a technology-specific solution and not a scientifically sound approach. A3.5 TTW energy consumption and A3.6 WTW energy consumption are also excluded from further analysis as they do not have any significant benefits over the CO_2 design options: energy consumption of various types of powertrains is poorly related to GHG emissions and primary energy consumption is an irrelevant parameter when comparing renewables with fossil energy sources.
A4 Embedded emissions	A4.2. (embedded emissions in metric with defaults) discourages particular technologies as defaults need to be based on the current embedded emissions of vehicle production, while these emissions may be completely different in the longer term. Thereby, it does not provide incentives to improve performance (as it is based on defaults).
B1 Measuring TTW vehicle parameters	No options excluded.
B2 Determining WTT parameter(s)	Single year options (B2.1 – EU and B2.3 – MS) are not accurate (esp. if emission reduction of electricity starts to go very rapidly). Marginal default values are not transparent, difficult to determine and provides wrong signals to transport users.
B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal	Default values (B3.1 and B3.2) are excluded from further assessments as it is not accurate and provides no incentives for improvements.
C1 Rewarding off-cycle reductions	No options excluded.
C2 Rewarding or penalising technologies	C2.3 (Debits) increase WTW emissions, reduce cost-effectiveness.
C3 *Aggregation & weighting*	C3.1 None: Limit value for each vehicle reduces flexibility of OEMs, increases compliance costs and may result in market distortions. C3.3 (per segment) has a lower cost-effectiveness. Moreover, an unambiguous definition of segments is very difficult and perverse effects around the boundaries between segments can be expected. Also sales averages based on MSs sales are excluded as the regulation has a EU-wide scope.
D1 *Approach for target setting*	No options excluded.
E1 *Utility parameter*	No options excluded[5].
E2 *Shape and slope of the target function*	E2.1 (zero slope target function) is special case of E2.2 and therefore not further distinguished as a separate option.

[4] With this approach, which was assessed in some previous studies, the metric would remain the TTW emissions, but with a notional (non-zero) CO_2 emission value for ZEVs, to take account of the relatively higher WTT emissions of these vehicles.

[5] Mass as utility parameter was concluded to be a suboptimal option but kept for further analysis on request of DG CLIMA, as it is a key modality in the current regulation and may be complicated to change.

Modality	Options that were not selected for further analysis and reasons why
F1 Pooling	F1.3 Pooling of targets between cars and vans can result in unfair competition to those who do not produce both vehicle types.
F2 *Trading CO_2 credits*	F2.2 (Trading passenger cars) and F2.3 (Trading vans) are excluded for further analysis, as it is unfair to only allow trading for one group and not for the other. F2.5 (trading between cars and vans) may result in higher real world emissions due to the higher mileages of vans.
F3 *Banking and/or borrowing*	No options excluded.
F4 Excess emission premiums	No options excluded.
F5 Derogations	No options excluded.
F6 Adjusting U_0 in target function	F6.2 (No adjustment of U_0 in target function) may cause the target not being met.

Besides the literature review, also a stakeholder survey has been carried out in the first half of 2015. The main preferences expressed on this occasion are listed in Table 7. It is clear that different types of stakeholder groups have very different preferences. The full results of the stakeholder survey can be found in Annex D.4.

Table 7 Preferences of different stakeholder groups for the future Regulations

Design option:	Related modality	Vehicle OEM	Component OEM and material supplier	Environmental NGO	Energy carrier representative
Inclusion of embedded emissions	A4		X		
Inclusion of WTT emissions	A3		X		X
Real world measurements	B1			X	
Broaden Eco-innovations	C1	X	X		
Extend Super credits	C2	X			
Eliminate super credits	C2			X	
Flexible mandate for ULEVs	C2			X	
Lifetime mileage weighting	C3			X	
Footprint as utility parameter	E1			X	
More flexibilities	F1, F2	X			
Banking and borrowing	F3	X	X	X	
Lower excess emissions premium	F4	X			

Box 1 Considerations regarding the future development of ZEV

The main time horizon in this study is 2025-2030. However, when developing the CO_2 regulation for LDVs after 2020, it is also important to consider developments beyond 2030, taking into consideration the global policy framework (the 2015 Paris agreement setting a goal of limiting global temperature rise to 1.5 to 2 Centigrade) and the emission reduction target proposed for transport GHG emissions in the 2011 White Paper (60% reduction between 1990 and 2050). For meeting these targets it is likely that the emissions of new LDVs need to be drastically reduced.

A key development in this context is how the development and sales of ZEVs will evolve worldwide. Fast developments in battery or fuel cell technology in the coming years could result in a faster increase in market shares for ZEVs and that would completely change the context in which CO_2 target levels operate. In case of very low CO_2 targets, many of the current modalities would become irrelevant (e.g. utility parameter, mileage weighting), while others are likely to become increasingly important (metric, embedded emissions, energy efficiency of ZEV). Another element that may become increasingly important are the impacts of ITS and self-driving vehicles. When these technologies are taken up at a larger scale, they may affect significantly the real world emissions.

2.5 Overview of the assessment of modalities

The long list of selected options for modalities as shown in Table 5 has been the starting point for the further analysis of the design options for the post-2020 regulations. As almost all options for the various modalities could be combined, there is, at least in theory, a huge number of design options for the regulation (about 1 million options, apart from target level and target year).

The analysis has been carried out in structured way. First the assessment criteria on which the various options are evaluated have been selected and defined. This is presented in Section 2.5.1. Next the assessment of policy variants on these criteria has been carried out in a few steps.

2.5.1 Assessment criteria

The policy options will assessed against the following criteria:
- effectiveness;
- cost-effectiveness (efficiency);
- competitiveness;
- distributional impacts across manufacturers;
- social equity.

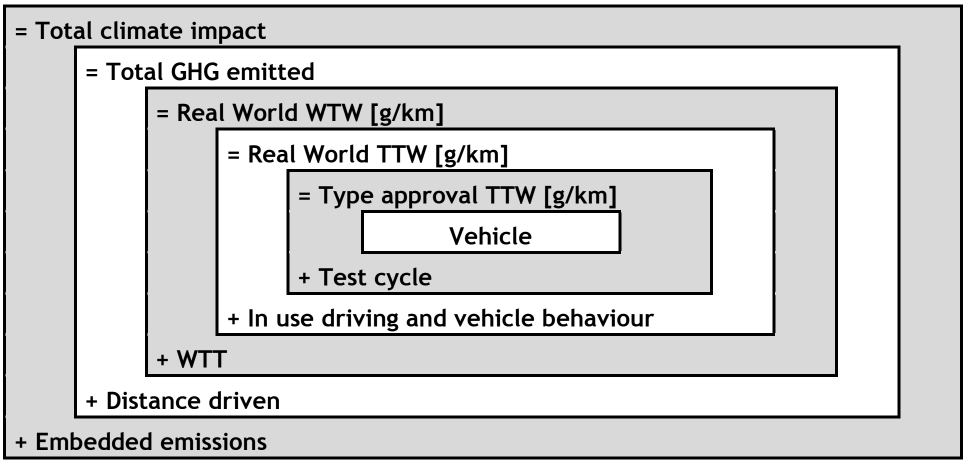
These criteria have been selected in line with the Commission's impact assessment guidelines. Below each of these criteria is defined.

Effectiveness

As shown in Figure 2, emissions associated with LDV use depend not only on the type approval TTW emissions, but also in use driving and vehicle behaviour, WTT emissions and the distance driven. In addition, when determining total climate impacts from LDVs (beyond their use phase), embedded emissions from vehicle manufacturing and from disposal at their end-of-life could also be considered.

For the purpose of this study, the effectiveness of the policy is determined on the basis of the resulting overall WTW GHG emissions.

Figure 2 Schematic overview of various levels on which CO_2 emissions from LDV can be defined



Cost-effectiveness

Cost effectiveness is the ratio between the cost and the effectiveness of a certain policy variant. The cost impacts can either be defined from a manufacturer perspective, an end user perspective or a societal perspective:

- **Manufacturing costs** are the changes in the costs for manufacturing the vehicle. Emissions regulation will generally result in an increase in manufacturing cost because manufacturers need to apply energy saving technologies (e.g. improved transmissions, weight reduction, hybridisation, etc.) or alternative powertrains (BEV, PHEV, REEV or FCEV).
- **End-user costs** are the sum of the increase in sales price (i.e. vehicle manufacturing costs plus a 23.5% mark-up for ex-factory costs and profit margins and also including taxes[6]) and the change in energy costs (incl. energy taxes). The energy costs generally decrease because of the policy. The net end-user cost will be negative (i.e. the policy yields net benefits for the end-user) when the net present value of the energy cost savings exceeds the increase in sales price. Differences in taxes between vehicle types due to fiscal measures (e.g. tax exemptions for BEVs) are not taken into account.
  As end-users in their purchase decisions usually take account of a limited time period, the end-user costs were estimated by adding the depreciated additional vehicle cost in the first five years to the net present value of the fuel cost savings over the same period.
- **Societal costs** are defined as the sum of the changes in manufacturing costs (including the same mark-up for ex-factory costs and profit margins as used for end-user cost) and the net present value of the changes in energy costs over the entire vehicle lifetime (all without taxes[7]). Impacts on external costs ('co-benefits' of the policy, such as reduction of air pollution or noise) are not included.
- **Societal cost effectiveness** is defined as the ratio between the societal costs and the WTW GHG emission reduction over the entire vehicle lifetime. It should be noted that societal cost effectiveness is not a useful concept for comparing policy variants for which the change in societal

[6] See: Impact Assessment accompanying the Communication from the Commission to the Council and the European Parliament - Results of the review of the Community Strategy to reduce CO_2 emissions from passenger cars and light-commercial vehicles (SEC(2007) 60, 7.2.2007).

[7] Societal costs are always defined without taxes as from a societal perspective taxes are transactions no costs.

costs is negative (i.e. net societal benefits). The reason is that in that case the ratio is between environmental (GHG) and societal benefits and no longer between costs and benefits.

Technology neutrality

A criterion closely linked to cost effectiveness is technology neutrality. In its most fundamental definition this refers to the absence of 'steering' of OEM choices. That implies that all compliance options are valued according to the degree to which they contribute to meeting the overall objective. To the degree to which the approach deviates from this, it will become less technology neutral.

Less fundamental definitions of technology neutrality say that the legislation should not explicitly prescribe the technologies with which the target should be met, but allow OEMs to meet the target:

- with technology of their choice, irrespective of the costs;
- with multiple technologies at comparable additional manufacturer costs; or
- with multiple technologies with achievable shares of alternatives.

It is generally believed that allowing manufacturers to choose technologies that they consider optimal for complying with the regulation leads to the highest cost-effectiveness. As such the strive for technology neutrality can be considered a derivative of the strive for cost-effectiveness. Therefore policy options are assessed on the criteria effectiveness and cost effectiveness and not also on a separate criterion 'technology neutrality'.

Competitiveness

The criterion 'competitiveness' as used in this study is the way in which the choice for a certain policy variant affects the competitive position of the European economy compared to other regions.

This includes two aspects:

1. The impacts on the competitive position of all vehicle manufacturers in the EU in comparison to non-EU manufacturers.
2. The impacts on the wider EU economy due to changes in vehicle cost, energy efficiency and resulting impacts on energy use and cost.

The contribution of manufacturers to the European economy is mainly defined by the extent to which European labour is employed to develop and manufacture vehicles and vehicle components, and therefore by the share of vehicles and components developed and produced within the EU. Competitiveness between regions is therefore related to (the location of) manufacturing rather than to manufacturers. Depending on the production location, the contribution to the European economy differs per manufacturer, even per vehicle sold.

The requirements for manufacturers are independent of their regional situation as imported vehicles are subject to the same regulations as domestic (European) manufactured vehicles. However, the average vehicle produced by manufacturers producing (mainly) within the EU differs from the average vehicle sold within the EU by a OEM producing mainly outside the EU in terms of:

- the average utility parameter;
- sales distribution over segments;
- sales distribution over drivetrain types (e.g. petrol and diesel);
- baseline CO_2 emission levels;
- baseline average vehicle prices.

Therefore, different policy variants may affect EU-based and non-EU-based OEMs differently on average. As it is not possible to determine for every vehicle sold within the EU whether it was (fully) manufactured within the EU, the competitiveness effects are studied for ACEA manufacturers versus non-ACEA manufacturers. Based on a recent study on competitiveness in the EU car manufacturing industry[8], this is assumed to be a valid proxy to study the differences in competitive position resulting from a policy option. Vehicle characteristics data are available for all EU LDV sales from EU monitoring as provided by the EEA.

Comparable to the methodology used in recent study on competitiveness study[8], it is assumed that the effect of policy on the competitive position of European manufacturers is defined by the relative change in the vehicle price compared to a business as usual reference scenario (see Section 3.3.6). In reality the competitiveness of manufacturers is determined by more criteria than the vehicle price, e.g. built quality and personal preference. However, since these are not objectively quantifiable parameters, the single parameter selected to express the competitive position is the relative price increase.

The impacts on the wider economy are defined as impacts on GDP, sectoral output and employment, price and trade effects.

Social equity

Social equity is defined as the impact on income due to the differences in car ownership and car use between various household income groups. Households are mainly car owners/users and make much less use of vans. Therefore, the social equity analysis has been limited to passenger cars.

Social equity impacts are expressed in the differences between various income groups regarding:
- gross capital income;
- gross labour income;
- social benefits;
- taxes;
- unemployment income;
- total income;
- unemployment rate.

Administrative burden

Administrative costs are defined in the Commission's Better Regulation Toolbox as the costs incurred by enterprises, the voluntary sector, public authorities and citizens in meeting legal obligations to provide information (in a broad sense, i.e. including labelling, reporting, registration, monitoring and assessment needed to provide the information) on their action or production, either to public authorities or to private parties. Administrative costs consist of (i) the business-as-usual costs (resulting from collecting and processing information which would be done by an entity even in the absence of the legislation) and (ii) administrative burdens, which stem from the part of the process which is done solely because of a legal obligation.

---

[8] Assessment of competitiveness impacts of post-2020 LDV CO_2 regulation. Multiple framework contract for the procurement of studies and other supporting services on impact assessments and evaluations (ENTR/172/PP/2012/FC). Final Report. April 10, 2015.

2.5.2 Assessments methodology per modality and criteria

The assessment of the policy options involved both a quantitative assessment and a qualitative assessment. Table 8 provides an overview of the type of assessment applied for each criterion as well as which models are used.

Table 8 Type of assessment and models used per assessment criterion

Criteria	Indicators	Quantitative assessment for long list of policy variants (Chapter 3)	Quantitative and qualitative assessment for 4 selected policy variants (Chapter 4)	Qualitative assessment on other modalities (Chapter 5)
Effectiveness	Overall GHG emission reduction (WTW)	Cost Assessment Model*	Cost Assessment Model MOVEET model**	Qualitative assessments for some modality options
Cost effectiveness	Societal cost Additional manufacturer cost End-user cost	Cost Assessment Model	Cost Assessment Model	Qualitative assessments for some modality options
Competitiveness	Relative price increase of ACEA- members vs. non-ACEA members GDP, employment, investment, consumption, trade effects	Cost Assessment Model	 E3ME model	
Distributional impacts across manufacturers	Differences in the cost increase for various manufacturers	-	Cost Assessment Model	Qualitative assessments for some modality options
Social equity	Change in total income per income group Gini coefficient (a measure for income inequality)		EDIP model	
Administrative burden				Qualitative assessment for all modalities

* Cost Assessment Model: assessment of direct vehicle and energy cost impacts.

** MOVEET: assessment of indirect impacts on transport system.

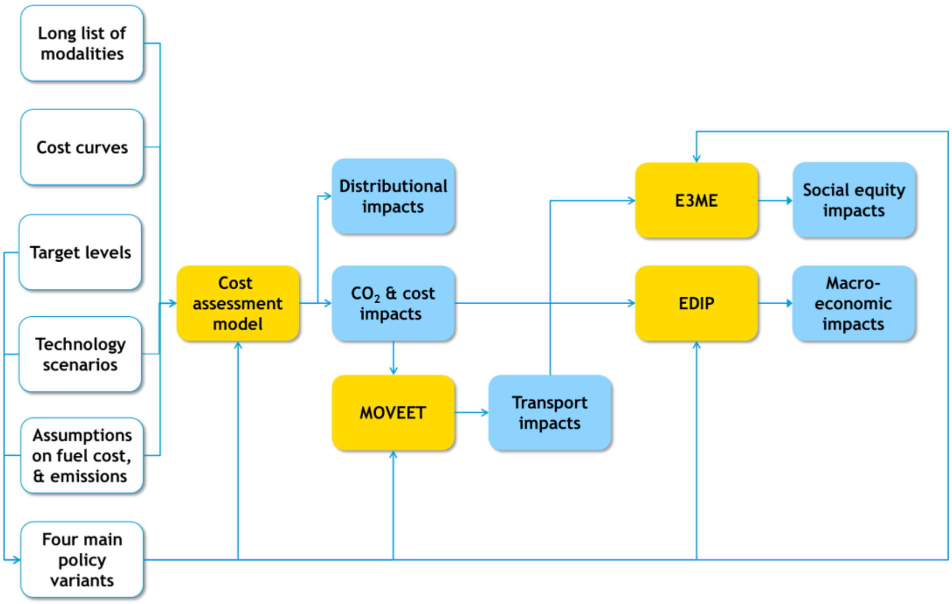
The most detailed assessments are carried out by the cost assessment model which was designed for analysing CO_2 vehicle standards for cars and vans. With this model the impacts on emissions and cost are assessed for a very high number of policy variants representing all possible combinations of those modalities and modality options that can be assessed by the cost assessment model. The cost assessment model is run for both cars and vans, for 2025 and 2030, for three target levels and five technology scenarios.

Based on the results of this assessment, four policy variants are selected which are then fed into the other models for assessing other impacts. The selection of these four policy variants has been based on the results of the extensive cost assessment, also taking account of the abilities and limitations of the other models used.

The other three models are more general models which are not tailor-made for the vehicle standards. Therefore, these models can assess the impacts just on a more aggregated level. These models estimate the wider impacts on transport, economy and social equity based on the changes in vehicle cost and energy consumption and cost calculated by the cost assessment model.
They are just run for four main policy variants and use besides the target levels, technology scenarios and assumptions on fuel cost and emission factors also the output from the cost assessment model on vehicle cost. EDIP and E3ME also use the transport impacts provided by MOVEET.

The links between the various models and the type of input and output of each model are shown in Figure 3.

Figure 3 **Schematic overview of how the output of the cost assessment model is used to determine social equity and macro-economic impacts**



The assessment is completed by qualitative assessments for:
- criteria which cannot or only partly be assessed by any of the four models used (see Table 8);
- modalities that cannot be covered by the cost assessment model.

This qualitative assessment is largely based on existing literature (see Annex D), complemented by some additional qualitative assessments, particularly for modalities and options not yet sufficiently covered by literature.

Table 9 provides an overview of how each modality will be covered, either by the cost assessment model, or by additional qualitative assessment. Modalities and modality options not listed are just assessed based on existing literature (see Annex D).

Table 9 Overview of the assessment of modalities on costs and GHG emissions with the costs assessment model and qualitative cost assessments

Modality	Quantitative assessment using the cost assessment model (results in Chapter 3)[9]	Qualitative assessment (results in Chapter 5)
A1 Regulated vehicle category	A1.1 Separate targets for M1 and N1	-
A2 Regulated entity	**A2.1 Manufacturer groups** **A2.2 Brands**	Additional qualitative assessment on the same options (A2.1 and A2.2)
A3 Metric(s)	**A3.1 TTW CO_2 emissions (as in existing Regulation)** **A3.4 WTW CO_2 emissions**	-
A4 Embedded emissions	A4.1 Embedded emissions excluded in the metric	A4.3. Embedded emissions excluded in the metric but included with another approach (e.g. reporting of embedded emissions)
B1 Measuring TTW vehicle parameters	B1.1 Type Approval test result (WLTP)	B1.2 Type Approval test result + correction for real-world divergence B1.3 Type Approval test result + OEM to provide ECU data on real world fuel consumption B1.4 Real-world measurements (e.g. PEMS or monitoring of ECU data) B1.5 One of the options B1.1, B1.2 or B1.3 combined with specific test procedures for energy using devices and/or off-cycle energy saving technologies
B2 Determining WTT parameters	B2.2 Default values for the entire EU projections differentiated to target year	-
B3 Determining parameters w.r.t. vehicle manufacturing & disposal	-	B3.3 Harmonised LCA reporting by OEMs (per vehicle or e.g. per kg of vehicle weight) (together with A4.3)
C1 Rewarding off-cycle emission reductions	**C1.1 Eco-innovations (as in existing Regulation)** **C1.3 None**	C1.2 Off-cycle technology credits (as in the US Regulation)
C2 Rewarding or penalising technologies	C2.4 None	C2.2 Minimum share of advanced technologies in vehicle sales C2.3 Flexible minimum share of advanced technologies in vehicle sales
C3 Aggregation & weighting	**C3.2 Limit based on overall sales-weighted average (as in existing Regulation)** **C3.5 Combining C3.2 with mileage weighting**	C3.4 Technology specific targets: limit based on overall sales-weighted average per technology
D1 Approach for target setting	D1.1 Targets for fixed date(s) without phase-in	-
E1 Utility parameter	**E1.2 Mass as a utility parameter** **E1.4 Footprint as a utility parameter**	-
E2 Shape and slope of the target function	**E2.2 Linear target function with finite slope**	-

9 Printed bold when more than one modality value has been assessed in the cost assessment model.

Modality	**Quantitative assessment using the cost assessment model (results in Chapter 3)[9]**	**Qualitative assessment (results in Chapter 5)**
F1 Pooling	F1.1 No pooling of targets	F1.2 Pooling between car or van manufacturers (as in existing Regulation)
F2 Trading CO_2 credits	No	F2.4 Allowing trading of credits for vans and passenger cars separately
F3 Banking/borrowing	F3.1 No banking/borrowing	F3.2 Allowing only banking (maximum period and maximum banked amount to be specified) F3.3 Allowing banking and borrowing (maximum period and maximum banked/borrowed amounts to be specified)
F4 Excess emission premiums	-	F4.1 Excess emission premium of €X per excess g/km, possibly with lower premium for the first few g/km exceedance
F5 Derogations	None	F5.2 For manufacturers with niche volume (EU) sales (as in existing Regulation) F5.4 For manufacturers with niche volume (global) sales
F6 Correction for autonomous utility change	None	-

3 Detailed assessment of impacts on CO_2 emissions and cost

3.1 Introduction

Chapter overview	
Goal	Assessment of the impacts on cost and emissions for the long list of promising policy variants (i.e. combinations of modalities and target levels) and various technology scenarios.
Output	– Detailed analysis of impacts on GHG emissions (TTW and WTW), end-user, manufacturer and social cost and cost effectiveness. – Synthesis of the detailed assessment on emission and cost impacts by applying a multi criteria analysis.
Annexes	Annex F, Annex G, Annex H.

In this chapter the results are presented of the assessment of the impacts on cost and emissions for the long list of promising policy variants (i.e. combinations of modalities and target levels) and various technology scenarios. This has been done using TNO's tailor made cost assessment model for CO_2 regulations of LDVs (see Annex F.2).

3.2 Overview of the modalities and policy variants

The following modalities (as mentioned in Table 9) are assessed in a quantitative way using TNO's cost assessment model (all other modalities are not varied, see also Table 9):
- *Regulated Entity (A2)*: manufacturer groups (current regulation) or brands;
- *Metric (A3)*: TTW emissions (current parameter) or WTW emissions;
- *Rewarding off-cycle emission reductions (C1)*: eco-innovations (as in the current regulation) or not;
- *Mileage weighting (C3.5)*: accounting for the different average lifetime mileages of different drivetrain types and vehicle segments or not (current parameter);
- *Utility parameter (E1)*: mass (current parameter) or footprint;
- *Shape and slope of the target function (E2)*: five slope values from a zero slope limit function to a steep slope.

The possible modality values are compared for:
- two different target years: 2025 and 2030[10];
- two different vehicle categories: passenger cars and vans;
- three different target values per year per vehicle type;
- five different fleet compositions per year per vehicle type ('technology scenarios', see Section 3.3.2).

[10] As is the case for the Regulation (EC) No 443/2009 and Regulation (EU) No 333/2014 it is assumed that the target level set has to be met until the next target year.

All possible combinations of modality values for the different years, vehicle types, targets and fleet compositions, resulted in 9,600[11] different policy variants (see Table 10).

Table 10 **All policy variants that are assessed with the 'Cost Assessment Model'**

Modalities and modality options		
Modality	**Modality options**	**Number of options**
A2. Regulated entity	Individual OEM Manufacturer group	2
A3. Metric	TTW WTW	2
C1. Rewarding off-cycle technologies	Excluded Included	2
C3. Aggregation & weighting	Mileage weighting excluded Mileage weighting included	2
E1. Utility parameter	Mass Footprint	2
E2. Limit function slope	5 slopes (including zero slope)	5
Other variables in the policy variants		
Variable	**Variable options**	**Number of options**
Target year	2025 2030	2
Vehicle type	Passenger cars Vans (LCVs)	2
Target level	3% annual reduction 4% annual reduction 6% annual reduction	3
Technology scenarios	Mixed xEV Ultra efficient ICEV Extreme BEV Extreme PHEV/REEV Extreme FCEV	5

3.3 Main assumptions

3.3.1 Distinguished drivetrain types and segments

To get a sufficiently detailed picture of the impacts, a wide range of drivetrain types and size segments are used in the analysis. In this study eight different drivetrain types are distinguished in the same way as in (Ricardo-AEA, 2016), i.e.:

1. SI+Hybrid (petrol vehicles, including non-plug-in hybrids).
2. CI+Hybrid (diesel vehicles, including non-plug-in hybrids).
3. SI PHEV (petrol plug-in hybrid electric vehicles).
4. CI PHEV (diesel plug-in hybrid electric vehicles).
5. SI REEV (petrol range extender electric vehicles).
6. CI REEV (diesel range extender electric vehicles).
7. BEV (battery electric vehicles).
8. FCEV (fuel cell electric vehicles).

Drivetrain technologies 3 to 8 all include a form of electric drive. This group is therefore indicated as 'xEV' vehicles.

11 2 x 2 x 5 x 2 x 2 x 2 x 2 x 2 x 3 x 5 = 9,600.

For passenger cars four size segments are distinguished, i.e. (for definitions of segments, see Ricardo, 2016):
- small (market segment A and B);
- lower medium (market segment C);
- upper medium (market segment D);
- large (market segment E and larger).

For Vans only three size segments are distinguished, i.e.:
- small (<1.8t Gross vehicle weight (GVW));
- medium (1.8-<2.5t Gross vehicle weight (GVW));
- large (2.5-3.5t Gross vehicle weight (GVW)).

These are also taken from (Ricardo-AEA, 2016).

3.3.2 Fleet composition developments (or technology scenarios)

In order to assess the effect of different possible fleet compositions, so-called 'technology scenarios' have been defined in (Ricardo, 2016). For consistency reasons, these technology scenarios are also used in this study.

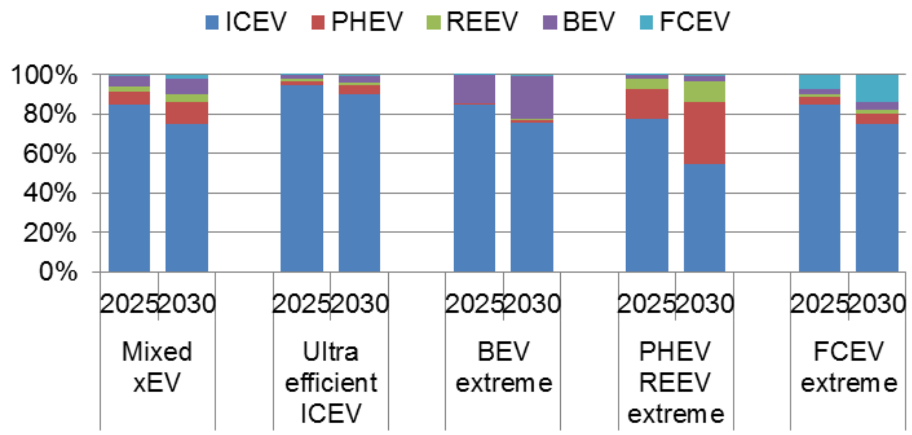
The fleet composition is an input parameter to the cost assessment model, meaning that the sales distribution over the different segments and drivetrain types is fixed in a given year. Consequently, changing the share of some drivetrains (in particular increasing the share of low-emission vehicles or shifts from petrol to diesel) is a model input and not a result. In the model analysis, manufacturers can only reduce their emissions by applying CO_2 reducing technologies to one or more combinations of drivetrains and size segments. The cost of these technologies are based on the cost curves that are used (see Section 3.3.3).

To take account of the impacts of possible changes in drivetrain technologies, all policy variants are assessed for multiple fleet compositions, called 'technology scenarios'. This analysis reveals how the impacts of the various policy variants are sensitive to such changes in the fleet composition.

The five different fleet composition developments considered are '*Mixed xEV*', '*Ultra efficient ICEV*', '*Extreme BEV*', '*Extreme PHEV/REEV*' and '*Extreme FCEV*'. These technology scenarios were developed in (Ricardo-AEA, 2016) and are shown in Figure 4, and the underlying data in Table 11.

Three of the five 'technology scenarios' are more or less extreme situations in which one alternative drivetrain technology is relatively dominant in terms of sales (BEV Extreme, PHEV/REEV Extreme and FCEV Extreme). The Mixed xEV scenario assumes a more mixed fleet development and could be regarded as a mid-scenario. The Ultra-efficient-ICEV scenario assumes a low uptake of alternative powertrains. This scenario could be considered most likely in case there is no further tightening of the existing regulations after 2020/2021 and without significant breakthrough in alternative powertrain technology.
With tightening of targets after 2020/2021, one of the more extreme scenarios becomes increasingly likely. Apart from this, the various scenarios are considered equally likely.

Figure 4 **Assessed fleet composition developments or 'technology scenarios'**



Source: Ricardo, 2016.

Table 11 **Assessed fleet composition developments or 'technology scenarios'**

	2025					2030				
	Mixed xEV	Ultra efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme	Mixed xEV	Ultra efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme
ICEV	85%	95%	85%	78%	85%	75%	90%	76%	55%	75%
PHEV	6.8%	2.3%	0.75%	15%	3.8%	11%	4.5%	1.5%	32%	5.3%
REEV	2.3%	0.75%	0.25%	5.0%	1.3%	3.8%	1.5%	0.50%	11%	1.8%
BEV	5.0%	2.0%	14%	2.0%	3.0%	8.0%	3.0%	22%	3.0%	4.0%
FCEV	1.0%	0.30%	0.20%	0.20%	7.0%	2.0%	1.0%	0.50%	0.50%	14%

3.3.3 Other vehicle characteristics

In this assessment, the shares of the various drivetrain types (ICEV, PHEV, REEV, BEV and FCEV) are based on the technology scenarios. These fixed shares are used for all manufacturers and are therefore not manufacturer specific.

The electric energy use is taken from (Ricardo-AEA, 2016) and differs per segment (small, lower medium, upper medium and large) but is also not manufacturer specific.

In contrary, the shares of petrol and diesel vehicles (for ICEVs, PHEVs and REEVs) as well as the distribution over the different segments (small, lower medium, upper medium and large) are manufacturer specific and are based on the proportion in the baseline situation (2013).

The average footprint is also manufacturer specific and taken from the 2013 situation. It is assumed that the average footprint of PHEVs, REEVs, BEVs and FCEVs is equal to that of ICEVs of the same segment. For mass this is also the case, but taking account of the weight of batteries using a correction factor taken from (Ricardo-AEA, 2016). These factors are shown in Table 12.

Table 12 **Mass correction (in kg) relative to ICEVs to take account of the additional weight of batteries**

	SI PHEV	CI PHEV	SI REEV	CI REEV	BEV	FCEV
2025	36	63	103	119	48	99
2030	21	48	81	97	7	72

3.3.4 Cost curves

Cost curves represent the relation between CO_2 reduction levels and the lowest additional manufacturer costs at which these reduction levels can be achieved. These cost curves are based on the costs of packages of CO_2 reducing technologies per drivetrain type per segment. The cost curves used in this study are obtained from (Ricardo-AEA, 2016) and from the JRC (see below). It concerns cost curves for:
- cars and vans separately;
- various drivetrain types (as indicated in Section 3.3.1);
- different segments (as indicated in Section 3.3.1);
- two different target years, i.e. 2025 and 2030;
- including and excluding off-cycle vehicle technologies;
- various 'technology cost scenarios' (more explanation below);
- mass and footprint as utility parameters (more explanation below).

Future technology costs are uncertain. Therefore, three different levels of technology costs are included for ICEVs in (Ricardo-AEA, 2016), i.e. 'low', 'typical' and 'high' costs. Moreover, technology costs are affected by economies of scale. In (Ricardo-AEA, 2016), it is assumed that CO_2 reducing technologies for ICEVs are sold in large numbers. However, for technologies that can be deployed to reduce energy use of xEVs three different costs levels are defined depending on the economies of scale, i.e. 'low', ''typical' and 'high' costs.

A separate set of cost curves was developed by JRC to account of the fact that in case of mass being the utility parameter, the CO_2 reduction resulting from light-weighting is not fully rewarded as a lower average mass for manufacturers leads to a stricter emission target. JRC has developed cost curves in which this effect is accounted for.

Depending on the vehicle type (cars or vans), the target year, the fleet composition and the policy variant, the cost curves per drivetrain type and vehicle segment are selected. For cars this set consists of 32 curves (eight drivetrain types and four segments) and for vans a set consists of 24 curves (eight drivetrain types and three segments). The cost curves that are selected for a certain policy variant depend on the utility parameter (mass or footprint) and whether or not off-cycle technologies are rewarded.

The 'typical', 'low' and 'high' cost curves were used for the different technology scenarios as shown in Table 13. This table indicates for instance that in case of the 'Mixed xEV' scenario the cost for all technologies was assumed to be 'typical', whilst in case of a high sales share of BEVs ('BEV Extreme') the technology costs for BEVs and PHEVs/REEVs are 'low', the technology costs for ICEVs are 'typical' and costs for FCEVs are 'high'.

Table 13 Cost curves applied in the different technology scenarios

Cost curve scenario	Technology scenarios				
	Mixed xEV	Ultra-efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme
ICEV	Typical	Typical	Typical	Typical	Typical
PHEV/REEV	Typical	High	Low	Typical	Typical
BEV	Typical	High	Low	Typical	Typical
FCEV	Typical	High	High	High	Low

3.3.5 Conversion factors (WLTP/NEDC)

In order to define a 2013 baseline for all manufacturers in terms of CO_2 emissions and sales distribution over the various segments, 2013 NEDC CO_2 emissions of vehicles had to be converted to WLTP emissions. Moreover, conversion factors were needed to determine WLTP targets corresponding with the selected NEDC-based targets (see Section A.4), and to determine the WLTP emission values for 2013.

The conversion factors used to convert NEDC into WLTP emission values were developed in the context of (Ricardo-AEA, 2016). These factors are summarised in Annex G.2 (Table 43)

3.3.6 Target values and equivalent targets

The effectiveness of the policy depends strongly on the target levels. In this study, an assessment has been made of target levels that are consistent with meeting the overall 2050 GHG reduction goals for transport or the 2030 reduction goal for the non-ETS sectors. Also a comparison was made with targets set in other parts of the world. The results of this analysis can be found in Annex A.

The targets that are needed for meeting the overall goals depend on a broad range of assumptions, such as:

- development of transport demand in all transport modes;
- CO_2 reductions to be achieved in non-road transport modes (particularly aviation and shipping);
- CO_2 reduction in other road vehicles than LDVs (in particular HDVs);
- blending of biofuels and CO_2 reduction accounted to this;
- development of the gap between real world (RW) and type approval (TA) CO_2 values (for the assessment, a constant gap of 45 g/km between TA and RW emissions was assumed for ICEV).

A brief summary of the results of the top-down assessment is presented in Table 14. This shows a very large bandwidth for the cars and vans target levels. Some of the uncertainties are dependent on other policies, e.g. development of biofuel blending depends on EU and national fuel and renewable energy policies, the development in GHG emissions on other transport modes depend on policies targeting these sectors, transport demand growth is affected by pricing and infrastructure policies, etc.

Table 14 2025 and 2030 targets that resulted from the top-down analysis

	2025 (mid value; bandwidth between brackets)		2030 (mid value; bandwidth between brackets)	
	Target level in g/km (NEDC)	Corresponding annual reduction rate	Target level in g/km (NEDC)	Corresponding annual reduction rate
Cars				
Levels required to meet 2050 goal	70 (43* to 84 g/km)	7% (18% - 3%)	55 (0 to 72 g/km)	6% (infinite - 3%)
Levels required to meet 2030 goal	65 (0 to 95 g/km)	9% (infinite - 0%)	44 (0 to 95 g/km)	6% (infinite - 0%)
Vans				
Levels required to meet 2050 goal	116 (59 to 130 g/km)	5% (17% - 2%)	89 (0 to 113 g/km)	5% (infinite - 3%)
Levels required to meet 2030 goal	100 (59 to 131 g/km)	7% (17% - 2%)	66 (0 to 116 g/km)	8% (infinite - 2%)

* Assuming that all AFVs are ZEVs; in case these are (partly) PHEVs/REEVs, the lower end of the bandwidth will be lower, down to 0 g/km).

Following consultation with DG CLIMA, for each target year, three target values for cars and three target values for vans have been selected for the assessment of the policy variants. They are based on annual reduction rates of 3, 4 and 6% starting from the targets set for 2020 (vans) and 2021 (cars). These rates are all within the large bandwidth resulting from the top-down assessment presented in Annex A, generally at the lower end.

WLTP target values

As the cost curves used for the cost assessment are based on WLTP type approval values, the NEDC targets have been translated to WLTP targets as shown in Table 15. The approach for this is explained in Annex G.

Equivalent WTW target levels

As indicated in Table 10, two different metrics are assessed, i.e. TTW and WTW-emissions. In case of a WTW-based metric, manufacturers have to meet a sales weighted average WTW CO_2 emission target. As WTW emissions are higher than TTW emissions, meeting the same TTW target level under a WTW-based metric would result in higher TTW CO_2 reductions and therefore higher additional manufacturer costs. In order to allow comparing the impacts of policy variants with different metrics (TTW or WTW) 'equivalent targets' under both metrics are determined. These are also shown in Table 15.
The methodology used to determine these 'equivalent targets' is explained in Annex G.

Table 15 Overview of equivalent targets in g/km (mixed xEV technology scenario)

Vehicle type	Target year	Target scenario	TTW NEDC targets	Equivalent TTW WLTP target	Equivalent WTW WLTP target
Passenger car	2025	6% annual reduction	74	82.0	98.0
		4% annual reduction	81	89.8	107
		3% annual reduction	84	93.1	111
	2030	6% annual reduction	54	60.7	76.8
		4% annual reduction	66	74.2	92.0
		3% annual reduction	72	80.9	99.6
Vans	2025	6% annual reduction	108	125	146
		4% annual reduction	120	139	161
		3% annual reduction	126	146	169
	2030	6% annual reduction	79	91.7	113
		4% annual reduction	98	114	137
		3% annual reduction	108	125	150

3.3.7 Business as usual (BAU) scenario

The baseline year for the cost curves used in this study is 2013. In order to use the cost curves correctly, the required CO_2 emission reduction to comply with the target and the resulting additional manufacturer costs are in first instance determined relative to this baseline year (2013).

Since, in 2013 the target levels set in the current Regulations were not yet (fully) applicable, a more appropriate reference fully reflecting the existing policies is the 'Business as Usual' BAU scenario, which assumes that already adopted policies are continued and no additional policies are implemented. Under this BAU scenario the target levels for passenger cars (95 g/km NEDC) and Vans (147 g/km NEDC) would continue beyond 2020/2021. The impact of new regulation in 2025 and 2030 is then represented by the additional manufacturer costs and GHG emission reduction relative to meeting 95 g/km NEDC for passenger cars and meeting 147 g/km NEDC for vans.

As a BAU scenario including all existing policies is commonly used in EU impact assessments, this approach is also chosen in this study.

However, further assumptions are needed as regards the fleet composition under the BAU scenario. The effects of the different policy designs on costs and GHG emission reductions are determined using the 'cost assessment model' for all five technology scenarios (see Section 3.3.2). By comparing the runs with the five technology scenarios, the one with lowest cost could be deemed the most likely fleet development scenario. However, this is based on the assumption that OEMs can fully control the sales distribution over different drivetrain types. In reality this is only partly the case as consumers decisions in vehicle purchasing depend on multiple factors, not all of which can be directly influenced by car manufacturers, e.g. road taxes. Moreover, not all technology scenarios may become available at the cost assumed in the selected cost curves, as these technology cost are also dependent on external developments. Finally, besides costs the attractiveness of a vehicle also depends on the vehicle's performance, user friendliness, availability, infrastructure, etc.

There are two possible ways to define the BAU scenario in relation to the technology scenarios (fleet composition):

1. A technology scenario dependent BAU scenario in which the fleet composition is equal to the fleet composition of the policy variant assessed.
2. A technology scenario independent BAU scenario in which one fleet composition is selected for all combinations of technology scenarios and policy variants assessed.

An important drawback of a technology scenario dependent BAU scenario is that it is not possible to determine directly whether differences in certain outcomes of different policy variants are the result of the modality values assessed or the result of the reference technology scenario being different. Since this drawback does not occur using a technology scenario independent BAU scenario, this option is preferred.

This approach requires the selection of one single fleet composition together with BAU policy assumptions that will be the reference against which all combinations of policy variants and technology scenarios are assessed. In order to select that single technology scenario, the 'cost assessment model' was run for all technology scenarios under BAU assumptions, to meet the targets currently set in the Regulations for respectively passenger cars and vans (105 g/km and 167.2 g/km WLTP, which are equivalents of respectively 95 g/km and 147 g/km NEDC) in 2025 and 2030.

As shown in Table 16, the sales weighted average emissions in 2030 are lower than the BAU targets (i.e. 95 g/km and 147 g/km NEDC), in all technology scenarios except for 'Ultra-efficient ICEV'. This is the result of the share of (UL)EVs being so large that even if the emission factors of new ICEVs would not (much) decrease compared to the 2013 situation, the average emissions would still be below the BAU target levels.

Consequently, for meeting the BAU targets, the CO_2-reductions required from ICEVs are zero (in most technology scenarios) or relatively limited (in the 'Ultra-efficient ICEV' scenario). Therefore the additional manufacturer costs of ICEVs in these cases are also zero or relatively limited. Compared to these ICEVs, the additional manufacturer costs of (UL)EVs are relatively high in most technology scenarios, making that the overall additional manufacturing costs are also higher than in the Ultra-efficient ULEV scenario. This is especially so for the scenarios with high shares of (U)LEVs. As the share of (UL)EVs increases between 2025 and 2030, the average additional manufacturer costs can even increase over time, despite the fact that for individual drivetrain type additional manufacturer costs decrease (see Figure 5). However, this also translates into average NEDC emission levels in 2030 that are lower than in 2025.

Given these phenomena, the additional manufacturer costs of vans are lowest for the 'Ultra-efficient ICEV' fleet composition. For passenger cars, the 'BEV Extreme' technology scenario (which has a significant share of BEVs (13% in 2025 and 22% in 2030)) results in slightly lower additional manufacturer costs than the 'Ultra-efficient ICEV' technology scenario. However, the 'BEV Extreme' technology scenario assumes a very strong price decrease of battery technology and is therefore not an appropriate BAU scenario. Therefore, also for passenger cars, the 'Ultra-efficient ICEV' fleet composition is used for the BAU scenario.

The share of alternative drivetrains increases in the 'Ultra-efficient ICEV' fleet composition between 2025 and 2030. This increase is assumed to be an exogenous effect as also other factors than the CO_2 regulation affect the sales share of alternative drivetrains.

Figure 5 **Additional manufacturer costs in €/vehicle relative to 2013 for passenger cars (left) and vans (right) for 2025 and 2030 for five different fleet compositions under BAU (i.e. for meeting the WLTP equivalents of 95 g/km (cars) and 147 g/km NEDC (vans))**

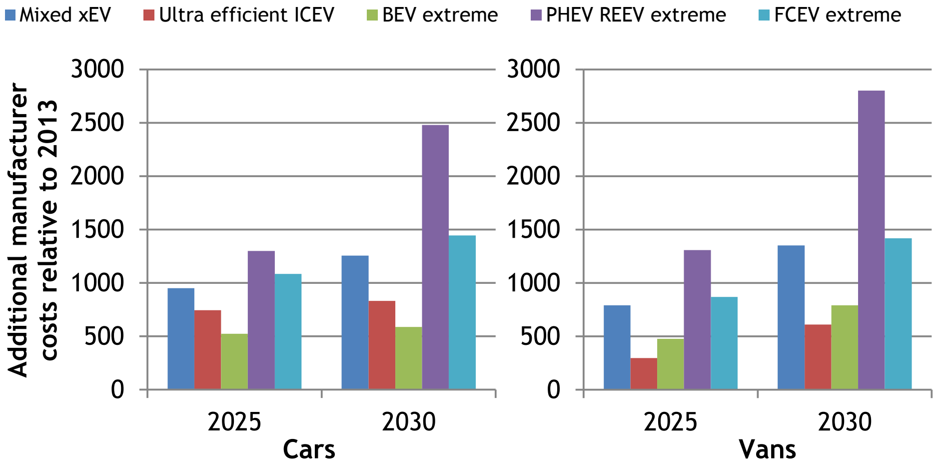


Table 16 **Average TA emissions and additional manufacturer costs relative to 2013 situation**

		Target		Final average WLTP emissions				
		NEDC	WLTP	Mixed xEV	Ultra-efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme
Passenger cars	2025	95	105	105	105	105	105	105
	2030	95	105	104	105	102	89	103
Vans	2025	147	167	164	167	164	160	163
	2030	147	167	155	166	156	128	151

		Target		Additional manufacturer cost relative to 2013				
		NEDC	WLTP	Mixed xEV	Ultra-efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme
Passenger cars	2025	95	105	951	745	524	1,300	1,085
	2030	95	105	1,257	831	588	2,479	1,443
Vans	2025	147	167	764	283	455	1286	836
	2030	147	167	1347	595	791	2812	1420

3.3.8 Other parameters

A number of other assumptions are used in this quantitative analysis regarding mileages, fuel properties, depreciation rates, discount rates, share of real world electric driving of PHEVs and REEVs and the assumed gap between type approval and real world CO_2 emissions. These are described below.

Mileages

A fixed lifetime mileage is assumed for every combination of drivetrain type and segment. This lifetime mileage is determined by adding up the annual mileages over the lifetime of passenger cars and vans as obtained from (TML, 2016). Average annual mileage decreases with vehicle age.

A recent Ricardo study[12] is then used to convert the overall average lifetime mileage for passenger cars and vans to mileages for different segments and drivetrain types, depending on the average mass. Because of their limited range, it is assumed that BEVs have relatively low lifetime mileages, i.e. the same lifetime mileage as SI vehicles. Since PHEVs, REEVs and FCEVs have larger ranges their lifetime mileage is assumed to be equal to the lifetime mileage of CI vehicles.

Moreover this study[12] is used to determine the 'survival rate' of vehicles, which is used to determine the sales weighted average annual mileage of all vehicles sold within a certain year. Also vehicles that are scrapped or exported out of the EU are taken into account when calculating the average mileage although their mileage is zero.

Table 17 **Assumed lifetime mileages (km) for the various segments and drivetrain types**

	Passenger car				Van		
	Small	Lower medium	Upper medium	Large	Small	Medium	Large
Petrol/BEV	152,099	173,142	183,830	184,654	136,442	150,521	177,312
Diesel/PHEV/REEV/FCEV	232,266	252,158	263,350	276,100	195,425	210,271	244,477

Fuel related parameters

Fuel related parameters used in this assessment include the WTT (or upstream) emissions in Table 18 and fuel prices as summarised in Table 19. The WTT factors, fuel prices and excise duties are all assumed to be exogenous parameters. These values take account of biofuel blending in petrol and diesel as well as of the decarbonisation of power generation induced by EU climate and energy policies like Renewable Energy Directive and the ETS.

Table 18 **WTT emissions in g/MJ**

Year	Petrol	Diesel	Electricity	Hydrogen
2025	11.2	7.6	98.2	104.3
2030	11.1	7.2	87.3	104.3

Sources: WTT emission factors for petrol and diesel-based on (EC, JRC, 2013) taking into account expected shares of different types of biofuel feedstock as estimated by (ICF, 2015). WTT emission factors for electricity and hydrogen are from SULTAN tool (2014) and take account of climate and other policies for the power sector.

12 Improvements to the definition of lifetime mileage of light duty vehicles (Ricardo, 2014).

Table 19 **Fuel and electricity prices**

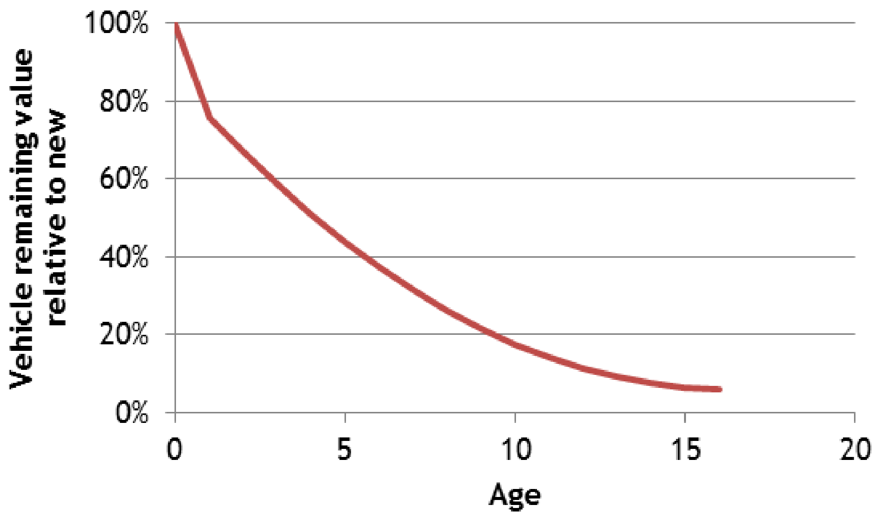
		Petrol	Diesel	Electricity	Hydrogen
2025	Fuel price, excluding taxes	0.90 €/l	0.89 €/l	0.040 €/kWh	0.025 €/MJ
	Excise duty	0.62 €/l	0.48 €/l	0.008 €/kWh	0 €/MJ
2030	Fuel price, excluding taxes	1.01 €/l	1.00 €/l	0.048 €/kWh	0.025 €/MJ
	Excise duty	0.62 €/l	0.48 €/l	0.008 €/kWh	0 €/MJ

Sources: Energy prices and taxes were based on the Oil bulletin (petrol and diesel), E3ME model (electricity) and SULTAN (hydrogen); energy taxes on MOVEET (petrol/diesel) and E3ME (electricity).[13]

Depreciation and discount rates

Depreciation rates of vehicles have been based on the in-depth analysis on second hand car prices in the EU as carried out in (TML, 2016). The remaining value as percentage of the purchase price is shown in Figure 6.

Figure 6 **Depreciation: the remaining value as percentage of the purchase price**



In line with the EU Impact Assessment Guidelines (TOOL #54)[14], a societal discount rate of 4% has been used in this assessment. As usual, the discount rate for end-users is higher and a value of 8% was used.

Share of 'real-world' electric driving of PHEVs/REEVs

Both the current share of real world electric driving of PHEVs/REEVs as well as the development of this parameter in the future is uncertain because of the limited EU sales and the limited availability of data on the charging frequency. As in the Netherlands the sales of PHEVs have been relatively high over the last years and relatively much data has been gathered on the charging

13 www.ec.europa.eu/energy/en/statistics/weekly-oil-bulletin

14 www.ec.europa.eu/smart-regulation/guidelines/tool_54_en.htm

frequency, those data are used to determine the Share of 'real-world' electric driving.

In the Netherlands the real world share of electric driving with vehicles with both an electric and ICE drivetrain is approximately 26.1%[15]. This is significantly lower than the share according to the NEDC type approval which is typically between 66% (50 km electric range on the NEDC) and 77% (80 km electric range on the NEDC). The difference between the real world share and the share of electric driving on the type approval procedure is the result of the less frequent charging by the end user than assumed in the NEDC. This lower frequency is a combination of:

– a limited real world electric range (which is lower than the electric range on the NEDC); and
– high average mileages driven by the end users of these vehicles, which are mainly sold in the high vehicle segments (D segment and above).

The 26.1% share of real world electric driving also includes vehicles with a type approval electric range of more than 80 km on the NEDC, which would be categorised as an REEV in this study. For PHEVs as categorised in this study (electric range of 50 km on the NEDC), the real world electric driving share is therefore even lower. On the other hand, the share of real world electric driving found in the Netherlands may have been biased because of the type of consumers driving these vehicles. These vehicles were especially attractive for consumers with relatively high mileages for whom fuel costs were covered by their employer. This leads to a low incentive to charge the vehicle.

Since the magnitudes of these effects are unknown, it is assumed for this study that the batteries are charged every 140 km, which corresponds with one way commuting trips of 70 km and charging overnight. However it is noted that depending on the type of use of the consumers who will be acquiring such vehicles in the future, the charging frequency may change over time.

The average 'real world' share of electric driving for REEVs and PHEVs under WLTP is then assumed to be:

Real world share of electric driving = WLTP electric range / 140 [km]

Given the assumed NEDC-based electric range of PHEVs of 50 km (Ricardo-AEA, 2016) and the conversion factors (as discussed in section 3.3.5), the WLTP-based electric range of PHEVs is approximately 38 km. Therefore, the assumed average 'real world' share of electric driving for PHEVs becomes 27% (38/140), close to what was found in the Netherlands.
For REEVs the assumed NEDC-based electric range is 80 km (Ricardo-AEA, 2016). Given the conversion factors, the WLTP-based electric range is approximately 61 km, leading to a 'real world' share of 44% (61/140).

RW/TA factor
According to a study by the ICCT of vehicles sold in 2013, the real world CO_2 emissions were approximately 48 g/km (so 38% of 127 g/km) higher than the type approval values (TNO; IFEU; ICCT, 2014) and increasing. This was partly based on an extensive real-world monitoring study (TNO, 2014a) which was updated (TNO, 2015a) showing an increased gap.

[15] Norbert E. Ligterink, Richard T.M. Smokers. Monitoring van plug-in hybride voertuigen (PHEVs) april 2012 t/m maart 2015. TNO 2015 R10802, 10 juni 2015.

For vehicles driving on an electromotor less insights are available about the gap between type approval and real world energy use. Therefore only an indication can be provided. As to a large extent manufacturers can use the same flexibilities for BEVs/FCEVs as for ICEVs, the same relative gap (38%) as for ICEVs is used to derive the gap between the TA and RW energy use of BEVs and FCEVs.

Assuming an average energy use of 0.5 MJ/km for BEVs the real world energy use would thus be 0.69 MJ/km (0.5 * 1.38). Taking into account an offset of 0.05 MJ/km for off-cycle energy use from the auxiliary systems (energy consumption not used on the type approval test, e.g. lights and heating), a relative difference of 30% remains (0.64 vs. 0.5 MJ/km). This translates to the following relation for BEVs and FCEVs:

*BEV and FCEV RW energy use = 1.3 * TA energy use [MJ/km] + 0.05 [MJ/km]*

For PHEVs/REEVs the same factors are used for the two parts of the driving cycle separately. For the share of the cycle driven in ICE mode the RW/TA factor of ICEVs is applied. And for the share driven in EV mode, the factor of BEVs is applied.

3.4 Methodology

The methodology to assess a policy variant consists of a three-step process, i.e.:

1. running the 'cost assessment model' for each policy variant (vehicle type, set of modality values, technology scenario, target year and target value) to determine the cost optimal solution from manufacturer's perspectives;
2. determining for this solution the relevant impacts, e.g. on:
   - TTW and WTW CO_2 emissions per segment;
   - additional manufacturer costs;
   - end user costs:
   - societal costs;
   - overall GHG emission reduction.
3. comparing the assessed policy variants, to determine the impacts of the modality values, technology scenarios and target values in terms of their various impacts.

3.4.1 Running the 'cost assessment model' to determine the cost optimal solutions (Step 1)

In the cost assessment model the assumed way in which manufacturers will respond to new regulation is assumed to be by reducing CO_2 emissions in the different segments and drivetrains at the lowest possible overall manufacturer costs in order to meet the targets. These likely manufacturer responses to possible regulation designs have been modelled for all combinations of a wide range of modality values.

Based on these inputs, the model calculates for each manufacturer how the overall target can be met against the lowest cost by distributing the necessary CO_2 reduction across the different segments and drivetrains. Based on these likely manufacturer responses, the overall cost of complying with the policy variant and resulting CO_2 emissions are determined.

Likely manufacturer responses are modelled for a large number of possible policy variants as listed in Section 3.2. This is done using TNO's 'cost assessment model'. This model was developed in 2004, was later refined by TNO to assess the impacts of the 2015 and 2021 targets for passenger cars i.a. (TNO; IEEP; LAT, 2006), (TNO, et al., 2011b) and the 2017 and 2020 targets for vans (TNO, et al., 2011a).

The 'cost assessment model' is a mathematical model that allows to determine the CO_2 reductions and resulting additional manufacturer costs per segment for individual OEMs to comply with a certain policy variant by reducing emissions of their new vehicles at the lowest possible costs.

The lowest possible costs to comply with a certain policy variant, including a type approval CO_2 target, are determined in the following way:

1. Firstly the 2013 baseline situation is determined for every legal entity in terms of their sales and average TA CO_2 emissions per segment per drivetrain type. For this study, 2013 is the selected baseline as the cost curves provided are also based on and therefore applicable to 2013 new registrations. This baseline is only determined once and is independent of the policy design assessed.
2. Hereafter the fleet composition in the target years (2025 and 2030) are defined, as explained in Section 3.3.2. As the vehicle characteristics apart from the energy use (and therefore CO_2 emissions) are assumed constant over time, the utility parameter can then be determined for the target years. Since the fleet composition changes over time and the vehicle characteristics differ per drivetrain type, the 'average' utility value changes as well. N.B. effects from light-weighting on the target level have been accounted for in the cost curves as explained in Section 3.3.4 and is therefore not assumed to affect the target level.
3. Thirdly the target year situation is assessed:
   - The target applicable to the legal entity in the target year is based on the entity's average utility value (point 2) and the selected utility function.
   - Every legal entity's cost optimal CO_2 (or energy use) reductions per segment between the base year and the target year to meet their target are calculated by using the cost curves for every segment and drivetrain type. It is assumed that the target set will be met in such a way that the total additional costs for each individual legal entity are as low as possible. The required relative reductions in every segment for every drivetrain for every legal entity are found using a solver-function which minimises the total additional costs (costs for realising the target in the target year, starting from the base year) for the manufacturer group by varying the reductions per car for the different segments. At this minimum, the emission reduction levels are such that the marginal costs are equal for all segment and drivetrain types.
4. Finally, the additional cost and resulting CO_2 reduction are determined relative to the BAU scenario as explained in Section 3.3.6.

The costs are determined for two target years, i.e. 2025 and 2030, using two separate sets of cost curves taken from (Ricardo-AEA, 2016). The costs indicate the additional manufacturer costs in a target year compared to the baseline situation (2013). As no technology cost (curves) are available for intermediate years, the costs determined for a certain target year are not affected by the CO_2 emission trajectory between the baseline year and the target year. As a result, the costs for meeting the 2030 target are not affected by the assumed target level for 2025.

More information about the 'cost assessment model' is provided in Annex F.

Effects of changing the values of the modalities mentioned in Section 3.1 can all be modelled using this 'cost assessment model' and the manufacturer's cost optimal solution for a given combination of modality values can be determined. Table 20 summarises how these modalities are assessed in the model. The methodology used for assessing the various modalities in the cost assessment model is further explained in Section 3.4.3.

Table 20 Methodology used for the assessment of each modality, using the cost assessment model

Modality	Methodology used with cost assessment model
Regulatory metric	The 'cost assessment model' finds the manufacturer's cost optimal CO_2 emissions per drivetrain type and segment to meet its target. The target and emissions of the different drivetrain types and segments were defined either as *TA TTW emissions*, or as *WTW emissions*.
Mileage weighting	Currently targets and emission values are defined per kilometre. However, the average lifetime mileages of vehicles per drivetrain type and per segment can be accounted for in the 'cost assessment model' by optimising over the *lifetime emissions* rather than the *emissions per kilometre*.
Off-cycle technologies	Certain technologies, which reduce a vehicle's CO_2 emissions in use, do not affect its type approval emissions (e.g. energy efficient HVAC) and are therefore *excluded* from the cost curves for CO_2 reduction on the type approval test. These off-cycle technologies can be accounted for by *including* them in alternative cost curves.
Utility parameter	Given a utility function, a manufacturer's average utility parameter value determines its target. Depending on the utility parameter prescribed in the policy (*mass* or *footprint*), a manufacturer's target and therefore required effort will be different.
Legal entity	The 'cost assessment model' was used to assess the effect of either every individual OEM having to comply with its own target as well as of a policy allowing OEMs to pool into one entity.
Target function slope	Besides the utility parameter prescribed in the policy, also the slope of the target function determines the target manufacturers have to comply with, depending on their average utility value. This slope can be anything from flat to very steep. *Five different slope* values are assessed.

NB: The methodology used for assessing the various modalities in the cost assessment model is further explained in Section 3.4.3.

3.4.2 Determining the relevant impacts

At the manufacturer's cost optimal solutions, the CO_2 emissions and additional manufacturer costs are determined. Based on these values in combination with other assumptions (as described in Section 3.3), a large number of other characteristics of the solution can be determined, e.g.:

- overall GHG emission reduction;
- amount of overall GHG emission reduction per unit societal cost;
- amount of overall GHG emission reduction per unit end user cost;
- amount of overall GHG emission reduction per unit additional manufacturer cost;
- relative price increase for ACEA members vs. non-ACEA members (proxy for impact on competitive position of EU automotive industry, see Section 2.5.1).

These parameters are used to compare the different policy variants based on the criteria described in Section 2.5.1 and Annex F.

Table 21 Overview of the main input and output of the cost assessment model

Input	Output
– Cost curves – Manufacturer average TTW CO_2 emissions (in 2013) – Manufacturer sales distribution (in 2013)	– CO_2 emissions per drivetrain type per segment per manufacturer – Additional manufacturer cost per drivetrain type and segment per manufacturer
– Mark-up factor	– Relative price increase
– Annual and lifetime mileage – Depreciation rates – RW/TA factor – Cost of energy carrier	– Overall GHG emission reduction – Societal cost – End user costs
– ACEA members	– Average price increase ACEA members vs non-ACEA members

3.4.3 Methodology for assessing the impacts of various modalities

In order to assess the impact of different modality choices, elements of the model are changed. For some modalities this is done by simply changing the value of a certain parameter, for other modalities this requires more changes in the modelling. Below, the changes made to the model to assess the effect of a certain modality are explained.

Metric

Two different metrics are assessed, i.e. TTW and WTW emissions. The effects of the policy variants in which the regulatory metric is WTW CO_2 emissions, are determined using the methodology described in Section 3.4.1. The WTT emissions are based on the TA energy use (in [MJ/km]) and the WTT factors in the target year. Changes in WTT factors are the result of changes outside the transport system and are not the effect of the policy assessed in this study. Reductions resulting from lower WTT factors should therefore not be taken into account as this would result in double counting.

Hereafter the target function is determined as explained under 'slope of the target function' below, based on these WTW emissions.

The lowest possible additional manufacturer cost for complying with the WTW-based target are determined in a similar way as described in Section 3.4.1. Similar as described in that section, the emission reductions (in this case WTW emissions) are only the result of applying CO_2 emission reducing or energy use improving technologies. The WTT factors are assumed to be exogenous parameters which cannot be influenced by manufacturers.

As only vehicle related measures are taken into account, the same cost curves are applied as in the policy variants with a TTW-based metric. As explained above, changes in the WTT factors are not taken into account. As a result a relative TTW emission or energy use reduction results in equally much WTW emission or energy use reduction. Therefore the TTW cost curves can also be applied in case the metric is WTW rather than TTW.

Using a solver routine the optimal (lowest cost) distribution of relative TTW emission reduction over all segments and drivetrain technologies is found at which the manufacturer's average WTW emission level is equal to its WTW-based target. As explained in Section 3.4.1, the fact that at the cost optimal solution the marginal costs are the same for all segments and drivetrain types is used to find this solution. In case of a TTW-based target these marginal costs are expressed as (Δ additional manufacturer cost)/(Δ TTW emission reduction) while under a WTW-based metric, the marginal costs are expressed as (Δ additional manufacturer cost)/(Δ WTW emission reduction).

Legal entity

Policy variants with two different types of legal entities are assessed, i.e. manufacturer groups and individual manufacturers. Depending on the legal entity chosen in a certain policy variant, the average utility parameter and CO_2 emission targets are determined either per manufacturer or per manufacturer group.

Utility parameter

Two different options for the utility parameter are assessed, i.e. mass in running order (being the utility parameter used in the current Regulations) and footprint. The least squares method is used to determine the relation between CO_2 emissions and mass or between CO_2 emissions and footprint in the baseline situation (being the year 2013).

Slope of the target function

For all assessments a linear target function is assumed. Five different slopes for this target function are assessed.

One is a completely flat limit function (zero slope). In that case all manufacturers have to comply with the same target value and thus the utility parameter is irrelevant. This limit function therefore yields the same results for mass and footprint.

A second slope ('medium slope' or 'equal relative reduction over the UP range')[16] is determined as follows. Firstly, the least squares fit is determined of the TA CO_2 emissions and the utility parameter values of all 2013 sales (with TA CO_2 values corrected from NEDC to WLTP, see Section 3.3.5). Hereafter, an equal relative emission reduction over the utility parameter range is applied down to the level at which the average CO_2 emissions are equal to the target level (indicated by arrows in Figure 7), assuming the utility parameter value of individual vehicles will not change. This slope represents a situation that requires an equal relative reduction from all manufactures compared to the baseline situation.

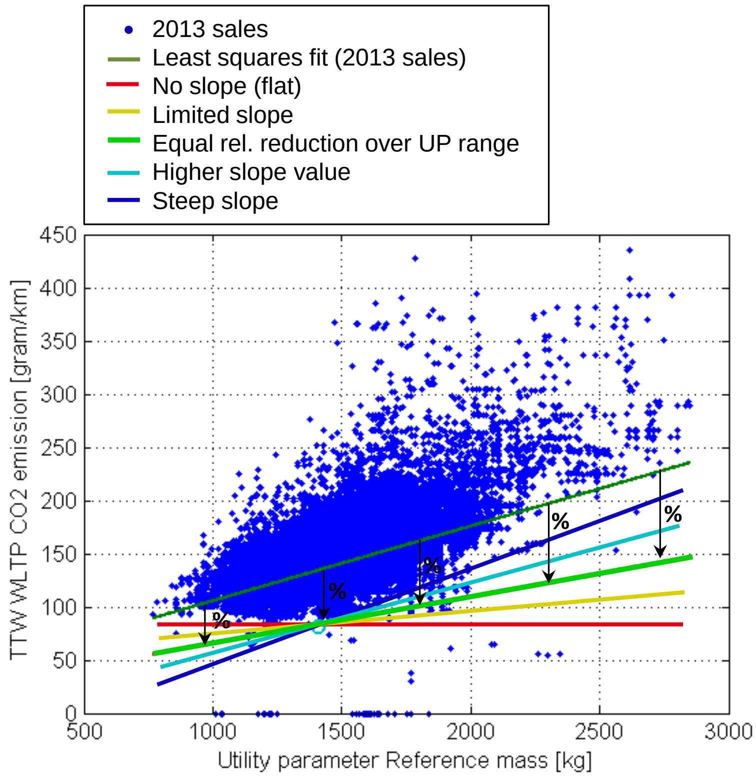
The remaining three slopes are derived from this 'medium' slope. One of these three is half as steep ('limited slope'), a second one is 1.5 times as steep ('higher slope value') and the last slope assessed is twice as steep as the 'medium' slope ('steep slope').

The absolute slope values are different for different utility parameters, target levels, vehicle types, passenger cars vs. vans), technology scenarios and metrics. For clarity reasons, these qualitative names are used rather than presenting the absolute slope values.

An example is shown in Figure 7.

16 This slope was in previous studies known as the '100%' slope.

Figure 7 **Example of the different limit function slopes assessed for the case of a TTW-based target and mass as utility parameter**



From previous studies it was concluded that the effect of the target function slope on the average effects on additional manufacturer costs, societal costs and effectiveness of the policy is rather limited, as long as no extreme slope value is selected. However, the slope of the target function very strongly affects the distributional impact of the policy amongst manufacturers (groups).

Mileage weighting

Two different options are considered: accounting for or not accounting for vehicle mileage.

As actual mileages of individual vehicles cannot be used, default lifetime mileage values are defined, which differ for the various segments and drivetrain types depending on the vehicle mass. These default lifetime mileage values are shown in Table 17 in Section 3.3.6.

In case the lifetime mileage is accounted for, the type approval emission value of a vehicle is multiplied by the lifetime mileage assumed for the segment to which that vehicle belongs. In that case the target is defined in grams of CO_2 emissions instead of g/km and it is calculated by multiplying the target level without mileage weighting by the sales weighted average lifetime mileage.

Using the lifetime GHG emissions of the 2013 vehicles instead of the TA CO_2 emissions also affects the limit function. Compared to Figure 7, the y-axis becomes lifetime emissions rather than TA emissions. As the lifetime mileage is based on vehicle mass (larger, heavier vehicles are assumed to have higher mileages), the limit function slope also changes when accounting for lifetime mileage.

Also the emission reductions are defined as lifetime emission reductions by multiplying the emission reductions by the lifetime mileage.

Rewarding off-cycle technologies
There are several technologies for which the CO_2 benefits are not, or not fully measured during the type approval test procedure, e.g. start-stop systems, energy efficient auxiliaries such as air conditioners, LED lighting, advanced cruise control, etc.

The ‘eco-innovations’ approach established under the current Regulations allows rewarding some of those ‘off-cycle’ technologies through a credit systems. In order to be eligible, technologies have to meet the conditions set out in the legislation and the implementing act (e.g. innovative character, contribution to CO_2 savings is verifiable, manufacturer/supplier is accountable for those savings, at least 1 g/km savings achieved, …). In addition, it limits the total contribution of those technologies to reducing the specific emissions target of a manufacturer (maximum 7 g/km). The technologies and their savings are evaluated and validated by the Commission, based on the claims made by manufacturers.

There are various other possible modalities (design options) for rewarding the emissions reductions from ‘off-cycle technologies’:
- Default credits for eligible options: this system is similar to the US approach. Default credits could be established on the basis of independent testing and assessments by the Commission.
- Adapting the laboratory-based type approval test procedure, or complementing it with specific test elements that assess the benefit of off-cycle technologies.
- replacing or augmenting the laboratory-based type approval test procedure with on-road testing (using PEMS) or using ECU data.

In this study the impacts of such specific modalities have not been modelled, as these depend on a large number of design details which cannot be specified or even overseen at this stage. Instead the model has been used to assess in a more generic way the potential impacts of including a defined set of off-cycle technologies on the reduction potential and the costs of reaching the emission targets.
This was done by comparing the results of model runs using cost curves that exclude off-cycle technologies with model runs using cost curves that include such reduction options. Both sets of cost curves were taken from (Ricardo-AEA, 2016) which also provides the list of the off-cycle technologies concerned.

The difference between the two runs shows the maximum potential and cost-effectiveness of accounting for the application of off-cycle technologies, e.g. by using the modalities mentioned above. The pros and cons of the various approaches are discussed in Section 5.4.1.

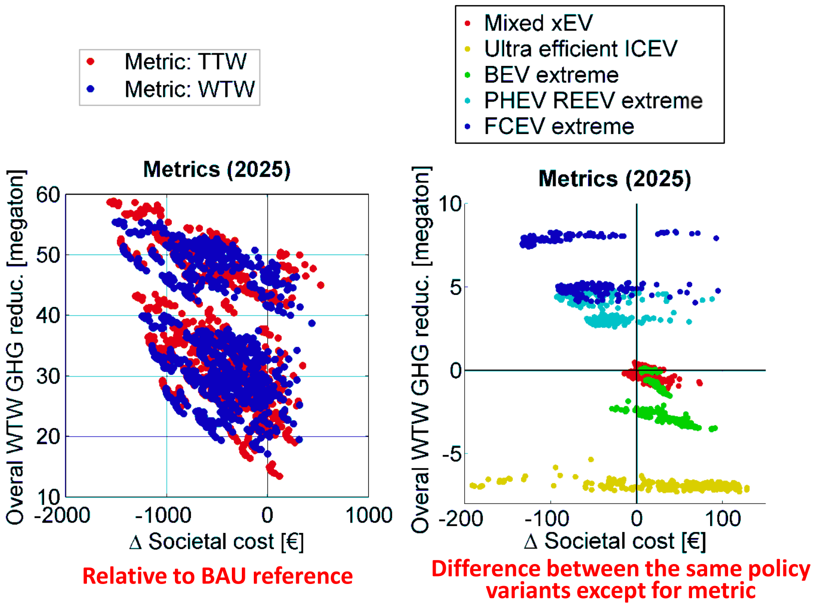
Target year
The target years assessed are 2025 and 2030. For both years cost curves are available. It is assumed that manufacturers have to continue complying with the established target value until the next target year. The options look at both target years separately (so either the new targets assessed apply from 2025 on or they apply from 2030 on).

Technology scenarios
All policy variants are assessed for five different technology scenarios or fleet compositions as explained in Section 3.3.2. These technology scenarios also have an effect on a legal entity's average vehicle mass, as xEVs have higher masses than ICEVs because the drivetrain is heavier. A shift to xEVs therefore results in higher average mass. In case mass is the utility parameter, these sales shifts affect the limit function and the resulting targets of the legal entities.

3.4.4 Comparison of the assessed policy variants

After all parameters that are used to compare different modality values have been determined for all possible policy variants, the various values per modality can be compared. For this, the results from the 'cost assessment model' are plotted in various types of figures. As the number of policy variants that have been assessed is very high, the average results are presented for many scenarios. In addition, two types of 'scatter plots' are used to show the results in a more detailed way showing the impacts of two modalities in one graph. Figure 8 is an example of two such scatter plots.

Figure 8 Examples of figures used to compare options for the modality '*regulatory metric*' on the criterion '*cost-effectiveness*'. Left the effect of policy relative to BAU, right the effect of changing the metric from TTW to WTW



Explanation of the examples shown in Figure 8
In the example case in Figure 8, the 'overall WTW GHG emission reduction' (i.e. the measure for the effectiveness) is plotted against the change in the total societal costs ('Δ societal costs') for every policy variant assessed for passenger cars in the target year 2025. The ratio of these two parameters is the (societal) cost effectiveness of the policy variant. All values are relative to the BAU reference situation (Section 3.3.6).
In this case, the modality assessed is the '*regulatory metric*', with TTW and WTW emissions as the two possible modality values.
In the left figure, every dot represents one policy variant, so the figures show the outcome for the whole range of target levels, modalities and technology scenarios assessed in this study.

All policy variants for 2025 in which the regulatory metric was 'TTW emissions' are coloured red (2,400 dots), while policy variants in which the regulatory metric was 'WTW emissions' are coloured blue (2,400 dots). The figure shows that, the 'overall WTW GHG reduction' in 2025 (compared to BAU) is in the range of 15 to 60 Mton per year and the additional societal costs per registered new car range from € -1,500 to € 500 across the policy variants considered. The left figure does not show the effect of changing from one metric (TTW) to another one (WTW) as it cannot be seen which blue and red dots only differ in terms of the 'regulatory metric' applied.

This is why the right figure is included, where each dot shows the difference between two model results with the same target levels, technology scenario and modality values except for the regulatory metric. In this case the Δ societal costs and overall WTW GHG emission reductions in case of the current modality value, i.e. TTW emissions, are subtracted from the corresponding policy variants with the alternative regulatory metric, i.e. WTW emissions. The figure thus shows the net effect in Δ societal costs and effectiveness of moving from a TTW to a WTW metric. Since the figure shows the difference between two policy variants, it contains 2,400 dots.

For the technology scenario 'Mixed xEV', this figures shows that the both the overall GHG emission reduction and the societal costs are not so much affected by the change of the regulatory metric. This can be explained by the fact that equal effectiveness, i.e. the overall GHG emission reduction, is a boundary condition in determining a WTW target equal to a certain TTW target level.

Figures like the ones shown in Figure 8 can be used to assess the performance of each modality on the various assessment criteria. Given that six modalities are assessed in this analysis (i.e. Utility parameter, Legal entity, Regulatory metric, Mileage weighting, Off-cycle technologies and Limit function slope) based on three criteria (i.e. Effectiveness, Cost effectiveness and Competitiveness) and for some criteria multiple parameters are used (see Table 8), more than 24 sets of figures would be required.

However, not all criteria are relevant for all modalities. For example the selected legal entity does not (significantly) affect the effectiveness of the regulation as the overall CO_2 emissions target has to be met independent of the legal entity. At the same time, the target is met in a slightly different way, resulting in different costs for meeting the same target. Therefore the legal entity may significantly affect the cost effectiveness.

3.4.5 Caveats

Conversion factors

WLTP/NEDC conversion factors were used to determine equivalent emission values in 2013, and to determine the WLTP targets which would be equivalent with the selected NEDC-based targets (see Section A.4).
However, these conversion factors have a number of important caveats, i.e.:

- The factors are based on a small number of 2013 vehicles and a single factor was derived for every segment and every combination of drivetrain type and segment.
- The factors will most likely differ from the outcome of the official NEDC-to-WLTP target translation, which will be established by the Commission.
- The factors are largest for large vehicles, while generally it is assumed that the difference between both test cycles is smaller for larger vehicles.
- The 2013 vehicles were very likely optimised to have low CO_2 emissions on the NEDC. After this cycle is replaced by the WLTP, it may be expected

that manufacturers will optimise their vehicles on WLTP and that the difference between the NEDC- and WLTP-based emissions from then on will become smaller. As a result the 2025 and 2030 equivalent WLTP-based target levels may differ from what is derived based on the 2013 correlation factors.

In case other factors would be used, the WLTP target level would be different, but also the baseline and BAU WLTP CO_2 emissions that were derived from the 2013 NEDC CO_2 emission levels. The effect on the overall required effort would therefore be negligible. However, if the conversion factors of the different segments would be changed to different extents, the required effort of manufacturers with different portfolios (in terms of vehicle mass or footprint) would change differently, affecting the competitive positions.

Type approval emissions of PHEVs and REEVs under WLTP

In line with (Ricardo-AEA, 2016), the WLTP type approval emissions of PHEVs and REEVs are determined using the same method as in the NEDC[17], i.e.

$$C_{TA} = \frac{D_{av} * C_{ICE}^{TA}}{D_e + D_{av}} = \frac{C_{ICE}^{TA} * 25}{D_e + 25}$$

With
- C_{TA} = TA CO_2 emissions of PHEVs and REEVs;
- D_e = electric range (until full battery is depleted);
- D_{av} = assumed distance between charging, i.e. 25 km in the NEDC;
- C_{ICE}^{TA} = CO_2 emissions per kilometre when driving on the combustion engine.

It was found in (Ricardo-AEA, 2016) that the electric range on the WLTP is shorter than on the NEDC and that TA CO_2 emissions of PHEVs and REEVs on the WLTP are higher than on the NEDC. These findings are also used in this study.

However, since the WLTP has not yet been introduced, the effect of the WLTP on the TA share of electric driving and therefore also on the TA emissions of PHEVs and REEVs are rather uncertain. Therefore also the development of the gap between TA and RW emission values of PHEVs and REEVs is yet unclear. In case other gap sizes would have been used, the calculated effectiveness of the policy would have been different. Assuming a smaller gap would result in a higher effectiveness; a greater gap would result in a lower effectiveness.

'Holes' in cost curves

Certain cost curves have 'holes': parts of the reduction range at which no technology packages are available for the cost indicated by the cost curve. In these sections the cost curves are less representative. This is typically the case with high cost technologies with high reduction potentials, e.g. hybridisation. Certain solutions found with the cost assessment model may therefore require a reduction level at which the cost of the available most cost effective technology package actually is higher than implied by the cost curve. Because of the large number of vehicle drivetrain types and segments distinguished in this analysis and therefore the large number of cost curves used per policy design (i.e. 32), the effect of this artefact on the sales

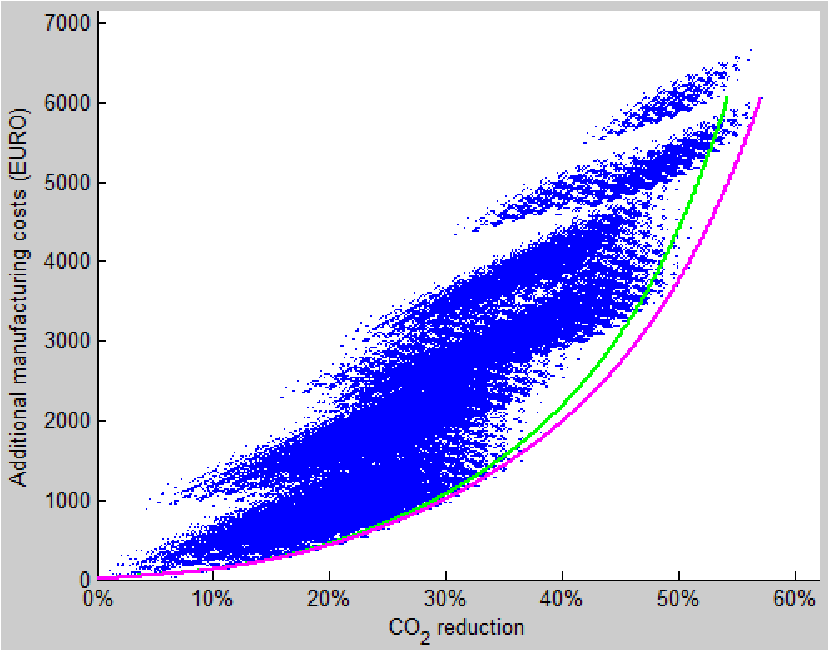
---

17 As the final text of the WLTP Regulation was not yet available during this study and (Ricardo-AEA, 2016),the actual methodology for determining the TA emissions of PHEVs/REEVs under WLTP may differ from what is used here.

weighted average outcomes is limited[18].

An example is shown in Figure 9 in which at a level of around 40% emission reduction, no packages of technologies are available with the reduction potential and additional manufacturer costs that are implied by the cost curve.

Figure 9 *Example* of packages of CO_2 reducing technologies and the resulting cost curve



Fleet composition development

As explained in Section 3.3.2, various possible fleet compositions (or technology scenarios) were used as defined in (Ricardo-AEA, 2016).

The actual future fleet composition is unknown and the provided technology scenarios only assume overall shares of drivetrain technologies not divided into segments or manufacturers. It is therefore assumed that every manufacturer will have the same share of alternative drivetrains. In reality however, it is likely that different manufacturers will apply different strategies and will sell different shares of drivetrain types.

Assuming different shares of the various drivetrain types for different manufacturers will affect the calculated additional manufacturer costs and therefore also the societal cost. Also the overall WTW GHG emission reduction (i.e. effectiveness) will change as different drivetrains are assumed to have different lifetime mileages and gaps between real world and type approval emissions. Finally for different manufacturers will be affected differently, therefore also the relative competitive positions will change.

---

18 At an equal sales distribution over the 32 distinguished segments, a cost optimal solution form a manufacturer perspective at which the most cost effective technology package is € 500 more expensive than indicated by the cost curve, would lead to a sales weighted average deviation of € 15, i.e. (=500/32).

Mileages assumed
For the modality 'mileage weighting', a fixed lifetime mileage is assumed for every segment and drivetrain type, as explained in Section 3.3.8.
The difference in lifetime mileage between segments is based on a linear relation between lifetime mileage and vehicle mass. This relation is a simplification of reality, as for instance high mass sports vehicles generally have lower mileages than lighter luxury sedans.
In case different lifetime mileage would have been assumed, the overall WTW GHG emission reduction (i.e. effectiveness) would have been different. In case mileage weighting is included and the relative difference in lifetime mileage between vehicle segments would change, also the manufacturer costs may change. This would result in different overall manufacturer costs and therefore in different societal costs. Moreover, this would affect the relative competitive position of OEMs.

3.5 Effectiveness: WTW GHG emission reduction

The graphs shown in this Section are only the most relevant ones, showing the impacts of the modalities that have the larger impact on the various indicators.

3.5.1 Cars

The effectiveness is determined by comparing the WTW CO_2 emissions[19] over the entire lifetime of vehicles sold in 2025/2030 under the policy scenarios with those emissions under the BAU scenario. As mentioned before, the total number of vehicles sold and the fleet shares of the various size segments are assumed to be the same as in 2013 and to remain constant over time.

The results for passenger cars are shown in Figure 10 (2025) and Figure 11 (2030) for different target levels and technology scenarios. Each bar represents the average across different policy variants. The overall WTW GHG emission reduction over their lifetime (compared to BAU) of all new cars sold in a single year is on average in the order of 25 to 50 Mton for cars sold in 2025 and 50 to 100 Mton for cars sold in 2030. Not surprisingly, the more stringent the target, the higher the emission reduction. There are also slight differences between the technology scenarios which are discussed hereafter in more detail.

19 Including non-CO_2 GHG-emissions, so actually WTW CO_2-equivalents, see Section 1.3.

Figure 10 Total lifetime WTW emission reduction of all new cars sold in 2025, compared to BAU

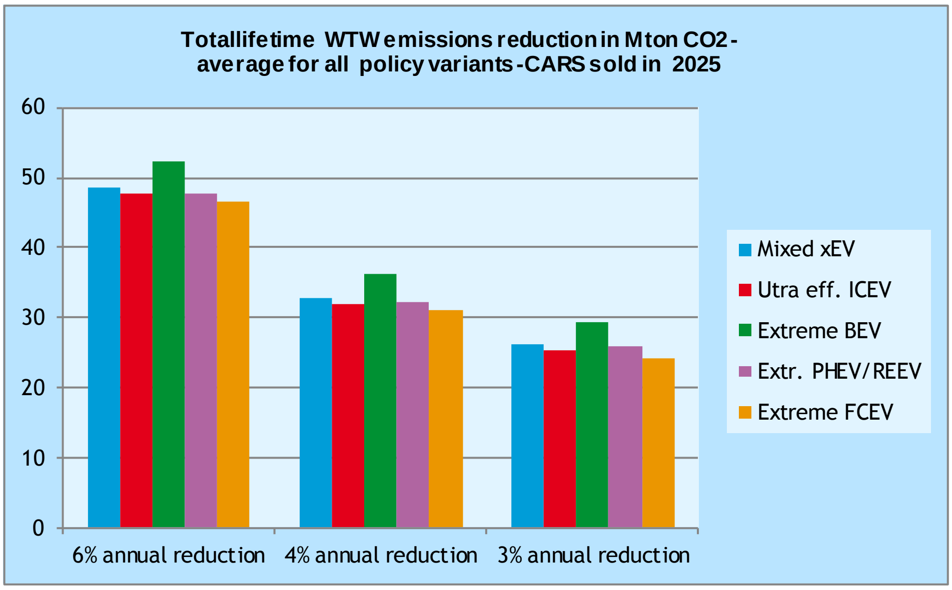
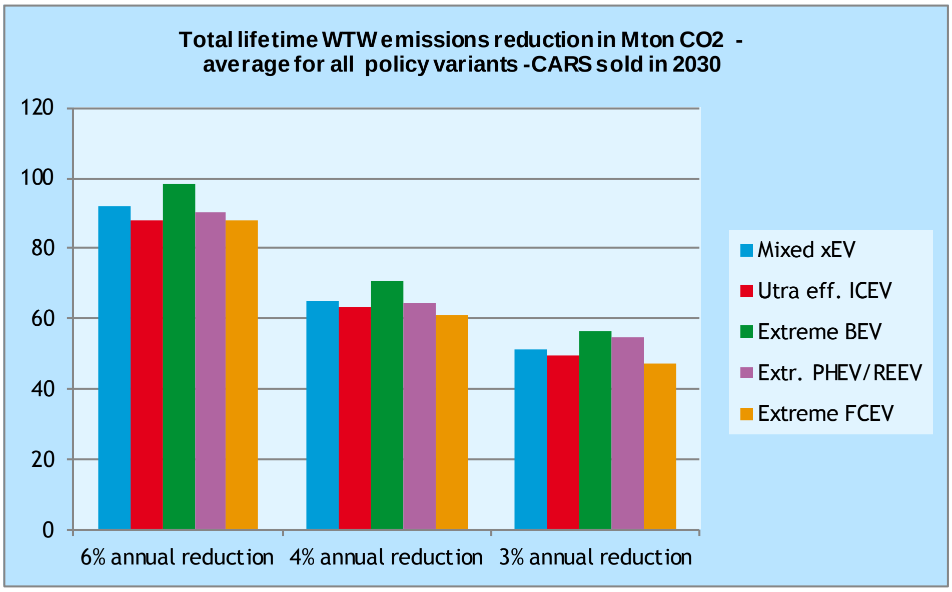


Figure 11 Total lifetime WTW emission reduction of all new cars sold in 2030, compared to BAU



Hereafter the impacts of the various modalities are assessed in detail.

Regulatory metric

The overall GHG emission reduction is the same for the cases in which the regulatory metric is WTW emissions as for the cases in which the regulatory metric is TTW emissions as this is a boundary condition in determining the equivalent WTW target. As a result, the effectiveness is the same for both regulatory metrics.

However, the equivalent targets are derived for one specific set of modalities and fleet composition, i.e. the 'mixed xEV' fleet composition. Therefore, the effectiveness is only equivalent for this specific set of modalities and fleet composition. The effectiveness of other assessed modalities and fleet compositions varies to some extent. *The differences in effectiveness can* *therefore be interpreted as an artefact of the way the 'equivalent targets' are defined*. However, as in reality the actual development of the fleet composition is likely to differ from the ex-ante estimate of the fleet composition in the target year used to derive a WTW target. The difference in effectiveness between a TTW and WTW metric are exemplary for what could happen in reality.

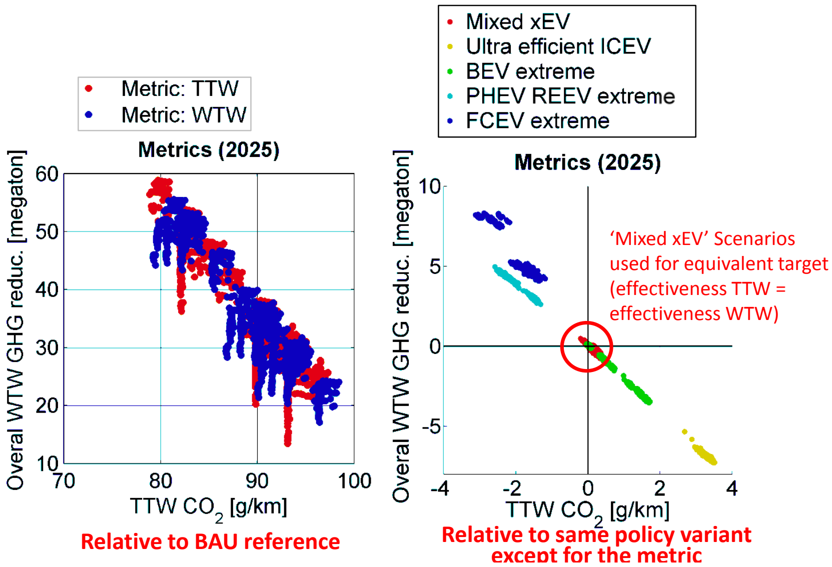
Figure 12 illustrates the effect of the choice of regulatory metric on the effectiveness of the policy variants. The y-axis represents the effectiveness. The x-axis shows the overall average TTW emissions.

In the graph on the right hand side, it can be seen that the results for the mixed xEV scenario, which was used to determine the equivalent targets, are all close to the origin of the system of coordinates, as for that technology scenario the effectiveness of the policy variants with a TTW-based target is equal to the effectiveness of the policy variants with a WTW-based target.

For a fleet composition with a large share of FCEVs or PHEVs/REEVs, the overall WTW GHG emission reduction is higher under a WTW-based target as such target provides an incentive for manufacturers to improve the energy efficiency of the alternative drivetrains, which is not the case under a TTW-based target. Up to 2030 the difference between the TA CO_2 emissions and the overall WTW GHG emissions of FCEVs and PHEVs/REEVs is expected to be relatively high because of respectively high WTT emissions and a lower 'real world' share of electric driving than in the test procedure. Reducing the energy use of these vehicles (especially of FCEVs) results in a high overall GHG emission reduction.

In case of the 'Ultra efficient ICEV' fleet composition, the effectiveness of a WTW target is lower than for a TTW target. In this case, a manufacturer can (almost) only reduce the energy use of ICEVs to meet the target. Since the share of WTT emission in the WTW emissions is relatively small for ICEVs compared to other drivetrain types, the effect on the WTW emissions is limited. In the 'Mixed xEV' fleet composition, which was used for determining the equivalent targets, manufacturers have larger shares of BEVs and FCEVs, for which WTT emissions are a relatively large share of the WTW emissions. Hence, the effectiveness of a WTW-based target is lower for the 'Ultra efficient ICEV' fleet composition when compared to the 'Mixed xEV' fleet composition.

Figure 12 Effects of the selected regulatory metric on the effectiveness of the policy for passenger cars in 2025

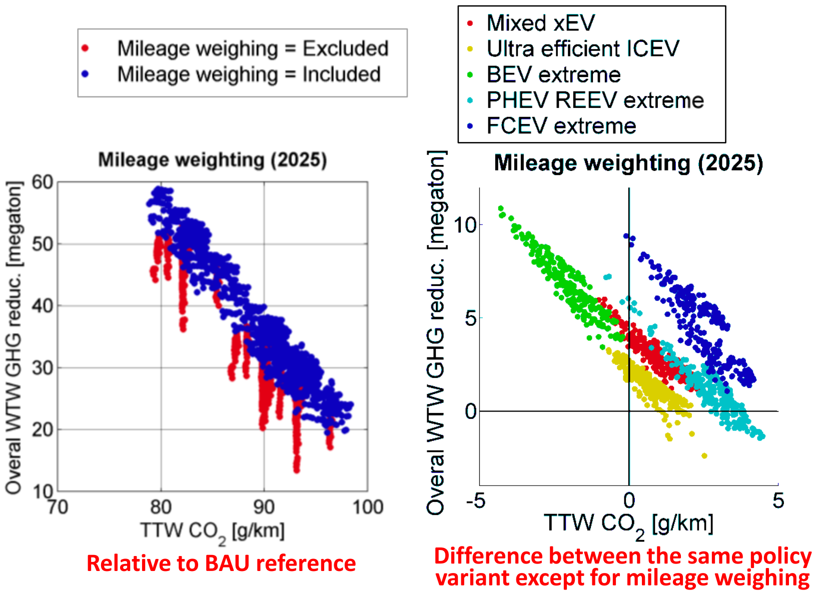


Mileage weighting

The assumed mileages for this exercise were explained in Section 3.3.8. The left of Figure 13 shows that including mileage weighting results in higher effectiveness in most assessed policy variants. This is the case because the least costly response to including mileage weighting is to reduce relatively more CO_2 emissions from vehicle with high lifetime mileages.

However, as can be seen from Figure 13, including mileage weighting may also result in lower overall CO_2 reduction (negative values) and this is especially the case for technology scenarios with high shares of PHEVs and REEVs. This is due to the assumption that the actual share of electric driving for vehicles with such drivetrains will be lower than on the type approval test. Since PHEVs and REEVs are expected to be relatively large vehicles with high mileages, because of mileage weighing it becomes more cost effective for manufacturers to reduce CO_2 emissions for these vehicles. However, the actual resulting WTW GHG emission reduction in practice (real world) is expected to be less than for vehicles with other drivetrains.

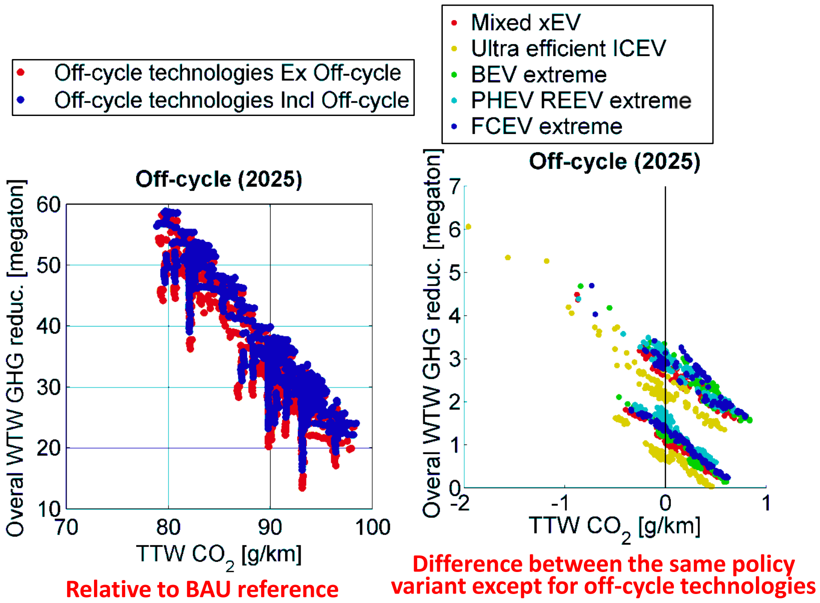
Figure 13 Effects of excluding or including mileage weighting on the effectiveness of the policy for passenger cars in 2025



Off-cycle technologies

Accounting for off-cycle technologies in the type approval value has limited effect on the effectiveness. While in case off-cycle technologies are included, manufacturers are likely to deploy the off-cycle technologies with high cost effectiveness) to meet their targets, the actual CO_2 reductions achieved in the different segments and drivetrain types are rather similar. Therefore, the effectiveness is not very sensitive to whether off-cycle technologies are accounted for or not.

Figure 14 Effects of excluding or including off-cycle technologies on the effectiveness of the policy for passenger cars in 2025



Utility parameter
Similar to the case for the off-cycle technologies, the utility parameter selected (mass or footprint) has a limited effect on the effectiveness.

Legal entity
Also the choice for a legal entity does not affect the effectiveness of the policy significantly. Allowing manufacturers to pool provides more flexibility to the way the target is met regarding the CO_2 emission reductions in different segments, but the overall effect on the reductions per segment is limited.

Target function slope
The limit function slope, in combination with a legal entity's average utility value determines it target. The slope therefore has a strong effect on individual targets of legal entities. However, a more stringent target for one legal entity results in a less stringent target for another and therefore the overall effect on the effectiveness of the policy is limited.

Target level
Besides these modalities and the fleet development, also the selected target level heavily influences the effectiveness of the target. A more stringent target obviously results in more overall GHG emission reduction and is therefore more effective.

3.5.2 Vans
Like for cars, the effectiveness for vans is determined by comparing the lifetime WTW CO_2 emissions of the new vehicles sold in 2025/2030 under the policy scenarios to the emissions under the BAU scenario. The average results of the effectiveness of all policy variants for vans are shown in Figure 15 (2025) and Figure 16 (2030). The graphs make clear that the lifetime vehicle emission reduction (compared to BAU) is on average 5 to 11 Mton for all vans sold in 2025 and 8 to 17 Mton for all vans sold in 2030. Like for cars, the more stringent the target, the higher the emission reduction. The impacts of the various modalities as were found for passenger cars in Section 3.5.1, also apply to vans.

Figure 15 Total lifetime WTW emission reduction of all new vans sold in 2025, compared to BAU

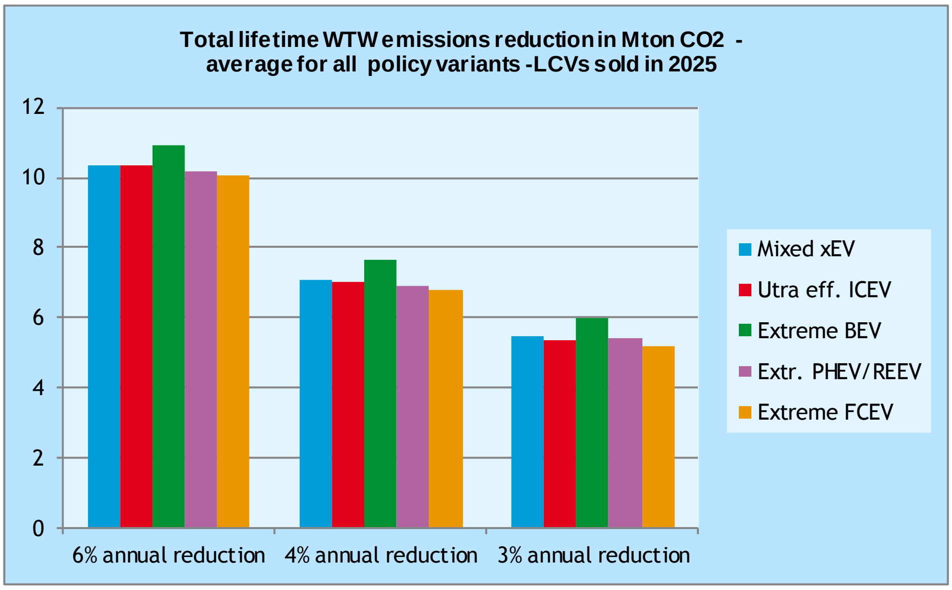
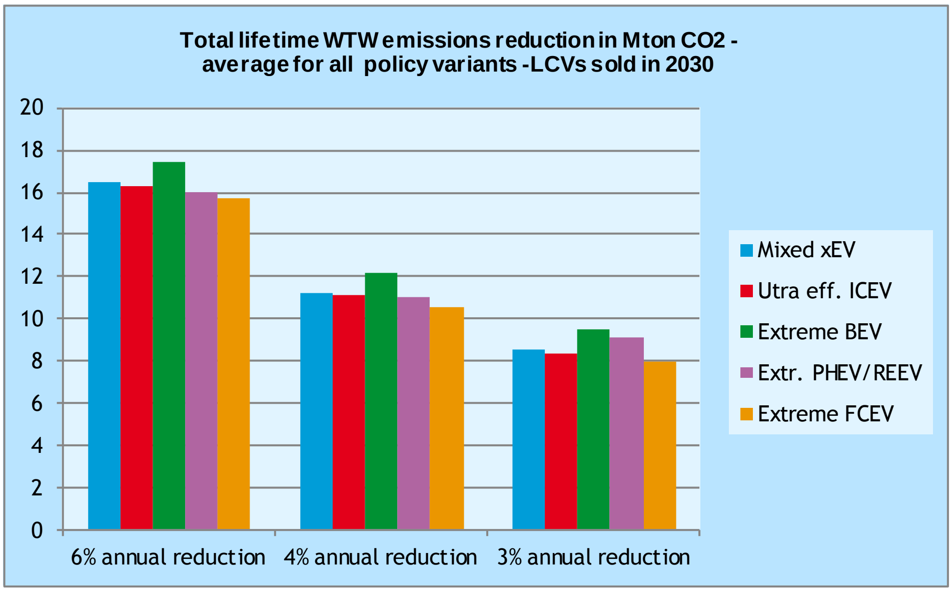


Figure 16 WTW emission reduction of all new vans sold in 2030, compared to BAU



3.6 Cost effectiveness

3.6.1 Cars

Various cost impacts have been assessed: impacts on societal costs, manufacturer costs and end-user costs. As the societal cost impacts turn out to be negative, the cost effectiveness (in terms of euro per tonne of CO_2 reduced) is no useful measure for comparing policy variants (see Section 2.5.1).

The change in net societal costs are the additional vehicle costs resulting from the policy minus the energy carrier cost savings over the vehicle lifetime, all excluding taxes. The results (averages over all policy variants) for passenger cars are shown in Figure 17 (2025) and Figure 18 (2030). The graphs make clear that the net societal benefits (counted over the vehicle lifetime) depend strongly on the technology scenario, much more than on the target level. When comparing the societal benefits with the WTW CO_2 reductions, than it is clear that higher societal benefits match with the largest CO_2 reductions; both are achieved with the most strict target level.

In all cases, there is a net societal benefit on average, ranging up to € 1,150 in 2025 and € 2,050 in 2030, both with the strictest target level and the extreme BEV scenario[20]. In the Mixed-EV scenario, the average societal benefits range from € 350 to almost € 600 per vehicle sold in 2025 and € 800 to € 1,100 per vehicle sold in 2030.

[20] The societal benefits are higher than in some previous studies. Main explanations are the new set of cost curves, the much lower costs for AFVs, in particular EVs, and the inclusion of off-cycle reduction options (see Section 3.4.3).

Figure 17 Change in societal costs over vehicle lifetime for all new cars sold in 2025, relative to BAU

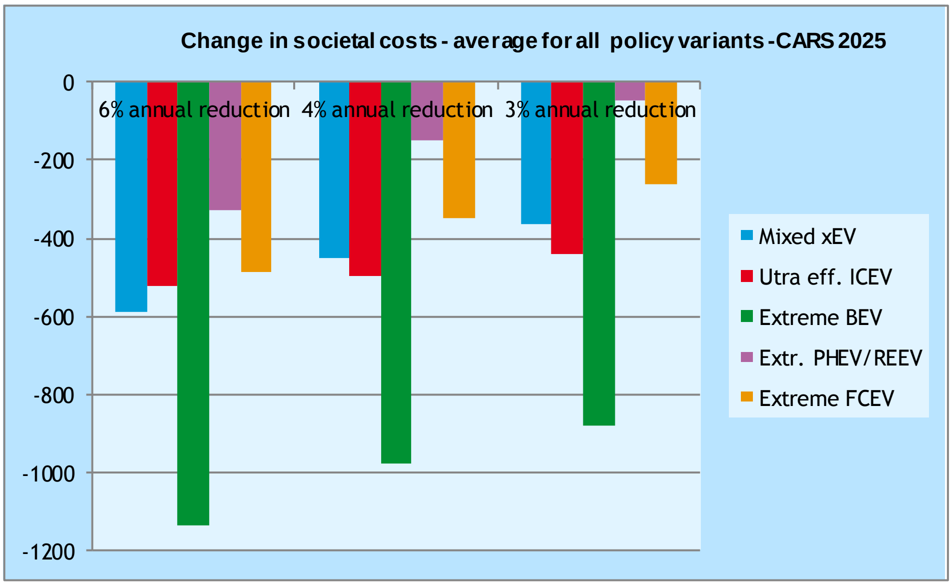
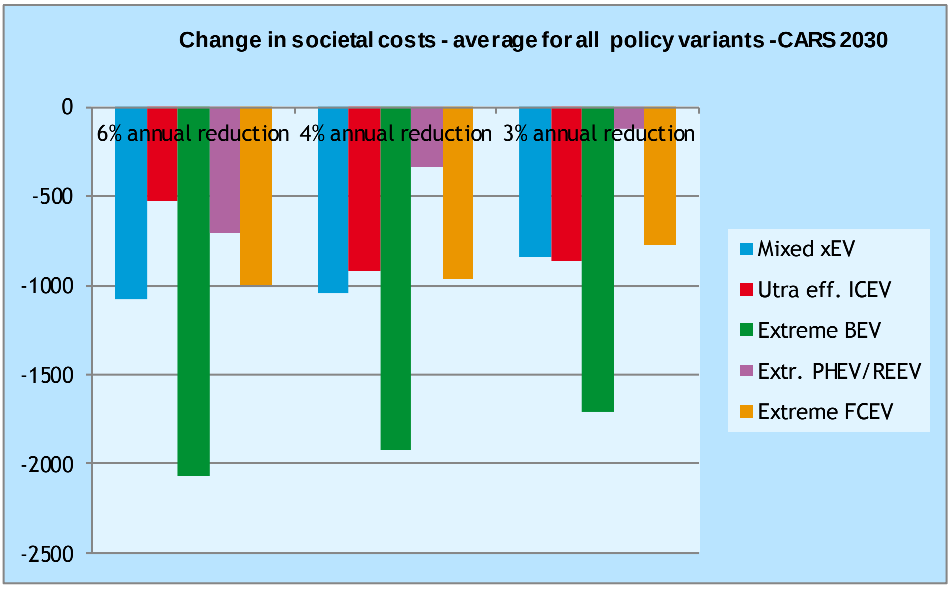


Figure 18 Change in societal costs over vehicle lifetime for all new cars sold in 2030 relative to BAU



Besides impacts on the societal costs, also cost impacts for vehicle manufacturers and end-users have been quantified.

The average additional manufacturing costs (i.e. additional to the costs under the BAU scenario in the same year) go up with the stringency of the target level, but are also very dependent on the technology scenario. They range from € 100 to € 1,200 per car in 2025 and are up to € 2,500 per car in 2030. The increase in manufacturer costs are lowest in the Extreme-BEV scenario.

In the Mixed-EV scenario, average manufacturer costs increase by € 500 tot € 1,000 per vehicle sold in 2025 and € 800 to € 2,000 per vehicle sold in 2030.

Figure 19 Average additional manufacturer costs per car sold in 2025, compared to BAU

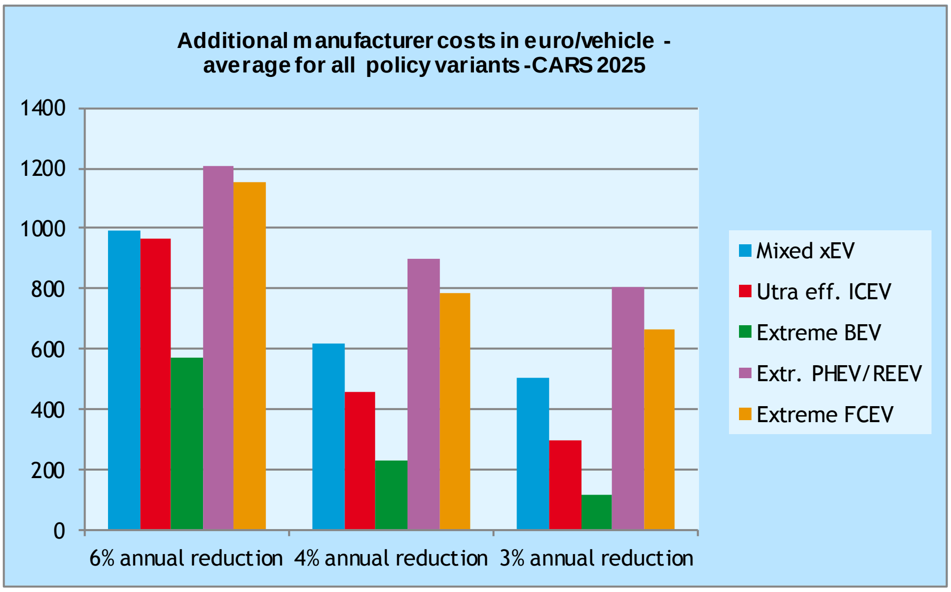
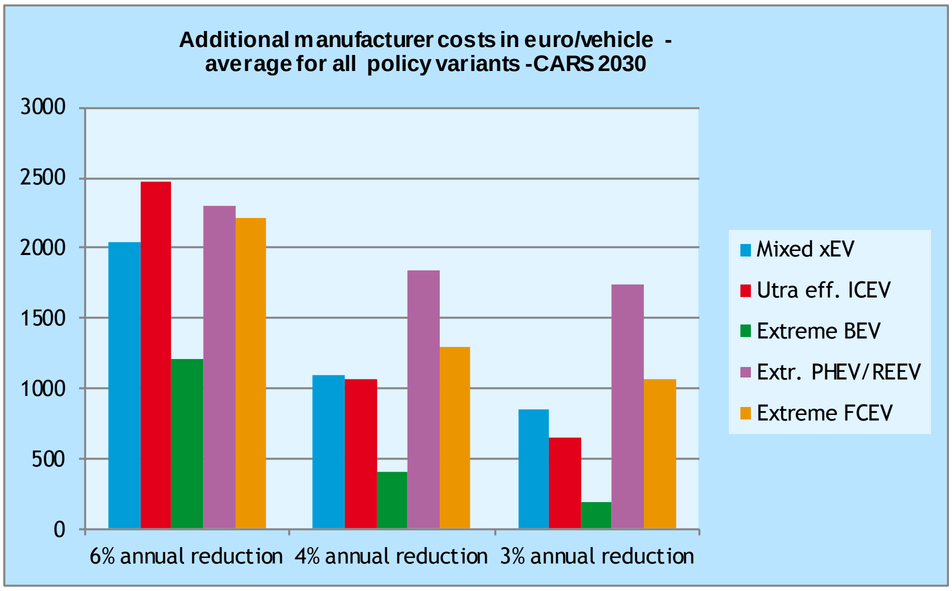


Figure 20 Average additional manufacturer costs per car sold in 2030, compared to BAU



The impacts on end-user cost were estimated by adding the depreciated additional vehicle cost in the first five years (plus a mark-up for the manufacturer's profit margin and taxes) to the net present value of the fuel cost savings over the same period (so this equals the change in the total cost of ownership over the first five years; excluding vehicle maintenance and insurance). Differences in vehicle taxes between various powertrains have not been taken into account.

The average results for the end-user costs for cars are shown in Figure 21 and Figure 22. The results show that also from the perspective of end-users. the increase in vehicle costs are more than compensated by fuel cost savings over the first five years of the vehicle life. This results in a net reduction in cost for end-users up to € 1,100 per car in 2025 and € 2,000 per car in 2030 (including taxes; over the first 5 years). The end user cost savings are highest in the Extreme-BEV scenario.

In the Mixed-EV scenario, the average change in end-user costs range from € 350 to € 600 for vehicles sold in 2025 and € 800 to € 1,150 for vehicles sold in 2030.

Figure 21 Average change in total end-user costs of the first 5 years for cars sold in 2025, compared to BAU

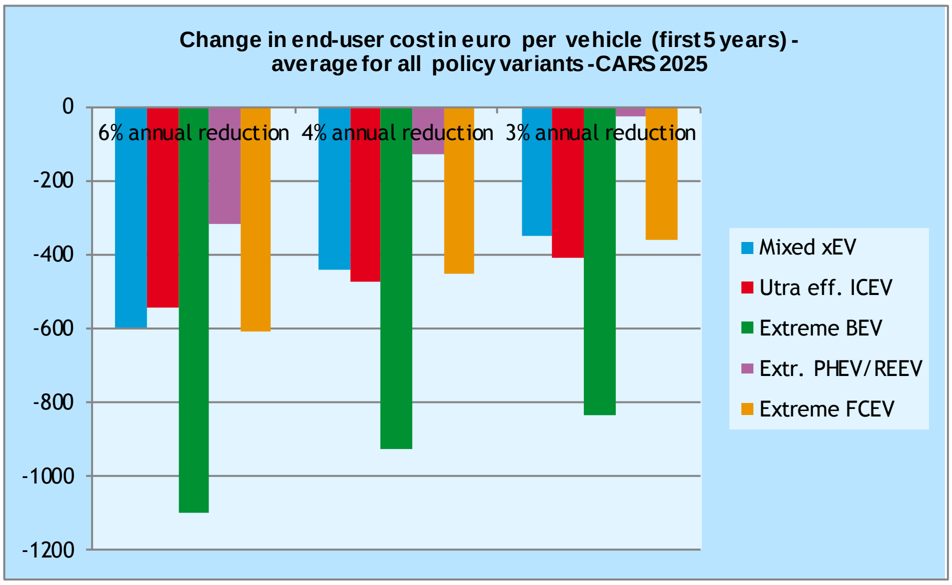
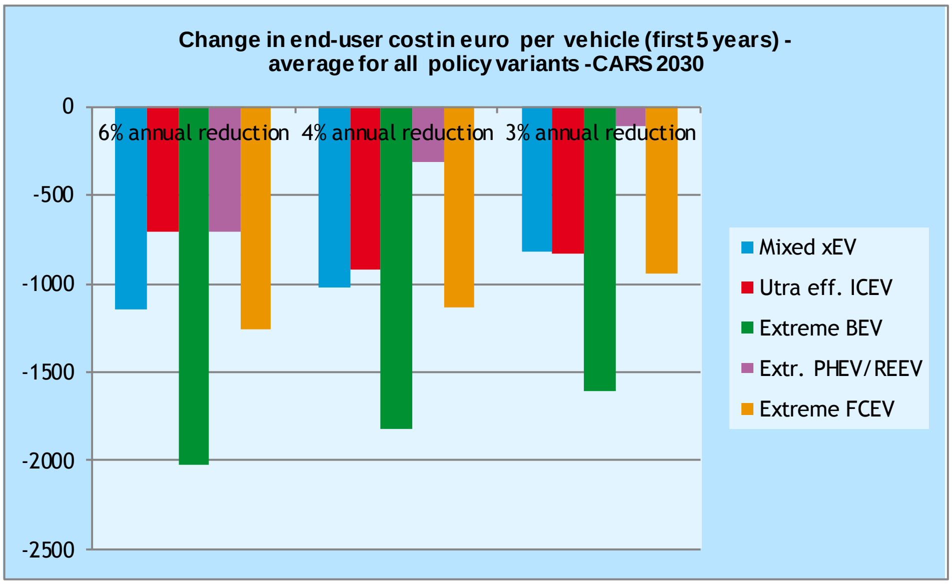


Figure 22 Average change in total end-user costs of the first 5 years for cars sold in 2030, compared to BAU



Hereafter the impacts of the various modalities are assessed in detail.

Regulatory metric

As explained in Section 3.5.1, the effectiveness of the TTW- and WTW-based metrics is in principle the same, due to the way the equivalent targets have been derived.

As can be seen on the right side of Figure 23, the effect on the societal cost of changing to a WTW-based metric depends on the fleet composition and is in most cases relatively limited (in most policy variants less than € 100 on a scale from € -1,500 to € 200). For some fleet compositions, i.e. FCEV extreme and PHEV/REEV extreme, the effect is larger. This is mainly the result of the equivalent targets being derived from one specific combination of fleet composition (i.e. 'Mixed xEV') and policy variant (see Annex G). This causes some targets to be 'too high' or 'too low', in such cases also the costs for complying are lower. Therefore policy variants with higher positive effects on societal costs (e.g. FCEV Extreme) have a less GHG emission reduction. On the other hand policy variants with higher negative effects on societal costs (e.g. 'BEV Extreme') result in higher GHG emission reduction.

This is confirmed in Figure 24, which shows that the cost effectiveness is hardly affected by the choice for a certain metric. Even for the policy variants which are outliers with regard to the effect of the metric on cost or effectiveness, the cost effectiveness is rather comparable as effects on one (cost or effectiveness) are compensated by effects on the other (cost or effectiveness).

Figure 23 **Effects of the selected regulatory metric on the costs and the effectiveness of the policy for passenger cars in 2025**

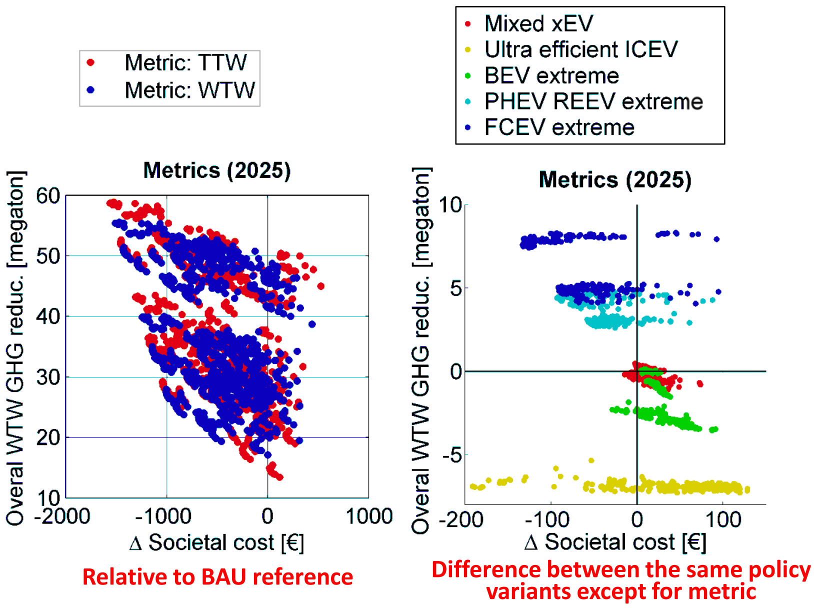
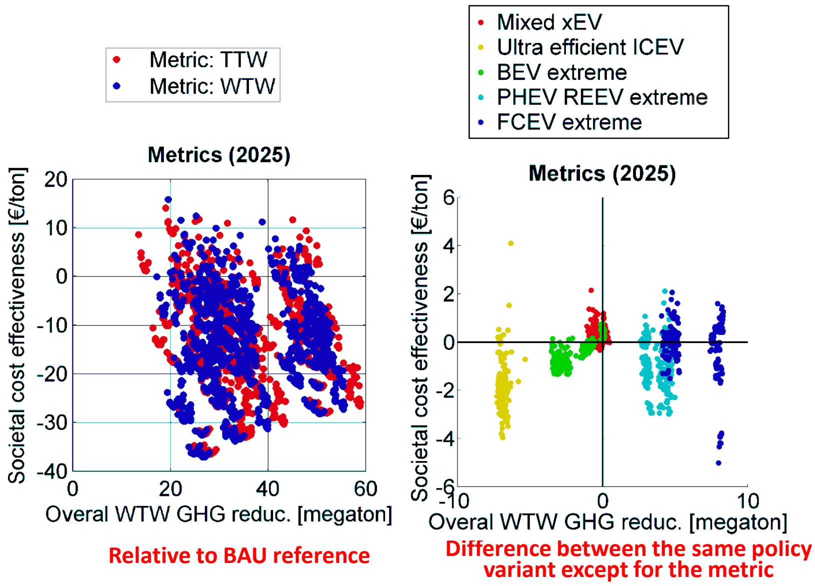


Figure 24 Effects of the selected regulatory metric on the cost-effectiveness of the policy for passenger cars in 2025



The conclusion that the cost effectiveness is hardly affected by the choice for a regulatory metric may seem counterintuitive as vehicles with a (partly) electric drivetrain have a larger leverage under a TTW-based target.
This difference in leverage is however already accounted for in determining the WTW target (approach based on equal effectiveness, see Section 3.5.1).

Also the additional manufacturer costs (and therefore also the societal costs) are not much affected by the choice of metric. In case of a TTW metric, manufacturers are likely (and therefore assumed) to manufacture ZEVs at the lowest possible costs. Beyond that any energy efficiency improvements are not rewarded as the TTW emissions do not become lower as a result. Under a WTW metric, manufacturers have a greater incentive to improve energy efficiency of ZEVs because then the (average) WTW emissions are lowered. However, based on the cost curves, the marginal cost for improving energy efficiency of ZEVs is equal or greater than for ICEVs. As a result, the emissions of ICEVs are reduced to comply with the target and costs are the same as under a TTW metric.

Mileage weighting

In Section 3.5.1 it was concluded that accounting for the variation of lifetime mileages of different vehicle types results in more overall GHG emission reduction and is therefore more effective.

As shown in Figure 25 in certain cases accounting for lifetime mileage also results in higher societal costs. This is especially the case for the 'Ultra efficient ICEV' and to a lesser extent for 'BEV Extreme' fleet composition scenario. In such fleet compositions, vehicles with relatively low mileages (i.e. respectively petrol ICEVs and BEVs) have relatively large sales shares. As a result, the required reductions from other drivetrain types are higher. Because of the non-linearity of the cost curves this results in higher costs.

Figure 26 shows the cost effectiveness (societal cost per amount of CO_2 reduction) on the vertical axis. The right part of the figure shows that the effect of accounting for different lifetime mileages is relatively limited, i.e. approximately -5 €/ton to +10 €/ton. As a comparison, the variation of the overall difference in cost-effectiveness (left part of Figure 26) of the various policy designs assessed, is -40 €/ton to +10 €/ton.

Figure 25 **Effects of accounting for different lifetime mileage for different vehicle segments on the costs and effectiveness of the policy for passenger cars in 2025**

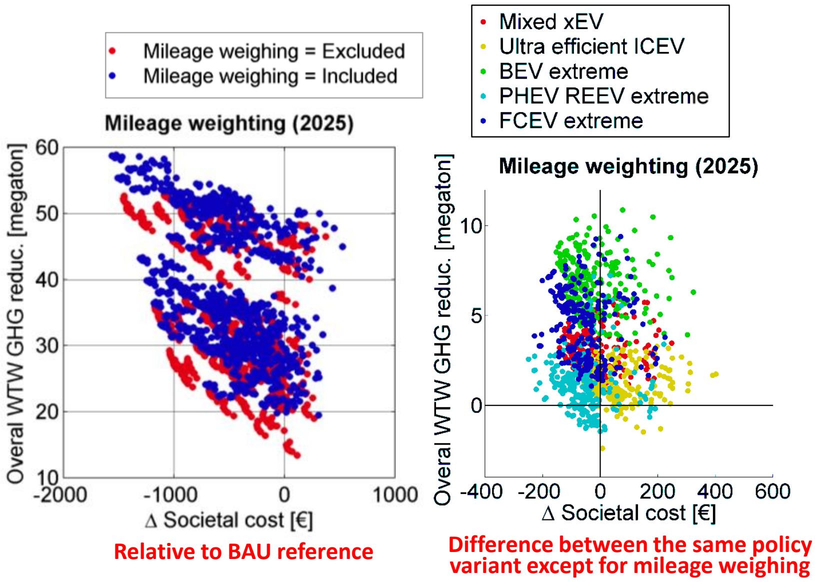
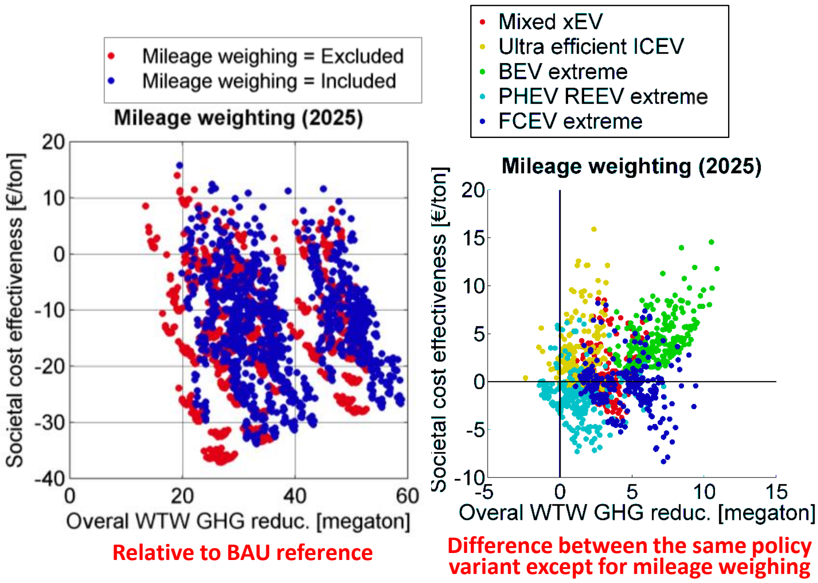


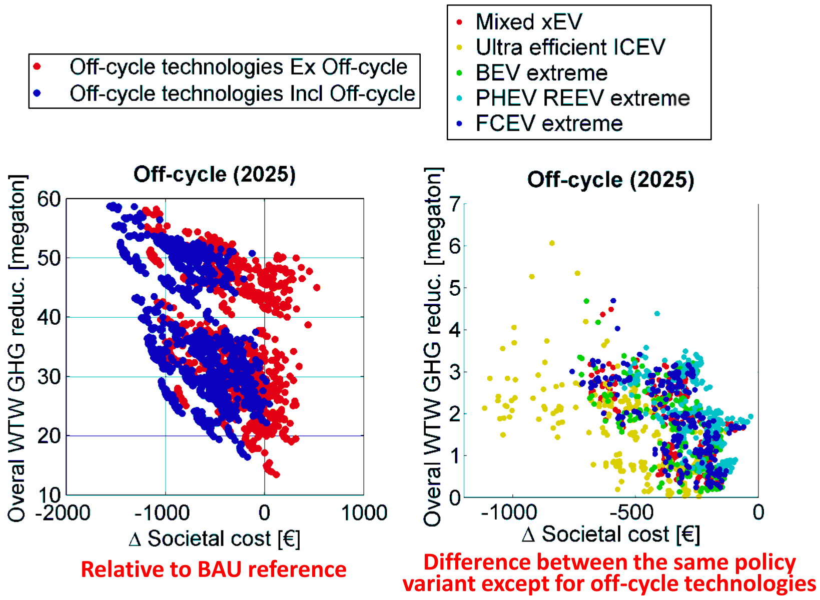
Figure 26 **Effects of accounting for different lifetime mileage for different vehicle segments on the cost-effectiveness of the policy for passenger cars in 2025**



Off-cycle technologies

As explained in Section 3.5.1, the effectiveness is not significantly affected by including off-cycle technologies. However, including off-cycle technologies results in significantly lower additional manufacturer costs and therefore also societal costs (Figure 27). This effect occurs because certain off-cycle technologies are more cost effective than the least cost effective on-cycle technology applied otherwise.

Figure 27 Effects of accounting for off-cycle technologies on the costs and effectiveness of the policy for passenger cars in 2025

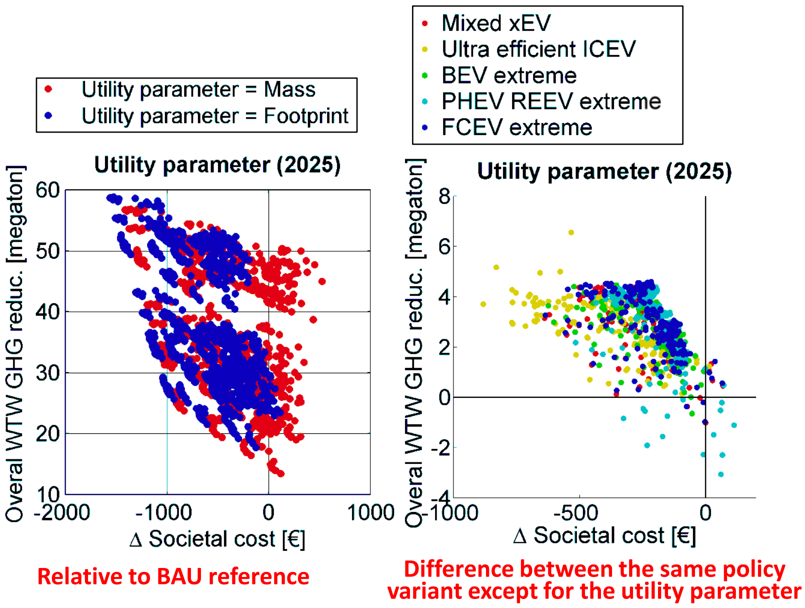


Utility parameter

For the utility parameter the same reasoning applies as for the off-cycle technologies, but to a lesser extent. The effectiveness is not significantly affected by the utility parameter selected, but the costs for meeting the target are lower in case of a footprint-based utility parameter. This is mainly because certain CO_2 reducing technologies aimed at mass reduction of the vehicle are not fully 'rewarded' as the lower vehicle mass also results in a more stringent target for the manufacturer. This has been modelled by using an alternative set of cost curves that take account of this effect.

Since a car's footprint is not affected by applying CO_2 reducing technologies, the cost effectiveness of weight reducing technologies is higher in case of a footprint-based utility parameter than in case of a mass based utility parameter. Therefore, targets can be met at lower additional manufacturer costs and thus also lower societal costs. Changing the utility parameter can have a relatively large effect on the reduction of societal cost, up to € 500 per vehicle (Figure 28).

Figure 28 **Effects of the selected utility parameter on the costs and effectiveness of the policy for passenger cars in 2025**



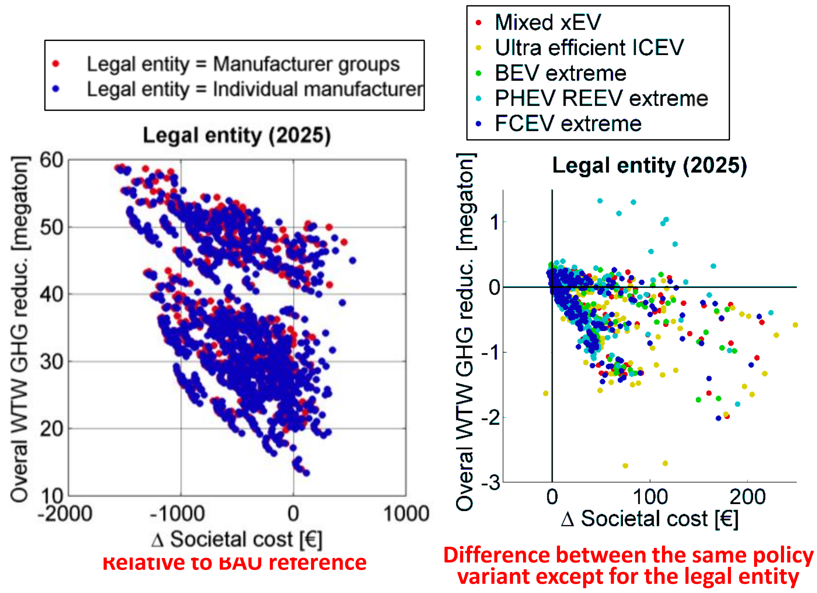
Target function slope

The slope of the limit function does not have a significant impact on the overall GHG emission reduction (see Section 3.5.1). Also the effect on the average additional manufacturer costs is very limited. Only in case of the more stringent targets assessed, a (nearly) flat slope or a very steep slope result in significantly higher costs. Therefore, a medium slope, as explained in Section 3.4.3, results in the lowest additional manufacturer costs and therefore lowest price increase. Such a slope or slightly flatter results in the highest cost-effectiveness. This is shown in more detail in Section 4.5.1.

Legal entity

The choice for the legal entity that has to comply does not have a significant impact on the effectiveness. However, regulating manufacturer groups instead of brands increases the variety of vehicle segments covered by one entity and thus provides more flexibility as to the way the target is met. As a result, with regulating manufacturer groups instead of brands, the same emission reduction can be achieved at slightly lower societal costs, i.e. up to approximately € 100 per vehicle (Figure 29).

Figure 29 Effects of the legal entity (changing from groups to brands) on the cost, and effectiveness of the policy for passenger cars in 2025



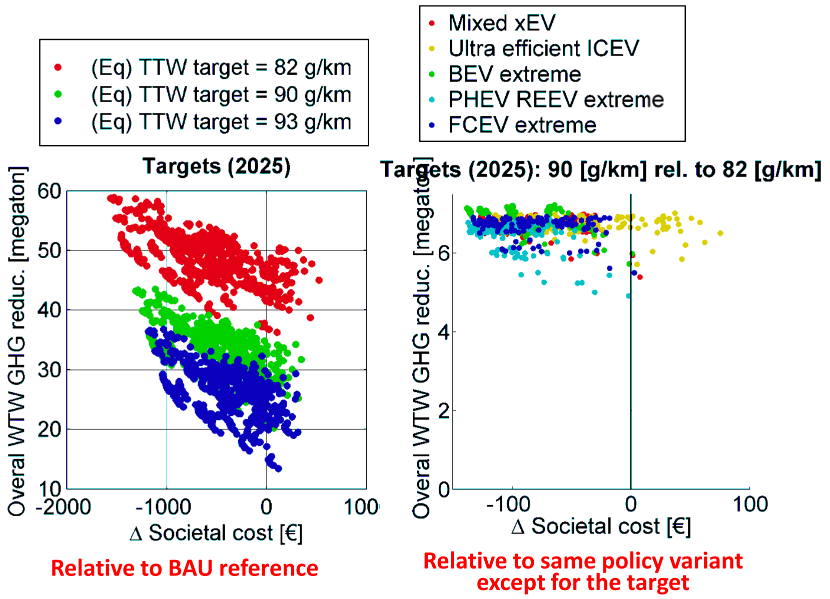
Target level

As concluded in Section 3.5.1, a more stringent target is more effective, also shown in the left part of Figure 30 (the vertical axis is the effectiveness).

This figure also shows that the (additional) societal costs of the policy can be lower for higher targets. This means that although the additional manufacturer costs and therefore vehicle prices are higher for more stringent targets, the lower fuel costs (excluding tax) resulting from improved energy efficiency of vehicles more than compensate these higher prices (excluding tax). It can be concluded that for 2025 the most stringent target level assessed (82 g/km TTW (WLTP)) has the highest societal benefits.

For 2030, the most cost-effective target level depends more on the policy design. For most policy variants assessed, either the middle target level, i.e. 74 g/km (WLTP), or the strictest target level, i.e. 61 g/km (WLTP) has highest societal benefits.

Figure 30 Effects of the selected target level on the costs and effectiveness of the policy for passenger cars in 2025



3.6.2 Vans

Like for cars, impacts on societal costs, manufacturer costs and end-user costs have been assessed. Also for vans, the societal cost impacts turn out to be negative, the cost effectiveness (in terms of euro per tonne of CO_2 reduced) is no useful measure for comparing policy variants (see Section 2.5.1).

The average results on the change in the societal costs (over the entire vehicle lifetime) for vans are shown in Figure 31 (2025) and Figure 32 (2030).
The graphs make clear that the net societal benefits depend strongly on the technology scenario and also on the target level. Like for cars, higher societal benefits match with the largest CO_2 reductions; both are achieved with the most strict target level. The impact of technology scenarios is somewhat smaller than for cars, which can be explained by the lower marginal costs for meeting the 2020 targets. Beyond 2020, the same ICEV CO_2 reduction therefore results in much higher additional manufacturer costs for cars than for vans. As the fleet composition significantly affects the CO_2 reductions of these ICEVs, the effect of the fleet composition is larger for cars than for vans.

In all cases, there is a net societal benefit on average, ranging up to € 2,400 in 2025 and € 3,850 in 2030, both with the strictest target level and the extreme BEV scenario[21]. In the Mixed-EV scenario, the average societal benefits range from € 1,100 to € 1,900 per vehicle sold in 2025 and € 1,800 to almost € 2,850 per vehicle sold in 2030.

---

[21] The societal benefits are higher than in some previous studies. Main explanations are the new set of cost curves, the much lower costs for AFVs, in particular EVs, and the inclusion of off-cycle reduction options (see Section 3.4.3).

Figure 31 Change in societal costs over vehicle lifetime for all new vans sold in 2025

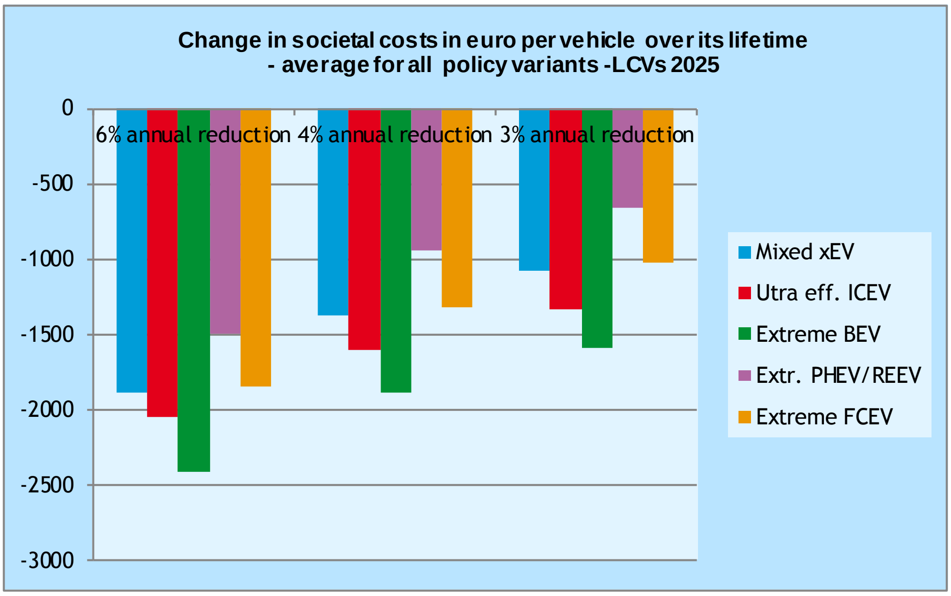
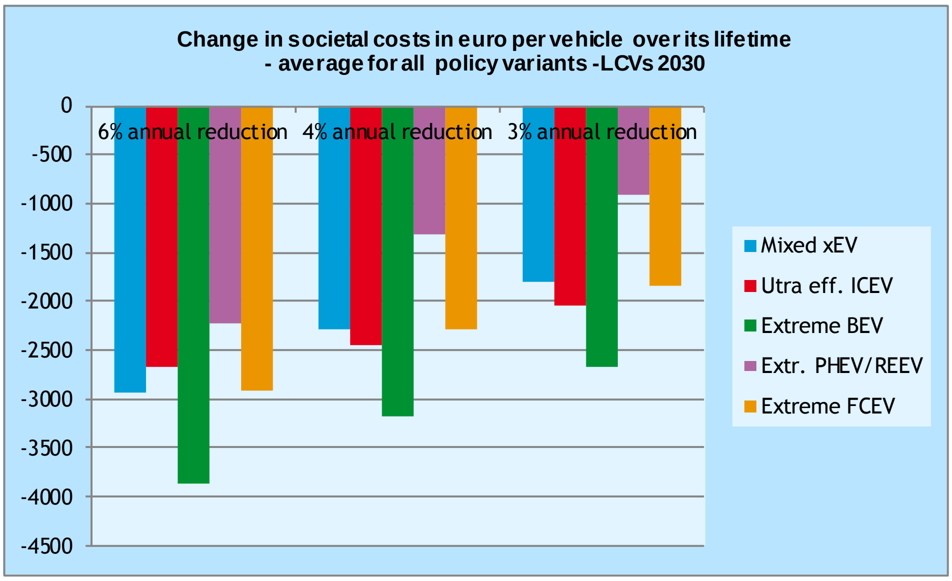


Figure 32 Change in societal costs over vehicle lifetime for all new vans sold in 2030



The average additional cost for van manufacturers are shown in Figure 33 and Figure 34.

The average additional manufacturing costs go up with the stringency of the target level, but are also very dependent on the technology scenario. They range from minus € 200[22] to € 1,050 per van in 2025 and up to € 2,000 in 2030 (all compared to BAU in the same year).The increase in manufacturer cost is lowest in the Extreme-BEV scenario, except for the two least stringent target levels in 2025 for which the Ultra-efficient ICEV scenario has the lowest manufacturing cost increase. In the Mixed-EV scenario, the additional

22 The fact that manufacturer costs are negative is the result of the negative costs at the lowest part of the cost curves used. The negative cost are the result of emission reduction measures that lead to lower manufacturing costs (e.g. some types of weight reduction or down-sizing).

manufacturing costs range from € 250 to € 700 per van sold in 2025 and from € 350 to € 1,400 per van sold in 2030.

Contrary to cars, the average additional manufacturer costs for vans increase in case mileage weighting is included. This is because the cost for reducing CO_2-emissions is higher for larger vans. In case of mileage weighting, emission reductions from smaller vans with lower CO_2-reduction cost are less rewarded and therefore average additional manufacturer costs increase.

Figure 33 Average additional manufacturer costs per van sold in 2025

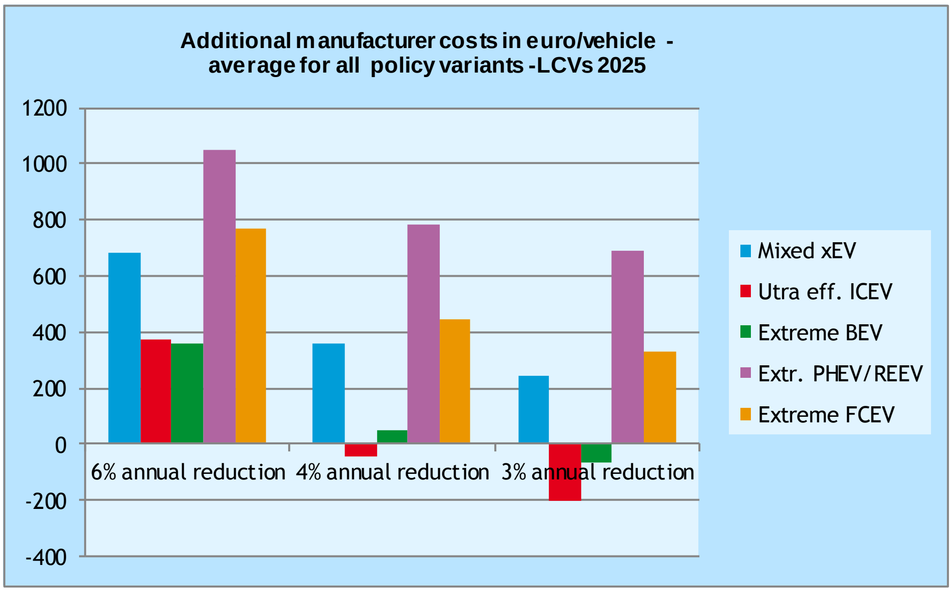
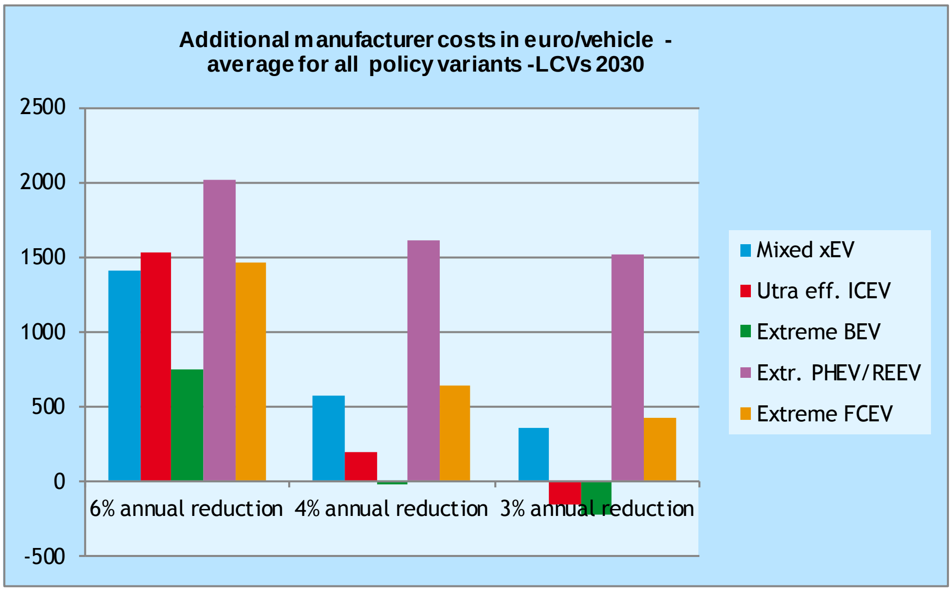


Figure 34 Average additional manufacturer costs per van sold in 2030



The average additional cost for the end-user (over the first 5 years of the vehicle lifetime) are shown in Figure 35 and Figure 36.

Like for cars, the higher vehicle cost for end-users of vans are more than compensated by fuel cost savings. This results in a net reduction in cost for end-users of € 1,500 to € 2,300 in 2025 and € 2,500 to € 3,700 in 2030 (including taxes, over the first 5 years). The end user cost saving are highest in the Extreme-BEV scenario, but are also significant in all other technology scenarios. In the Mixed-EV scenario, the cost savings for end-users range from € 1,000 to € 1,800 per van sold in 2025 and from € 1,700 to € 2,900 per van sold in 2030.

Figure 35 Average change in total end-user costs of the first 5 years for vans sold in 2025

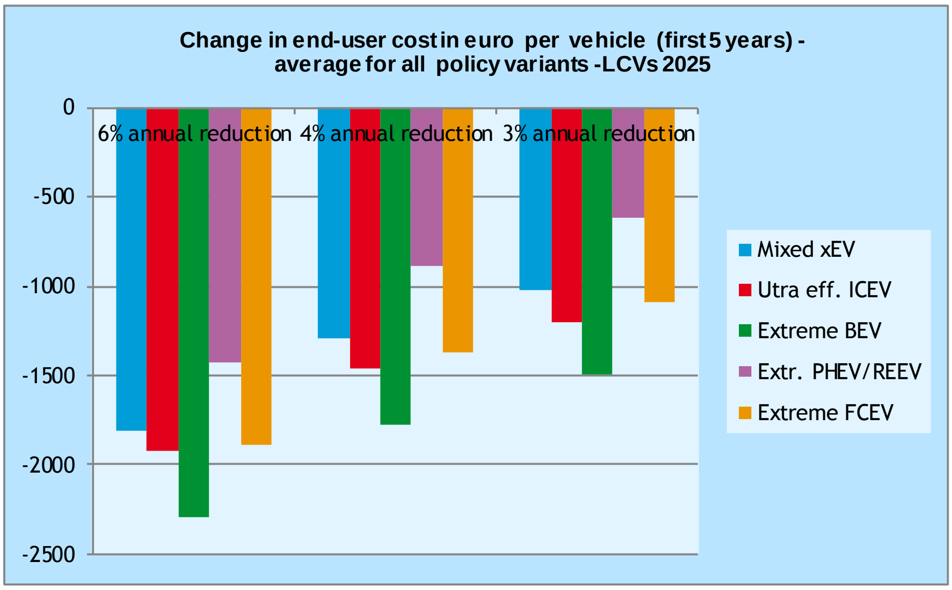
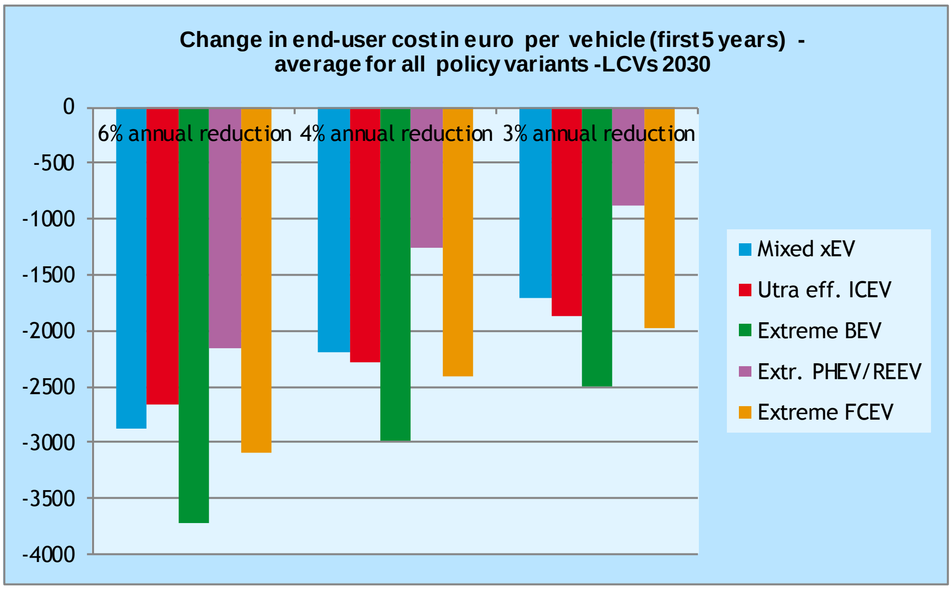


Figure 36 Average change in total end-user costs of the first 5 years for vans sold in 2030



The cost impacts of the various modalities as were found for passenger cars in Section 3.6.1 also apply to vans.

3.7 Competitiveness

As explained in Section 3.4.2, a comparison of impacts on relative price increase for ACEA members vs. non-ACEA members is used as a proxy to assess whether a policy variant, in interaction with differences in overall sales portfolios, would lead to possible competitiveness impacts. Since it is assumed that the share of xEV is equal for all manufacturers and that the same cost curves are applied for all manufacturers, all differences between the impacts of various policy variants are the result of differences in sales portfolios (in terms of sales shares over the segments) and the average utility parameter value affecting the target value.

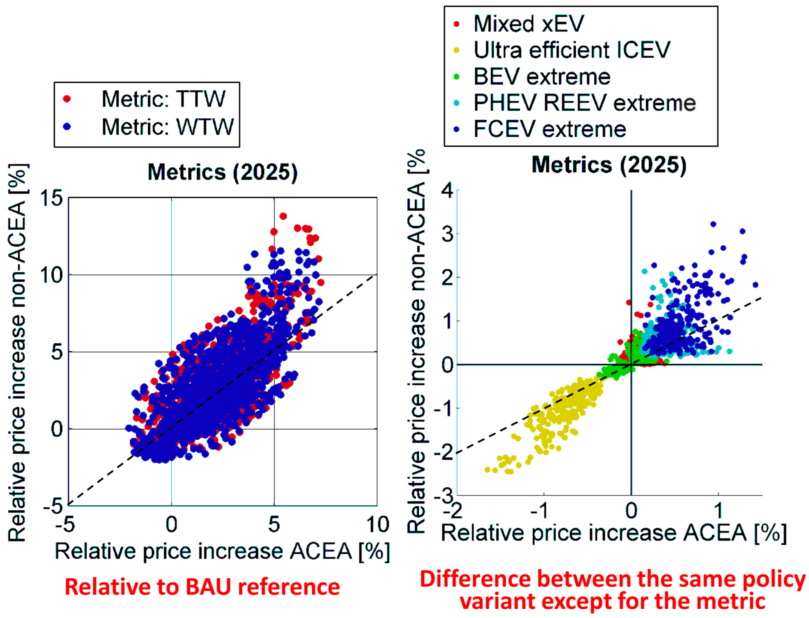
3.7.1 Cars

Regulatory metric

The difference in relative price increase for ACEA members vs. non-ACEA members, used as an indicator for possible competitiveness impacts is not sensitive to the choice for a certain metric. This can be deduced form Figure 30, as all policy variants are close to the 45° diagonal (from bottom left to upper right).

This can be explained by the assumption (in our model) that all manufacturer new car fleets will have the same share of BEVs. As the choice for a metric mainly has an effect on such vehicles, the effect is equal for all manufacturers (including both ACEA and non-ACEA manufacturers).

Figure 37 Effects of the selected regulatory metric on the competitive position of ACEA members for passenger cars in 2025

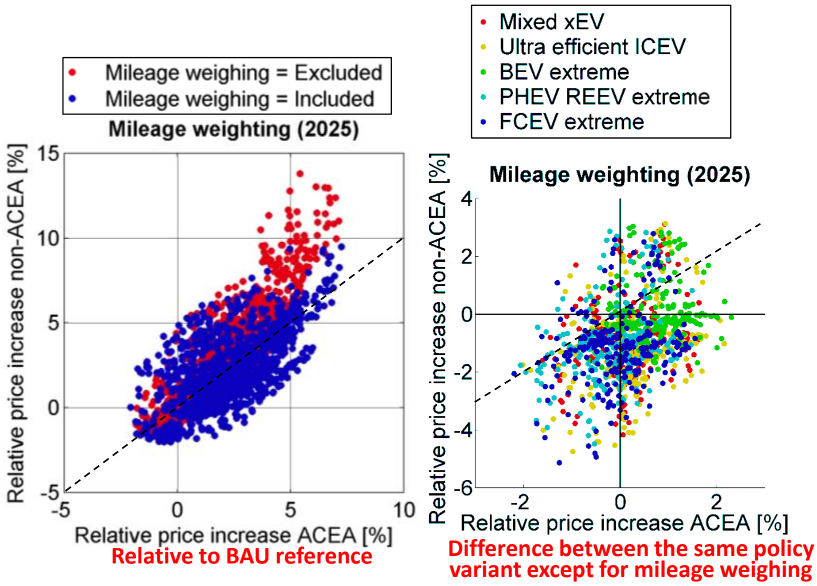


Mileage weighting

Taking account of lifetime mileages of different vehicle segments has a negative impact on the competitive position of ACEA members in most policy variants. This can be concluded from the right part of Figure 38, as most policy variants are below the 45° diagonal.

This effect is the result of ACEA member sales being more in the upper size segments compared to the non-ACEA members and thus having a higher average mass. As the attributed lifetime mileage is based on the vehicle mass (higher mass is higher mileage), the average lifetime mileage of ACEA members' sales is higher. Since energy use improvements on vehicles with higher lifetime mileages reduce manufacturer's distance to target relatively much, taking account of different lifetime mileages of different vehicle segments results in relatively greater cost-effectiveness for ACEA manufacturers compared to non-ACEA manufacturers meeting their targets. In other words, less technologies have to be applied and as a result the relative price increase is lower for the average vehicle of ACEA members. The effect of mileage weighing is causing a relative price increase in the order of 1% for ACEA members compared to non-ACEA members.

Figure 38 Effects of the accounting for different lifetime mileage of different vehicle segments on the competitive position of ACEA members for passenger cars in 2025



Off-cycle technologies

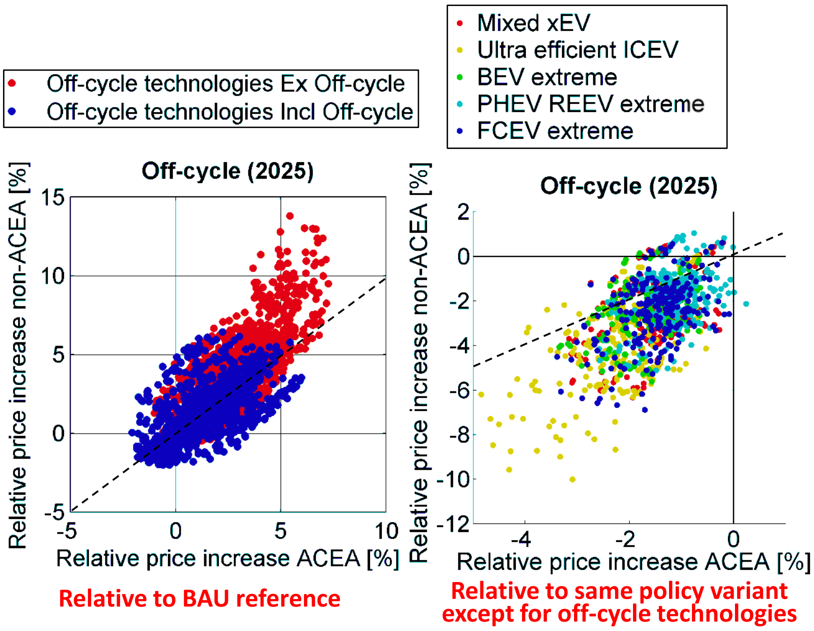
In most policy variants assessed, including off-cycle technologies results in a slightly lower price increase for ACEA members than for non-ACEA members. This therefore improves the competitive position of ACEA members slightly. This is the result of ACEA members on average manufacturing larger and heavier vehicles.

The degree to which this difference affects competitiveness strongly depends on the selected slope of the utility function. For utility function slopes lower than the 2013 sales weighted average slope (in absolute terms) the required average absolute CO_2 reduction of ACEA members is greater than for non-ACEA members. As a result, the absolute reductions that ACEA members have to achieve to meet their targets require more CO_2 reducing technologies. This results in higher manufacturer costs for ACEA members than non-ACEA members.

However, as more (also cost effective) technologies become available, chances are that the advantage is relatively larger for manufacturers that have to deploy more technologies. In other words, a relatively flat slope has a negative effect on the competitive position of ACEA members, but this is partly countered in case off-cycle technologies are accounted for.

On the other hand, a relatively steep slope is competitively more advantageous for ACEA members. This lowers the required CO_2 emission reductions and therefore also the amount of technologies that have to be deployed. This also reduces the relative positive effect that off-cycle technologies have.

Figure 39 **Effects of including/excluding the awarding of off-cycle technologies (eco-innovations) on the competitive position of ACEA members for passenger cars in 2025**



Utility parameter

Keeping mass as the utility parameter, rather than changing to footprint, results in a lower price increase for ACEA than for non-ACEA manufacturers. This is the result of ACEA manufacturers having a relatively high mass-to-footprint ratio, making their footprint-based targets relatively (compared to non-ACEA members) stricter than their mass-based targets. This conclusion is (almost) independent of the final fleet composition and choices for other modality values and therefore robust.

Target function slope

A steeper limit function improves the competitive position of ACEA members compared to non-ACEA members. As mentioned above, compared to non-European manufacturers, ACEA members make relatively large vehicles with relatively high mass. With a steeper limit function, the target gets less stringent for such manufacturers and compliance costs will be lower.

Legal entity
Regulating manufacturer groups instead of brands creates a competitive advantage for ACEA manufacturers over non-ACEA manufacturers. This is due to certain ACEA manufacturers with relatively high sales making relatively large vehicles with high mass. If they form a manufacturer group with manufacturers that make smaller cars, this increases the flexibility of these manufacturer groups to reduce emissions in the segments in which the average CO_2 emissions can be lowered at the lowest cost.

Target level
A less stringent target improves the competitive position of ACEA members compared to non-ACEA members. This is the case for all assessed targets in 2025 and 2030.

A more stringent target requires more (absolute) reductions from manufacturers making large or heavy vehicles. Since ACEA members on average produce larger and heavier vehicles than non-ACEA members, stricter targets result in a relatively higher costs for ACEA members and therefore also in higher relative price increase.

3.7.2 Vans
Compared to cars, the share of non-ACEA vans sales are limited. The absolute effect of competitiveness advantage is therefore smaller.

As regards the effects on competitiveness, most of the findings and conclusions for cars also apply. Taking account of off-cycle technologies has a slightly larger positive effect on the competitiveness of ACEA members for vans than is the case for passenger cars. This is the effect of a larger difference between the average utility of ACEA and non-ACEA members for vans than for cars.

3.8 Synthesis of detailed assessment of impacts on CO_2 emissions and cost

Figure 40 to Figure 43 show the average impact of changing the various modalities that were assessed and of setting different target levels, on the overall GHG emissions (WTW), total societal cost, additional manufacturer cost, end-user cost and competitiveness of ACEA members. The ‘average’ impact is determined by averaging the impacts of all policy variants assessed, i.e. covering different target levels, technology scenarios and modalities.

The coloured bars represent the effect of changing the current modality value (TTW metric, mass as utility parameter, slope based on baseline sale characteristics (see Section 3.4.3), no mileage weighting, manufacturer groups as regulated entity) to the alternative (WTW metric, footprint as utility parameter, different slopes, ,including mileage weighting and individual manufacturers (brands) as regulated entity). In addition, the graphs show the difference between in- or excluding off-cycle emissions and making the target level more stringent.

The error bars indicate the deviation between the different policy variants considered in the assessment, with 80% of all assessed policy variants falling within the range of the error bars. The error bars are therefore a proxy for the robustness of the policy variant with respect to the choice for other modalities.

The graph shows that a stricter target level has by far the highest impact on effectiveness (GHG emission reduction). As regards costs, changing the target level, including off-cycle emissions and changing the utility parameter have the largest impacts. Varying the other modalities has relatively small impacts.

Figure 40 Average effect of changing the modality from value/choice in current regulations to alternative value/choice for the case of passenger cars in 2025

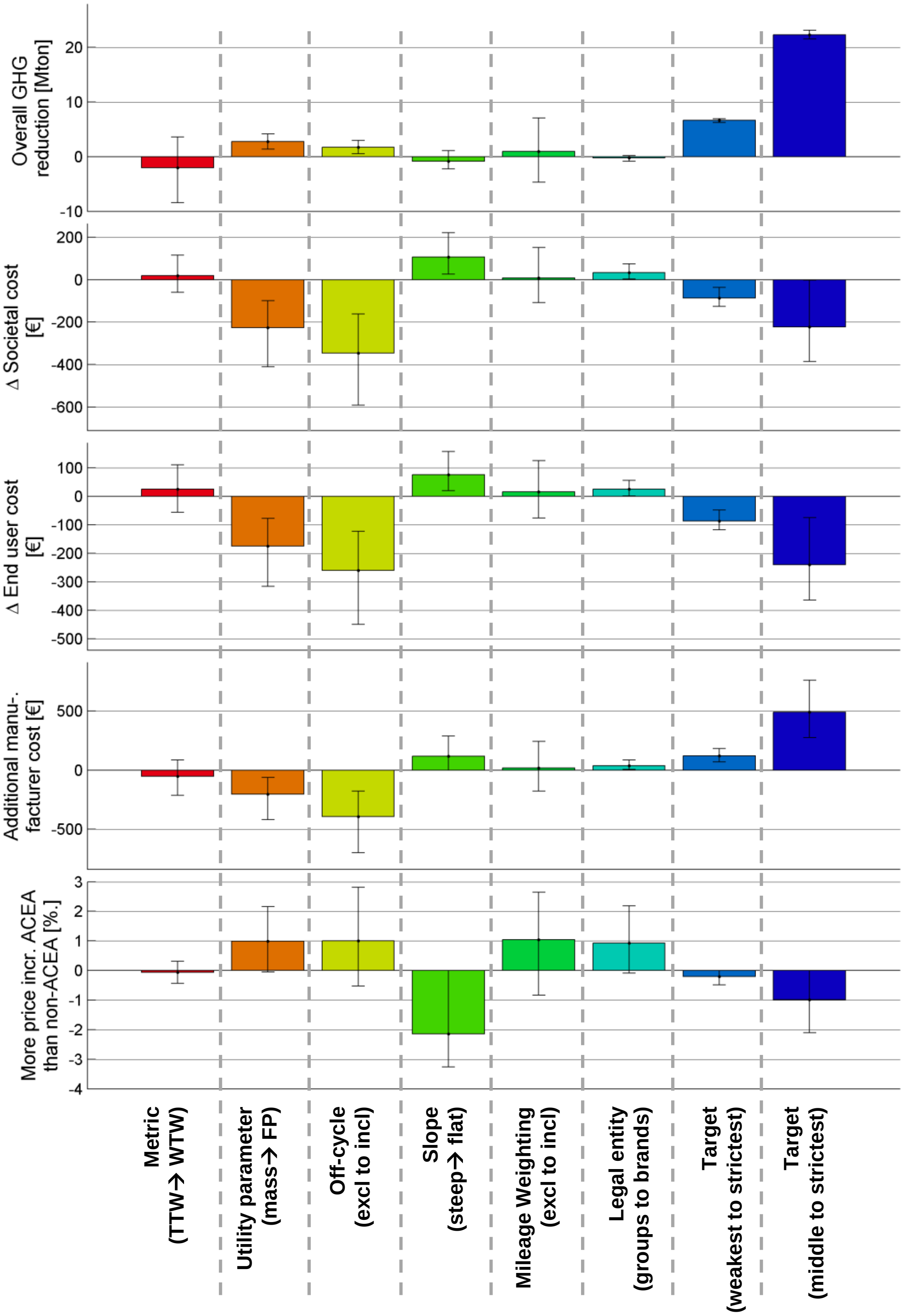


Figure 41 Average effect of changing the modality from value/choice in current regulations to alternative value/choice for the case of passenger cars in 2030

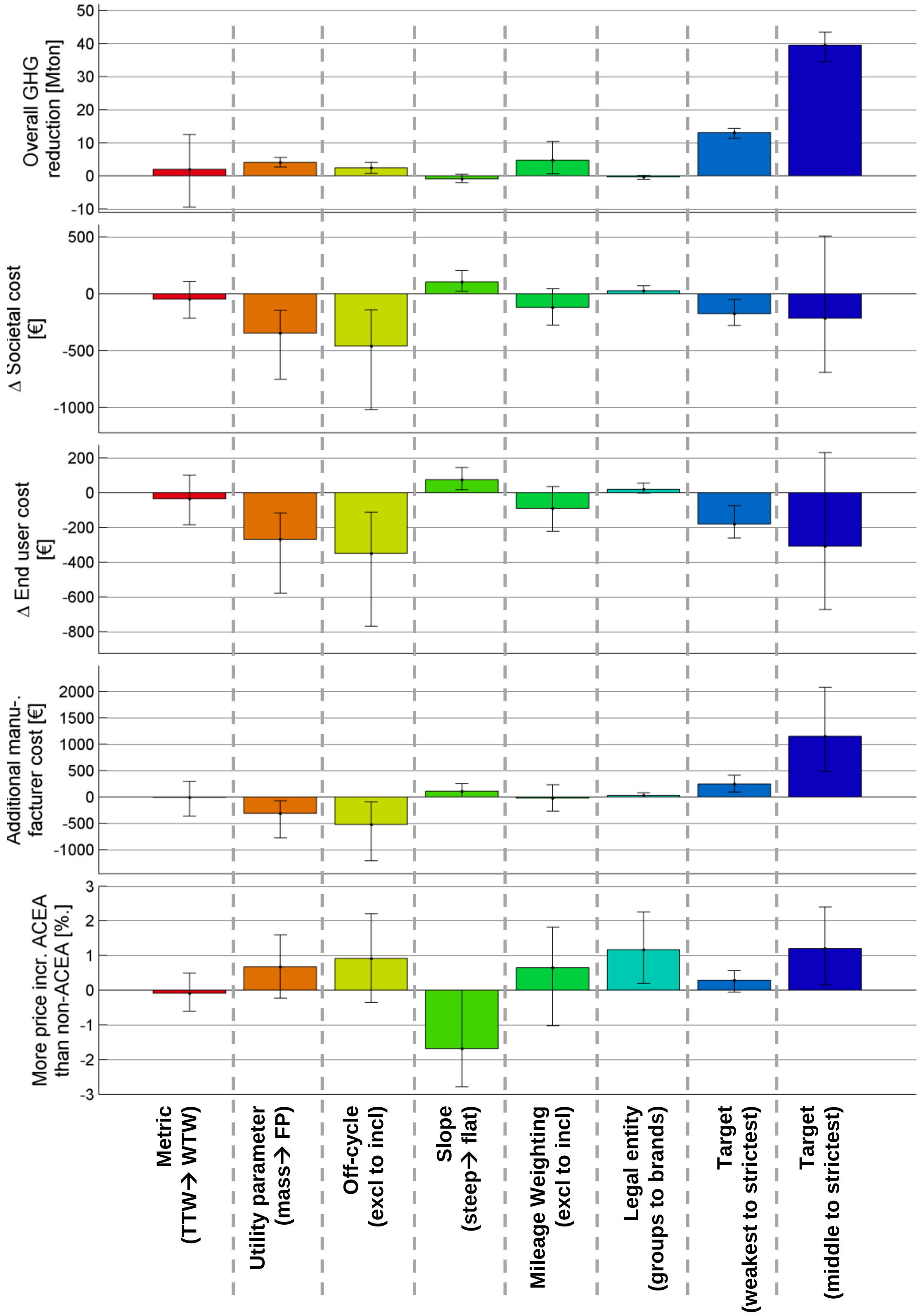


Figure 42 Average effect of changing the modality from value/choice in current regulations to alternative value/choice for the case of vans in 2025

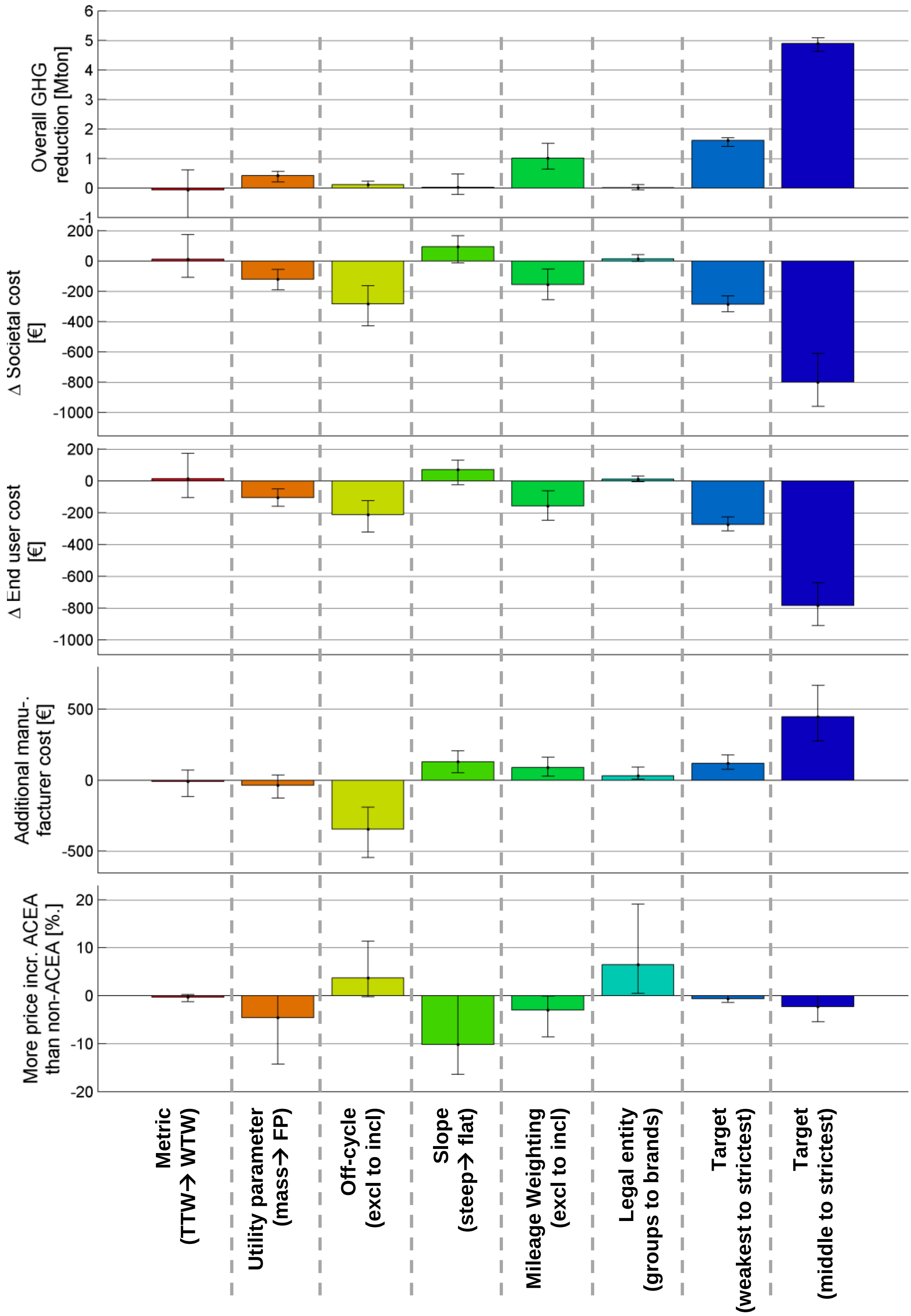
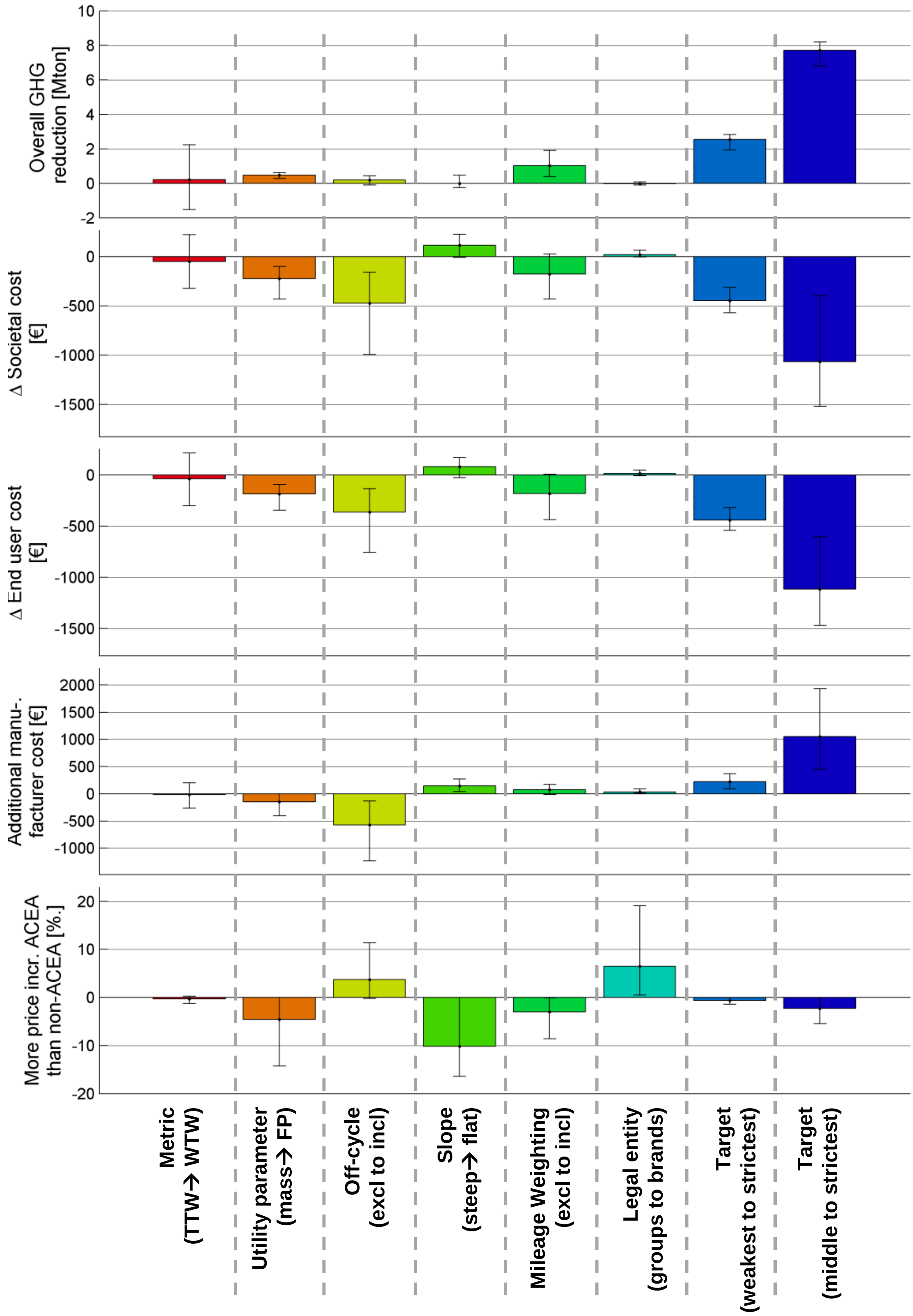


Figure 43 Average effect of changing the modality from value/choice in current regulations to alternative value/choice for the case of vans in 2030



4 Assessment of selected policy variants on all criteria

4.1 Introduction

Chapter overview	
Goal	Assessing four selected policy variants on all assessment criteria.
Output	– Detailed analysis of impacts on GHG emissions (TTW and WTW), end-user, manufacturer and social cost and cost effectiveness. – Impacts on competiveness. – Distributional impacts across OEMs. – Impacts on social equity.
Annexes	Annex F, Annex G, Annex H.

In this chapter the results of the assessment of a short list of four policy variants on all assessment criteria is presented, including the wider impacts on transport, economy and social equity.

The assessments have been made using the cost assessment model (for cost and CO_2 impacts, as also used for the assessments presented in the previous chapter) and the models MOVEET, EDIP and E3ME (see Annex F).

The main aim of the assessments with the other models presented in this chapter, is to get a picture of the size of the impacts on the transport sector and the overall economy. These impacts are mainly dependent on the energy efficiency of the vehicles (affecting the energy cost of transport) and the average vehicle purchase price increase. Both impacts are output of the cost assessment model as explained in Section 3.4. Each combination of energy efficiency improvement and vehicle cost can be the result of various combinations of modalities.

The four policy variants have been selected on the following considerations:

– The energy efficiency of the vehicles is mainly determined by the target level. Therefore the high and the low target level are selected, to get the largest spread in results.
– The impact on vehicle cost is mainly determined by the target level and a broad range of modalities. Therefore two sets of modality values are used: one set as in the current regulation and one set which on average can be expected to result in the lowest societal cost. This implies changes regarding metric, utility parameter and mileage weighting.

The combination of high and low target levels and the two sets of modalities result in the four policy variants that have been assessed as summarised in Table 22.

Table 22 Short list of selected policy variants

	S1 Current approach, 3% annual reduction	S2 Current approach, 6% annual reduction	S3 Alternative approach, 3% annual reduction	S4 Alternative approach, 6% annual reduction
Target level	Target level based on 3% annual reduction on NEDC	Target level based on 6% annual reduction on NEDC	Target level based on 3% annual reduction on NEDC	Target level based on 6% annual reduction on NEDC
A2 Regulated entity	Manufacturer groups	Manufacturer groups	Manufacturer groups	Manufacturer groups
A3 Metric	TTW	TTW	WTW	WTW
C3 Aggregation	Sales weighted, no mileage weighting	Sales weighted, no mileage weighting	Sales weighted, with mileage weighting	Sales weighted, with mileage weighting
C1 Rewarding off-cycle emission reductions (eco-innovations)	Yes	Yes	Yes	Yes
E1 Utility parameter	Mass	Mass	Footprint	Footprint
E2 Shape and slope of the target function	Equal relative reduction over the utility parameter range*	Equal relative reduction over the utility parameter range*	Equal relative reduction over the utility parameter range*	Equal relative reduction over the utility parameter range*

* The required relative reduction is equal over the whole utility parameter range from the lowest to the highest utility parameter value. For the assessment of distributional impacts in Section 4.5, also other slopes have been tested.

As the number of model runs with the other three models was limited to four per vehicle type (car or van) and target year (2025 and 2030), the four policy variants could not be run for all technology scenarios. When varying both the target level, modality values and technology scenario, it would be hard to interpret the results as it would not be clear which variation (target level, modalities or technology scenario) could explain the differences in impacts. Therefore the four policy variants have just been run for the ‘middle’ technology scenario, i.e. the mixed xEV scenario.

The BAU situation (to which all policy variants have been compared) is the same as used in the previous chapter and again just run for the Ultra-efficient ICEV scenario as this can be considered as the most likely scenario in the BAU policy variant (see Section 3.3.7).

4.2 Effectiveness

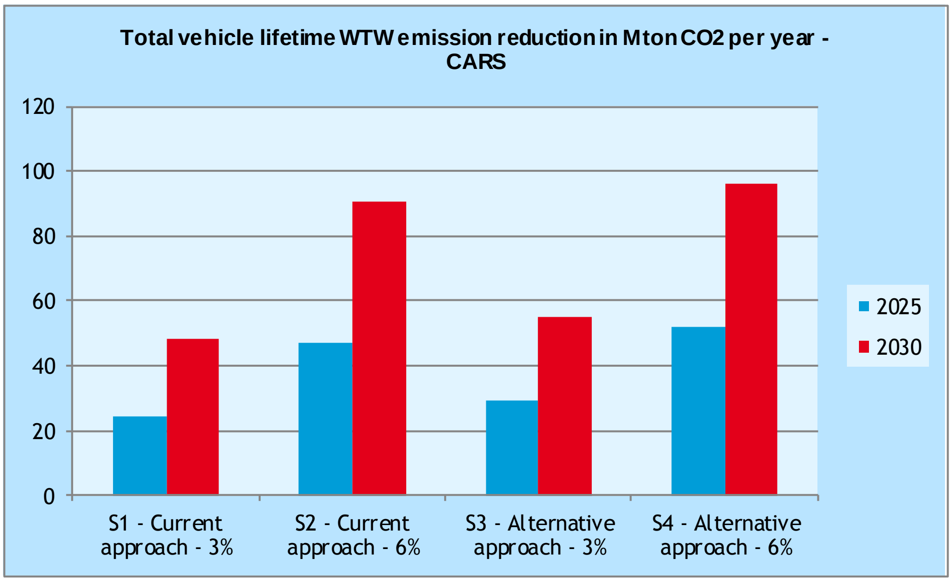
4.2.1 WTW CO_2 emission reduction

The WTW CO_2 reduction over the lifetime of a vehicle under the four selected policy variants (and compared to BAU) for cars is shown in Figure 44 and for vans in Figure 45.

The graphs show clearly that the policy variants with a more stringent target level (policy variant 2 and 4) result in much higher emission reductions than the policy variants with a less strict target (reductions are about twice as high, both for cars and vans). They also show that the differences between the modality choices (metric, utility parameter, mileage weighting) on the effectiveness of the policy are relatively small (overall emissions reduction increases by only 6 to 19% for cars and 7 to 30% for vans). Amongst those, accounting for mileage weighting has the largest impact on the effectiveness.

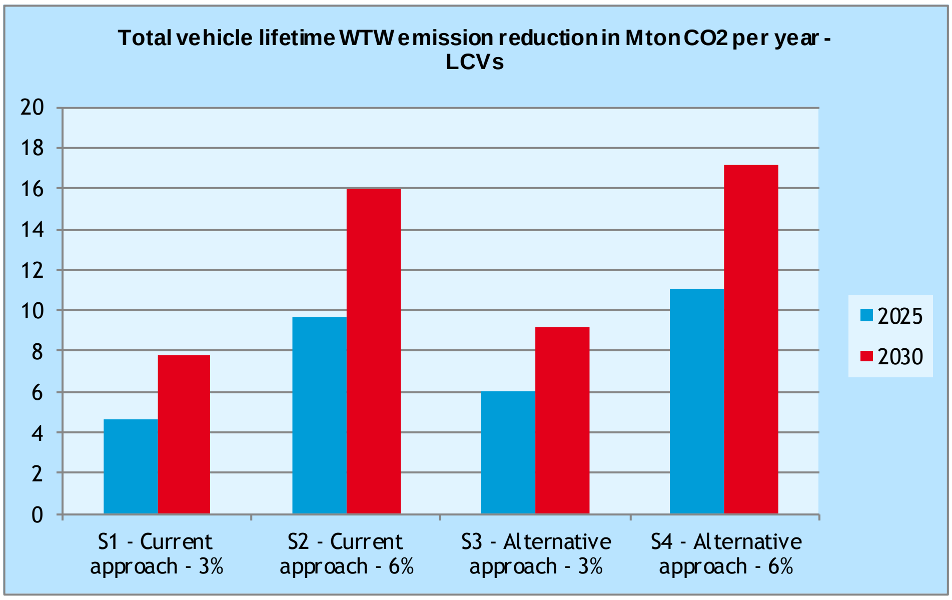
Cars

Figure 44 Vehicle lifetime WTW emission reduction of all new cars sold in 2025/2030 relative to BAU



Vans

Figure 45 Vehicle lifetime WTW emission reduction of all new vans sold in 2025/2030 relative to BAU



4.2.2 Transport demand, modal split and impact on WTW emissions from passenger transport

The impacts of the four policy variants (considering only passenger cars) on the overall (passenger) transport system have been modelled by the MOVEET model. The impacts are expressed in the following indicators:

– change in passenger kilometres by **all** passenger transport modes (see Figure 46);
– modal split: change in passenger kilometres by passenger cars (see Figure 47) and by public transport modes (see Figure 48).

As the MOVEET model (unlike the cost assessment model) does not merely look at the sales in a certain year, but also contains a fleet model, the 2030 fleet in MOVEET is affected by the sales in previous years. In the MOVEET model runs, it was assumed that all targets set in 2030 are on top of targets set in 2025, with in both years the same design of the regulation.

The results make clear that the impact on the overall passenger transport volume is very small (in all scenarios less than 0.15% increase). The modal split shows that there is an increase in the transport demand by passenger cars of less than 0.2 up to 0.9%, which is in part a result of a shift from public transport modes to passenger cars. This can be explained by the fact that the end-user costs for car users are significantly lower in the policy scenarios than in the BAU scenario. The total transport demand of rail, tram and bus transport decreases by 0.5 to 1.3% in 2025 and by 1.1 to 2.7% in 2030.

Figure 46 Change in total passenger transport volume in 2025/2030 relative to BAU

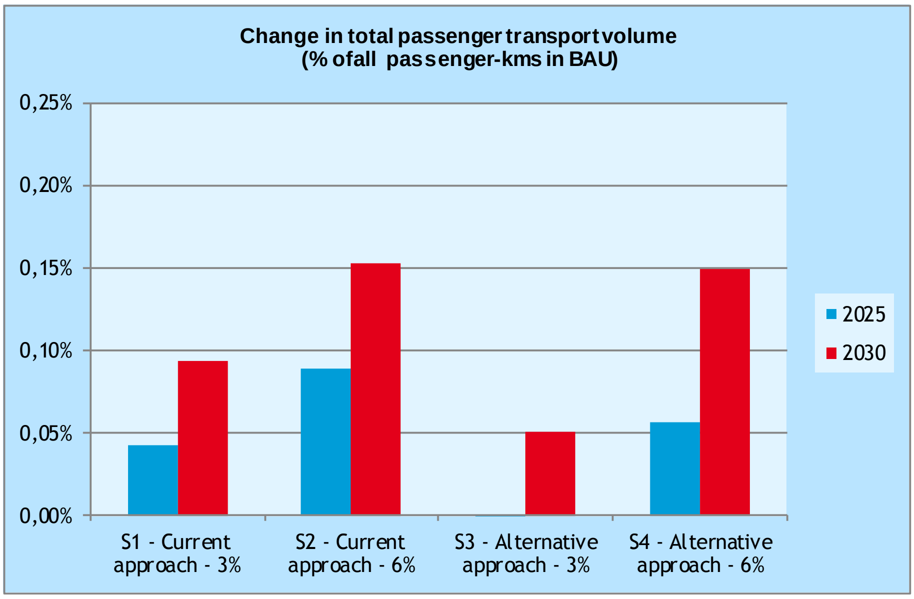


Figure 47 Change in transport volume of passenger cars in 2025/2030 relative to BAU

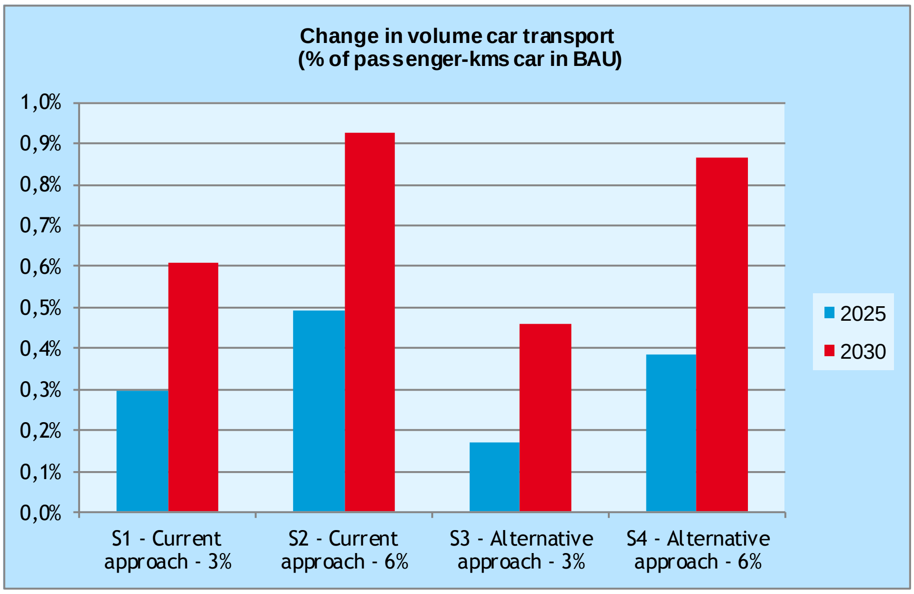
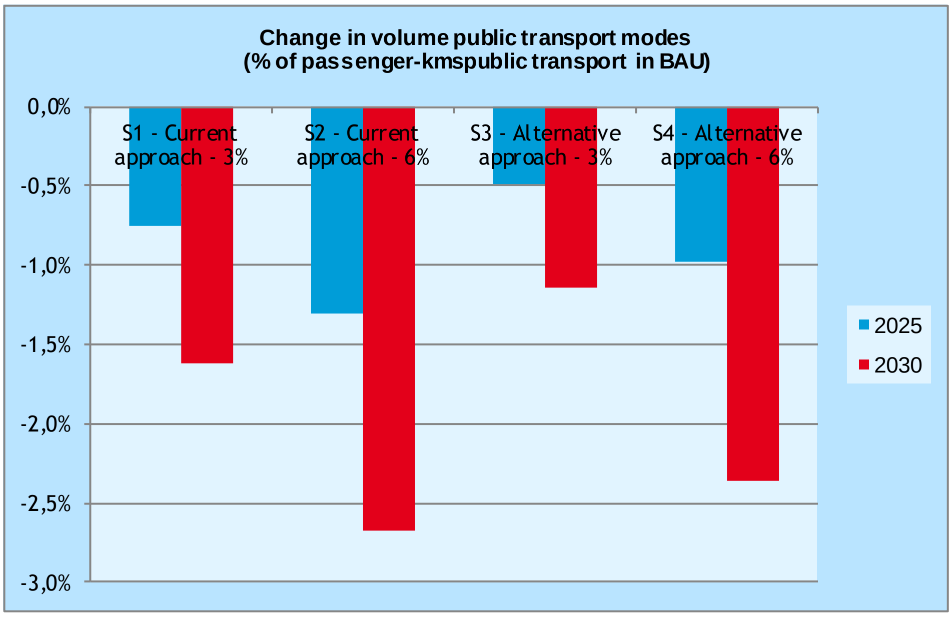


Figure 48 Change in transport volume of public transport modes (train, tram, bus) in 2025/2030 relative to BAU

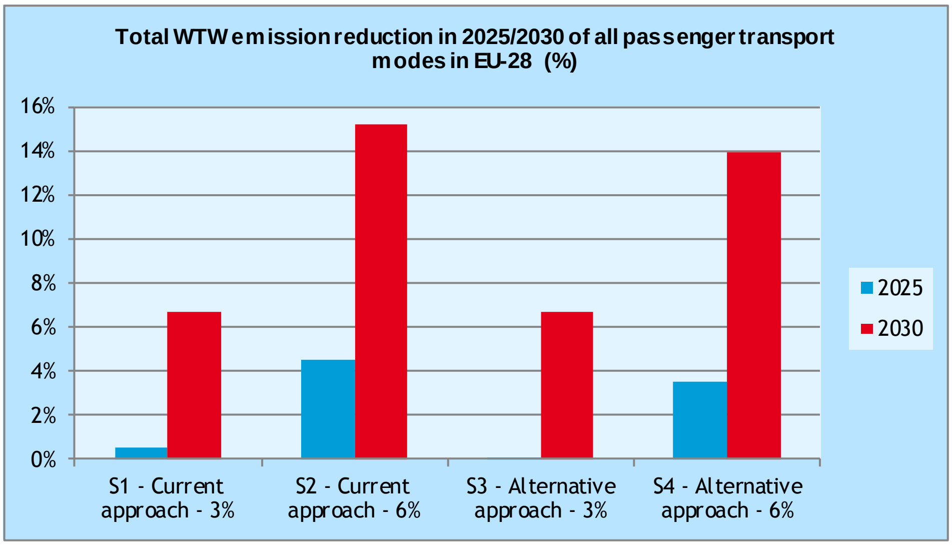


MOVEET has also been used to estimate the total GHG emission reductions for all passenger transport modes for the four policy variants when including the changes in transport demand and the modal shift. For the TTW emissions values for the other transport modes, the baseline values from MOVEET were used. The WTT values were the same as the ones used for cars and vans (see Table 19). The results are shown in Figure 49.

While the GHG emissions impacts shown in Section 3.5 and 4.2.1 are the GHG emissions reductions of the *new vehicles sold in 2025 or 2030 over their entire lifetime*, the impacts shown in Figure 49 reflect the impacts on the *total passenger transport emissions in 2025 or 2030*.

Despite the modal shift and volume effects, the overall GHG emissions of cars are reduced significantly. The overall GHG emission reduction increase over time as the share of the fleet that is affected grows year by year. In the variants with the more stringent target level, the total emissions of passenger transport in 2030 are expected to be reduced by close to 15% compared to the BAU scenario. The small impacts in 2025 can be explained by the fact that by then only a very small share of the fleet has been assumed to be affected by the stricter targets that come into force in that year. It should be noted that the emission reduction percentages will increase further after 2030 as a higher share of the fleet will be renewed. The full impacts of the 2025/2030 targets will become visible once the entire fleet is renewed, so likely only after 2050.

Figure 49 WTW GHG emission reduction in 2025/2030 relative to BAU



4.3 Cost effectiveness

The cost impacts are expressed in three indicators:
- total societal cost (Section 4.3.1);
- manufacturer cost (Section 4.3.2);
- end-user cost (Section 4.3.3).

4.3.1 Societal cost

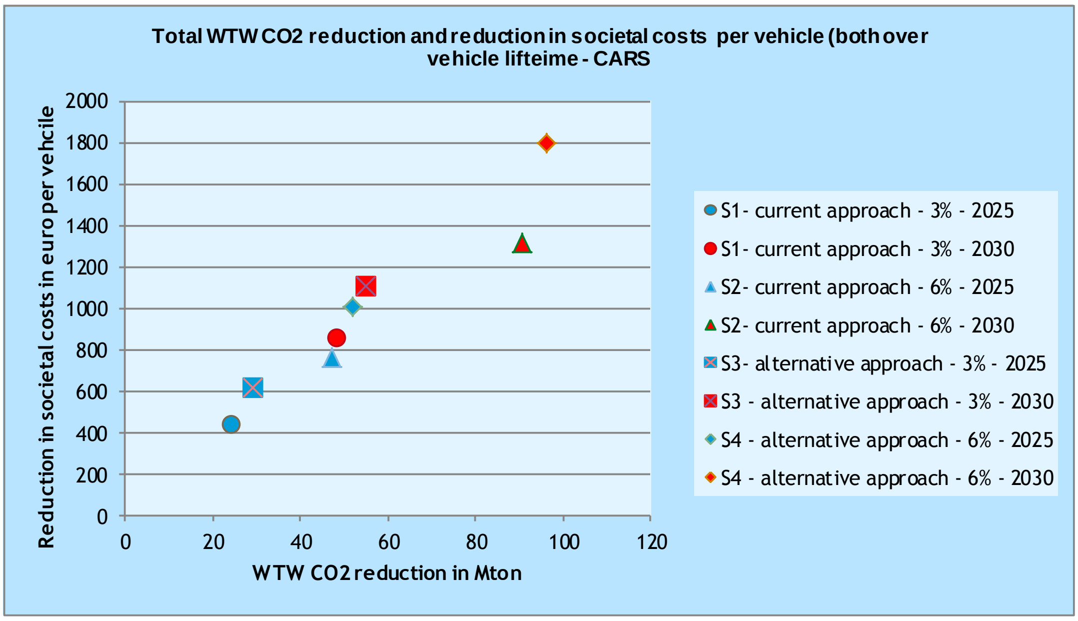
The average societal benefits per vehicle sold in 2025/2030 over the entire lifecycle is shown in Figure 50 (cars) and Figure 51 (vans). For comparison, the graphs also show the corresponding WTW emission reductions (as also presented in Section 4.2.1). The societal benefits include the energy cost savings over the entire vehicle lifetime, minus the additional manufacturing costs; so no external cost savings.

The graphs show that the largest net societal benefits are achieved with the most stringent target level and the alternative design of the regulations. They also show that both for cars and even more for vans, the societal benefits and WTW emission reduction are very well correlated. This means that for the four scenarios assessed changes that increase the effectiveness also increase the net financial societal benefits. This means that both on effectiveness and on cost effectiveness (i.e. societal benefits), the strictest target levels that were assessed and the alternative design score best.

For cars we see that the target level has the largest impact on effectiveness, and the choice for the modalities on the net societal benefits. For vans, the additional societal benefits of the alternative design are smaller, while the impacts on effectiveness are similar.

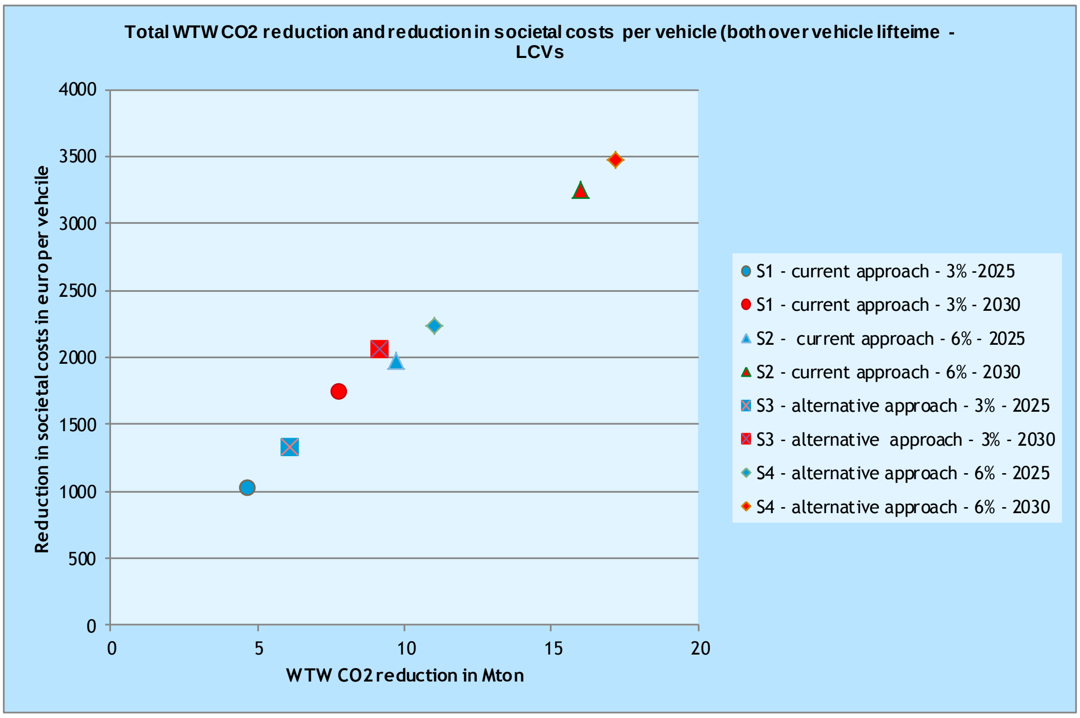
Cars

Figure 50 Societal benefit per car sold in 2025/2030 (vertical axis) and WTW CO_2 reduction (horizontal axis), both over the entire lifetime, relative to BAU



Vans

Figure 51 Societal benefit per van sold in 2025/2030 (vertical axis) and WTW CO_2 reduction (horizontal axis), both over the entire lifetime, relative to BAU



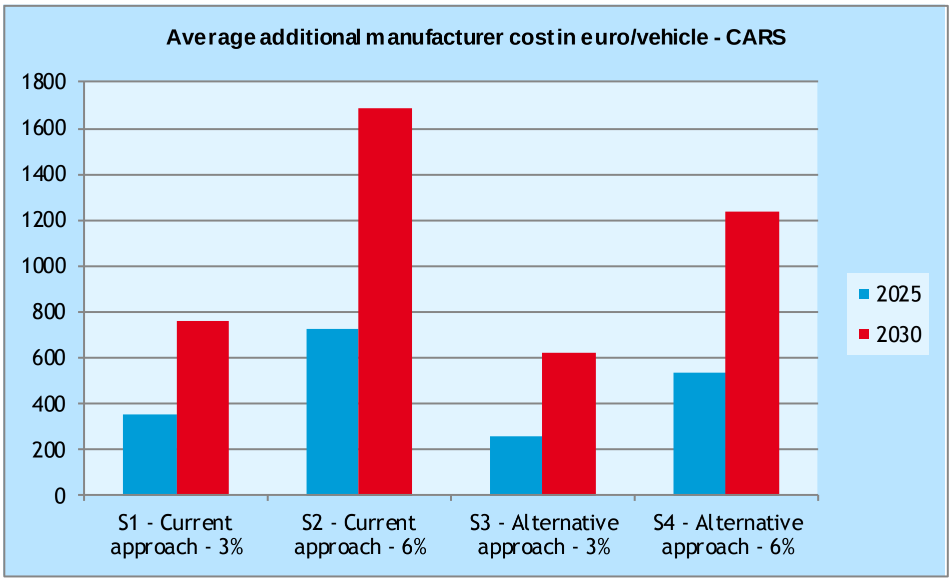
4.3.2 Manufacturer cost

The additional manufacturing costs, as shown in Figure 52 (cars) and Figure 53 (vans), are highest in the policy variants with the most stringent target. For cars, the costs are somewhat lowered in the case of alternative modality values, which is in line with what we saw in chapter 3 (see particularly Figure 40 and Figure 41 in Section 3.8). The alternative design of the modalities (in particular the change of utility parameter) results in societal cost savings.

For vans, the alternative design does not result in lower manufacturer costs, which has to do with the impact of mileage weighting. As explained in Section 3.6.2 and as shown in the figures in Section 3.8, mileage weighting generally results in lower costs for cars but in higher costs for vans. For cars, the changes in metric, utility parameter and mileage weighting all separately result in lower additional manufacturer costs. Therefore the cost of S2 and S4 are lower than in respectively S1 and S3. However, for vans, the higher costs resulting from mileage weighting are not compensated by the lower costs resulting from a different metric (i.e. WTW) and utility parameter (i.e. footprint). Therefore for vans the average additional manufacturer costs in S2 and S4 are higher than in respectively S1 and S3.

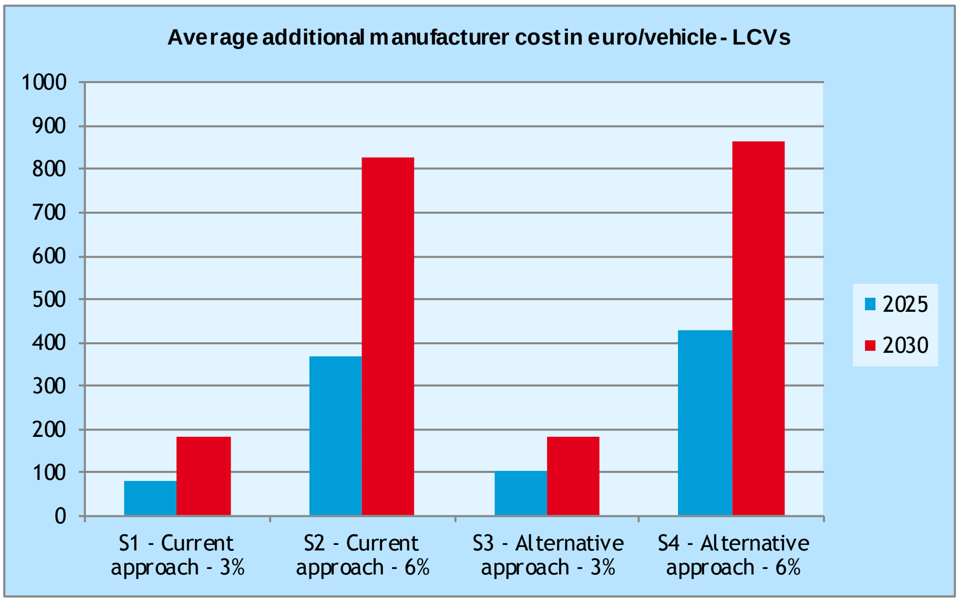
Cars

Figure 52 Average additional manufacturer cost for cars in 2025/2030 relative to BAU



Vans

Figure 53 Average additional manufacturer cost for vans in 2025/2030 relative to BAU

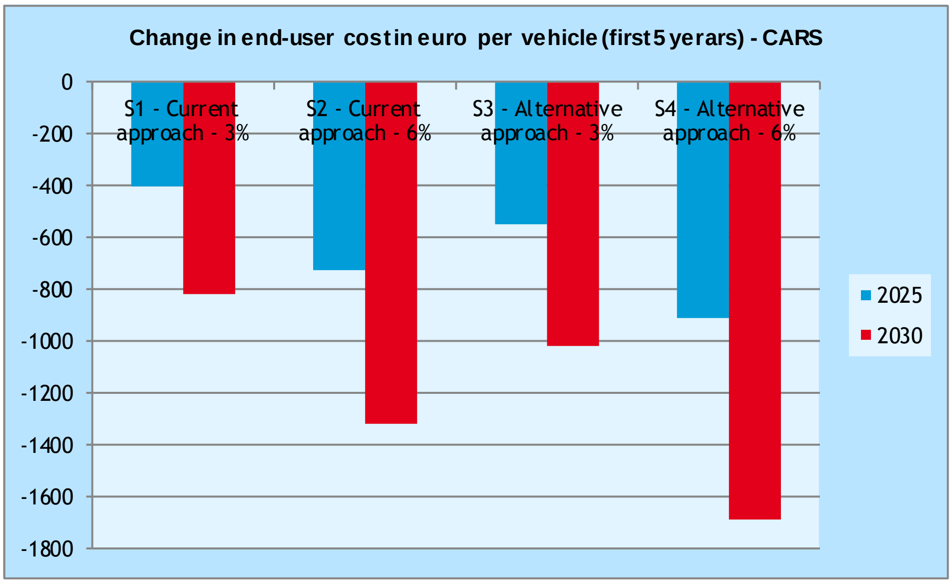


4.3.3 End-user cost

In all policy variants the net end-user cost reduce significantly. The impacts are shown in Figure 54 (cars) and Figure 55 (vans). The end-user costs are lowest in the scenarios with the stricter target levels (S2 and S4). With the stricter targets, the reduction in end-user cost are 62 to 81% higher for cars and 70 to 97% for vans. Furthermore, the alternative design of modalities also results in lower end-user cost: an additional decrease of 25 to 36% for cars and 7 to 31% for vans.

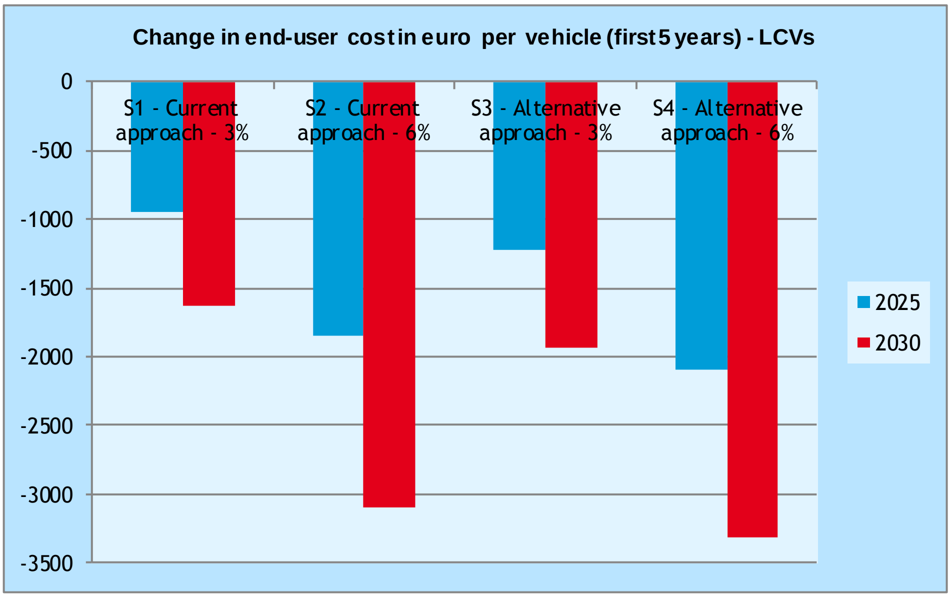
Cars

Figure 54 Average change in total end-user cost in the first 5 years for cars sold in 2025/2030 relative to BAU



Vans

Figure 55 Average change in annual end-user cost in the first 5 years for vans in 2025/2030 relative to BAU



4.4 Competitiveness: impacts on the economy

The economy-wide impacts have been modelled by the E3ME model. Only the impacts of the passenger car regulation have been modelled. For the E3ME model runs, the MOVEET model results were used as input data. The impacts are expressed in the following indicators:
- GDP;
- employment;
- consumption;
- investment;
- trade effects (external imports and exports).

In brief, the economic impacts can be summarised as follows:
- **Energy sector**: the improvements of the CO_2 emissions of vehicles lead to a reduction in demand for petrol and diesel and an increase in demand for electricity. Imports of oil and petroleum fall and output in the domestic electricity sector increases.
- There is an expansion of the **vehicle manufacturers** supply chain to provide more fuel-efficient vehicle technologies. This leads to a small increase in gross output and employment in the motor vehicles supply chain. The increase in employment leads to a small increase in real incomes and consumption.
- There is an increase in the capital cost of vehicles, but a reduction in the running costs (due to fuel efficiency improvements and a transition to electric vehicles). Overall **consumers** benefit. Despite facing higher vehicle costs, they spend less on relatively expensive fuels and can spend more on other goods and services (for which a greater portion of the supply chain is located domestically). Consumer prices fall and real incomes increase, leading to an increase in consumption and GDP. This has some multiplier effects - the increase in GDP leads to an increase in investment and an increase in output and employment, which drives further increases in consumption. The increase in consumption also drives

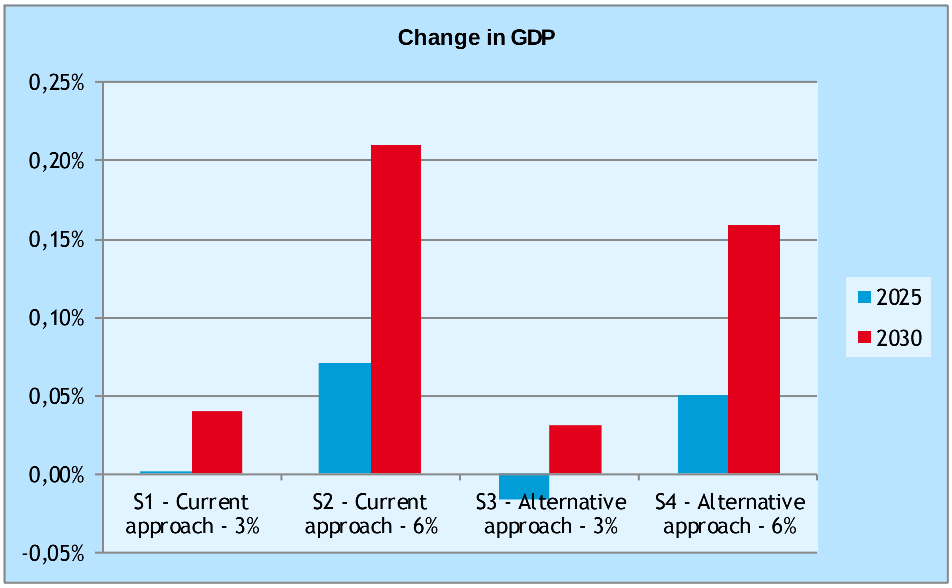
an overall increase in imports (despite lower oil and petroleum imports in these scenarios).

Below the E3ME model results for various indicators are presented.

4.4.1 GDP

In most cases there is an increase in GDP as shown in Figure 56. The increase in GDP results from a transfer of expenditure away from imported oil and petroleum products towards domestically produced electricity, leading to an increase in output and employment in the domestic electricity supply sector. The low-carbon vehicle transition also leads to an expansion of the motor vehicles supply chain and boosts employment in manufacturing sectors. Despite higher vehicles costs, consumers benefit from a reduction in the total cost of car ownership, as there is a large reduction in spending on fuel. This leads to a boost in real incomes, consumer expenditure and further increases GDP. The largest impacts were found for scenario 2 and 4 in 2030 (as these scenarios have the largest reduction in societal cost) with an increase in GDP of close to 0.2%, relative to the BAU in the same year. The GDP increase is slightly larger in the scenarios with the current design (scenario 1 and 2) compared to scenarios with an alternative design.

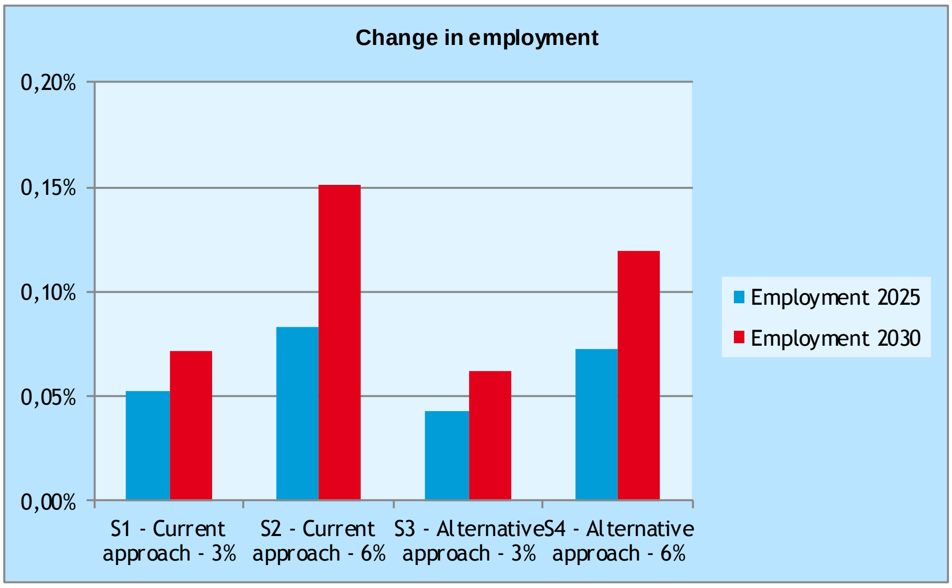
Figure 56 Change in GDP in 2025/2030 relative to BAU



4.4.2 Employment

Figure 57 shows the impact on the employment in the EU. In all scenarios, employment increases slightly by 0.04 up to 0.15%, relative to the BAU in the same year. Many of the additional jobs created are in the electricity supply sector and in the motor vehicles supply chain, but the net increase in employment also reflects additional multiplier effects. Real incomes increase from the initial boost to employment and consumers also benefit from lower costs of vehicle ownership. As a result, consumers can spend more on other goods and services, leading to increases in output and employment in those sectors. Again, the largest impacts were found for the scenarios with the most strict target levels, scenario 2 and 4 in 2030.

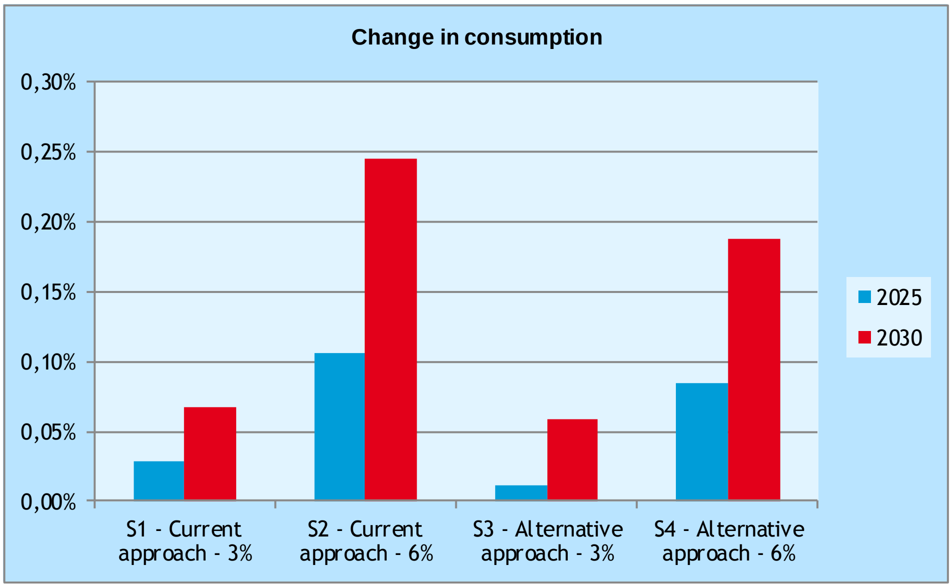
Figure 57 Change in employment in 2025/2030 relative to BAU



4.4.3 Consumption

Figure 58 shows the impact on consumption. In all scenarios consumption increases. This is primarily due to an increase in real incomes following the increase in employment. The largest impacts are found for scenario 2 and 4.

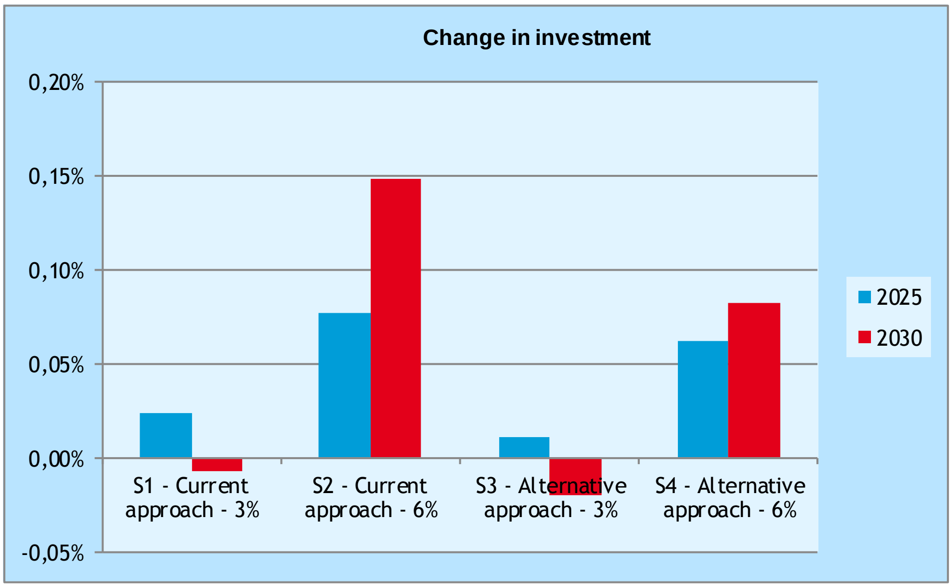
Figure 58 Change in consumption in 2025/2030 relative to BAU



4.4.4 Investment

The impacts on investments are shown in Figure 59. There is an increase in investments in scenario 2 and 4. In the scenarios with the less tight target levels, the impacts on investments as modelled by E3ME are negligible. It is important to note that the investment impacts do not include the effects of increased charging infrastructure requirements and simply reflect the effect of a more positive environment for investment following the boost to GDP.

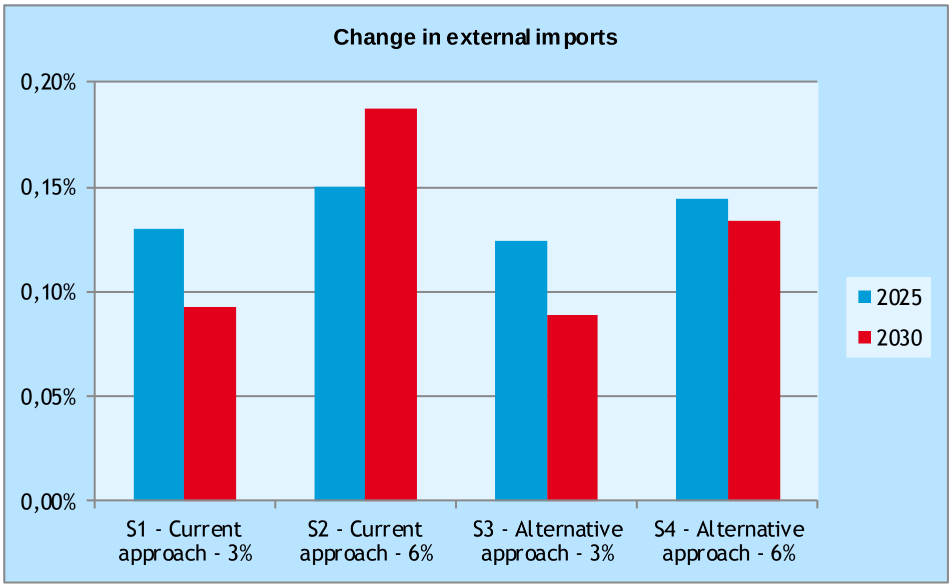
Figure 59 Change in investment in 2025/2030 relative to BAU



4.4.5 Trade effects

The impacts on exports to countries outside the EU is very small (less than 0.025% in all scenarios). The impact on imports is larger and shown in Figure 60. The imports from countries outside the EU increase in all scenarios by roughly 0.1 to 0.2%, relative to the BAU in the same year.

Figure 60 Change in external imports in 2025/2030 relative to BAU



4.5 Distributional impacts across OEMs

The impact of the different options on the cost distribution over the different legal entities is assessed by the cost assessment model. This has been done using the modelling approach explained in Chapter 3. This section presents the results of this assessment for the four policy variants that have been selected.

As explained in Section 3.4.3, the distributional effects of the policy amongst OEMS is very sensitive to the slope of the limit function. In order to gain insights in the distributional impacts is therefore essential to do the assessment for multiple target function slope values.

In this section, the additional manufacturer costs and relative price increase are depicted for different manufacturer groups. The intention is not to forecast the actual additional costs and price increases for these manufacturer groups. This is not possible as the price increase is affected by many more parameters than the policy variants assessed, e.g. pricing strategy, (luxury) options on vehicles, etc. Instead, the aim is to provide an indication of the effect of different policy variants on manufacturers with different characteristics.

4.5.1 Cars

In Figure 61, the impact of varying the target function slope on the relative price increase of various manufacturer groups is shown for 'policy variant S1'. The relative price increase, relative to the BAU scenario, is depicted for various slopes of the target function (using mass as the utility parameter) in 2025 for passenger cars.

As shown in the figure, policy variant S1 has a relatively large impact on the relative price increase for manufacturer groups selling vehicles at a relatively low price (e.g. Fiat, Hyundai-Kia and Suzuki). For manufacturers selling mainly high priced vehicles (e.g. Mercedes, Geely and TATA), the effect of the policy on the price increase is smaller.

The figure shows that for manufacturer groups with vehicles with relatively low average mass (e.g. Fiat), the relative price increase is higher for steeper slopes. In case of a steep slope, the targets of manufacturer groups with average mass below the fleet wide average mass are relatively strict. (The same principle would of course apply when using a different utility parameter, e.g. footprint).

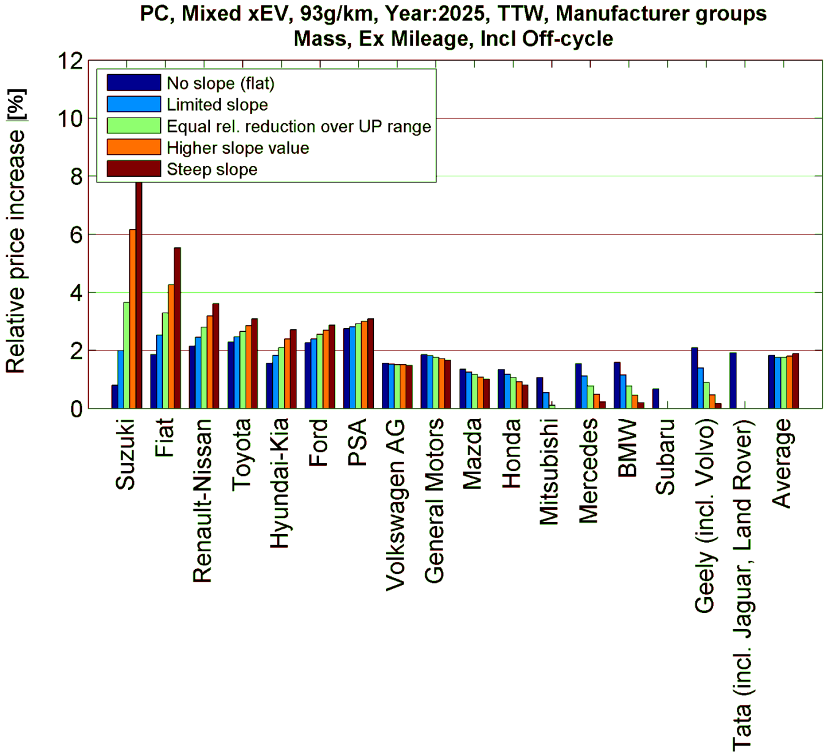
The opposite effect takes place for manufacturers manufacturing vehicles with a relatively high average mass, e.g. BMW. Targets of such manufacturers become less stringent as the limit function gets steeper.

Manufacturer groups with average utility values close to the fleet-wide average utility values are relatively insensitive to changes in the slope value.

The additional manufacturer costs for meeting in 2025 the 3% annual reduction target, are approximately € 350 per vehicle relative to BAU (see also Section 4.3.2). As shown in Figure 61, this results in an average relative price increase of approximately 1.8%.

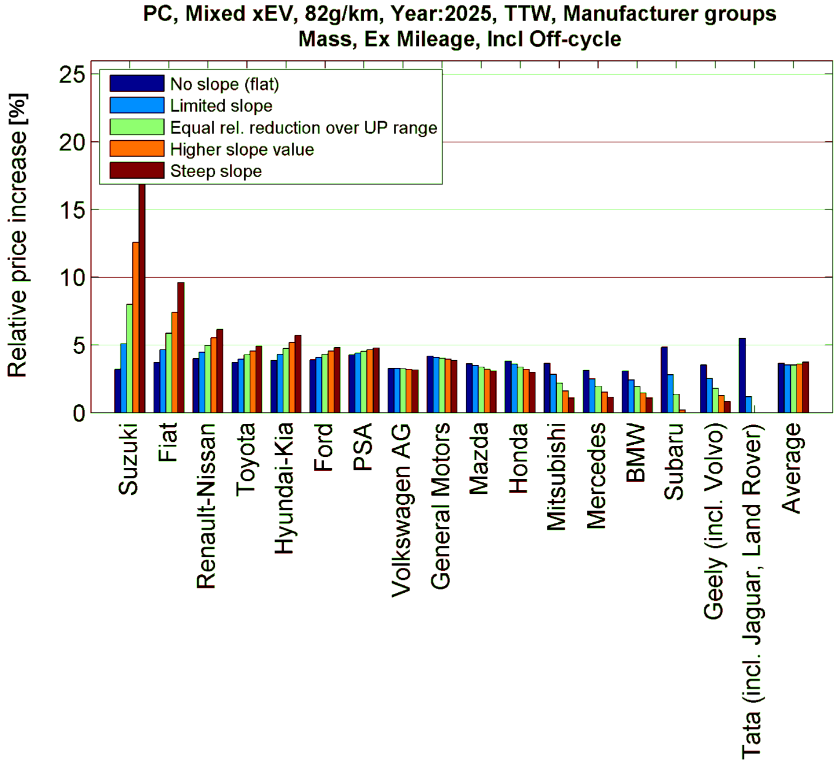
For more extreme slope values the average relative price increase is slightly higher. For manufacturer groups with very high or very low average utility values, targets can become rather strict in case of more extreme slope values. Since the cost curves increase more than linearly, the costs for such manufacturers can then become very high (e.g. costs for TATA are very high in case of a flat slope, while the costs for Suzuki are very high in case of a very steep slope. Such manufacturers affect the overall average costs and price increase negatively in case of flat or very steep slopes.

Figure 61 **Impact of the slope of the target function in 2025 for passenger cars (mixed xEV technology scenario) on the relative price increase of various manufacturer groups under 'policy variant S1'. Manufacturers are sorted from left to right based on their average utility value**



In policy variant S2, the target is more stringent (6% reduction). As a result, the additional manufacturer costs are significantly higher (€ 725) and therefore also the relative price increase (3.5%). Given that the utility parameter is 'mass' as is also the case for policy variant S1 and given that sales distribution over the segments and drivetrain types is equal to that in S1 (i.e. the same technology scenario 'Mixed xEV'), the distribution of this effect over the various manufacturer groups is comparable to that in policy variant S1.

Figure 62 **Distribution of impact of the slope of the target function in 2025 for passenger cars on the relative price increase of various manufacturer groups depending under 'policy variant S2'. Manufacturers are sorted from left to right based on their average utility value**

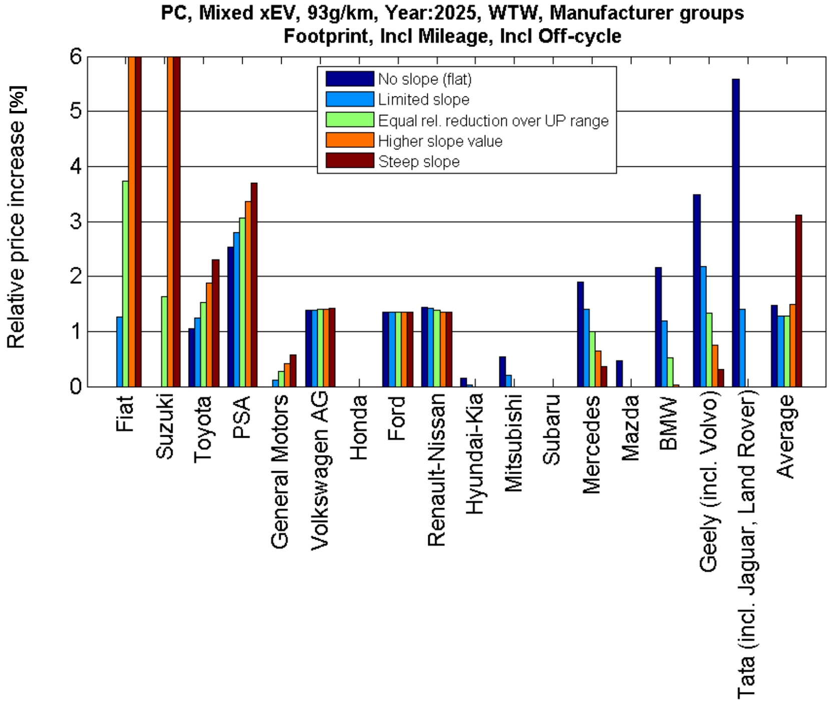


In policy variant S3 (see Figure 63), the utility parameter is changed to footprint. As explained in Section 3.6, the overall average relative price increase are approximately 30% lower than in policy variant S1, i.e. (approximately € 250 per vehicle compared to BAU, as mentioned in Section 4.3.2).

Changing the utility parameter (UP)from mass to footprint also affects the distribution of efforts across manufacturers. For manufacturers having a greater average footprint than the fleet wide average but a lower than average mass (e.g. Hyundai-Kia), a steeper slope when using footprint as the UP results in lower costs (while costs would become higher with an increasing slope in case of mass as utility parameter).

Moreover, in policy variant S3, mileage weighting is included. This reduces the average compliance costs. as costs for manufacturers producing large vehicles (having a higher average lifetime mileage) become lower, while costs for manufacturers making small vehicles increase, especially in case of a relatively steep target.

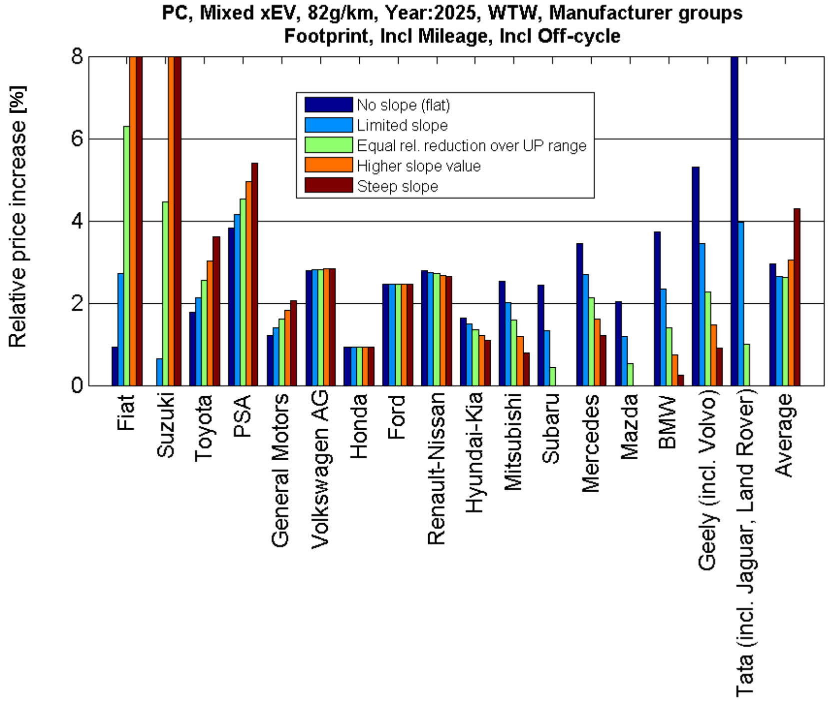
Figure 63 **Distribution of impact of the slope of the target function in 2025 for passenger cars on the relative price increase of various manufacturer groups depending under 'policy variant 3'. Manufacturers are sorted from left to right based on their average utility value**



In policy variant S4 (Figure 64), the target is again stricter than in policy variant S3. As a result the average compliance costs are higher (i.e. € 525 as shown in Section 4.3.2). As a result also the average relative price increase is higher.

Compared to policy variant S2 the effect on average manufacturer costs is smaller because including mileage weighting and changing the utility parameter result in lower compliance costs.
Given that the utility parameter is 'footprint' as is also the case for policy variant S3 and given that sales distribution over the segments and drivetrain types is equal to that in S3 (i.e. the same technology scenario 'Mixed xEV'), the distribution of this effect over the various manufacturer groups is comparable to that in policy variant S3. The differences compared to policy variant S1 and S2 are similar as the differences between S3 on the on hand and S1 and S2 on the other.

Figure 64 Distribution of impact of the slope of the target function in 2025 for passenger cars on the relative price increase of various manufacturer groups depending under 'policy variant 4'. Manufacturers are sorted from left to right based on their average utility value



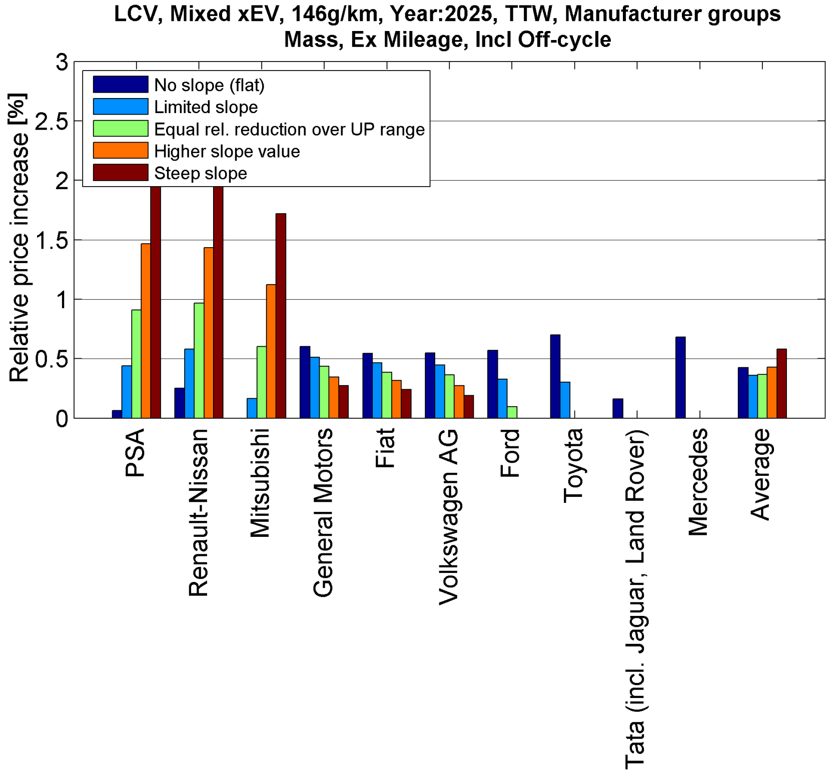
4.5.2 Vans

For 'policy variant S1' the average additional manufacturer costs are € 75 to € 125 per vehicle in 2025 (as shown in Section 4.3.2) depending on the slope of the target function, resulting in a relative price increase of approximately 0.4 to 0.6% compared to BAU. In 2030 the additional manufacturer cost increase is € 175 to € 240 per vehicle and the relative price increase 1.5 to 1.9% compared to BAU.

Similar as for passenger cars, the more extreme slope values, i.e. flat and very steep slopes result in the highest average additional manufacturer costs and therefore also in the highest relative price increase. As shown in Figure 65, a slope requiring equal relative reduction over the whole utility parameter range (see Figure 7 in Section 3.4.3) compared to the 2013 situation or a slightly flatter slope, result in the lowest additional manufacturer costs and therefore lowest price increase for policy variant S1.

For certain manufacturer groups that produce both cars and vans, the effect of the policy is different for vans than for passenger cars, depending on how their average utility value compares with the fleet wide average utility value (e.g. Fiat passenger cars have a lower mass than the fleet-wide average for cars, while the average Fiat van mass is higher than the fleet-wide average for vans).

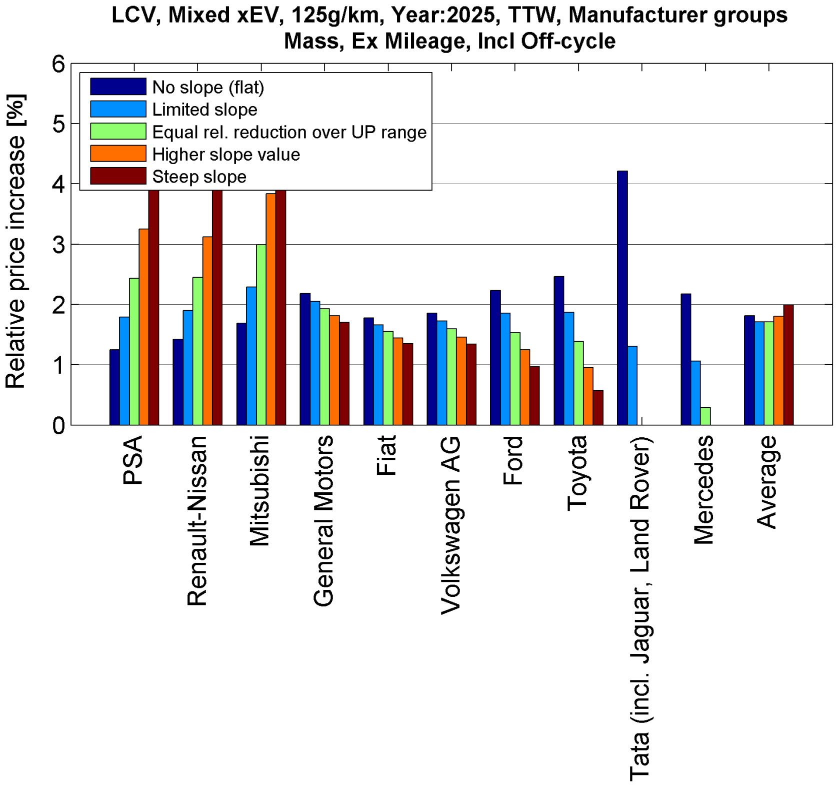
Figure 65 Distribution of impact of the slope of the target function in 2025 for vans on the relative price increase of various manufacturer groups depending under 'policy variant 1'. Manufacturers are sorted from left to right based on their average utility value



In policy variant S2, the target is more stringent. As a result the additional manufacturer costs are higher, i.e. between € 370 and € 430 per vehicle in 2025 and between € 815 and € 970 in 2030 compared to BAU.

As both the utility parameter and the sales distribution over the segments and drivetrain types are equal to that in S1, the distribution over the various manufacturer groups is comparable to that in policy variant S1.

Figure 66 Distribution of impact of the slope of the target function in 2025 for vans on the relative price increase of various manufacturer groups depending under 'policy variant 2'. Manufacturers are sorted from left to right based on their average utility value



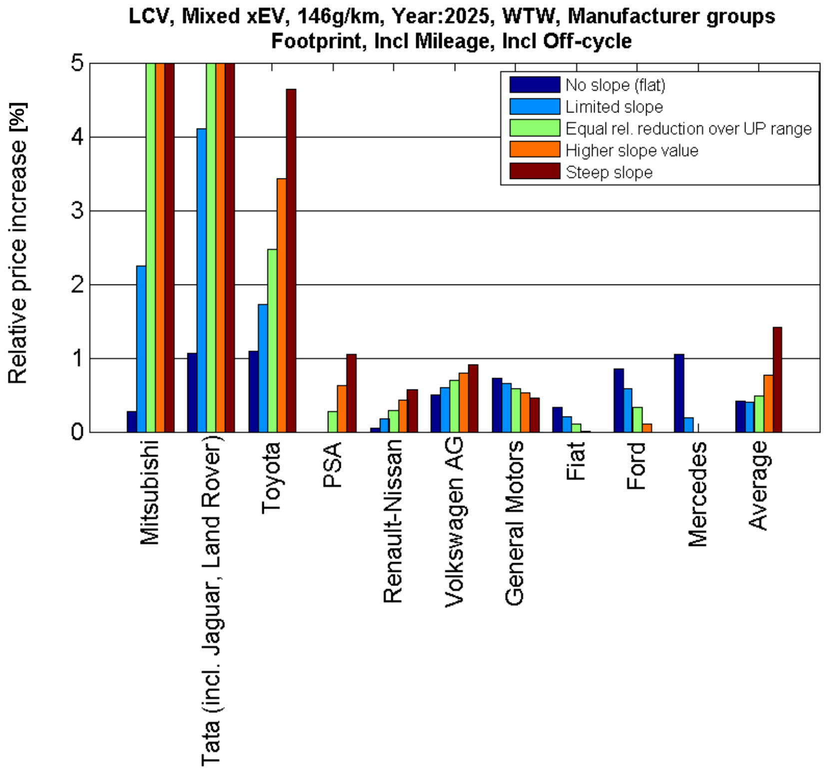
In policy variant S3 compared to 'policy variant S1', the utility parameter is footprint instead of mass. Moreover, mileage weighting is included and the metric has been changed to WTW.

In this case, additional manufacturer costs are slightly lower, i.e. between € 90 and € 305 in 2025 and between € 160 and € 330 in 2030 per vehicle depending on the slope of the target function. This results in a relative price increase between 0.4 and 1.4% in 2025 and between 0.8 and 1.5% in 2030 compared to BAU.

Contrary to 'policy variant S1' the additional manufacturer costs in this case are lowest at the flat slope. This is the effect of including mileage weighting. A flatter slope increases the absolute distance to target for manufacturer groups with high average utility values. The costs for closing this distance to target are lower for such manufacturer groups in case mileage weighting is included. As a result, the overall average additional manufacturer costs decrease at flatter slopes compared to policy variants without mileage weighting.

This also works the other way around. In case of a steep target, mileage weighting results in high costs and price increase for manufacturer groups with low average utility values, e.g. Mitsubishi (see Figure 67).

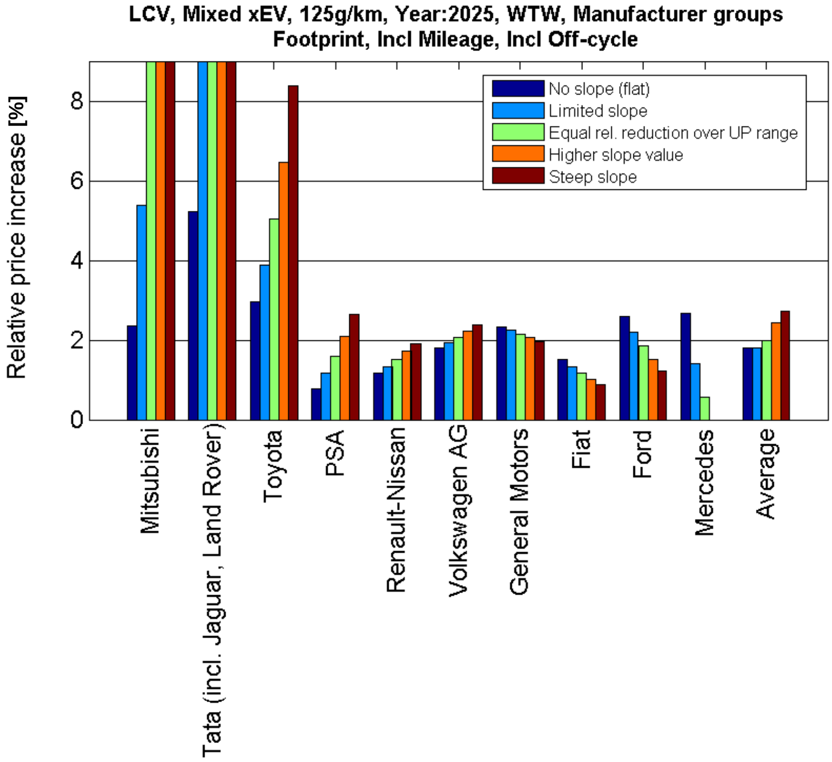
Figure 67 Distribution of impact of the slope of the target function in 2025 for vans on the relative price increase of various manufacturer groups depending under ‘policy variant 3’. Manufacturers are sorted from left to right based on their average utility value



The ‘policy variant S4’ has the stricter target level than S3. It also takes account of mileage weighting, the utility parameter is footprint and the regulatory metric is WTW emissions. These modalities result in slightly lower additional manufacturer costs than in S3, i.e. between € 385 and € 585 per vehicle in 2025 and between € 775 and € 905 in 2030.

As both the utility parameter and the sales distribution over the segments and drivetrain types are equal to that in S3, the distribution over the various manufacturer groups is comparable to that in policy variant S3, i.e. relatively high price increase for manufacturer groups with low average footprint in case of steep target functions. This is shown in Figure 68.

Figure 68 Distribution of impact of the slope of the target function in 2025 for vans on the relative price increase of various manufacturer groups depending under 'policy variant 4'. Manufacturers are sorted from left to right based on their average utility value



4.6 Social equity

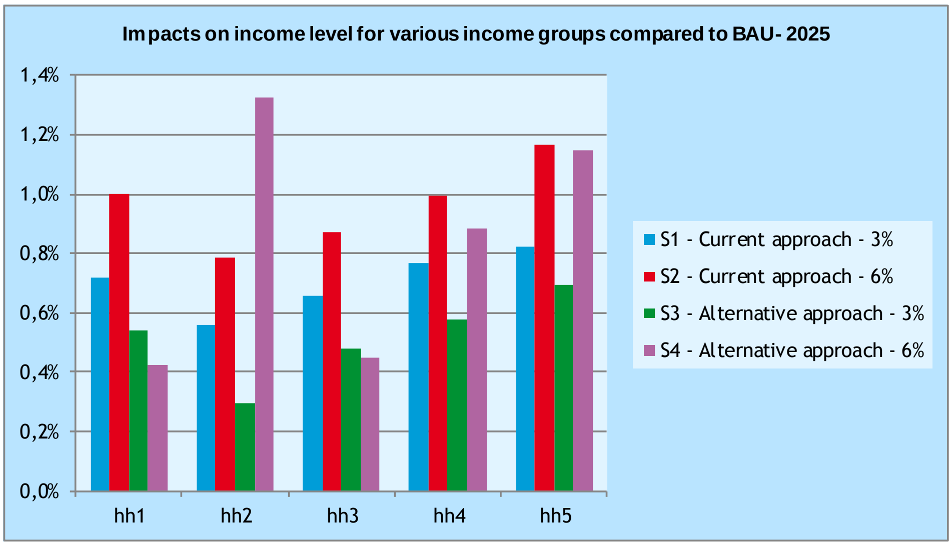
The impacts on the total income levels of different household groups have been modelled by EDIP, based on the changes in vehicle cost and fuel cost modelled by TNO's cost assessment model and MOVEET. This assessment has only been made for the passenger car regulation.

A limitation in the assessment is that in this project no shifts between size classes are assumed. This is however a minor limitation as we consider the shift of consumer choice between car segments a second-order effect.
Figure 69 and Figure 70 show the impacts on total income of various household groups for the various policy variants in 2025 and 2030, compared to BAU.
The income group hh1 represents the households with the lowest 20% income level in a country, hh2 the next 20%, etc. Income group hh5 represents the households with the highest income level.

The graphs make clear that in all four scenarios, the income levels increase in all income groups by 0.25 to 1.3% in 2025 and 0.4 to 1.4% in 2030. In most scenarios, the relative increase is highest in the highest income levels.
It should be noted that some second order impacts could not be quantified, in particular impacts on second hand car market, differences between Member States and shifts between size segments.

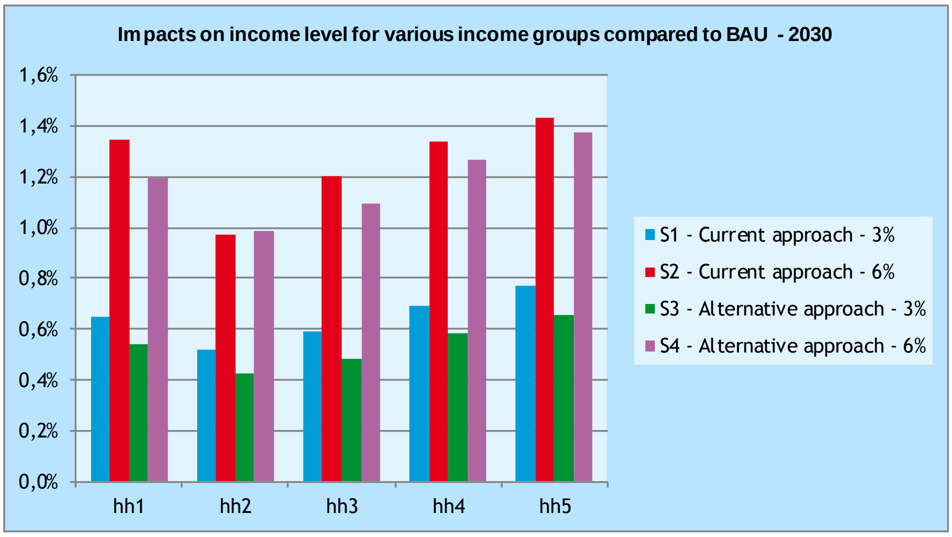
To quantify the impact more clearly, also the impact on the Gini coefficient[23] has been modelled by EDIP. The results of this are shown in Figure 71. A higher Gini coefficient means a higher income inequality. The graph shows that the income inequality slightly increases, but that the impacts are in all cases very small (in all scenarios less than 0.2% increase).

Figure 69 Impacts on total income of various income groups in %, compared to BAU - 2025



hh1: lowest 20% income level, hh2: 20-40%, hh3: 40-60%, hh4: 60-80%, hh5: highest 20% income level.

Figure 70 Impacts on total income of various income groups in %, compared to BAU - 2030

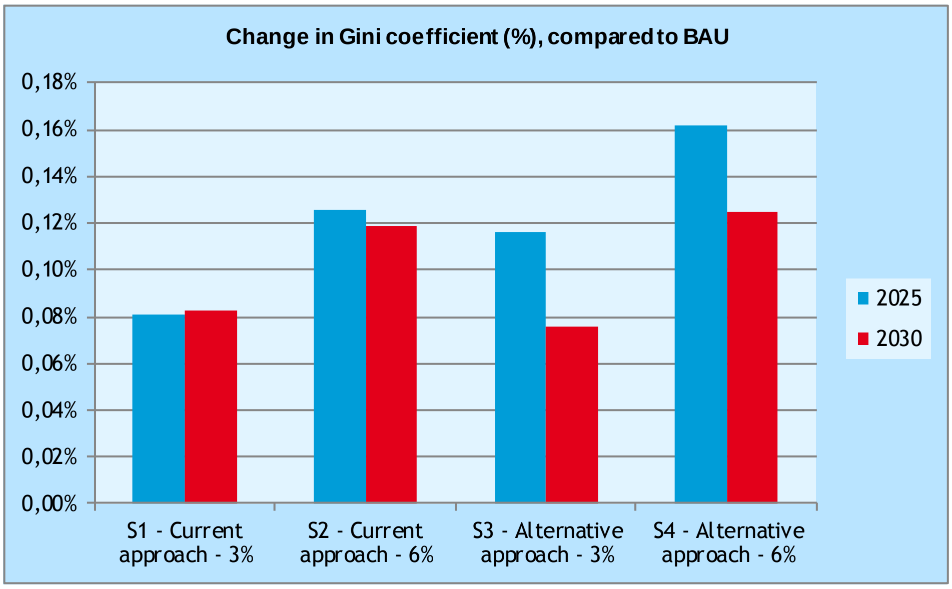


hh1: lowest 20% income level, hh2: 20-40%, hh3: 40-60%, hh4: 60-80%, hh5: highest 20% income level.

---

23 See Annex F.4 for an explanation.

Figure 71 Impacts on the Gini coefficient (in %, compared to BAU - 2025



5 Qualitative assessments

5.1 Introduction

Chapter Overview	
Goal	Assessing the impacts of modalities that could not be covered by the quantitative assessments, in particular: – Scope of the regulation (regulated entity and embedded emissions). – Approach for determining the TTW parameters. – Approach for including specific technologies in the overall performance: rewarding off-cycle emissions reductions, rewarding certain technologies (e.g. ZEV or ULEV mandates) and technology specific targets. – Various options for providing flexibility to OEMs (pooling and trading, banking and borrowing and derogations). – Impacts on administrative burden.
Output	– Qualitative analysis on all these modalities and impacts.
Annexes	Annex D.

Some modalities could not be (fully) assessed by the models used for the work presented in Chapter 3 and 4. Therefore, to complement the assessment made in these two chapters, this chapter contains a qualitative assessment of other modalities on the same criteria used for the quantitative assessment (see Table 8):
– effectiveness;
– cost effectiveness;
– competitiveness;
– distributional impacts across manufacturers;
– social equity;
– administrative burden.

In Section 5.2, the choice between regulating brands or manufacturing groups and approaches for including embedded emissions (related to vehicle manufacturing and disposal) are assessed.

In Section 5.3 various options for monitoring the TTW emissions are discussed. These modalities are particularly aimed at reducing the gap between the type approval and real world emissions.

Next, in Section 5.4, options for rewarding off-cycle emissions (including eco-innovations), rewarding specific technologies (e.g. by introducing (flexible) ZEV or ULEV mandates) and the introduction of technology specific targets are assessed.

Section 5.5 covers various modalities related to flexibility for OEMs: pooling and trading, banking and borrowing, excess premiums and derogations.

Finally, in Section 5.6, a qualitative assessment is made of the impacts on the administrative burden. This done for all modalities.

5.2 Scope of the Regulation

5.2.1 Manufacturer groups or brands as regulated entities

Description of the issue

Regulating manufacturer groups[24] (A2.1) is recommended by literature as it is considered the most cost-effective option. However, several stakeholders (incl. a small majority of the consulted vehicle OEMs) expressed a preference for regulating individual manufacturers (i.e. brands) (A2.2.) instead of groups, mainly because the latter limits the possibilities for pooling and puts brands which are not part of a larger manufacturer group in a disadvantaged position. Therefore, the pros and cons of both options have been explored in more detail with an additional qualitative assessment.

Qualitative assessment

According to previous studies, both manufacturer groups and brands score well on a long list of assessment criteria (e.g. practicability and enforceability). Both 'manufacturer groups' and 'brands' can take action to reduce their emissions and they can influence their sales averages by adjusting their prices/changing their marketing.

Previous studies conclude that the advantage of regulating manufacturer groups over regulating brands is that the burden of the target can be shared between brands. Such efforts are argued to result in lower average costs per car in meeting the target compared to a situation where individual brands are regulated (ref. 3). Hence, this option is seen as the most cost-effective option, with lowest average compliance costs to OEMs. This is confirmed by the quantitative cost assessment (see Section 3.6).

However, it should be noted that the option of regulating brands in combination with pooling was not included in this.
Such an approach would potentially have at least the same benefits of sharing efforts, resulting in lower costs. This would however also have the advantage of increasing OEM's flexibility, as they can decide themselves if they want to pool with the brands within their group, or not. When manufacturer groups are regulated, this is not a choice to be made by the OEMs, as it can be considered as a form of mandatory pooling. This explains why OEMs were generally more in favour of regulating brands.

Conclusion

Previous studies and also the quantitative assessment in this study showed that regulating manufacturer groups results in lower costs than regulating brands (see Section 3.6). However, when combined with pooling, regulating brands can have potentially even higher cost savings and also increases the flexibility for OEMs.

5.2.2 Embedded emissions

Description of the issue

Emissions associated with vehicle manufacturing (incl. the mining, processing and manufacturing of materials and components), maintenance and disposal (hereafter embedded emissions) currently cause only 16% of the total lifetime CO_2 emissions, while the remainder results from vehicle operation (i.e. fuel/electricity consumption and production) (ref. 12). Therefore, it is

[24] Groups of OEMs who are part of one larger legal entity.

considered appropriate that embedded emissions have so far been excluded from the scope of the existing Regulation to date (ref. 8), also in view of the technical complexity of this issue and the high administrative burden (see Section 5.6).

However, the relevance of embedded emissions is expected to increase significantly in the long-term, as new technologies, particularly hybrid and electric powertrain technologies, result in higher embedded emissions compared to ICEVs and as emissions from vehicle use are expected to reduce at a faster rate than the embedded emissions of materials used in the vehicle (ref. 2; ref. 12). Also some light weight material can have larger embedded emissions than conventional materials. As a result of these factors, embedded emissions are expected to become increasingly important (ref. 12).

In the evaluation of the existing Regulation, the exclusion of embedded emissions has therefore been identified as one of its three key weaknesses in terms of the realised real-world (global) emission reduction (ref. 8). This is also an important issue resulting from both the online stakeholder consultation and the stakeholder workshop (see Section D.4).

It was concluded in the assessment of individual modalities and design options (Annex D) that the inclusion of embedded emissions in the metric (A4.2) would not be further assessed. The inclusion of embedded emissions in the metric with default values (e.g. fixed values per kilogram) does not have any added value as it would just give incentives for reducing the amount of materials used, but not take account of the often large differences between the emissions related to various materials, or to materials from different sources (e.g. virgin versus recycled materials).

Inclusion of the embedded emissions in the metric using a pre-described LCA approach that is sufficiently meaningful and providing the right incentives to manufacturers for reducing the carbon footprint of the production, maintenance and disposal chain is useful but would be too complex to develop and agree upon in a short timeframe.

A more feasible alternative may be to document embedded emissions without including them in the metric (modality option A4.3). This could be achieved through either mandatory or voluntary reporting, possibly combined with a credit system. The remainder of this section briefly discusses what such approaches could look like and what the main pros and cons would be.

Qualitative assessment

A logical first step regarding embedded emissions would be to oblige or incentivise OEMs to:

- monitor and report the embedded emissions; and/or
- improve the quality, accuracy and comparability of the monitoring; and/or
- continuously improve their performance with respect to their embedded emissions.

Measuring the actual performance with respect to embedded emissions requires highly complex Life Cycle Assessments (LCAs), as thousands of vehicle components are used which are sourced from all over the world (ref. 2).

There are two main practical options for determining embedded emissions: with default values (per vehicle types and/or per kg weight) or with harmonised LCA reporting by the OEMs.

As stated above, monitoring and reporting of embedded emissions based on very aggregated default values is not meaningful, as not all efforts from OEMs to reduce their true embedded emissions would be rewarded.

Hence, for emission reporting purposes, it is preferable to rely on LCA reporting by OEMs. This would first require a methodology with guidelines (and possibly tools) for OEMs. To guarantee a level playing field, a harmonized approach is preferred. This requires several choices to be made for example as regards the scope, level of detail, and GHG emission values per type of material (differentiated by source). Input parameters can be related to emissions resulting from materials only or from production processes as well. If needed, on the approach could be extended beyond CO_2 emissions to also include other GHG emissions, air, water and soil pollutants and toxics.

The embedded emissions reported could be the total embedded emissions of all LDV sales of an OEM in a particular year, total emissions of all cars and all vans sold (i.e. two separate numbers), or an average embedded emission figure for an average car/van of an OEM or for each car/van model produced. Reporting embedded emissions in relative terms (i.e. an average per car/van (model)) has the advantage of enabling a comparison between OEMs.

Mandatory reporting on embedded emissions using a standardized approach has the advantage that all manufacturers will have to set up an LCA approach and provide data that can be compared. This could then later on be further developed to a system that is integrated in the metric. Mandatory LCA reporting could be combined with the obligation to monitor the progress made with reducing the embedded emissions and granting credits on the CO_2 regulation when sufficient progress has been made.

An alternative approach could be to develop a harmonised LCA reporting methodology, but to leave it to the OEMs to apply it or not. This leaves some more flexibility to the OEMs, but it does not provide for harmonised reporting on embedded emissions by all OEMs.

A link with credits could be considered where it is proven that embedded emissions are effectively reduced over time above some minimum reduction rate. This could then give an incentive for monitoring and reducing embedded emissions.

After experience with reporting embedded emissions is gathered and methodologies/guidelines have proven to be sound and reliable, a next step could be considered, e.g. to include embedded emissions in the metric and/or to share information with consumers.

Conclusion
Including embedded emissions in the metric is not considered feasible in the short term due to the technical complexity of the issue. First, one would need to improve the reporting of those emissions by OEMs.

However, to enable mandatory monitoring, agreed harmonised guidelines are needed including on the scope of the embedded emissions to be considered. An alternative might be to set up voluntary harmonised LCA reporting guidelines. A link with credits could be considered where it is proven that embedded emissions are effectively reduced over time above some minimum reduction rate. This would however require further research.

In all cases, the administrative burden and complexity of these options are expected to be potentially high, both for OEMs, Member States and the European Commission as it requires gathering and verification of large amounts of detailed data and defining a rather sophisticated and detailed LCA methodology.

5.3 Measuring TTW emissions

Description of the issue

The TTW CO_2 emissions as measured during the type approval test are in general lower than the actual CO_2 emissions of vehicles in-use on public roads, due to various reasons [25]. This gap between the type approval value and the real-world CO_2 emissions has increased over the last decade and the reasons for this have also been extensively documented in an earlier study[26].

As a result of this increased gap, the overall reduction of GHG emissions from LDVs has been lower than what could be expected based on observed reduction of type approval emissions.

In order to define the policy in such a way that the intended goal is actually met, it is crucial to get a grip on the development of the 'gap'.
The introduction of a new test procedure (WLTP) with a more realistic test cycle should improve the situation but may also provide new possibilities for OEMs to exploit flexibilities that contribute to widening the 'gap'.

Qualitative assessment

A possible way to (partly) close this gap and to therefore ensuring the effectiveness of the policy, would be to determine vehicle emissions in a different way than (only) the current type approval testing. There are multiple possibilities to determine emission values that are closer to the real world emissions, e.g.:

- **Type Approval test result + general correction for real-world divergence**
  A real-world divergence correction factor can for instance be based on large scale fuel consumption statistics (TNO, 2014a), (TNO, 2015b), (TNO, 2014b). A drawback of this type of correction is that the correction factors need to be generic and may not be correct for specific technologies and may not do justice to OEMs that make efforts in reducing the gap between TA and RW values. Deriving more reliable average real world emissions for individual models would require much more data than is currently available.
- **Type Approval test result + specific correction on the basis of OEM-provided ECU data**
  Alternatively, the type approval values could be corrected by using real-world ECU data on the actual energy use of in-use vehicles provided by manufacturers. From this energy use, the TTW CO_2 emissions can be determined depending on the energy carrier. Rather than a generic correction, this method could be used to derive real-world emission values for specific models.
  In order for such a system to work, a procedure for determining a

25 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. Framework Contract No ENV.C.3./FRA/2009/0043. Final Report. Date: December 5th, 2012.

26 TNO 2016 R10419: Supporting analysis on real-world light-duty vehicle CO_2 emissions.

correction based on ECU data would need to be developed and this may be a rather complex task. Also the verification of the energy consumption monitoring and methods to ensure the robustness of the system could be complex to develop and implement.
As the ECU data will only become available after a significant number of vehicles of a certain vehicle model have been sold and monitored, for at least some of the models sold in a certain target year, no or not sufficient ECU-based data will be available. The accuracy of ECU data is also a prerequisite for the robustness of such a system. This could be overcome by temporarily using a declared value, provided by the OEM, which is replaced by an actual figure as soon as sufficient statistics is available[27].

- **Real-world measurements (e.g. PEMS or monitoring of ECU data) possibly additional to Type Approval test**
  Adding (independent) vehicle measurements by means of for instance PEMS or ECU can provide additional insights in the real-world CO_2 emissions of vehicles. The difference with the previous option is that the PEMS or ECU test would be carried out as part of the type approval procedure.
  This approach has therefore the advantage that for all vehicle models sold, ECU or PEMS data become available before they enter the market. This option would also allow to have model specific real-world CO_2 emissions rather than a generic correction. A procedure for determining RW CO_2 emission values based on ECU or PEMS data still would need to be developed, which could turn out to be rather complex. In addition, determining vehicle specific real-world CO_2 emissions (e.g. using PEMS or ECU) is expected to pose much higher demands on the accuracy and comparability of test results, compared to when monitored RW data are used for a correction factor.
- **One of the options above combined with specific test procedures to assess the TTW emissions resulting from energy using devices or from off-cycle energy saving technologies**
  This is an alternative for the current eco-innovations, which are voluntary and allow OEMs to propose their own procedure for assessing the impact of off-cycle CO_2 reducing technologies. Instead it would be made mandatory to include the impact of energy using devices and off-cycle energy saving technologies on the TTW emissions using prescribed specific test procedures.
  As a result of the implementation of such a procedure, the share of energy using devices in total energy consumption/emissions becomes larger, as vehicles become more efficient. This option therefore provides an incentive for improving the energy efficiency of these devices. Also it stimulates the application of energy-saving technologies that do not contribute to CO_2 reduction on the TA test. Similar as for the possible correction procedures above, appropriate specific test procedures need to be developed. The work to develop procedures for mobile air conditioners (MAC) has shown that this can be a complex task.

Conclusion
Multiple options are available to bring the monitored (regulated) TTW emissions closer to the real-world emissions. However, for all options considered, there is a trade-off between on the one hand the effectiveness (reducing the gap), and on the other hand the technical complexity and the administrative burden. More generic approaches have a relative low additional

[27] It should be kept in mind that real-world monitoring data for a complete year are needed in order to allow averaging over the significant seasonal variations present in the fuel consumption and resulting CO_2 emissions.

administrative burden, but are not vehicle specific and have the risk of not significantly improving the effectiveness. More vehicle specific methods require more effort because of additional testing or data gathering/processing.

5.4 Determining overall performance

5.4.1 Eco-innovations and other types of off-cycle technology credits

Description of the issue

The performance of some energy-saving devices or technologies is not (or not fully) measured on the test cycle, either because they are not switched on or because their real world benefits are not accurately estimated with the tests. The current Regulations allow OEMs to apply for emission credits for implementing such technologies meeting certain criteria (called eco-innovations), which is argued to improve the cost-effectiveness of the Regulations (EC, 2012a and b); (Ricardo-AEA; TEPR, 2015). Although all stakeholders prefer the continuation of this design option, some argue that it can be improved, e.g. by simplifying procedures, broadening the scope, raising or even removing the cap and/or making sure that the eco-innovation credits are taken into account in the target setting.

Qualitative assessment

First of all it should be clear that granting credits for eco-innovations is meant to complement the approach for determining TTW emissions. In the current NEDC test cycle, various CO_2 reducing measures are not rewarded because they apply to auxiliaries or devices that are not switched on during the test or because their impacts are not or not accurately measured on the test.
The need for rewarding such so-called off-cycle technologies by granting credits is therefore dependent on the approach chosen for determining the TTW emissions. In case TTW emissions would be based on on-road PEMS data, recorded in a sufficiently representative on-road test, or on ECU data, collected by monitoring vehicles in actual real world use, the impacts of what are now off-cycle technologies would be fully included in the official TTW emission value. In that case there is no need for off-cycle credits.

As far as the speed-time profile is concerned, the new WLTP test procedure better reflects real-world driving conditions. This reduces the need for rewarding off-cycle reductions by technologies that affect the energy required at the wheels or the energy efficiency of the powertrain (EC, 2012a and b). Although the precise implications of the switch to the WLTP test procedure for off-cycle reduction are not clear yet (Ricardo-AEA; TEPR, 2015), the introduction of the WLTP test procedure will not ensure that *all* energy-using devices will be accurately measured in the test (EC, 2012a and b).

From the quantitative assessment it has become clear (as from many previous studies) that incentivising off-cycle technologies improves the cost effectiveness of the regulation, which is obvious as it expands the range of technologies for reducing emissions and includes some options that are relatively cost effective.

The main drawback of the current approach of eco-innovation credits is its high administrative burden. This was confirmed by the stakeholder consultation that identified the **application procedures for eco-innovations** as time consuming and requiring a lot of data. This was also concluded in the report on the evaluation of the current Regulations (Ricardo-AEA; TEPR, 2015). Both sources mention the system adopted in the US as an alternative. In the

US, a pre-defined list has been established of eligible technologies and the credits OEMs can receive for each option. For each technology from this list that is applied by an OEM on a new vehicle, the pre-defined credits are awarded (Ricardo-AEA; TEPR, 2015). Additionally, OEMs can apply for credits for new technologies not previously listed if they provide sufficient evidence.

The downside of such an approach may be that all OEMs receive the same credit for a technology, while in reality the emission reduction may vary between products (variants of the same technology) and the vehicles models to which they are applied. The development of a predefined list of off-cycle reduction options with pre-defined credits would require an extensive study in order to select the relevant options and assess their reduction potentials under various real world conditions and based on that determining appropriate credits to be granted.

With regard to t**he scope of eco innovations**, the approach followed in the current EU regulation is preferred over the approach followed in the US Regulations that just provide credits to technologies which are not 'switched-on' during the tests. From the stakeholder consultation (see Annex D.4) it has become clear that some stakeholders (e.g. vehicle and component OEMs) would prefer that the scope of eco-innovations (i.e. of eligible technologies) is further broadened as this would reduce the cost and could potentially also increase the effectiveness of the regulation. As an example, air-conditioning technologies (cooler and heater) have a certain share in the off-cycle CO_2 emissions but are excluded from the current scope of eco-innovations as they do not meet the criteria for eligibility mentioned in the legislation. The report on the evaluation of the current Regulations (Ricardo-AEA; TEPR, 2015), recommended that eco-innovations should cover 'as wide a range of technologies as possible', if this can be supported by robust measurements to determine the emission reduction. The latter is expected to remain a challenge for some off-cycle technologies for which the impacts depend strongly on external factors like climate conditions (e.g. the case for the improved air conditioning systems) or driver behaviour.

Another issue is linked to the **interaction between granting credits for eco-innovations and the target level**. Granting credits for eco-innovations has the potential of improving the cost effectiveness of the legislation but carries the risk reducing its effectiveness. By broadening the scope through granting credits, not only the overall GHG emission reduction potential increases but also the combined potential of all measures that can be considered cost-effective from an end-user or societal perspective. This could be taken into account by lowering the overall target levels with the amount of eco-innovation credits that are expected to be granted. As long as such a correction is made, there seems no reason to keep a cap on the eco-innovations.

Conclusion

As long as the approach for determining the TTW emissions does not fully reward some so-called off-cycle technologies (auxiliaries or devices that are not switched on during the test or for which the impacts are not or not accurately measured on the test), eco-innovation credits are a helpful tool to improve the cost-effectiveness of the Regulations. However, to keep the eco-innovation credits in line with the type approval test, the implications of the change to the WLTP need to be investigated and taken into account.

The main drawback of the current approach of eco-innovation credits is its high administrative burden. This could be reduced by establishing a pre-defined list of eligible technologies and the credits OEMs can receive for each option (like in the US. Additionally, OEMs could still apply for credits for new technologies not previously listed if they provide sufficient evidence.

The scope of eligible technologies would benefit (in terms of cost effectiveness) from being as broad as possible (if robust measurement or assessment procedures exist). This is an argument to eliminate both the 1 g/km threshold and the maximum amount of eco-innovations (7 g/km). However, if not taken into account in the target levels, granting credits for eco-innovations carries the risk reducing the effectiveness of the regulation. To avoid this and as eco-innovation credits enlarge the range of reduction options, it is recommended to lower target levels in accordance with the additional emissions reductions that are expected from these technologies.

5.4.2 Incentivising low emission vehicles

Description of the issue

Increasing the share of low emission vehicles is an important means to reducing the overall GHG emissions from transport to reach the EU's 2050 target.

Two possible policy options for incentivising low emission vehicles were mentioned in Table 5 in Section 2.4, i.e.:
- minimum share of ULEVs or ZEVs (C2.2);
- flexible minimum share of ULEVs or ZEVs in vehicle sales (C2.3).

Qualitative assessment

In (parts of) the US a ZEV mandate[28] has already been implemented. Such a system requires manufacturers to produce ZEVs. In the States where the ZEV mandate has been implemented[29], one out of seven vehicles sold has to be either a BEV, PHEV, REEV or FCEV from 2018 onwards. After 2025, 3.3 million ZEVs are to be sold, or approximately 15% of new sales (ZEV Program Implementation Task Force, 2014).

Possible advantages of a mandate are the following:
- TTW emissions will reduce in case the mandate is higher than the share without the mandate.
- Overall GHG emission reductions are likely as the energy efficiency of ZEVs or ULEVs, especially BEVs, is higher than of comparable ICEVs. In case GHG emissions from electricity and hydrogen production are low enough, WTW GHG emissions will be significantly reduced.
- A certain level of economy of scale is reached, likely to lower ZEV or ULEV related technology costs.
- Possibly more investments in ULEV or ZEV related R&D.
- System is clear in what is expected from manufacturers.
- More certainty for investments in energy carrier infrastructure, e.g. charging stations or hydrogen refueling stations.

[28] The schemes in the USA are usually called ZEV mandate, but in reality they are rather ULEV mandates.

[29] California, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont (C2ES, 2015).

On the downside:
- mandates reduce the flexibility for manufacturers to comply with regulation;
- the design of a non-compliance mechanism is expected to be complex and controversial;
- increasing the share of ULEVs or ZEVs up to the mandate level is not necessarily the most cost effective way to meet a certain target in a certain target year;
- the acceptance levels of consumers may fall behind, making it difficult for manufacturers to sell vehicles at a high enough price to cover costs, possibly resulting in reduced profits;
- in case many technologies of ULEVs/ZEVs are to be imported from other geographical regions, this may result in reduced turnover for EU based companies;
- GHG emissions from ZEV energy carrier production, e.g. electricity and hydrogen, need to be sufficiently low to achieve the overall GHG emission reduction;
- a flexible (mandate granting OEMs a (too large) weakening of the CO_2 target level will reduce the overall effectiveness of the regulation, especially with a high share of ZEVs or ULEVs.

Conclusion
ZEV or ULEV mandates can be a promising way to ensure CO_2 emission reduction from transport (TTW) and also overall GHG emissions (WTW) in case the carbon intensity of energy carrier production (electricity and hydrogen) is low enough. However, the level and design of the mandate should be carefully considered in view of the ability of manufacturers to sell vehicles at high enough prices to prevent market distortion and to stimulate ZEV related technology development and production within the EU.
A flexible ZEV or ULEV mandate has the advantage that it provides more flexibility to OEMs, but carries the risk of reducing the overall effectiveness of the regulation.

5.4.3 Technology specific targets

Description of the issue
Currently, manufacturers' emission targets are defined as the sales weighted average TA CO_2 emissions. As a result, selling ULEVs or ZEVs for which TTW emissions are 0 g/km to 50 g/km, can have substantial leverage. Increasing the sales of ULEVs/ZEVs can be a strategy to comply with policy, reducing the need to reduce CO_2 emissions from vehicles with an ICE. However, in case the overall GHG emissions of certain ULEVs/ZEVs are (much) higher than their TA CO_2 emissions, because of higher mileage or because of limited charging of PHEVs/REEVs, the overall GHG emission reduction will be lower than expected based on the TA emission reductions.

Technology specific targets (e.g. separate targets for ICEVs, BEVs and PHEVs/REEVs) could contribute to reducing such 'leakage' of emissions. In such a system, the various drivetrain types will have to comply with separate targets. Therefore shifting sales to other drivetrain types will no longer be a strategy to comply. As the average mileages and gap between type approval and 'real world' emissions are known (to a certain extent), the targets in the policy can be chosen so that that the overall GHG emission reduction corresponds to the overall aim.

Such technology specific targets will result in CO_2 emission reductions for every drivetrain for which a separate target is set. This is different from the current situation, as under a TTW metric, energy efficiency improvements (and therefore also WTW CO_2 reduction) from ZEVs do not get a manufacturer closer to its target value. As a result, a single target for all drivetrains in case of a TTW metric types does drive the increase of energy efficiency of ZEVs.

Separate targets could be defined on various technology levels:
- ICEV (including (non-plugin) hybrids), which could be split in different ways, e.g.:
  - per combustion technology: spark ignition (SI) vs compression ignition (CI);
  - per fuel type: petrol, diesel, CNG, LPG.
- non-ICEV, which could be split in different ways, e.g.:
  - including combustion engine (e.g. PHEV, REEV) vs not including a combustion engine (e.g. BEV, FCEV);
  - per energy carrier: petrol/electricity (SI PHEV/REEV), diesel/electricity (CI PHEV/REEV), only electricity (BEV) and hydrogen (FCEV).

This means that anywhere between two and approximately eight different technologies could be distinguished for which separate targets would have to be defined.

Qualitative assessment
A trade-off exists between on the one hand preventing leakage and realising reduction from all drivetrain technologies and on the other hand the cost effectiveness of the regulation as a whole.

In order to prevent the most significant 'emission leakage' at the lowest societal cost, technologies with the greatest variation in the gaps between type approval and real world emissions should be distinguished, (1) ICEV, (2) PHEV/REEV and (3) ZEVs, i.e. BEV and FCEV. As the zero-emission vehicles have no TTW emissions, the target metric for this technology group would have to be energy-efficiency or WTW emissions.

A shift to a technology specific target would have the following advantages:
- Emissions of every drivetrain type are reduced and/or energy efficiency is increased.
- In case of separate targets for different technologies, shifting sales to other technologies with lower TA emissions, but with possibly a larger difference between TA and overall GHG emissions, is no longer a strategy to reduce average CO_2 emisisons. Separate targets could therefore prevent possible undesirable CO_2 leakage effects.
- In case of a general TTW metric, a separate WTW or energy based target for ZEVs would provide incentives to improve energy efficiency of ZEVs[30]. Therefore it is a way to drive the implementation of cost effective CO_2 reducing technologies for all drivetrain types.
- It makes the regulation possibly more robust in view of the uncertain future shares of different drivetrain technologies.

[30] It should be noted that the drive range is currently a main barrier for a further uptake of BEVs. As improving the energy efficiency increases the range, one could argue that as long as drive range is regarded a limitation of BEVs, there may be no need for additional incentives for improving the energy efficiency of BEVs.

The main disadvantages are:
- flexibility for manufacturer in the way to comply with policy is reduced, increasing the average manufacturer costs;
- it is difficult to set a target value for every 'technology', as many combinations of drivetrains exist;
- setting and monitoring more target levels results in an increased administrative burden for the Commission.

Conclusion
Technology specific targets may increase the effectiveness of the policy by reducing the possibility of leakage of overall GHG emissions from certain (drivetrain) technologies. Moreover it makes the policy more robust for the uncertain future shares of different drivetrain technologies.

However, this is likely to go at the expense of somewhat higher manufacturer costs, although this very much depends on the target levels set. To limit the uncertainty of the overall effectiveness of the policy, technology specific targets need to be combined with a ZEV or ULEV mandate requiring minimum share of such vehicles.

5.5 Flexibilities

5.5.1 Pooling and trading

Description of the issue
Allowing manufacturers to pool or trade CO_2 emission credits between manufacturers increases the flexibility for OEMs, and increases their ability to meet the target in a cost-effective manner. Considering that the cost for CO_2 reduction differs between different manufacturers, this additional flexibility is likely to result in lower total compliance costs especially for OEMs with sales distributions and/or vehicle portfolios that deviate most from the average in the market.

Qualitative assessment
The potential of allowing pooling and/or trading depends on the design and implementation of such systems. For instance, the potential could be limited by capping the amount of trading or pooling. Also, pooling and/or trading can be limited to passenger cars and/or vans only or for passenger cars and vans combined, allowing pooling and/or trading and also between vans and passenger cars.

Pooling
From previous studies it is clear that pooling has few negative consequences. If targets are based on sales-weighted averages, pooling can negatively impact the net real-world emission reduction if emission reduction is shifted from larger cars (with higher annual mileage) to smaller cars (with lower annual mileage). This would not be the case if (pooled) targets would be mileage based.
Pooling for passenger cars and vans combined would enhance OEMs' flexibility in meeting both targets (internal averaging), which can reduce their compliance costs. However, as a result it can occur that either the van or passenger car target is not met. The deviation from the target (in g/km) is likely to be larger for vans, which can be explained by the fact that the sales of vans are much smaller than car sales; a small deviation from the g/km target for cars has a much larger impact on the total under-/overachievement (g/km times total mileage and/or sales) than would be the case for vans.

Hence, it is much easier to compensate the over or under achievement for vans with cars than the other way around. Since the average lifetime mileage of vans is higher than that of passenger cars, this deviation will result in additional GHG emissions and lower the effectiveness.

Trading

In case of trading for cars and/or vans separately, no major issues are identified. When allowing trading between vans and cars, some additional (dis)advantages may arise. As the difference of marginal abatement costs is likely to be relatively larger between an average car and an average van compared to the differences between different cars or between different vans, the benefits of trading credits between cars and vans in terms of lowering overall compliance costs can also be significant. However, this in turn also result in the risk of not achieving both the car and van target, as relatively more effort will be assigned to improving the vehicle category with lowest abatement costs. As explained above, depending on the factors that affect the gap between TA emissions and lifetime 'real world' emissions (e.g. mileage, gap, etc.), such a redistribution of efforts may affect the overall effectiveness. In other words, allowing trading between cars and vans may have an impact on the overall GHG fleet emissions, as both the divergence between test-cycle and real-world emissions and the lifetime mileage are likely to be different for cars and vans. Obviously, this disadvantage is only relevant in case separate targets are set for vans and cars.

In case trading is allowed, a definition of what is traded (unit) is required, which can be for example g/km (sales average) either TTW or WTW, or lifetime grams (g/km multiplied by the average mileage of the OEM concerned).

In case of trading g/km, the real-world fleet emission reduction can be (negatively or positively) impacted, due to differences in average mileages between categories and between OEMs. This can be especially significant if car emission credits are traded with vans. Additionally, it should be determined if the credits that are traded can be banked and/or borrowed or not. Banking and borrowing does increase OEMs' flexibility and hence reduces compliance costs further.

Cost impacts of pooling or trading for 2025 and 2030

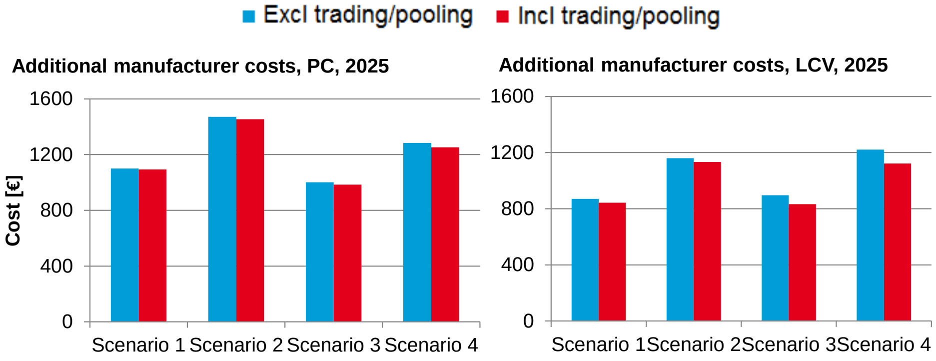
Pooling or trading has mainly an impact on the cost effectiveness of the regulations as they result in lower additional manufacturer costs. The precise size of the cost reductions depends on which manufacturers decide to pool or trade and cannot be assessed with the 'cost assessment model'.

However, in order to get an indication of the maximum potential manufacturer cost reduction of such systems within a single vehicle category (no trading and/or pooling between passenger cars and vans), the additional manufacturer costs are determined for the four policy variants selected in Section 4.1 both for a situation in which the legal entities are manufacturer groups and also for the situation in which trading would be allowed for manufacturer groups.. This latter variant models the hypothetical situation that all manufacturers would pool together or the case in which all manufacturers trade optimally resulting in the lowest possible overall costs.

The results are shown in Figure 72. The additional manufacturer costs in case of optimal use of pooling and/or trading are 1 to 3% lower than when regulating manufacturer groups for passenger cars, depending on the policy variant. For vans the effect is larger, i.e. 3 to 8%. This larger effect for vans is partly due to the lower absolute additional manufacturer costs. Although the absolute cost reduction resulting from pooling/trading are not much higher for vans than for passenger cars, the relative effect for vans is larger. A second factor is that several van manufacturers with high sales focus on a specific vehicle segment, e.g. large vans, while passenger car manufacturers with high shares tend to have a relatively wide portfolio. As a result, pooling/trading would have more effect for vans than for passenger cars.

It should be notes that in reality the potential will be smaller, as the trading or pooling will not be as optimal as modelled in this hypothetical case.

Figure 72 **Additional manufacturer costs for the selected four policy variants in case of manufacturer groups being the legal entities ('excl. trading/pooling') and in case the potential of pooling and trading is fully used ('incl. trading/pooling')**



Conclusion

Pooling and trading increase flexibility for manufacturers to comply with policy and therefore reduce costs. Pooling results in lower manufacturer costs compared to a situation in which every individual manufacturer would have to comply. The theoretically maximum reduction in manufacturing costs are about 1 to 3% for cars and 3 to 8% for vans. However in practice, cost reductions will be lower.

5.5.2 Banking and borrowing

Description of the issue

If a banking and borrowing scheme is in place, manufacturers have more flexibility in complying with an emissions target for a given year. When the average CO_2 emission of the new vehicle sales is below the specific emission target for that year, the manufacturer or group of manufacturers can bank these emissions as emission allowances. In case the average CO_2 emission value exceeds the specific emissions target in one of the following years, the manufacturer can offset these excess emissions with 'banked' emission allowances from preceding year(s) or 'borrow' emission allowances, which have to 'paid back' in subsequent years. This mechanism allows manufacturers to flexibly deal with the introduction of new technologies, decreasing the risk of paying excess emissions premiums, while maintaining the overall reduction trajectory. Such a scheme can thus be used to complement the trajectory of declining annual targets to provide manufacturers more flexibility in complying with the annual targets.

Qualitative assessment

The main advantage of banking and borrowing is the flexibility it provides for manufacturers to react to changing circumstances. It could also increase the cost-effectiveness of implementing the necessary technologies for reducing the emissions as well as providing flexibility with respect to the development and implementation cycles of new models.

Negative impacts of allowing banking and borrowing include an increased risk of ‘under fulfilment’, due to the possibility of borrowed emission allowances that may not be neutralised, or paid back, by manufacturers at the end of the scheme’s duration. Additionally, if manufacturers are allowed to borrow emission allowances before they have banked, and the duration of the scheme extends beyond the target year, the specific fleet average emissions target might not be met. From a perspective of the underlying intentions of the regulation, such a scheme might also be perceived as allowing manufacturers to delay developments and rollout of CO_2 reduction technologies for their passenger vehicles.

In the period in which banking and borrowing is allowed, annually declining ‘targets’ could be defined compared to which credits can be banked or borrowed. Alternatively, in case such annual targets are not defined, credits are granted for performing better than the existing target level until the next target level. As manufacturers on average tend to reduce CO_2 emissions in a linear trajectory between two successive targets, a lot of credits are granted for the business as usual situation, leading to ‘free credits’ for manufacturers. Manufacturers will most likely borrow these credits after the target year. The target will in that case only be met after the target year, leading to additional CO_2 emissions and reduced effectiveness.

For banking and borrowing, two possible configurations could be considered.

1. Manufacturers are only allowed to bank and borrow during the annual step targets period before the target year.
2. Manufactures have a period beyond the target year to neutralise their banked or borrowed ’emission credits’.

Conclusion

In TNO (2011) it was concluded for the different banking and borrowing scenarios assessed that

– The total impact on the CO_2 emitted by passenger vehicles is small, as long as the banked or borrowed emission allowances balance are neutralised by the end of a banking and borrowing period with sufficiently limited duration (5 to 10 years).
– Banking and borrowing does not provide an incentive for manufacturers to postpone the application of CO_2 reducing technologies. Borrowing CO_2 credits prior to banking increases the net costs of meeting the target averaged over a longer time period. Therefore manufacturers will only delay their CO_2 emissions reduction if the costs of changing their model cycles are higher than the additional costs of compensating for their borrowed CO_2 credits. Hence it is safe to allow banking and borrowing.
– In order to manage the risk of manufacturers not being able to balance out a negative amount of CO_2 credits, a maximum amount of borrowed CO_2 credits can be considered.

5.5.3 Excess emission premiums

Description of the issue

Under the current Regulations, in case the average CO_2 emissions of a manufacturer's new vehicle fleet exceed its target value, the manufacturer has to pay an excess emissions premium for each car registered. This premium amounts to € 95 for every g/km of exceedance from 2019 onwards.

Qualitative assessment

In Figure 73 and Figure 74, the marginal costs for realising the final 1 g/km CO_2 to meet the manufacturer's target are depicted for respectively 2025 and 2030 (under the four policy variants described in Chapter 4). The relative reduction at which the marginal costs are equal to the excess premium level of € 95/g/km (which is a proxy of the hypothetical reduction effort after which it could become cheaper to pay the premium) is different for every manufacturer, because the 2013 baseline emission values (on which the relative reductions are based) are different (see Section 3.3.3).

As can be concluded from these figures, the marginal costs of S1 and S2 are higher than that of respectively S3 and S4. In S3 and S4 the regulatory metric is WTW. Therefore energy efficiency improvements of BEVs and FCEVs are rewarded, in contrary to S1 and S2. As the marginal costs for energy use reductions from BEVs and FCEVs are lower than for ICEVs, it is assumed that manufactures will increase the energy efficiency of such vehicles. Therefore less CO_2 reduction is required from ICEVs. As the cost curves are strongly non-linear, lower marginal costs for the drivetrain with the highest marginal costs results in lower average marginal costs.

The excess premium level from 2019 onwards is significantly higher than the average marginal cost for the last gCO_2/km needed to meet the target for all manufacturers in 2025. For certain manufacturers producing vehicles with relatively high CO_2 emissions, meeting this target level leads to high manufacturer costs and, given the non-linearity of the cost curves, also high marginal costs.

For the shortlist of policy variants in 2030, the marginal costs are higher as the target is more stringent than in 2025. In 2030, the excess premium level of € 95/g/km would still be a sufficient incentive for most manufacturer groups to reduce CO_2 emission levels of their vehicles to the targets. Only a few manufacturer groups (e.g. Subaru and Tata) have higher marginal costs, especially in policy variant S2 in which the target is strictest, mileage weighting is not included, a TTW-based target and mass being the utility parameter.

Figure 73 **Marginal costs for various manufacturer groups for the shortlist policy variants for passenger cars in 2025**

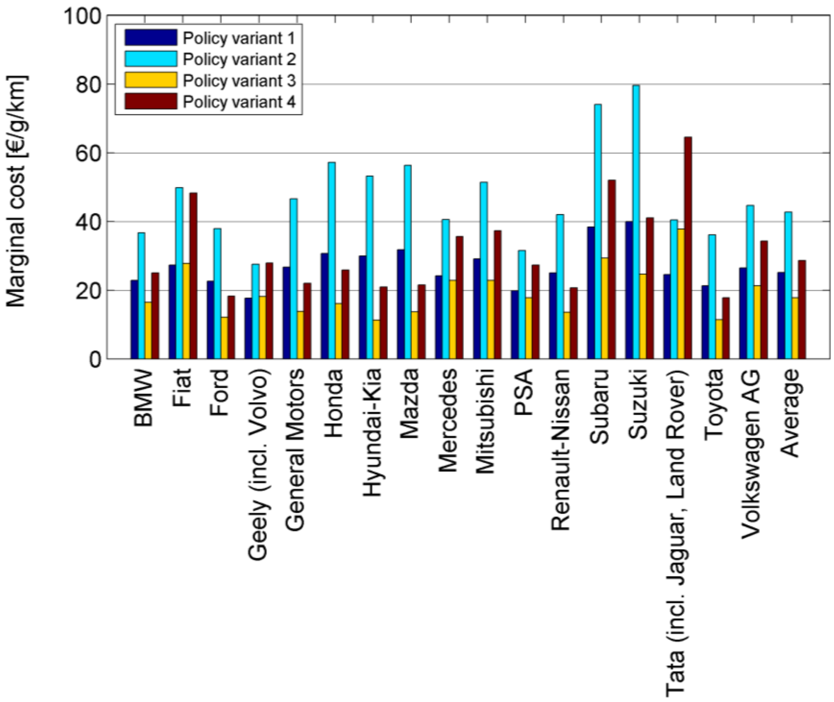
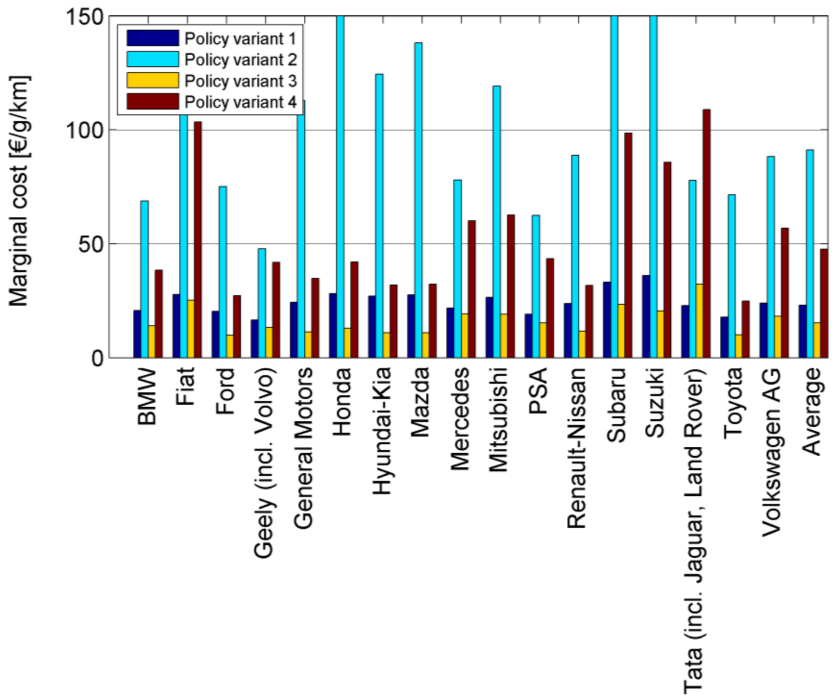


Figure 74 **Marginal costs of various manufacturer groups for the shortlist policy variants for passenger cars in 2030**



Conclusion
All in all, the € 95/g/km level of excess premium should provide enough incentive for the vast majority of manufacturers to reduce the CO_2 levels of their vehicle fleet rather than paying the penalty for exceeding their limit value. In order for the excess premium to be an incentive for all manufacturers in all policy variants to reach their specific targets, this excess premium level should however be significantly higher. However, in case of vary high excess premiums, the flexibility for OEMs may be in practice be reduced as just slightly overshooting the target would then result in relatively high cost.

5.5.4 Derogations

Description of the issue
The existing Regulations allow derogations for small car manufacturers (defined as annually registering <10,000 cars), as for such OEMs it may not be possible to meet a target which is determined with the average target function (EC, 2012a) (EC, 2012b). These manufacturers are allowed to propose their own specific target, to be approved by the EC. The contribution of small volume OEMs as currently defined is estimated to be below 0.01% of the total CO_2 emissions (EC, 2012a) (EC, 2012b). Therefore, the market distortion and GHG emissions impacts of this specific derogation are likely to be limited; (Ricardo-AEA; TEPR, 2015).

Derogations from the overall emission target may also be granted to 'niche' car manufacturers (defined as annually registering 10,000–300,000 cars), but not for vans. OEMs which are granted this derogation must reduce their average specific emissions by 25% (in 2015) resp. 45% (in 2020) compared to their average specific emissions in 2007. The impacts of this derogation on market distortion and impacts on effectiveness of the regulation may be larger (ibid).

LCV manufacturers selling less than 22,000 vehicles per year in the EU may also apply for a derogation from the target as set by the average target function for LCVs. Instead such an OEM may propose "a specific emissions target consistent with its reduction potential, including the economic and technological potential to reduce its specific emissions of CO_2 and taking into account the characteristics of the market for the type of light commercial vehicle manufactured."

Some concerns have been expressed about the fact that niche derogations are defined in relation to EU sales, which can result in a situation where OEMs with leading global sales can apply for a niche derogation in the EU.

Moreover, some niche OEMs compete with larger OEMs (Ricardo-AEA; TEPR, 2015). This section explores the impacts of (not) continuing with niche derogations in the future Regulations.

Qualitative assessment
Given their small impacts on the overall effectiveness of the regulations, the derogations for small vehicle manufacturers might be continued.

The evaluation of the current regulations concluded however that for the niche derogations, there are larger risks of reduced effectiveness and market distortions (unfair distributional impacts across manufacturers). The reason is that the upper threshold of 300,000 car registrations per year is relatively high and hence, at least some of the niche OEMs with EU sales between 150,000

and 300,000 per year are competing with (specific sales segments of) larger OEMs (which do not qualify the criteria) rather than with other niche OEMs. Some of these are major global manufacturers with relatively small sales in the EU, (EC, 2012a) (EC, 2012b). This may result in a distortion of the market and may provide new entrants in the EU market a competitive advantage.
If derogations would be based on global sales rather than EU sales, this issue would be solved.

According to (Ricardo-AEA; TEPR, 2015), the competitive distortion may be rather small for the moment, as larger niche OEMs have not applied for the derogation so far (see Figure 75). However, this may be mainly due to the method used for defining the alternative target for the niche OEM, which was based on a prescribed reduction relative to the OEMs specific average emissions in 2007. For niche OEMs which had emissions higher than the average fleet wide emissions (of all OEMs) in 2007, it was beneficial to apply for a niche derogation (the further away, the larger the benefit) (Ricardo-AEA; TEPR, 2015). Hence, most of the 7 OEMs which have applied for a niche derogation, had emissions above the fleet-wide average in 2007. Four OEMs also had higher than average emissions but did not apply for a derogation; three of these OEMs took part in a pool though.

In case the method for determining the alternative target would be changed, the situation may be different and larger niche OEMs may also apply for a derogation. If this is expected, the potential market distortion can be reduced by lowering the threshold for example.

Figure 75 Number of OEMs using niche derogations in 2013 (for different sales numbers)

Source: (Ricardo-AEA; TEPR, 2015).

In addition to impacts on the competitive neutrality of the Regulations, niche derogations can weaken the effectiveness of the Regulation. For example, if the OEMs which applied for and received niche derogations (in 2013) would have missed their original target (without the derogation) with 50 g/km, a 1.4% lower CO_2 reduction would be achieved with the Regulation. However, currently only one-third of the niche OEMs uses derogations, covering only one fifth of the sales of all OEMs eligible for these derogations. Hence, if all these

OEMs would use niche derogations (and would undershoot their target), the impact on the CO_2 reduction realised with the Regulation can become much larger and significantly reduce the effectiveness of the regulation (Ricardo-AEA; TEPR, 2015).

Conclusion

The contribution of small volume OEMs (<10,000 cars or <22,000 vans) is very small (below 0.01% of the total CO_2 emissions). Therefore, the market distortion impact is likely to be limited. However, derogations provided to niche car manufacturers (10,000–300,000 cars) have some drawbacks in terms of competitive neutrality and may weaken the effectiveness of the future Regulation. Currently, the larger niche OEMs do not use the derogations, and hence, both impacts have been limited in the existing Regulations. In the future Regulation, this situation may be different though, as the alternative target for niche OEMs is likely to be calculated from another base year.
To prevent potential negative consequences, it may be desirable to lower the upper threshold of OEMs eligible for niche derogations or to eliminate them all together. An alternative may be to base the limits on global sales. However this would require further assessment on global sales numbers in relation to EU sales to define a suitable lower and upper limit.

5.6 Administrative burden

In this section, impacts on administrative burden for governments and/or the industry of all modalities considered are assessed in a qualitative way.

Administrative costs are defined in the Commission's Better Regulation Toolbox as the costs incurred by enterprises, the voluntary sector, public authorities and citizens in meeting legal obligations to provide information on their action or production, either to public authorities or to private parties. Information is to be construed in a broad sense, i.e. including labelling, reporting, registration, monitoring and assessment needed to provide the information.

Administrative costs consist of two different components: the business-as-usual costs and administrative burdens. While the business-as-usual costs correspond to the costs resulting from collecting and processing information which would be done by an entity even in the absence of the legislation, the administrative burdens stem from the part of the process which is done solely because of a legal obligation.

Table 23 provides a qualitative evaluation of the impact of each modality on the administrative burden related to:
- amount and type of data that needs to be gathered and time, labour and facilities needed for this;
- the burden of the verification of the required data and time, labour and facilities needed for this.

Impacts are estimated relative to the administrative burden of the existing legislation.

The assessment shows that the following changes would result in the highest increase in administrative burden of both the EC/MSs and OEMs:

- mandatory or voluntary reporting on embedded emissions and developing and applying an EU-wide harmonised LCA approach and data set;
- complementing or replacing the WLTP type approval by test PEMS measurements or complementing it by ECU data;
- trading CO_2 credits or introducing banking and borrowing.

Some other changes would reduce the administrative burden:

- removing credits for eco-innovations (lower burden for both EC/MSs and OEMs) or replacing the existing system based on specific reduction estimates by manufacturers with default credits for eligible technologies;
- removing derogations (just lower administrative burden for EC/MSs);
- remove possibility of pooling.

The net impact on administrative burden of replacing the WLTP test by ECU data is yet unclear. Once the system has bene set up, data gathering could be largely automated.

Table 23 Assessment of the administrative burden of particular design options for the modalities

Modalities	Design options per modality	Main impacts on administrative burden	Impact on administrative burden relative to current approach	
			EC/MSs	OEMs
A. What is the scope of the Regulation?				
A1 Regulated vehicle categories	A1.1 Separate targets for M1 and N1 A1.2 Separate targets for M1 with smallest N1 on the one hand, and remaining N1 on the other hand	No significant impact as the same data need to be reported; just the calculations are different.	Equal Equal	Equal Equal
A2 Regulated entities	A2.1 Manufacturer groups A2.2 Brands	No significant impact as the same data need to be reported and also amount of data processing needed is similar; just the calculations are different.	Equal Equal	Equal Equal
A3 Metric(s)	A3.1 TTW CO_2 emissions (as in existing Regulation) A3.2 TTW CO_2 emissions for ICEVs only (with exclusion of Zero Emission Vehicles) A3.4 WTW CO_2 emissions	There are no additional data requirements under a WTW metric compared to a TTW metric as the fuel types and energy use of vehicles are already reported, and WTT emission factors will be default values.	Equal Equal Equal	Equal Equal Equal
A4 Embedded emissions	A4.1 Embedded emissions excluded in the metric A4.3 Embedded emissions excluded in the metric but included with another approach (e.g. reporting of embedded emissions)	Mandatory or voluntary reporting on embedded emissions (A4.3) requires a lot of data gathering and verification for both the EC/MSs and OEMs.	Equal Much higher	Equal Much higher

Modalities	Design options per modality	Main impacts on administrative burden	Impact on administrative burden relative to current approach	
			EC/MSs	OEMs
B. How to measure the parameters needed for determining the overall performance?				
B1 Measuring TTW vehicle parameter(s)	B1.1 Type Approval test result (WLTP) B1.2 Type Approval test result + correction for real-world divergence B1.3 Type Approval test result + OEM to provide ECU data on real world fuel consumption B1.4 Real-world measurements (e.g. PEMS or monitoring of ECU data) B1.5 One of the options B1.1, B1.2 or B1.3 combined with specific test procedures for energy using devices and/or off-cycle energy saving technologies	B1.3 would require a lot of additional data from ECU or PEMS testing, increasing the burden, particularly for OEMs. Also option B1.5 requires significant additional data gathering compared to B1.1 or B1.2. With B1.4, PEMS or ECU data would replace WLTP tests. PEMS testing is expected to take more time and be more expensive per vehicle than a WLTP, but data gathering based on ECU may for a large part be automated, which might even result in a net reduction of administrative burden. So, the net impact of option B1.4 on administrative burden is yet unclear.	Equal Equal Higher Unclear Much higher	Equal Equal Higher Unclear Much higher
B2 Determining WTT parameters	B2.2 Default values for the entire EU projections differentiated to target year B2.4 Default values per MS projections differentiated to target year	This modality is only relevant in case a WTW metric is used (A3.4). Once the WTT emission factors per energy carrier have been set (which could be based on MS specific projections, e.g. projections already made for other EU energy and climate policies), no additional data is required than what is already reported.	Equal Equal	Equal Equal
B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal	B3.3 Harmonised LCA reporting by OEMs (per vehicle or e.g. per kg of vehicle weight)	This modality is only relevant in case reporting of embedded emissions is incentivised or made mandatory (A4.3). It requires a lot of additional data gathering and analysis on emissions related to vehicle manufacturing and materials (LCA reporting for all materials used), for the EC/MSs and even more for OEMs.	Higher	Much higher
C. How to determine the overall performance?				
C1 Rewarding off-cycle reductions	C1.1 Eco-innovations (as in existing Regulation) C1.2 Off-cycle technology credits (as in the US Regulation) C1.3 None	Eco-innovation credits as in the current regulation have a high administrative burden, as for each OEM the emission reduction needs to be assessed for each innovation. Predefined credits as in the US would reduce the burden and removing credits for off-cycle reduction even more.	Equal Lower Much lower	Equal Lower Much lower

Modalities	Design options per modality	Main impacts on administrative burden	Impact on administrative burden relative to current approach	
			EC/MSs	OEMs
C2 Rewarding or penalising technologies	C2.1 Super credits C2.2 Minimum share of advanced technologies in vehicle sales C2.3 Flexible minimum share of advanced technologies in vehicle sales C2.6 None	None of these options do require additional data from OEMs. No significant impact as the same data need to be reported; just the calculations are different.	Equal Equal Equal Much lower	Equal Equal Equal Much lower
C3 Aggregation & weighting	C3.2 Limit based on overall sales-weighted average (as in existing Regulation) C3.4 Technology specific targets: limit based on overall sales-weighted average per technology C3.5 Combining C3.2 or C3.4 with mileage weighting	Technology specific targets would not increase administrative burden as the same data needs to be reported and verified. Also mileage weighting, with fixed mileages per segment requires no more data from OEMs than in the current regulation.	Equal Equal Equal	Equal Equal Equal
D. Approach for target setting				
D1 Approach for target setting[31]	D1.1 Targets for fixed date(s) without phase-in D1.2 Targets for fixed date(s) with phase-in (as in existing Regulation) D1.3 Annually declining targets	Phasing-in does not require additional verification, as currently the performance of OEMs is also monitored annually. The same is true for annual declining targets. It should be noted however, that annual declining targets require banking/borrowing which increases the administrative burden (see F3).	Equal Equal Equal[32]	Equal Equal Equal
E. How to fairly distribute the burden across regulated entities?				
E1 Utility parameter	E1.2 Mass as a utility parameter E1.4 Footprint as a utility parameter	The choice of the utility parameter has no impact on the administrative burden.	Equal Equal	Equal Equal
E2 Shape and slope of target function	E2.2 Linear target function with finite slope (including zero slope) E2.3 Truncated linear target function with a floor and/or a ceiling E2.4 Non-linear target function	The shape and slope of the target function has no impact on the administrative burden. Manufacturer specific targets are calculated with a single formula from vehicle and sales data that are already collected, so this does not cause administrative burden.	Equal Equal Equal	Equal Equal Equal

31 A target can be defined as the emission value itself or as a percentage reduction against a baseline. However, as a percentage can always be translated into a corresponding emission value, the two are identical.

32 Annually declining targets themselves do not increase the administrative burden, but as they need to be combined with banking and borrowing, the net impact of introducing them is an increase in burden.

Modalities	Design options per modality	Main impacts on administrative burden	Impact on administrative burden relative to current approach	
			EC/MSs	OEMs
F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?				
F1 Pooling	F1.1 No pooling F1.2 Pooling between car or van manufacturers (as in existing Regulation)	Pooling is not so complex as the data for various OEMs need to be merged; no new data are required. For OEMs pooling can increase the administrative burden as they need to analyse whether pooling is beneficial, negotiate terms with other OEMs and exchange data with other OEMs	Equal Equal	Slightly lower Equal
F2 Trading CO_2 credits	F2.1 No trading of credits F2.4 Allowing trading of credits for vans and passenger cars separately	Trading of credits increases the administrative burden significantly (particularly for the EC) as the credits need to be granted and the whole system needs to be managed.	Equal Much higher	Equal Higher
F3 Banking/borrowing	F3.1 No banking/borrowing F3.2 Allowing only banking (maximum period and maximum banked amount to be specified) F3.3 Allowing banking and borrowing (maximum period and maximum banked/borrowed amounts to be specified)	Allowing banking and/or borrowing increases the administrative burden as the under/over performance in one year needs to be monitored and translated into the target level of the next year.	Equal Higher Higher	Equal Higher Higher
F4 Excess emission premiums	F4.1 Excess emission premium of €X per excess g/km, possibly with lower premium for the first few g/km exceedance F4.2 No market access when targets are exceeded	Replacing excess premiums by blocking market access for OEMs not meeting their target would reduce the burden related to the excess premiums, but instead create a high burden related to the legal procedures for blocking market access. It is unclear which of the two would be higher for the EC.	Equal Unclear	Equal Unclear
F5 Derogations	F5.1 For manufacturers with small volume (EU) sales (as in existing Regulation) F5.2 For manufacturers with niche volume (EU) sales (as in existing Regulation) F5.3 For manufacturers with small volume (global) sales F5.4 For manufacturers with niche volume (global) sales F5.5 For certain vehicle types F5.6 Combination of the above	Removing derogations would decrease the administrative burden for the EC. Basing derogations on global sales does require additional data gathering and verification for the EC. Derogations for certain vehicle types would not require additional data, but just affect the calculation rules and therefore not increase administrative burden.	Equal Equal Slightly higher Slightly higher Equal Equal	Equal Equal Equal Equal Equal Equal
F6 Correction for autonomous utility change	F6.1 Adjustment of U_0 in target function	No change compared to current regulation.	Equal	Equal

Apart from the impacts of (changes in) the regulations on the administrative burden, it is important to be aware of the one-off burdens that changes of the regulation may entail. In general, changing the current approach to an alternative approach may result in additional complexity and effort for the EC, as some definitions or procedures may need to be adapted or added or default values (e.g. for WTT emissions) may have to be assessed and determined. It is important to be aware of the potential complexity of the processes, e.g. for defining certain parameters. Therefore some modalities that from a technical perspective are not so complex and have low data requirements can still be relatively difficult to design and may induce a lot of (political) discussion.

This is particularly the case for the following modalities:
- the introduction of a WTW metric as this requires agreement on setting the WTT emission factors for each energy carrier;
- adding (mandatory) reporting of embedded emissions, as this requires agreement on the requirements for such reporting;
- the definition and level of a (flexible) ZEV or ULEV mandates, (new levels of) super credits;
- the exact definition and levels of technology specific targets;
- introducing mileage weighting, requiring agreement on mileage numbers depending on e.g. the utility value or other vehicle characteristics.

6 Conclusions

6.1 Conclusions on the objectives and key design options (modalities)

The main objective of the CO_2 regulations for cars and vans is to contribute to the reduction of GHG emissions in order to mitigate climate change. They are part of a package of policy measures aimed at reducing the GHG emissions of transport in the EU. The specific objective of the regulation is to reduce the CO_2 emissions and energy consumption of new light duty vehicles.

For the design of these regulation there is a long list of modalities which can be considered (see Table 5). All these modalities are related to one of the following main design choices. For the design of these regulation, many modalities can be considered. Each modality (e.g. Regulated vehicle categories) is related to a main design choices (printed bold):

A. What is the scope of the Regulation?
- A1 Regulated vehicle categories.
- A2 Regulated entities.
- A3 Metric.
- A4 Embedded emissions.

B. How to measure the parameters needed for determining the overall performance?
- B1 Measuring TTW vehicle parameter(s).
- B2 Determining WTT parameters.
- B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal.

C. How to determine the overall performance?
- C1 Rewarding off-cycle reductions.
- C2 Rewarding or penalising technologies.
- C3 Aggregation & weighting.

D. Approach for target setting
- D1 Approach for target setting.

E. How to fairly distribute the burden across regulated entities?
- E1 Utility parameter.
- E2 Shape and slope of target function.

F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?
- F1 Pooling.
- F2 Trading CO_2 credits.
- F3 Banking/borrowing.
- F4 Excess emission premiums.
- F5 Derogations.
- F6 Correction for autonomous utility change.

6.2 Considerations regarding the level of ambition and target levels

The stringency of the regulation depends strongly on the target levels.
The assessment of target levels that are consistent with meeting the overall 2050 GHG reduction goals for transport or the 2030 reduction goal for the non-ETS sectors showed that these levels strongly depend on a broad range of assumptions, such as development of transport demand, CO_2 reduction in other transport modes and the contribution from biofuels.

Under a 'mid'-scenario that includes 25% biofuels, the (NEDC-based) target values allowing to meet the 2050 reduction goals would be 70 g/km (2025) and 55 g/km (2030) for cars and 116 g/km (2025) and 89 g/km (2030) for vans. Target levels needed to meet the 2030 objectives for non-ETS sectors would be lower: 65 g/km (2025) and 44 g/km (2030) for cars and 100 g/km (2025) and 66 g/km (2030) for vans.

Target levels that are fully robust for expected developments up to 2030 and also ensure that the long term goals are met in case of higher transport growth rates, lower or no shares of biofuels for LDVs or less GHG reduction in HDVs and other transport modes are (close to) 0 g/km in 2030 for both cars and vans.

6.3 Conclusions on effectiveness

The average results for passenger cars depend mainly on the target level. In the quantitative assessment three target scenarios have been used both for cars and vans, based on annual reduction rates of 3, 4 or 6%. This corresponds to NEDC-based target levels for cars of 74 to 84 g/km in 2025 and 54 to 72 g/km in 2030. For vans, targets of 108 to 126 g/km in 2025 and 79 to 108 g/km in 2030 were used. The cost impacts have been assessed for all these target levels in combination with many combinations of the choices made for the various modalities. Four of all these policy variants were assessed in more detail: two with the strictest target levels and two with weakest; two with the current choice for modalities and two with an alternative policy design.

For the target levels assessed, the vehicle life-time WTW emission reduction (compared to BAU) is on average (across policy variants) 25 to 50 Mton for all cars sold in 2025 and 50 to 100 Mton for all cars sold in 2030. For vans, the lifetime vehicle emission reduction is on average 5 to 11 Mton for all vans sold in 2025 and 8 to 17 Mton for all vans sold in 2030. The reductions for the policy variants with the weakest targets are close to the values at the lower-end of these ranges, while reductions in the policy variants with the strictest target levels are close to values at the higher end.
Both for cars and vans the GHG reduction that is achieved is also somewhat affected by the technology scenario (fleet composition). On average the scenario with the highest share of BEVs results in the largest WTW emission reduction, but the differences with the other technology scenarios are not so large (less than 10%).

The impact of the choice for the various modalities is in comparison to the impact of the target level relatively small. Changing the utility parameter from mass to footprint and incentivising the uptake of off-cycle technologies (e.g. by credits for eco-innovations) both slightly (less than 10%) increase the effectiveness. All other modalities have negligible impact on the effectiveness.

Besides the GHG reduction over the vehicle lifetime, also the impact on the GHG emissions in 2025 and 2030 has been estimated (using MOVEET).
These runs show that the scenarios considered for passenger cars would reduce the total emissions of passenger transport in the EU in 2030 (compared to BAU) by 7% to 15% (less and most stringent target level, respectively). This modelling takes account of fleet renewal rates and impacts on transport demand and modal split (which are discussed in Section 6.6). These reductions will further increase after 2030 when larger shares of the fleet will be affected by the new targets (due to fleet renewal). The impacts on the emission levels

in 2025 are much smaller as in that year only a small part of vehicle fleet has been affected by the new regulation.

6.4 Conclusions on cost impacts (for manufacturers, end-users and society)

The options for setting more stringent emission targets for cars and vans either in 2025 or in 2030 that have been assessed in detail in the previous chapters result in net benefits for society under all technology scenarios and policy variants considered. The highest societal benefits (in terms of net cost savings (excluding external cost impacts) are found with the most stringent target levels, both for cars and vans. The net benefits are also affected by various modalities. The societal benefits were found to increase when off-cycle emissions are included and the utility parameter is changed from mass to footprint. The other modalities have relatively small cost impacts.

In the Mixed-EV scenario, the average societal benefits (across many variants for the modalities) range from € 350 to almost € 600 per car sold in 2025 and € 800 to € 1,100 per car sold in 2030. With the current design of the regulation, the societal cost benefits of the least stringent target is almost € 450 for vehicles sold in 2025 to € 850 in 2030, which can be increased to over € 600 in 2025 and €1,100 in 2030 by choosing an alternative design (a WTW metric, footprint as utility parameter and with mileage weighting). With the most stringent target levels assessed, these benefits are € 750 to € 1,000 for vehicles sold in 2025 and € 1,300 to € 1,800 in 2030; with the higher values for the alternative design of the regulation. With the net societal benefits with the more stringent target are 54 to 77% higher than with the less stringent target.

For vans, the average net societal benefits in the Mixed-EV scenario are even higher, ranging from € 1,100 to € 1,900 for vans sold in 2025 to € 1,800 to € 2,850 in 2030. With the current design of the regulation, the societal cost benefits of the least stringent target is € 1,000 in 2025 and € 1,750 in 2030. Like for cars, the more stringent targets result in the higher net societal benefits and also the alternative design leads to higher benefits, up to € 2,250 in 2025 and almost € 3,500 in 2030.

The societal benefits are the result of the fact energy cost savings exceed the increase in manufacturing costs. The additional manufacturing costs for cars increase with the stringency of the target level, but are very dependent on the technology scenario. Averaged over policy variants, these costs range from € 100 to € 1,200 per car in 2025 and up to almost € 2,500 in 2030 (all compared to BAU in the same year).The increase in manufacturer costs is lowest in the Extreme-BEV scenario. In the Mixed-EV scenario, the manufacturer costs increase by € 250 to € 350 in 2025 and € 650 to € 750 in 2030 (for the less stringent target) up to € 550 to €750 in 2025 and € 1,250 to € 1,700 in 2030 (for the most stringent target level assessed). The lower values match with the alternative choices for modalities; the higher values with the current design.

These higher manufacturing costs translate in higher vehicle prices for end-users, but these are more than compensated by fuel cost savings. For the four scenarios assessed in detail, this results in a net cost reduction for end-users of € 400 to € 900 in 2025 and € 800 to € 1,700 in 2030 (including taxes; accounted over the first five years). The lowest values were found for the current the design and the least stringent targets, while the highest values are for the alternative design and the most stringent targets.

For vans similar types of cost impacts were found, but with lower values for the manufacturer costs and higher values for the end-user cost saving. For the four scenarios assessed in detail, the additional manufacturing cost for vans range from € 80 to almost € 450 per van in 2025 and € 200 to € 850 in 2030 (all compared to BAU in the same year).

Again, the higher manufacturing cost are more than compensated by energy cost savings over the entire vehicle lifetime. This results in a net reduction in cost for end-users (over the first five years) under all technology scenarios. For the four scenarios assessed in detail, the benefits are between € 950 and € 2,100 for vans sold in 2025 and € 1,600 to € 3,300 for vans sold in 2030 (including taxes).

6.5 Conclusions on the competitive position of ACEA-members

The competitive position of ACEA members (used as a proxy for the European automotive sector, i.e. manufacturers having their R&D and production facilities established within the EU, see Section 3.7) is not sensitive to the choice for a certain metric. Introducing mileage weighting has a slightly negative impact on the competitive position of ACEA members in most policy variants. The relative price increase with mileage weighting is slightly higher (about 1%-point) for ACEA members than for non-ACEA members. This effect is the result of ACEA member sales being more in the upper size segments compared to the non-ACEA members.

Including off-cycle technologies, keeping mass as utility parameter, manufacturer groups instead of brands, a steep target function and a less stringent target all result in a slightly improved competitive position of ACEA members.

6.6 Conclusions on the quantitative assessment of selected policy variants

The four policy variants that have been assessed in more detail were not just evaluated on their GHG and cost impacts but also on the wider impacts for the transport system, economic impacts and social equity, using various models.

The impacts on the transport system have been modelled by the MOVEET model (just for the passenger car regulation). The results show that the lower end-user cost result in an increase in passenger car transport of 0.2 to 0.9%. This is partly the result of some modal shift: the total transport demand of rail, tram and bus transport decreases by 0.5 to 1.3% in 2025 and 1.1 to 2.7% in 2030. The net impact on the total passenger transport demand is small (less than 0.15% increase).

The economic impacts of the passenger car regulation have been modelled by the E3ME model. In almost all scenarios there is an increase in GDP of up to 0.2%, relative to the BAU in the same year. The highest impacts are found in the scenarios with the most stringent target level. In these scenarios, employment increases by up 0.15%, consumption by up to 0.25% and investments by up to 0.15%. In the scenarios with less stringent targets, the economic impacts are smaller, better generally in the same direction.

The impacts on the regulation for cars on income levels has been modelled by EDIP. The results show that in all scenarios, the income levels increase in all income groups by 0.25 to 1.3% in 2025 and 0.4 to 1.4% in 2030. In most scenarios, the relative increase is highest in the highest income groups.

To quantify the impact income level more clearly, also the impact on the Gini coefficient has been modelled. The results show that income inequality slightly increases, but that the impacts are very small (in all scenarios less than 0.2% increase of the Gini coefficient).

6.7 Conclusions on modalities that have been evaluated qualitatively

Regulated entity, pooling and trading

Regulating manufacturer groups has the advantage of providing more options for cost optimization. However, regulating brands in combination with pooling offers manufacturers even a larger degree of flexibility in this respect.
The theoretical maximum reduction in manufacturing costs that can be achieved by pooling are about 1 to 3% for cars and 3 to 8% for vans. However in practice, cost reductions will be lower.

Trading could be an effective alternative, allowing manufacturers to decrease compliance costs without becoming dependent of each other, but has the drawback that it significantly increases the administrative burden of the policy. Furthermore, previous studies showed that the additional cost benefits of trading compared to pooling are very small.

Embedded emissions

Before considering to include embedded emissions in the scope of the Regulations, an important first step would be to ensure harmonised reporting of those emissions. Once sufficient experience is gained with reporting (and verifying) embedded emissions, including them in the metric of the Regulations and/or sharing them with consumers might be considered as a next step. However, reporting embedded emissions is expected to cause a relatively high administrative burden and to increase complex, both for OEMs and authorities, as it requires gathering and verification of large amounts of detailed data and defining a specific methodology.

Measuring TTW emissions and impacts of WLTP

The increasing gap between TA and RW emissions significantly reduces the effectiveness of the current CO_2 regulation and requires attention for the post 2020 regulations. The WLTP is likely to yield more representative type approval CO_2 emissions, but is not expected to completely close the gap between type approval and real-world CO_2 emissions.

As until now manufacturers have optimized their vehicles and vehicle testing to NEDC, the conversion factors from NEDC to WLTP are likely to change over time and the gap between WLTP TA values and RW emission levels is likely to increase in the coming years.

Promising options for closing this gap might be the monitoring of real-world emissions, by measurements based on either on road tests (e.g. using PEMS) or ECU data provided by vehicle OEMs.

Large scale fuel consumption data of in-use vehicles might be used to derive real-world emission values for specific models. In order for such a system to work, a number of procedures and arrangements would need to be developed and agreed upon, which can be complex.

An alternative could be to use real-world measurements (e.g. PEMS or monitoring of ECU data) additional to the Type Approval test. However, also this approach adds complication and will have a higher administrative burden.

Rewarding off-cycle emission reductions

The current approach of eco-innovation credits improves the cost-effectiveness of the Regulations as it allows to reward some off-cycle technologies (auxiliaries or devices that are not switched on during the test or for which the impacts are not or not accurately measured on the test) which reduce emissions at low cost. However, to keep the eco-innovation credits in line with the type approval test, the implications of the change to the WLTP need to be investigated and taken into account.

The main drawback of the current approach is its high administrative burden. The burden for OEMs could be reduced by establishing a pre-defined list of eligible technologies and the 'default' credits OEMs can receive for each option. Additionally, OEMs could still apply for credits for new technologies not previously listed if they provide sufficient evidence.

Enlarging the scope of eligible technologies would benefit the cost effectiveness if robust measurement or assessment procedures exist. However, the option of granting credits for off-cycle technologies should be taken into account when setting the target levels in order to avoid the risk of reducing the effectiveness of the regulation.

Rewarding low-emission technologies

ZEV/ULEV mandates may help to ensure reduction of direct CO_2 emissions (TTW) as well as overall WTW GHG emission reduction from transport in case the carbon intensity of energy carrier production (electricity and hydrogen) is low. Moreover, they could facilitate the transition towards the long term decarbonisation targets which require a higher share of ZEV. However, proper design of the mandate is very important to ensure technology neutrality, to prevent market distortion and to stimulate ZEV or ULEV related technology development and production within the EU. The minimum share of ZEVs or ULEVs could be combined with a bonus/malus for the average CO_2 target that needs to be met (less stringent value for OEMs with a relatively high share of ULEVs/ZEVs in their sale). Such a 'flexible ZEV or ULEV mandate' has the advantage that it provides more flexibility to OEMs, but carries the risk that it may reduce the overall effectiveness of the regulation.

Technology specific targets

The current regulations set a single target covering all types of powertrains. An alternative approach would be to have technology specific targets, i.e. a separate target for ICEVs and/or ULEVs and no target (or a separate energy efficiency target) for ZEVs. Technology specific targets may increase the effectiveness of the policy by reducing the possibility of leakage of GHG emissions due to certain (drivetrain) technologies with higher WTT emissions. To limit the uncertainty of the overall effectiveness of the policy, technology specific targets could be combined with a ZEV or ULEV mandate. However, this modality is likely to go at the cost of higher vehicle and societal cost.

Banking and borrowing

Banking and borrowing may reduce additional manufacturer costs significantly, especially if allowed before as well as after the target year. The impact on total CO_2 emissions is likely to be very small. In order to manage the risk of manufacturers not being able to balance out a negative amount of CO_2 credits, a maximum amount of borrowed CO_2 credits could be defined.

Excess premiums

The € 95/g/km level of excess premium provides enough incentive for the vast majority of manufacturers to reduce the CO_2 levels of their vehicle fleet rather than to pay the penalty for exceeding the target. However, in order for the excess premium to be an incentive for manufacturers with very high baseline CO_2 emissions (for instance because of a large share of their sales are sports cars and/or SUVs) to reach their targets, it should be much higher (well over € 1,000). The sales share of such manufacturers are however limited.

Derogations for small and niche manufacturers

The contribution of small volume OEMs (<10,000 cars or <22,000 vans) to total CO_2 emissions is very small (below 0.01%). Therefore, the market distortion impact of allowing a derogation for such OEMs to avoid excessive impacts is likely to be limited.

Derogations provided to 'niche' car manufacturers (currently defined as producing 10,000–300,000 cars/year) have drawbacks in terms of competitive neutrality and may reduce the effectiveness of the regulation.
Negative consequences could be prevented by lowering the upper threshold or by eliminating this derogation possibility. However, a more extensive quantitative assessment of the impacts of such options was not foreseen within the context of this study.

6.8 Summary of the stakeholder views on modalities

Different types of stakeholder groups have expressed very different types of preferences as regards the modalities. The main views expressed are:

– A majority of the vehicle OEMs are in favour of broadening eco-innovations, extending super credits, allowing more flexibilities, allowing banking and borrowing and having lower excess premiums.
– A majority of the component OEMs and the steel industry are in favour of including embedded emissions and WTT emissions in the regulation and broadening eco-innovations.
– Environmental NGOs are in favour of real world emission measurements, elimination of super credits, a flexible ZEV/ULEV mandate, mileage weighting, switching to footprint as utility parameter and allowing to bank & borrow emission between years.

6.9 Considerations regarding the future development of ZEV

In case of a quicker shift towards zero emissions vehicles beyond the technology scenarios assessed in this study, the impacts of the targets and modalities would have to be reconsidered. Such a shift might be triggered for example by fast developments in battery or fuel cell technology. This would allow CO_2 target levels to be much lower than what has been considered in this study, and would render many modalities irrelevant (e.g. utility parameter, mileage weighting), while others could become increasingly important (metric, embedded emissions).

6.10 Recommendations for further research

Some modalities options that are not further analysed in this study, are recommended for further quantitative analysis. These are in particular:

- TTW CO_2 emission targets for ICEs with exclusion of Zero Emission Vehicles;
- (flexible) minimum share of advanced technologies in vehicle sales (ZEV or ULEV mandates);
- technology specific targets: limit based on overall sales-weighted average per technology (without/with mileage weighting).

Also approaches for determining the TTW emissions as explored in this report (Section 5.3) deserve further research, as they are highly important for the effectiveness of the regulation.

Furthermore, to complement the assessments in this study, it is recommended to carry out additional sensitivity analysis on:

- other target levels, particularly more stringent targets (or even estimating optimal target levels;
- combinations of cost curves and technology scenarios (e.g. higher or lower cost scenarios for AFVs as well as for ICEVs);
- technology scenario (particularly in relation to quantifying the impacts a (flexible) ZEV or ULEV mandate);
- deviation between RW –WLTP –NEDC, differentiated to fuel type and size class;
- energy prices;
- WTT emission factors.

7 References

AEA ; TNO; CE Delft ; TEPR, 2012. *EU Transport GHG: Routes to 2050? II : Developing a better understanding of the secondary impacts and key sensitivities for the decarbonisation of the EU's transport sector by 2050,* London ; Brussels: AEA et al.

AEA; CE Delft ; TEPR ; TNO, 2012. *EU Transport GHG: Routes to 2050 II : Further development of the SULTAN tool and scenarios for EU transport sector GHG reduction pathways to 2050. Task 6 paper,* Brussels: European Commission Directorate-General Climate Action.

AEA; Ricardo; IHS Global Insight; TNO , 2012. *Supporting Analysis on Test Cycle and Technology Deployment for Reviews of Light Duty Vehicle Regulations (SR#6 of Framework Contract No ENV.C.3./FRA/2009/0043).,* Delft: TNO, innovation for life.

AEA, 2011. *Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy, Final Report to the European Commission –,* Didcot (UK): AEA Technology plc.

Bedsworth, L. W. & Taylor, M. R., 2007. Learning from California's. *California Economic Policy (ECP),* 3(4), p. 19 p..

CE Delft & DLR, 2013. *Zero emissions trucks : An overview of the state-of-art technologies and their potential,* Delft: CE Delft.

CE Delft; ICF; Ecologic, 2011. *Impact of electric vehicles : Deliverables 1-5 and summery report,* Delft: CE Delft.

CE Delft, 2012. *Marginal abatement cost curves for Heavy Duty Vehicles - Background report,* Delft: CE Delft.

EC, JRC, 2013. *Well-to-Tank Report Version 4.0 : JEC Well-to-Wheels Analysis* , Luxembourg: Publications Office of the European Union.

EC, JRC, 2014b. *WELL-TO-TANK Appendix 2 - Version 4.a. Summary of energy and GHG balance of individual pathways,* Luxembourg: Publications Office of the European Union.

EU, 2009. *Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles.,* Brussels: European Union.

EC, 2011a. *Commission Staff Working Document, Impact Assessment, Accompanying document to the communication from the Commission to the EP, the Council, the EES Committee and CoR, A Roadmap for moving to a competitive low-carbon economy in 2050 SEC (2011)288 final,* Brussels: European Commission (EC).

EC, 2011b. Commission Regulation (EU) No 678/2011 of 14 July 2011 replacing Annex II and amending Annexes IV, IX and XI to Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles..... *Official Journal of the European Union,* 185(15.7.2011), pp. 30-56.

EC, 2011b. *Energy Roadmap 2050 : Impact assessment and scenario analysis,* Brussels: European Commission (EC).

EU, 2011. Regulation (EU) No 510/2011 of the EP and of the Council of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO 2 emissions from light-duty vehicles .... *Official Journal of the European Union,* Issue L 145, pp. 1-18.

EC, 2012a. *Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO2 emissions from new passenger cars,* Brussels: European Commission (EC).

EC, 2012b. *Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO2 emissions from new passenger cars......amending Regulation ((EU) No 510/2011..,* Brussels: European Commission.

EEA, 2014. *Monitoring CO2 emissions from passenger cars and vans in 2013,* Copenhagen: European Enviroment Agency (EEA).

EMISIA; INFRAS; IVL, 2013. *Transport data collection supporting the quantitative analysis of measures relating to transport and climate change. (TRACCS), final report,* Thessaloniki: EMISIA SA.

EPA, 2010. Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final rule. *Federal Register,* 75(88), pp. 25323-25728.

EPA, 2012a. *EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks,* s.l.: United States Environmental Protection Agency (EPA).

EPA, 2012b. *Light-Duty Vehicle Mass Reduction and Cost Analysis - Midsize Crossover Utility Vehicle. Assessment and Standards Division. Office of Transportation and Air Quality,* s.l.: United states Environment Protection Agency (EPA).

ICCT, 2010. *An assessment of mass reduction opportunities for a 2017 – 2020 model year vehicle programme", March 2010, conducted by Lotus Engineering for ICCT.,* s.l.: The International Council on Clean Transportation.

ICCT, 2011a. *European Commission consultation on Reducing CO2 emissions from road vehicles – Additional comments,* Washington D.C.: The International Council on Clean Transportation (ICCT).

ICCT, 2011b. *European CO2 Emission Performance Standards for Light Commercial Vehicles,* Washington D.C.: The International Council on Clean Transportation (ICCT).

ICCT, 2013a. *European Vehicle Market statistics ; Pocketbook 2013,* Berlin: International Council on Clean Transportation Europe (ICCT).

ICCT, 2013b. *Summary of mass reduction impacts on EU cost curves, Working Paper 2013-1,* s.l.: The Internatioanl Council on Clean Transportation.

ICCT, 2014a. *CO2 emissions from new passenger cars in the EU: Car manufacturers"performance in 2013,* Washington D.C.: The International Council on Clean Transportation (ICCT).

ICCT, 2014b. *Global Comparison of Passenger Car and Light-commercial Vehicle Fuel Economy/GHG Emissions Standards. Update: February 2014.*. [Online]
Available at: http://www.theicct.org/info-tools/global-passenger-vehicle-standards
[Accessed December 2014].

ICF, 2015. *Impact of higher levels of bio components in transport fuels in the context of the DIRECTIVE 98/70/EC of the EU Parliament and of the Council of 13 October 1998, relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC,* s.l.: ICF.

IEEP; CE Delft; TNO, 2007. *Possible regulatory approaches to reducing CO2 emissions from cars (070402/2006/452236/MAR/C3), final report-technical notes,* Brussels: Eropean Commission, DG Clima.

Koffler, C. & Rohde-Brandenburger, K., 2010. On the calculation of fuel savings through lightweight design in automotive life cycle assessments. *International Journal of Life Cycle Assessment,* Volume 15, pp. 128-135.

National Research Council (US), 2013. *Transitions to alternative vehicles and fuels.* Washington D.C.: The National Academies Press.

Ricardo-AEA; CE Delft; TEPR; TNO, 2014. *EU Transport GHG: Routes to 2050 II , SULTAN (SUstainabLe TrANsport) Illustrative Scenarios Tool (adjusted by CE Delft.* [Online]
Available at: http://www.eutransportghg2050.eu/cms/illustrative-scenarios-tool/
[Accessed 2016].

Ricardo-AEA; TEPR; TU Graz; Cardiff Business School, 2015. *The potential for mass reduction of passenger cars and light commercial vehicles in relation to future CO2 regulatory requirements,* Didcot (UK): Ricardo-AEA.

Ricardo-AEA; TEPR, 2015. *Evaluation of Regulation 443/2009 and 510/2011 on the reduction of CO2 emissions from light-duty vehicles" Study contract no 071201/2013/664487/ETU/CLIMA.C.2,* Brussels: European Commission .

Ricardo-AEA, 2014. *Data gathering and analysis to improve understanding of the impact of mileage on the cost-effectiveness of Light-Duty vehicles CO2 Regulations (Framework contract CLIMA.C.2/FRA/2013/0006),* Brussels: European Commission.

Ricardo-AEA, 2016. *Supporting analysis on Improving understanding of technology and costs for CO2 reductions from cars and LCVs in the period to 2030 and development of cost curves Service Request 4 to LDV Emissions Framework Contract,* Brussels: European Commission.

Scenaria, 2012. *Weight reduction with aluminium: part of all cost-effective fuel economy strategies", September 2012, conducted by Scenaria for ,* Arlington: The Aluminium Association.

Smokers, R., Verbeek, M. & Zyl, S. v., 2013. *EVs and post 2020 CO2 targets for passenger cars: paper at EVS27 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium Barcelona, Spain, November 17-20, 2013.* Barcelona, s.n.

TML, 2016. *Data gathering and analysis to improve the understanding of 2nd hand car and LDV markets and implications for the cost effectiveness and social equity of LDV CO2 regulations",* Leuven: Transport and Mobilty Leuven (TML).

TNO, et al., 2011a. *Support for the revision of regulation on CO2 emissions from light commercial vehicles : Service request #3 for Framework Contract on Vehicle Emissions - No ENV.C.3./FRA/2009/0043,* Delft: TNO, innovation for life.

TNO, et al., 2011b. *Support for the revision of Regulation (EC) No 443/2009 on CO2 emissions from cars (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).,* Delft: TNO, innovation for Llife.

TNO; AEA; CE Delft; Ricardo, 2013. *Consideration of alternative approaches to regulating CO2 emissions from light duty road vehicles for the period after 2020 (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043),* Delft: TNO, innovation for life.

TNO; CE Delft, 2012. *Assessment of alternative targets and modalities for the CO2 regulation for light commercial vehicles,* Delft: TNO.

TNO, 2012a. *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.* Framework Contract No ENV.C.3./FRA/2009/0043. Final Report. Date: December 5th, 2012. Delft: TNO.

TNO; CE Delft, 2013. *Analysis of the influence of metrics for future CO2 legislation for Light Duty Vehicles on deployment of technologies and GHG abatement costs (Service request #8 for Framework Contract on Vehicle Emissions),* Delft: TNO, innovation for life.

TNO; CE Delft, 2014. *Indirecte en directe CO2-uitstoot van elektrische personenauto's,* Delft: TNO; CE Delft.

TNO; IEEP; LAT, 2006. *Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2 emissions from passenger cars ,* Delft: TNO.

TNO; IFEU; ICCT, 2014. *From laboratory to road: a 2014 update of official and 'real-world' fuel consumption and CO2 values for passenger cars in Europe. ,* Berlin: International Council on Clean Transportation (ICCT).

TNO, 2013a. *Travelcard Nederland BV data source document: Fuel consumption of Dutch passengers cars in business use 2004-2012,* Delft: TNO.

TNO, 2013b. *Praktijkverbruik van zakelijke personenauto's en plug-in voertuigen (Real-world fuel consumption of passenger cars for business use and plug-in Hybrid vehicles),* Delft: TNO.

TNO, 2014a. *Update analysis of real-world fuel consumption of business passenger cars based on Travelcard Nederland fuel pass data,* Delft: TNO, Earth, Life & Social Sciences.

TNO, 2014b. *Real-world fuel consumption of passenger cars presentaion at the 20th International Transport and Air Pollution Conference 2014, Graz, Austria, 18-19 September, 1-12*. Delft: TNO.

TNO, 2015a. *Potential CO2 reduction technologies and their costs for Dutch passenger car fleet,* Delft: TNO.

TNO, 2015b. *Run-in fuel consumption from Travelcard Nederland BV fuel-pass data,* Delft: TNO.

Valdani Vicari & Associati (VVA); Technopolis Group (TG); TNO, as part of Joint Institute for Innovation Policy (JIIP), 2015. *Assessment of competitiveness impacts of post-2020 LDV CO2 regulation, Project for DG CLIMA under the Multiple framework contract for the procurement of studies and other supporting services on impact assessments and evaluations (ENTR/172/PP/2012/FC),* Brussels: European Commission.

Annex A Level of Ambition and target levels

A.1 Introduction

In this annex, the results of the top-down assessment of appropriate levels of ambition for 2025 and 2030 are summarised (Section A.2),consistent with overall climate objectives, based on a top-down assessment. Additionally, a comparison is made to historical reduction rates and ambition levels in other regions (Section A.3). The synthesis of the level of ambition and the target values that have been selected for the quantitative assessment of policy variants are summarised in Section A.4. The impacts of various target levels are further analysed in the quantitative assessments which are presented in Chapter 3 and 4. Some background data used are provided in Annex B.

A.2 Top-down assessment of the leven of ambition

A.2.1 Introduction

In order to limit the global temperature rise resulting from climate change to 2°C, the EU has made the commitment to reduce its domestic GHG emissions with 80 to 95% by 2050 compared to 1990 (EC, 2011a). As a consequence of these long-term objectives, the EU transport sector is required to reduce its emissions by 54 to 67% compared to 1990 by 2050 with intermediate reduction targets of -20% and 9% by 2030 (ibid.).

More recently, the Council committed to a target of 30% by 2030 compared to 2005 for non-ETS sectors, in which road transport has a share of roughly 30% (EEA, 2014). If this target was to be met by transport it would translate into a target of 12% GHG emission reduction in 2030 compared to 1990.

These EU targets are defined in terms of TTW GHG emissions and apply to all transport modes except maritime. Electricity, biofuels and hydrogen count as zero emission (IPCC definition) (EC, 2011a)[33].

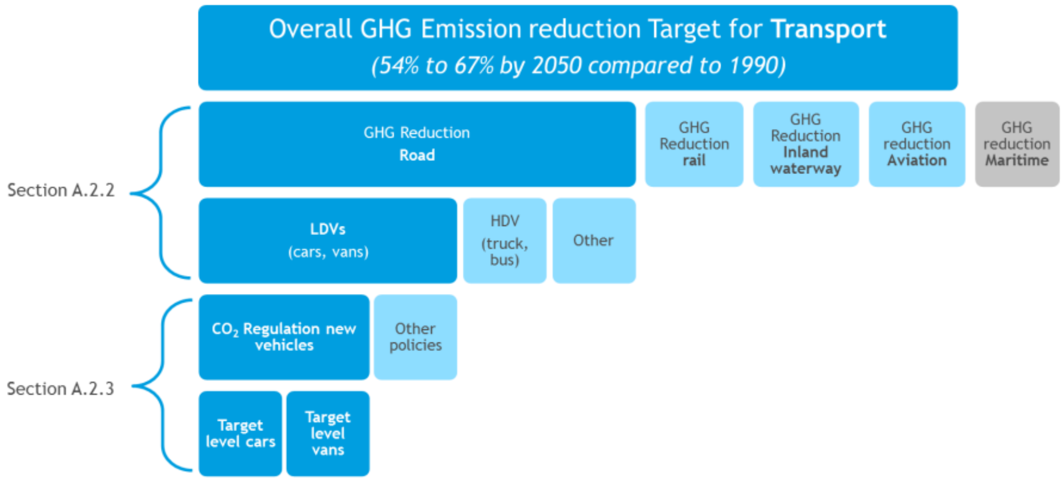
The top-down assessment of the level of ambition evaluates which target levels for LDVs would be consistent with meeting these long-term transport objectives. To determine these target levels, a first step is to assess the GHG emission reduction that would be required from LDVs and which share of the emission reduction should be realised within other transport modes. This is the topic of Section A.2.2. To take account of uncertainties (e.g. in the volume growth and GHG emission reduction rates in other sectors and other transport modes), the results are presented as bandwidths.

[33] It should be kept in mind that these alternative fuels do not have zero emissions in reality, as although there are zero emissions in the use phase (TTW), they are not in other parts of the lifecycle (WTT and embedded emissions). Consequently, defining TTW targets can result in carbon leakage, which can be a reason to adopt WTW targets. The pros and cons of applying a TTW or WTW metric is further discussed in Chapter 4 and in Annex C.

Hereafter, the target levels for both cars and vans can be determined, which is the topic of Section A.2.3. The target levels depend on the overall reduction rates for LDVs, but also on various other assumptions like the development of the total mileage of LDVs and the decarbonisation of energy carriers (e.g. by blending of biofuels). To take account of these uncertainties, the target levels are estimated with various assumptions.

The overall approach is shown graphically in Figure 76.

Figure 76 Overview of the top-down assessment



A.2.2 GHG emission reduction from LDVs

As shown in Figure 76, this sub-section covers the emission reduction that should be realised for LDVs, in order to meet the overall climate targets of the EU in a cost effective manner. If each transport mode would reduce emissions with 54 to 67%, the target would be met, but this would not be the most cost-effective way nor would it be feasible. Therefore, this section explores different scenarios.

Emission reduction from road transport

In 1990, total (direct) emissions from transport (excl. maritime) were 821 $MtCO_2$-eq. (SULTAN tool, 2014) which implies that the EU27 transport emissions should reach a level between 271 (67%) and 378 (54%) $MtCO_2e$ by 2050 in order to meet the long-term climate goals of the EU.

The emissions (and hence emission reductions) of each mode result from (changes in) three pillars: the CO_2 intensity of the energy carriers, the efficiency of the equipment (vehicles), and the total kilometres, as shown graphically in Figure 77.

Figure 77 Factors determining CO_2 emissions of a transport mode

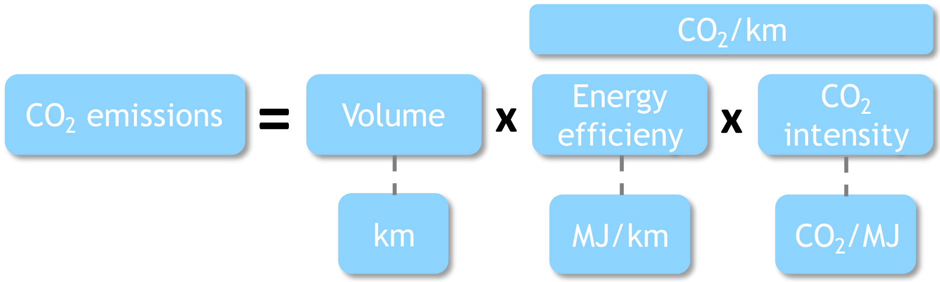
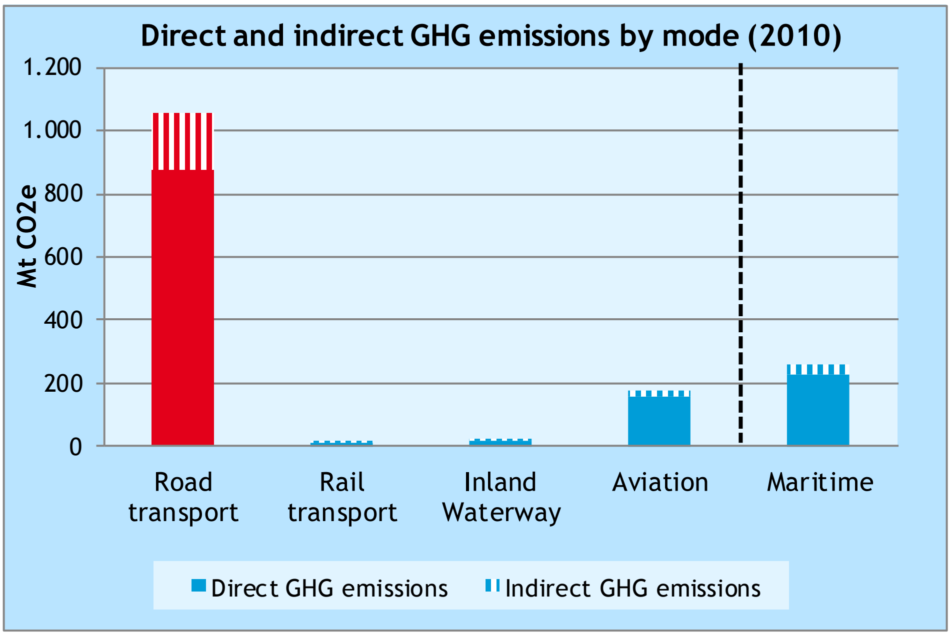


Figure 78 shows the contribution of the different main transport modes to the total transport emissions in 2010. At that time, road transport was responsible for approximately 83% of the total direct transport emissions (excl. maritime shipping).

The contribution of road transport to the overall GHG reduction of the transport sector depends on the emission reduction in the other transport modes under the target. As can be seen from Figure 78, this mainly concerns aviation emissions as the shares of rail transport and inland navigation are relatively small.

Figure 78 GHG emissions of Transport by main mode in 2010



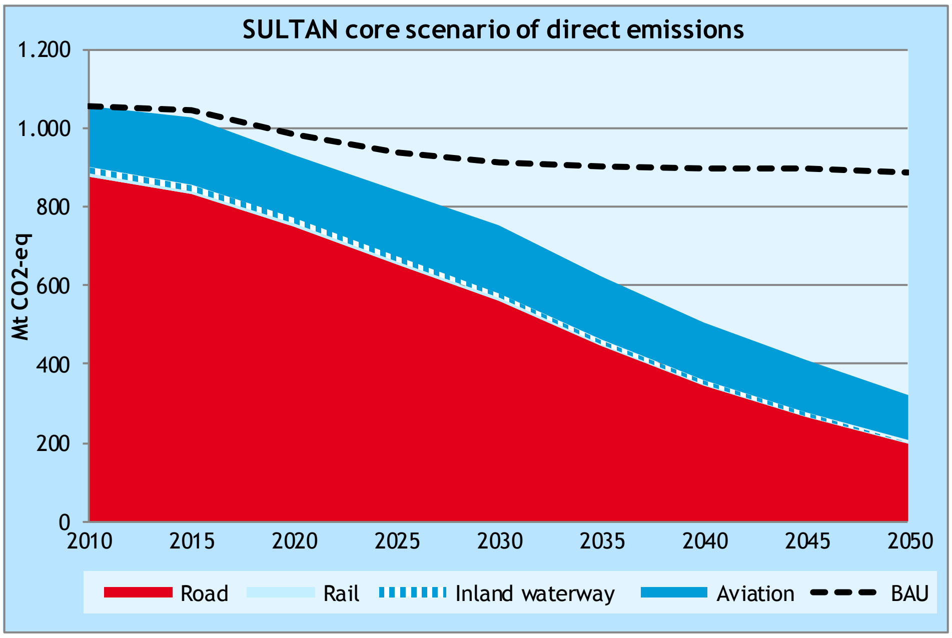
Note: Scope of the SULTAN tool is EU27.
Source: SULTAN tool (2014), adjusted by CE Delft.

This means that the minimal emission reduction for *road* transport is 45% to 60% compared to 1990, which is the emission reduction to meet the reduction targets if the non-road modes (rail, navigation and aviation) would have zero emissions by 2050. However, this is not realistic and most scenarios actually assume an increase of aviation emissions compared to 1990. Therefore the required emission reduction for road transport will be higher than 45-60%.

It should be noted that the inclusion of aviation in the EU ETS ensures that any increase in emissions from this sector is fully compensated with a decrease in emissions in other sectors. However, for meeting the transport goals in the road map – which include emissions from aviation – it is still relevant to take the developments, costs and reduction options (and hence, emission reduction) of aviation into account.

To determine the required reduction in road transport, available scenario studies can be used as a starting point. Very useful and transparent scenarios are the SULTAN scenarios from the 'EU Transport GHG Routes to 2050' project. In that study, reduction options for all transport modes were assessed and used for developing overall reduction scenarios for meeting a 60% overall reduction of TTW GHG emissions in 2050 compared to 1990. The SULTAN Core Reduction scenario (R1-b) is shown in Figure 79 and the main assumptions made for this scenario are summarised in Table 24.

Figure 79 SULTAN core reduction scenario for the EU transport GHG: Routes to 2050 II project



Note: Scope of the SULTAN tool is EU27.
Note: Based on SULTAN Scenario R1-b: 60% reduction of direct transport emissions.
Source: SULTAN tool (2014).

Table 24 Reduction of TTW GHG emissions by transport mode (Sultan Core scenario)

Main transport mode	Assumptions of the scenario: Development between 2010 and 2050		Emission reduction compared to 1990 levels to achieve an overall reduction of 60% by 2050
	Growth in activity (km)	TTW emissions per km of the fleet (g/km)	
Road	**29%**	**-82%**	**72%**
Non-Road	**66%**	**-58%**	**-9%**
Inland Navigation	40%	-70%	58%
Rail	82%	-84%	84%
Aviation	59%	-54%	-38%

Note: Based on SULTAN Scenario R1-b: 60% reduction of direct transport emissions.
Source: SULTAN tool (2014), adjusted by CE Delft.

In the SULTAN R1-b scenario, road transport reduces emissions with 72% by 2050 compared to 1990. The total emissions from non-road modes increase with 9%, which in turn is caused by the increase in emissions from aviation (due to volume increases).

It should be emphasized that any changes in the underlying assumptions for the non-road transport modes (e.g. volume, CO_2 intensity) would result in different emission levels and hence, in different targets for road transport. Therefore the sensitivity for the reduction rate of non-road transport modes has been explored. Table 2 summarises the goals for road transport for different non-road reduction scenarios, which are also shown graphically in Figure 80. The x-axis shows the overall transport reduction goals from the Roadmap, while the Y-axis shows the road reductions required for the different overall transport goals and for different non-road reduction scenarios.

The scenarios range from an increase of 55% in emissions from non-road modes by 2050 compared to 1990 to a decrease by 10%. The former scenario (+55%) would occur if non-road modes keep their total emission level constant from 2010 onwards (meaning that any volume growth between 2010 and 2050 will be off-set by reduction of the GHG-intensity of kilometres) and is used as the worst case. The mid value (yellow boxes) is based on the core reduction scenario of SULTAN, in which emissions from non-road modes increase by roughly 10% compared to 1990. Finally, the best case is chosen to be roughly 20% more optimistic scenario than SULTAN, in which non-road modes reduce emissions with 10% compared to 1990.

Table 25 Sensitivity analysis on road transport reductions needed for meeting the overall reduction goal for transport (incl. aviation)

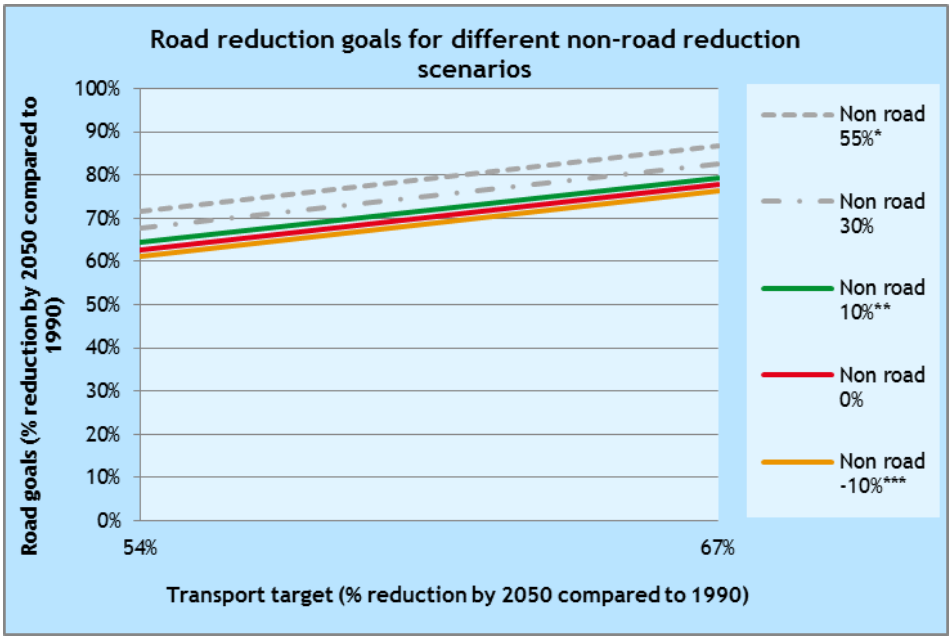
Year	Transport reduction goal from the carbon roadmap	Emission reduction of non-road modes by 2050 compared to 1990					Best guess
		-55%*	-30%	-9%**	0%	10%***	
2050	54%	72%	68%	**63%**	63%	61%	60 to 85%
2050	67%	87%	83%	**79%**	78%	76%	**(72%)**

* Emissions from non-road modes in 2050 are roughly equal to the 2010 level (= worst case).

** Emission reduction non-road modes based on SULTAN R1b scenario (= mid value).

*** Emission reduction non-road modes much more optimistic than SULTAN assumptions (= best case).

Figure 80 Sensitivity analysis on road transport targets



* Emissions from non-road modes in 2050 are roughly equal to the 2010 level (= worst case).

** Emission reduction non-road modes based on SULTAN R1b scenario (= mid value).

*** Emission reduction non-road modes much more optimistic than SULTAN assumptions (= best case).

To conclude on the table and figure above, emission reduction in the range of 60 to 85% (with a most likely value of 70%) for road transport in 2050 compared to 1990 seem necessary to meet the EU's overall emission reduction targets.

The whole assessment so far has been built on the 2050 reduction goals. As an alternative, also the 30% reduction target for non-EU ETS sectors by 2030 compared to 2005, as recently set by the European Council could be taken as starting point. If this target was to be met by road transport, it would translate into an intermediate target of 12% reduction by 2030 compared to 1990. For the remainder of the top-down assessment, the implications of this 30% reduction target (mid value) with a bandwidth of ±10% for 2030 will be assessed as well. The results of this are presented in text boxes, complementing the analysis of target consistent with meeting the 2050 reduction goal.

GHG emission reduction from LDVs vs. other road modes

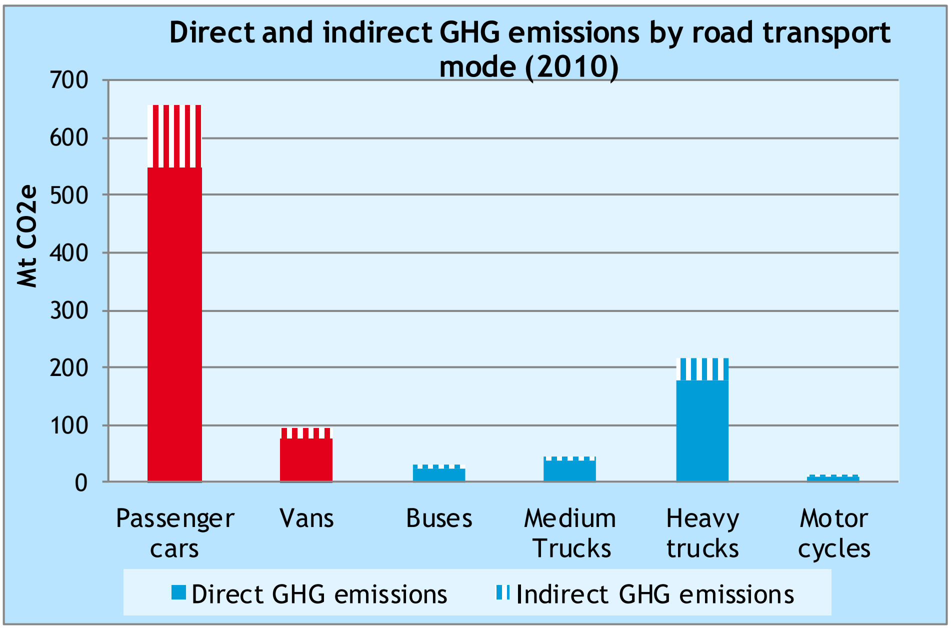
The next step of the top-down assessment is to assess the reduction required from different road transport modes, and of cars and vans in particular.

In 1990, road transport CO_2 emissions were 707 Mt in the EU27 (SULTAN tool, 2014). Hence, the 60 to 85% reduction by 2050 which resulted from the assessment presented above would imply that road transport emissions in the EU27 can be approximately 280 to 105 Mt by 2050 (and slightly higher for the EU28).

Figure 81 shows the emissions from different road transport modes in 2010. Cars and vans were responsible for 71% of the road transport emissions. This implies that even if other road transport modes reduce their emissions to zero, LDVs would need to reduce their emissions with 45 to 80% to result in a

60 to 85% reduction of road transport. However this is not a realistic scenario as especially for heavy trucks it is not likely that they will be completely decarbonised by 2050, as alternative powertrains with zero emissions (e.g. electric and hydrogen) are not feasible options yet, due to technical limitations (e.g. electric range, weight/volume of batteries and fuel cells, etc.) and cost constraints (CE Delft & DLR, 2013)[34].

Figure 81 **GHG emissions of road transport by mode in 2010**



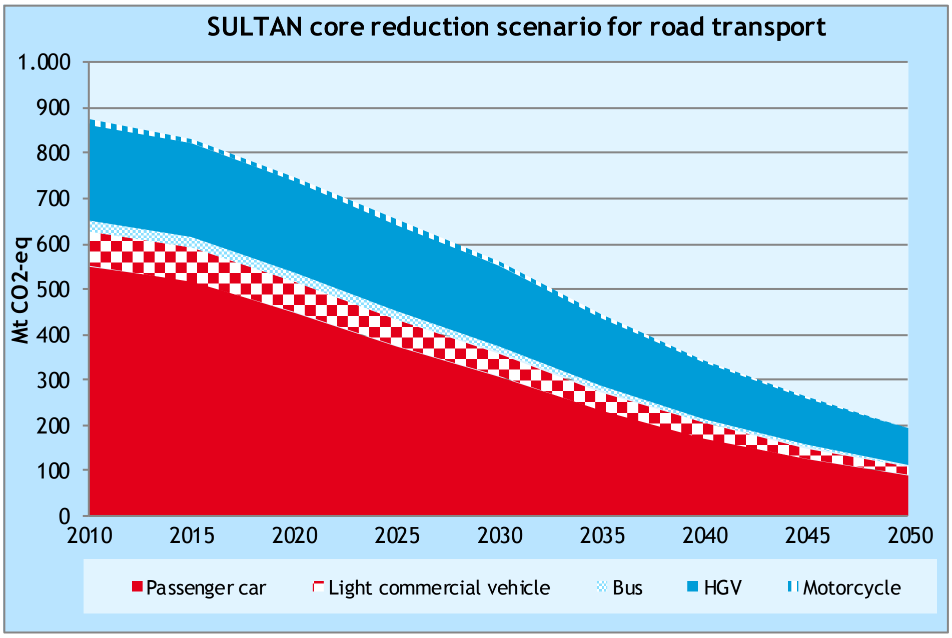
Note: Scope of the SULTAN tool is EU27.
Source: SULTAN tool (2014), adjusted by CE Delft.

To estimate the required emission reductions for LDVs, a similar approach is followed as previously for estimating the required reduction in road transport.

Figure 82 and Table 26 summarise the main assumptions and resulting emission reductions of the SULTAN core reduction scenario for different road transport modes, in which road transport reduces TTW emissions with roughly 72% (the mid value).

34 According to the MACH model of CE Delft (2012), the cost-effective reduction potential of conventional HDVs is 13 to 44%. The overall range of marginal abatement costs of all available reduction options ranging from € -275 to € 1,870 ton CO_2 (CE Delft, 2012).

Figure 82 SULTAN core reduction scenario: road transport



Note: Based on SULTAN Scenario R1-b: 60% reduction of direct transport emissions, with a 72% target for road transport.

Source: SULTAN tool (2014), adjusted by CE Delft.

Table 26 Reduction of (direct) GHG emissions by road transport mode (Sultan Core scenario)

Main transport mode	Assumptions of the scenario (development between 2010 and 2050)		Emission reduction compared to 1990 levels to achieve a 72% TTW reduction in road transport in 2050
	Growth in Activity (km)	TTW emissions per km of the entire fleet (g/km)	2050
LDV	27%	-87%	79%
Car	25%	-87%	81%
Van	50%	-85%	68%
Non-LDV	37%	-58%	52%
Bus	58%	-86%	79%
Motor	43%	-75%	54%
Medium truck	36%	-78%	59%
Heavy truck	29%	-69%	44%

Note: Based on SULTAN Scenario R1-b: 60% reduction of direct transport emissions, with a 72% reduction target for road transport.

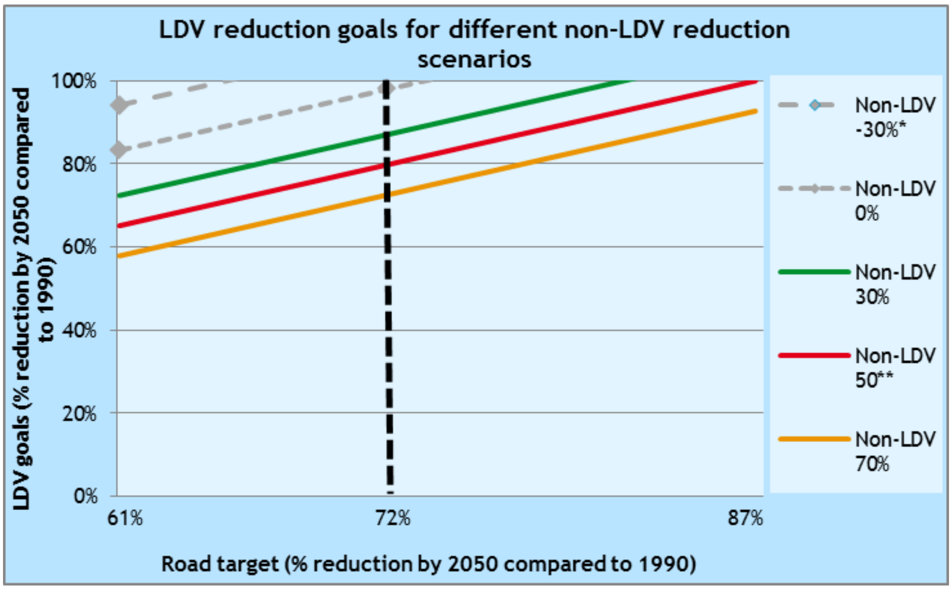
Source: SULTAN tool (2014), adjusted by CE Delft.

As shown in Table 26, the assumptions made for the SULTAN scenario as regards volume, efficiency and CO_2 intensity, result in an overall reduction of 79% by 2050 for LDVs (cars + vans), which is higher than the average road transport reduction of 72% that is assumed for this scenario. The total emissions from other road transport modes (i.e. buses + trucks + motor cycles) decrease relatively less than the average for road transport, resulting in a 52% reduction compared to 1990 by 2050.

Any changes in the assumptions made, result in different reduction goals for LDVs. Again, a scenario analysis has been made to assess the impacts hereof for the LDV emission reduction required, the results of which are shown in Figure 83.

The x-axis shows the overall road reduction goals that resulted from the previous section (60 to 85% with a mid-value of 72%). The Y-axis shows the LDV reductions required for the different overall road goals and for different non-LDV scenarios (trucks + buses + motor cycles). As can clearly be seen in the figure, the two 'worst case' scenarios (grey lines) where other road modes do not reduce their emissions compared to 1990 (0%) or even let their emissions increase compared to 1990 (-30%) are not compatible with the road transport goals, as they would require LDVs to reduce their emissions with more than 100%.

Figure 83 Sensitivity analysis LDV vs. non-LDV reduction targets



* Emissions from HDVs/Motor cycles in 2050 are roughly equal to the 2010 level (= worst case).

** Emission reduction HDVs/Motor cycles based on SULTAN R1b scenario (= mid value). The mid value in SULTAN is 52%, however, due to the large uncertainties in the reduction potentials, rounded numbers have been used.

Table 27 summarises the LDV goals resulting from the more likely scenarios (coloured lines in Figure 83). The lowest LDV reduction under these scenarios is 58% (grey box), but as this would imply that HDVs reduce emissions relatively more (70%) than LDVs (58%) this scenario is highly unlikely to be feasible or cost-effective. Therefore, the range assumed for LDVs ranges from 65 to 100%, with a mid-value of 80%. The mid value has been determined with the average of the reduction goals that resulted from the SULTAN scenario (i.e. the rounded 50% reduction of HDVs/Motor cycles for different road transport goals).

Table 27 **Sensitivity analysis on LDV reduction goals**

Year	Road transport reduction target (from the analysis above)	Emission reduction of non-LDV modes by 2050 compared to 1990			Best guess
		30%	50%*	70%	
2050	61%	72%	65%	58%	65 to 100% **(80%)**
2050	72%	87%	**80%**	73%	
2050	87%	107%	100%	93%	

* Emission reduction HDVs/Motor cycles based on SULTAN R1b scenario (= mid value). The mid value in SULTAN is 52%, however, due to the large uncertainties in the reduction potentials, rounded numbers have been used.

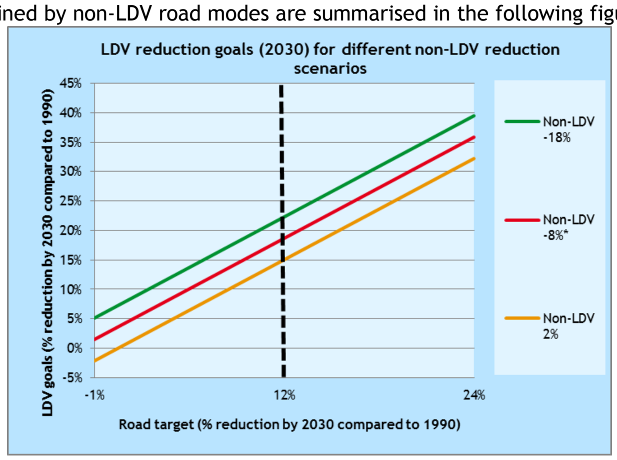
The core reduction scenario of SULTAN assumes a relatively larger emission reduction from cars (81%) compared to vans (68%), mainly due to the significantly larger volume growth assumed for vans (see Table 26).
When applying the same relative effort to the range that resulted from Table 25, total emissions from cars should be reduced 66 to 100% (with a most likely value of 83%), while total emissions from vans should be reduced with 55 to 100% (with a most likely number of 70%)[35]. Again, the implications for the 2030 targets are summarised in the following text box.

LDV reduction goals for 2030

As mentioned above, the European Council has recently committed to a 30% reduction target for non-EU ETS sectors by 2030 compared to 2005. If the same target is to be met by road transport, it would translate into an intermediate target of 12% reduction by 2030 compared to 1990.

The analysis presented in this section for 2050 has been replicated for these 2030 reduction goals, with a bandwidth of 20 to 40% reduction compared to 2005, which equals -1 to 24% reduction compared to 1990.

Again, the SULTAN core reduction scenario is taken as a starting point. This scenario assumes a reduction of 20% by 2030 compared to 1990 for road transport, and hence, is somewhere in the upper half of this range. In this scenario, emissions from non-LDV road modes increase with 8% by 2030 compared to 1990, which is assumed as the mid value. The result from varying reductions obtained by non-LDV road modes are summarised in the following figure.



* Emission reduction HDVs/Motor cycles based on SULTAN R1b scenario (= mid value).

[35] The mid values are slightly different from the SULTAN core reduction scenario due to the use of rounded reduction potentials in the calculations.

The figure shows that when assuming LDVs will reduce their emissions relatively more or equally to HDVs, **2030 reduction goals for LDVs range from 1 to 40% with a mid-value of 19% compared to 1990.** This translates into reduction goals for cars ranging from 2 to 43% with a mid-value of 20% and for vans ranging from 0% to 10% with a mid-value of 5% when assuming similar relative reduction efforts as those assumed in SULTAN's core reduction scenario (34% for cars and 8% for vans in 2030).

A.2.3 Required target levels for new LDVs

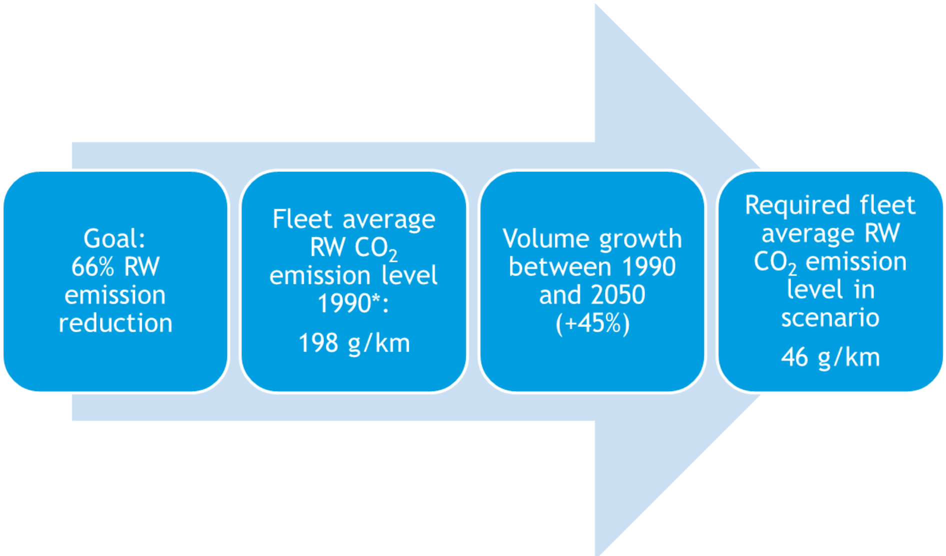
This section explores a wide range of scenarios with different assumptions for the required emission reduction, volume development and share of biofuels, which results in a set of target levels for cars and vans. First, the method used is described.

Method used to determine target levels

To determine the required target level for different scenarios, the same method has been applied to cars and vans. There are four main factors of influence on the target levels:
- the required emission reduction;
- the volume growth;
- the share of biofuels;
- the share of AFVs (and whether BEVs or PHEVs/REEVs are used).

The average Real World (RW) fleet emissions (in g/km) in 1990 have been taken as a starting point (for cars this is 198 g/km). When ignoring the impact of biofuels, the required fleet average RW emissions in 2050 can be determined with the required emission reduction and the expected volume growth, as illustrated in Figure 84. In the following example, the absolute emission reduction for LDVs in 2050 compared to 1990 is 66%. However, the fleet average reduction as higher as also some volume growth needs to be compensated (in this example 45%). Therefore the 2050 fleet average RW CO_2 emissions needs to be reduced by 77% compared to 1990, resulting in a fleet average RW emissions factor of 46 g/km by 2050.

Figure 84 Determining fleet average RW emissions



* Assumed Type Approval (TA) emissions of 180 g/km with a divergence between RW and TA of 18 g/km.

With the numbers calculated above, the fleet average RW emissions in 2050 (or in 2030) (46 g/km in the example above) can be translated into targets expressed for CO_2 emissions on the NEDC Type Approval test for new vehicles. This requires assumptions on development of the divergence between Type Approval (TA) and RW emissions and the age distribution of the fleet (i.e. share of new vehicles, one year old vehicles, two year old vehicles, etc.). The first has been assumed to increase from 19 g/km in 1990 to 45 g/km from 2015 onwards for conventional cars and from 21 g/km to 39 g/km for conventional vans (based on analysis provided in Annex A). The age distribution of the fleet is assumed to remain constant over time, so equal to today's age distribution. No account has been taken of potential differences in the average mileage of different powertrains or size segments.

Given the TTW CO_2 perspective of the passenger cars and vans target, vehicles on electricity and hydrogen count as zero emission, both in TA and in RW terms (i.e. they have no divergence between TA and RW emissions). PHEVs use both electricity and conventional fuel, and have a larger divergence between TA and RW emissions compared to conventional cars, as they have the above mentioned divergence when driving on the conventional engine and have an additional divergence due to the difference in the assumed and RW share of electricity in the kilometres driven. The share of AFVs therefore also impacts the divergence between RW and TA emissions, and hence, the required TA target levels.

The target levels then result from the best fitting linear extrapolation between 2020/2021 and 2050 (or 2030) target levels which, with the age distribution of the European fleet and the total divergence between TA and RW emissions, results in the required RW fleet average emissions by 2050 (or 2030) (-66%).

However, the situation is a bit different when biofuels are taken into account. Given the TTW CO_2 perspective of the passenger cars and vans target, the WTW benefits of biofuels are not rewarded. As mentioned previously, the IPCC definition does count biofuels as zero, and hence, they do contribute to the transport emission goals of the EU. Therefore, target levels could be less strict in case biofuels are applied. The example shown in Table 28, shows that in case fleet average TA emissions would need to reach 30 g/km and assuming cars with an ICE can maximally reduce TA emission levels to 70 g/km (TA) without changing the vehicle performance, the TA value in a scenario with 50% biofuels is much higher than in a scenario without. The share of biofuels reduces the TA CO_2 emission level in IPCC terms. Hereafter, the share of ICEVs/ZEVs can be calculated with the TA CO_2 emissions (IPCC) and the required fleet average CO_2 emissions (g/km).

Table 28 **Fleet average TA CO_2 emissions for different biofuel shares**

Scenario	Fleet average TA CO_2 in 2050	ICEVs TA CO_2 in 2050*	Share of biofuels	ICEVs TA CO_2 in 2050	ICEV share***	ZEV share
	g/km	g/km (TTW)	%	g/km (IPCC)	%	%
Without biofuels	30	70	0%	70	43%	57%
With biofuels	30	70	50%	35**	86%	14%

* Assumed that ICEVs can maximally reduce their TTW emissions to 70 g/km.

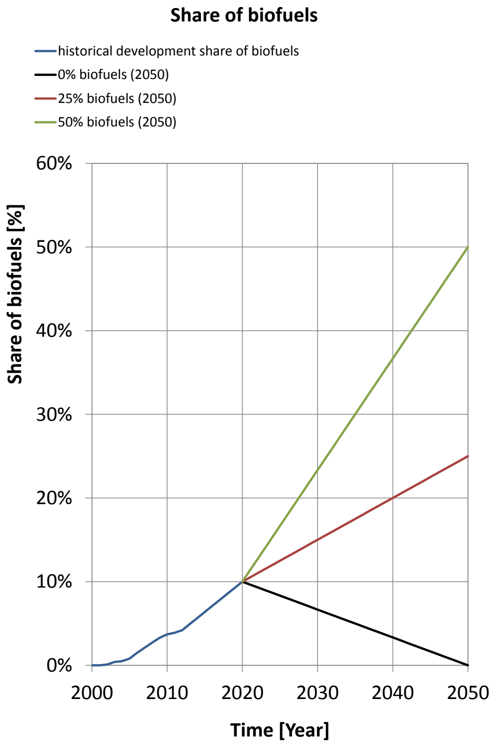
** 50% biofuel which counts as zero according to the IPCC definition, hence: 70 g/km (TTW) * 50% = 35 g/km (IPCC).

*** The required share of ZEVs is calculated based on the highest share of ICEVs resulting in the target. In the example above, 30 g/km (TA target) = 70 g/km (IPCC of ICEVs) * 43%. The remainder is met with ZEVs which have 0 g/km.

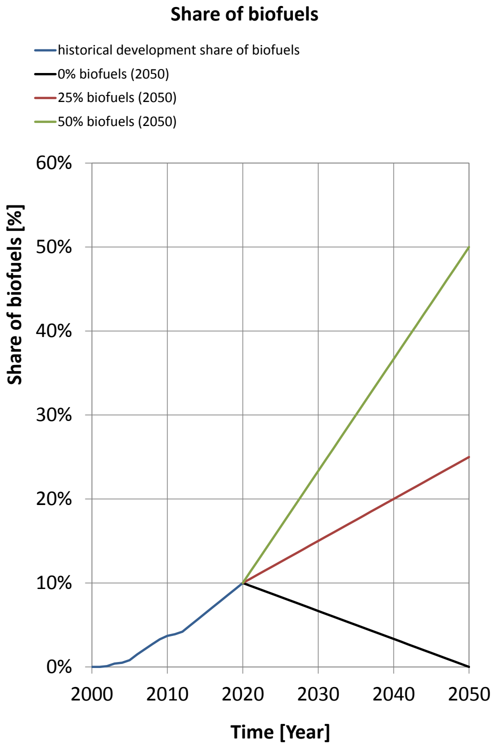
Two points are important to highlight. First, the minimal emission level of ICEVs assumed for this analysis is not a fixed level and it will depend on the costs of deploying additional technology on ICEVs instead of alternative low CO_2 options. If the resulting emission level turns out lower (i.e. more efficient ICEVs) than 70 g/km, the required shares of ZEVs is lower as well. Likewise, higher ICEV emission levels would require higher shares of ZEVs

Second, literature is divided about the use of biofuels in the passenger car and van segment: in the SULTAN scenario the share of biofuels for passenger cars and vans is 53% and 38% in 2050, respectively. However, others argue that the share of biofuels for LDVs should be very low to ensure availability of biofuels for other modes (EC, 2011b); (Smokers, et al., 2013). Therefore, three scenarios have been assessed (summarised in Figure 85): one with no biofuels in 2050 (0%), one with moderate levels of biofuels (25%) and one with high levels of biofuels (50%). For comparison, the share of biofuels was 3% for cars (265 PJ) and 4% for vans (43 PJ) in 2010. Hence, 50% may seem like a very strong growth, however, as ICEVs will have become much more efficient by then, 50% of their fuel consumption is a smaller increase in absolute terms (PJ). For the mid scenario for cars for example, 50% biofuel use of cars roughly translates in an absolute amount of 650 PJ by 2050, given the efficiency improvements in TTW emissions between 2010 and 2050.

Figure 85 Biofuel scenarios for cars and vans 2050



a) Passenger cars



b) Vans

Passenger car scenarios

As described in the previous paragraph, a wide range of scenarios have been assessed to investigate the uncertainty in several underlying assumptions. These underlying assumptions and the values assessed are summarised in Table 29. As shown, 54 scenarios (3 x 3 x 3 x 1 x 2 = 54) have been assessed for 2050 and 36 for 2030.

Table 29 Values used for different assumptions in the scenario definition

Assumption	Values 2030	Values 2050	Note
Emission reduction compared to 1990	2% 20% 43%	66% 83% 100%	This is the range in reduction goals for cars which has been determined in Section A.2.2.
Volume growth	50% 70% 90%	55% 75% 95%	The volume growth between 1990 and 2010 was 40% (PRIMES). SULTAN assumes a 25% volume growth between 2010 and 2050. Hence, the mid value is 75% for 2050 (1.4*1,25). For 2010-2030, SULTAN assumes 22% volume growth. Hence, the mid value is 70% for 2030. The lower/upper value are chosen ±20%.
Biofuel share	0% 20%	50% 25% 0%	See Figure 85.
RW/TA divergence	Increasing (19 g/km in 1990 to 45 g/km from 2015-2050)		The RW/TA factors are based on TNO (2015). Details can be found in Annex A.

Assumption	Values 2030	Values 2050	Note
AFVs in the fleet	- 100% ZEVs: BEVs and FCEVs - 100% PHEVs		As BEVs/FCEVs have zero TTW emissions and no divergence between TA and RW emissions, resulting target levels in scenarios with these vehicles are different compared to a scenario with PHEVs. Due to limitations of the model used, it was not possible to assess combined scenarios.[36]

Although target levels for new cars depend on the share of biofuels and type of AFVs used, the resulting RW fleet average emission level by 2050 (defined as g/km with an IPCC definition) is the same. As summarised in Table 30, this fleet average emission level by 2050 ranges from 0 g/km for the 100% reduction scenarios to 46 g/km for the least ambitious scenario (-66%) with lowest volume growth (+45%). The mid value is 20 g/km.

Table 30 Required average RW fleet emissions by 2050 for different scenarios

Scenario	Average RW fleet emissions in 1990	Volume growth between 1990-2050	Emission reduction by 2050 compared to 1990	Required average RW fleet emissions by 2050
a	198 g/km	45%	66%	46 g/km
b	198 g/km	65%	66%	41 g/km
c	198 g/km	85%	66%	36 g/km
d	198 g/km	45%	83%	23 g/km
e	**198 g/km**	**65%**	**83%**	**20 g/km**
f	198 g/km	85%	83%	18 g/km
g	198 g/km	85%	100%	0 g/km

The next sub-sections translate these fleet average emission levels into target levels for new passenger cars for different shares of biofuel in case all AFVs are Zero Emission Vehicles (ZEVs) or Plug-in Hybrid Electric Vehicles (PHEVs), respectively. This has been done for both the 2025, 2030 and 2050 target levels. These analyses take the 2050 reduction goals to meet the low carbon roadmap goals as a starting point.

In text boxes, these target levels resulting from this analysis are compared to the target levels that result from the analysis which takes the recently agreed reduction goals for non-ETS sectors as a starting point. This will show whether the target levels set to meet the 2050 goals for transport are sufficient for reaching the 2030 goals as well.

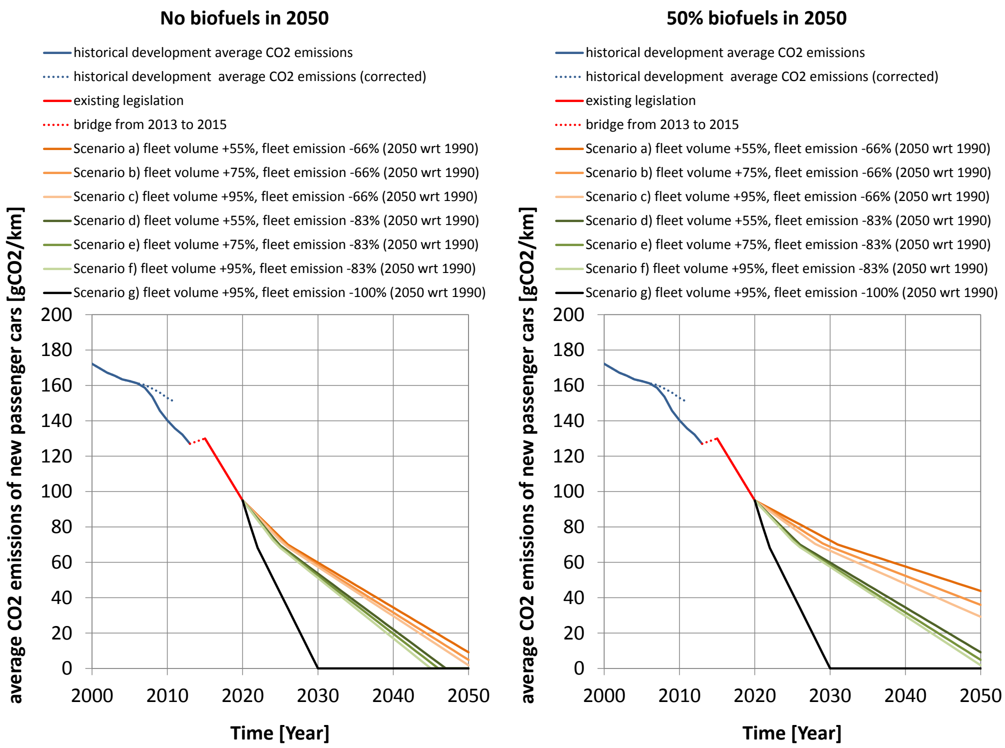
Target levels for new passenger cars when all AFVs are ZEVs

As explained previously, the fleet average RW emissions that must be met by 2050 can be translated into target levels for new passenger cars with the current age distribution for cars and the development of the RW/TA divergence. Figure 86 summarizes the results for target levels that are compatible with the methods of the existing CO_2 Regulation (i.e. TTW CO_2-based – NEDC type approval with no credits for biofuels) for a wide range of

36 As meeting 2050 targets requires the uptake of either FEVs/FCEVs or PHEVs, no scenarios have bene constructed with just ICEVs.

scenarios. Annex A.2.4 summarises these results in terms of real world TTW CO_2-based target levels.
The left hand side of Figure 86 summarises the scenarios in case no biofuels are used, while the right hand side summarises the scenarios in case a high level of biofuels is used. The orange coloured lines represent the scenarios where the overall reduction in emissions is -54% (the lower bound of the Carbon Roadmap goals) and where other (road and non-road) transport modes reduce their emissions significantly. In these scenarios, cars have to reduce their emissions with 'only' 66% compared to 1990. Likewise, the black line is another extreme scenario in which the upper bound of the Roadmap goals is aimed for (-67%) while other (road and non-road) modes reduce their emissions relatively modest. This scenario generates the same results irrespective of assumed volume growth with a goal of a 100% reduction. Finally, the green coloured scenarios represent the mid scenarios, which would result in a 60% overall reduction of transport, and where other (road and non-road) modes reduce their emissions in line with the assumptions made in Sultan (83% goal for cars).

Figure 86 TA new passenger car targets for different emission reduction levels (AFVs = 100% ZEV)



Note: The divergence between TA and RW emissions of ICEVs assumed to increase from 19 g/km in 1990 to 45 g/km from 2015 onwards; all AFVs required are ZEVs which have no divergence.

Note: Calculations of the required target levels have been based on the design of the existing Regulation (i.e. TTW CO_2-based – NEDC type approval with no credits for biofuels).

Note: The difference in slope within the scenarios is caused by the fact that from these points onwards, target levels cannot be met by ICEVs alone and hence, the share of AFVs increases. As AFVs have a different RW/TA divergence, this causes a discontinuity in target levels when translating required RW emissions in appropriate target levels.

A few general conclusions can be drawn from Figure 86:

- The overall bandwidth in target levels is broader in case biofuels are used: ranging from 0 to 60 g/km in 2030 in case no biofuels are used and from 0 to 72 g/km in 2030 if 50% conventional fuel is replaced by biofuels in 2050.
- The weaker the overall emission reduction goal, the larger the bandwidth in resulting target levels (i.e. the larger the impact of volume growth). E.g. in case 50% biofuels are used, the bandwidth for a 66% reduction is 67 to 72 g/km in 2030 and for a 83% reduction the bandwidth is 57 to 60g/km in 2030.

Table 31 shows the bandwidth in required TA TTW target levels for different scenarios from Figure 86. As shown, the bandwidth in target levels for 2025 ranges from 43 to 84 g/km, with a mid-value of 70 g/km. For 2030 it ranges from 0 to 72 g/km, with a mid-value of 55 g/km.

Table 31 Top-down assessment of car targets (AFVs = 100% BEVs)

Scenario	Target level new cars TTW NEDC in g/km			Required share AFVs* in new vehicle sales 2050
	2025	**2030**	**2050**	
Worst case scenario 100% reduction, 95% volume growth, 0% biofuel	43	0	0	100%
Lower-mid scenario 83% reduction, 95% volume growth, 0% biofuel	68	51	0	100%
Mid scenario 83% reduction, 75% volume growth, 25% biofuel	70	55	0	100%
Upper-Mid scenario 83% reduction, 55% volume growth, 50% biofuel	74	60	9	87%
Best case scenario 66% reduction, 55% volume growth, 50% biofuel	84	72	44	37%

* AFVs in the new vehicle sales are all BEVs (i.e. ZEVs with no divergence between TA and RW emissions).

Note: RW/TA factor assumed to be increasing (45 g/km by 2050), see Annex A.

Note: Calculations of the required target levels have been based on the design of the existing Regulation (i.e. TTW CO_2-based – type approval with no credits for biofuels).

Compatibility of the target levels for realising the 2030 reduction goal of non-ETS sectors
The target levels presented above have been estimated to result in the required RW emission reduction to meet the 2050 reduction goals for Transport. However, as already outlined in the previous section, more recently, the Council committed to a target of 30% by 2030 compared to 2005 for non-ETS sectors. Target levels for 2025 and 2030 have also been modelled with this goal as a starting point, in which case cars are likely to have to reduce their emissions with 2 to 43%:

Scenario	Target level new cars TTW NEDC in g/km		Required share AFVs* in new vehicle sales 2050
	2025	2030	
Worst case scenario ** 43% reduction, 90% volume growth, 0% biofuel	0	0	100%
Lower-mid scenario 20% reduction, 90% volume growth, 0% biofuel	43	0	100%
Mid scenario 20% reduction, 70% volume growth, 20% biofuel	65	44	37%
Upper-Mid scenario 20% reduction, 50% volume growth, 20% biofuel	80	66	5%
Best case scenario 2% reduction, 50% volume growth, 20% biofuel	95	95	0%

* AFVs in the new vehicle sales are all BEVs (i.e. ZEVs with no divergence between TA and RW emissions).

** Theoretically speaking, the emission reduction goal would be met in this scenario if TA emissions from new cars are 0 from 2025 onwards.

The resulting target levels range from 0 to 95 g/km in 2025 and in 2030 as well, depending on the emission reduction, volume growth and biofuel share. Except for the worst case scenario, this range falls within the range presented in the analysis above when taking 2050 as a starting point (see Table 31). Hence, most of the target levels presented in the 2050 analysis will also result in the required RW emission reduction to meet the newly agreed 2030 reduction goals of the Council, except the 2030 worst case scenario. However, this scenario requires a target level of 0 already in 2025, which is highly unlikely to be feasible.

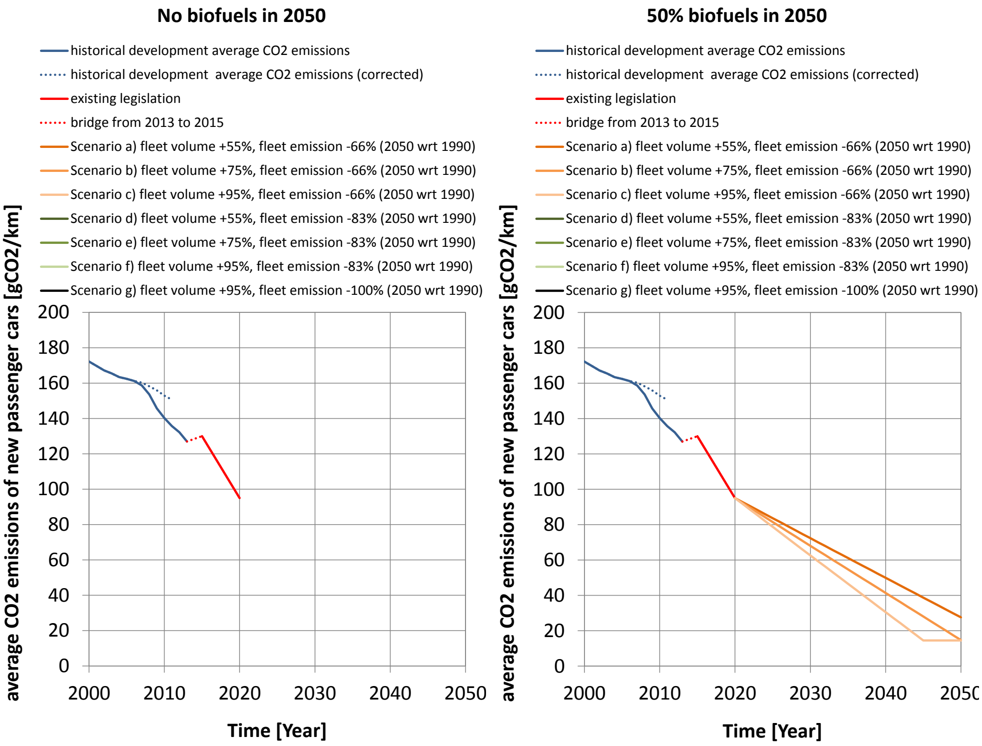
Target levels for passenger cars when all AFVs are PHEVs

The results presented above assumed that the emission reduction that cannot be met with ICEVs (in our analysis this is assumed to be emission levels below 70 g/km) are realised with ZEVs, either BEVs or FCEVs. However, in reality this may partially be met with PHEVs. This has two implications for the target levels and required shares of ZEVs presented above. First, the required share of AFVs will be higher, as a PHEV reduces the emission level less significantly compared to a ZEV. Second, with increasing shares of PHEVs, the TTW target levels need to be stricter, due to the fact that ZEVs have no divergence between TA an RW emissions, while PHEVs have a RW/TA divergence that is likely to be higher than that of ICEVs.

The development of the RW/TA factor of PHEVs is highly uncertain though. For ICEVs it is expected that most flexibilities in the test procedure have been exploited and therefore, the absolute divergence (45 g/km) is kept constant between 2015 and 2050. However, for PHEVs/REEVs the RW/TA divergence is highly dependent on the (development of the) share of electric kilometres in the EU. As an example, PHEVs or REEVs with an electric range of 100 km are assumed to drive 80% of their kilometres electric, according to the TA procedure. If in RW conditions only 50% of the kilometres are driven by these vehicles would be electric, the RW/TA factor for these vehicles would be 4.05 (44 g/km in RW conditions with TA emissions of 14.5). In contrast, an ICEV with TA of emissions of 70 g/km and RW emissions of (70+45) 115 g/km has a RW/TA factor of 1.64, see Annex A). Therefore, the larger the amount of PHEVs in the share of EVs, the stricter the TTW-based targets need to be to compensate for the relatively larger gap between TA and RW emissions.

To explore this impact, an extreme scenario in case only PHEVs are used (i.e. all AFVs are PHEVs) is explored, the results of which are shown in Figure 87 and Table 32. Annex A.4 summarises these results in terms of real world TTW CO_2-based target levels.

Figure 87 TA passenger car targets for different emission reduction levels (AFVs are 100% PHEVs)



Note: The divergence between TA and RW emissions of ICEVs assumed to increase from 19 g/km in 1990 to 45 g/km from 2015 onwards (also for PHEVs driving with the conventional motor); all AFVs required are PHEVs, which are assumed to drive 50% of their kilometres in the electric mode.

Note: Calculations of the required target levels have been based on the design of the existing Regulation (i.e. TTW CO_2-based - type approval with no credits for biofuels).

The results of
Figure 87 (and Table 32 below) show that none of the reduction goals for cars can be met in case there would be only PHEVs and no biofuels. With a higher share of biofuels, (some of the) scenarios with the least stringent reduction goal (66%) can be met. In order to reach more ambitious reduction goals (83% and 100%), ZEVs are required.

Table 32 Top-down assessment of car targets with 100% PHEVs

Scenario	Target level new cars TTW NEDC in g/km			Required share AFVs* in new vehicle sales 2050
	2025	2030	2050	
Worst case scenario ** 100% reduction, 85% volume growth, 0% biofuel	-	-	-	-
Lower-mid scenario ** 83% reduction, 85% volume growth, 0% biofuel	-	-	-	-
Mid scenario ** 83% reduction, 65% volume growth, 25% biofuel	-	-	-	-
Upper-Mid scenario ** 83% reduction, 45% volume growth, 50% biofuel	-	-	-	-
Best case scenario 66% reduction, 45% volume growth, 50% biofuel	84	72	28	76%

* AFVs in the new vehicle sales are all PHEVs (i.e. PHEVs which have divergence between TA and RW emissions).

** The lowest possible target levels in case all AFVs are PHEVs are not sufficient to meet the required emission reduction in this scenario.

Note: RW/TA factor assumed to be 45 g/km (also for PHEVs driving with the ICE) and a 50% share in electric kilometres for PHEVs in RW conditions (in contrast, TA share is 80%). Hence, the total RW/TA divergence for PHEVs is 44.8 g/km. See also Annex A.

Note: Calculations of the required target levels have been based on the design of the existing Regulation (i.e. TTW CO_2-based – type approval with no credits for biofuels).

The following text box explores the implications of the recently agreed upon reduction goals for non-ETS sectors in case all AFVs are PHEVs.

Compatibility of the target levels for realising the 2030 reduction goal of non-ETS sectors

In contrast to the 2050 analysis in case all AFVs are PHEVs, PHEVs can result in a sufficient RW emission reduction to meet the 30% reduction goals by 2030 compared to 2005 of the Council. Again, target levels for 2025 and 2030 have also been modelled with this reduction goal as a starting point:

Scenario	Target level new cars TTW NEDC in g/km		Required share AFVs* in new vehicle sales 2050
	2025	2030	
Worst case scenario ** 43% reduction, 90% volume growth, 0% biofuel	-	-	-
Lower-mid scenario ** 20% reduction, 90% volume growth, 0% biofuel	-	-	-
Mid scenario 20% reduction, 70% volume growth, 20% biofuel	61	28	76%
Upper-Mid scenario 20% reduction, 50% volume growth, 20% biofuel	80	64	11%
Best case scenario 2% reduction, 50% volume growth, 20% biofuel	95	95	0%

* AFVs in the new vehicle sales are all PHEVs (i.e. PHEVs with divergence between TA and RW emissions).

** The lowest possible target levels in case all AFVs are PHEVs are not sufficient to meet the required emission reduction in this scenario.

The resulting target levels range from 61 to 95 g/km in 2025 and from 28 to 95 g/km in 2030, depending on the emission reduction, volume growth and biofuel share. However, the worst case and lower mid case (both 0% biofuel) cannot be met with a PHEV scenario, as was the case for the target levels resulting from the 2050 scenario's as well. The best case scenario defined for 2030 can be met without further sharpening of the targets, but this would not be sufficient to meet the 2050 reduction goals as well. The mid and upper mid scenario are feasible to also reach 2050 goals. Or put differently: the 2025 and 2030 target levels resulting from the 2050 analysis are likely to be sufficient for meeting the 2030 reduction goals with an upper-mid scenario. The mid scenario requires stricter targets compared to the results from the 2050 analysis.

Passenger car targets: conclusion

Table 33 summarises the required target levels to meet the 2050 and 2030 reduction goals, respectively. As shown, the target levels for the mid scenarios are stricter for meeting the 2030 goals compared to meeting 2050 goals.
The bandwidth for 2025 ranges from 0 to 95 g/km, with mid values of 65 and 70 g/km. The bandwidth for 2030 ranges from 0 to 95 g/km as well, with mid values of 44 and 55 g/km.

Table 33 Summary of target levels for cars for 2025 and 2030

	Target levels of new passenger cars in g/km	
	Mid value 2025 (bandwidth in between brackets)	Mid value 2030 (bandwidth in between brackets)
Target levels required to meet 2050 goal	**70** (43* to 84 g/km)	**55** (0 to 72 g/km)
Target levels required to meet 2030 goal	**65** (0 to 95 g/km)	**44** (0 to 95 g/km)

* Assuming that all AFVs are zero-emissions; in case these are (partly) PHEVs, the lower end of the bandwidth will be lower, up to 0 g/km).

Most scenarios require ZEVs and cannot be met with PHEVs alone (except for the scenarios with the least stringent reduction goals and with biofuels.

Van scenarios

As described in the previous paragraph, a wide range of scenarios have been assessed to investigate the uncertainty in several underlying assumptions. These underlying assumptions and the values assessed are summarised in Table 34. As shown 27 scenarios (3 x 3 x 3 x 1 x 1 = 27) have been assessed for 2050 and 18 scenarios for 2030.

Table 34 Values used for different assumptions in the scenario definition

Assumption	Values 2030	Values 2050	Note
Emission reduction	0% 5% 10%	55% 70% 100%	This is the range in reduction goals for vans which has been determined in the Section A.2.2.
Volume growth	60% 80% 100%	90% 110% 130%	The volume growth between 1990 and 2010 was 40% (PRIMES). SULTAN assumes a 50% volume growth between 2010 and 2050. Hence, the mid value for 2050 is 110%. From 2010-2030, SULTAN assumes a volume growth of 30%. Hence the mid value for 2030 is 80%. The lower/upper value are ±20%.

Assumption	Values 2030	Values 2050	Note
Biofuel share	0% 20%	50% 25% 0%	See Figure 85.
RW/TA divergence	Increasing (21 g/km in 1990 to 39.5 g/km from 2015-2050)		The RW/TA factors can be found in Annex A.
AFVs	100% ZEVs: BEVs & FCEVs		As most vans currently on the market are ZEVs, no scenarios with 100% PHEVs have been assessed.

Although target levels for new vans depend on the share of biofuels, the resulting RW fleet average emission level by 2050 (defined as g/km with an IPCC definition) is the same. As summarised in Table 30, this fleet average RW emission level by 2050 ranges from 0 g/km for the 100% reduction scenarios to 54 g/km for the least ambitious reduction scenario (55%) with lowest volume growth (70%). The mid value is 33 g/km.

Table 35 Required average RW fleet emissions by 2050 for different scenarios (vans)

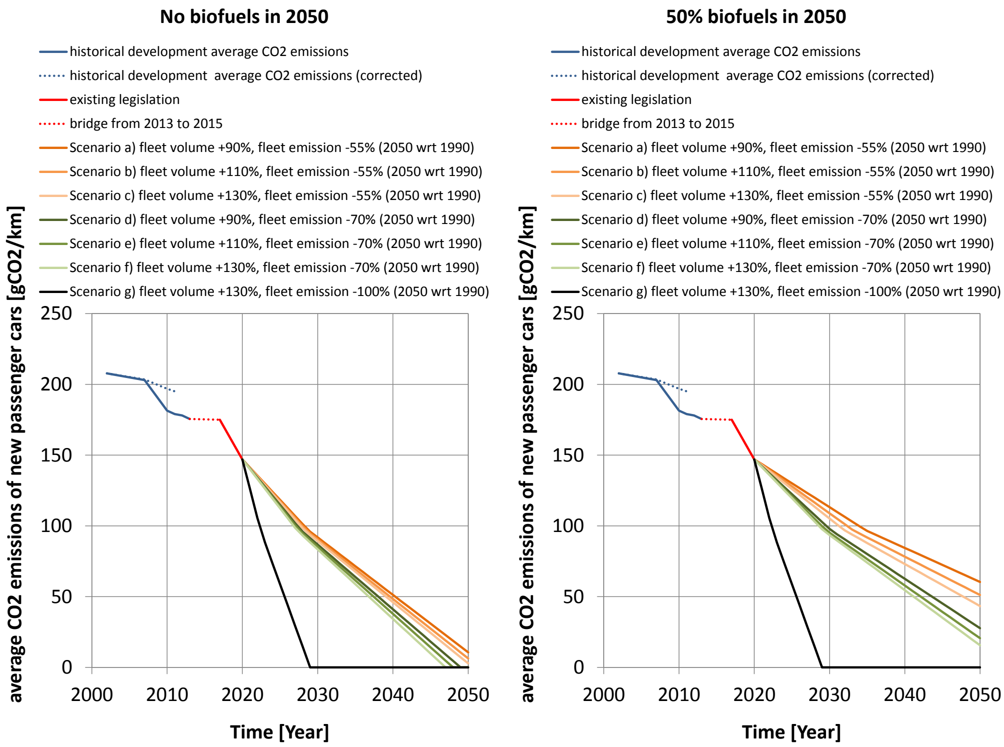
Scenario	Average RW fleet emissions in 1990	Volume growth between 1990-2050	Emission reduction by 2050 compared to 1990	Required average RW fleet emissions by 2050 (g/km IPCC)
a	229 g/km	90%	55%	54 g/km
b	229 g/km	110%	55%	49 g/km
c	229 g/km	130%	55%	45 g/km
d	229 g/km	90%	70%	36 g/km
e	**229 g/km**	**110%**	**70%**	**33 g/km**
f	229 g/km	130%	70%	30 g/km
g	229 g/km	130%	100%	0 g/km

The next sub-sections translate these fleet average emission levels into target levels for new vans for different shares of biofuels. As was the case for passenger cars, the analysis is made with taking the 2050 reduction goals as a starting point. In the text box it is assessed to what extent the target levels are feasible to meet the 2030 reduction goals as well.

Target levels for vans
The analysis presented above for cars is replicated for vans. Hence, the real world fleet average emissions that must be met by 2050 have been translated in target levels for new vans (defined in terms of TA TTW CO_2 emissions with no credits for biofuels) with the current age distribution of vans and the development of the RW/TA divergence. Annex A.4 summarises these results in terms of real world TTW CO_2-based target levels.

As was the case for cars, the left hand side of Figure 86 summarises the scenarios in case no biofuels are used, while the right hand side summarises the scenarios in case a high level of biofuels is used. The orange coloured lines represent the scenarios where the overall reduction in emissions is 54% (the lower bound of the Carbon Roadmap goals) and where other (road and non-road) transport modes reduce their emissions significantly. In these scenarios, vans have to reduce their emissions with ‘only’ 55% compared to 1990. Likewise, the black line is another extreme scenario in which the upper bound of the Roadmap goals is aimed for (67%) while other (road and non-road) modes reduce their emissions relatively modest. This scenario generates the same results irrespective of assumed volume growth with a goal of a 100% reduction. Finally, the green coloured scenarios represent the mid scenarios, which would result in a 60% overall reduction of transport, and where other (road and non-road) modes reduce their emissions in line with the assumptions made in Sultan (70% for vans).

Figure 88 **TA van targets for different emission reduction levels (AFVs = 100% ZEV)**



Note: The divergence between TA and RW emissions of ICEVs assumed to increase from 21 g/km in 1990 to 39.5 g/km from 2015 onwards; all AFVs required are ZEVs which have no divergence.

Note: Calculations of the required target levels have been based on the design of the existing Regulation (i.e. TTW CO_2-based – type approval with no credits for biofuels).

Note: The difference in slope within the scenarios is caused by the fact that from these points onwards, target levels cannot be met by ICEVs alone and hence, the share of AFVs increases. As AFVs have a different RW/TA divergence, this causes a discontinuity in target levels when translating required RW emissions in appropriate target levels.

Similar to the top down assessment of cars, Figure 86 shows that the bandwidth in target levels is larger in case biofuels are applied and the impact of volume growth is larger with the least ambitious scenarios.

Table 36 shows the bandwidth in required TA TTW target levels for different scenarios from Figure 86. As shown, the bandwidth in target levels for 2025 ranges from 59 to 130 g/km, with a mid value of 116 g/km. For 2030, it ranges from 0 to 113 g/km, with a mid value of 89 g/km.

Table 36 Top-down assessment of van targets with 100% ZEVs

Scenario	Target level new vans TTW NEDC in g/km			Required share AFVs* in new vehicle sales 2050
	2025	2030	2050	
Worst case scenario 100% reduction, 130% volume growth, 0% biofuel	59	0	0	100%
Lower-mid scenario 70% reduction, 130% volume growth, 0% biofuel	112	83	0	100%
Mid scenario 70% reduction, 110% volume growth, 25% biofuel	116	89	1	99%
Upper-Mid scenario 70% reduction, 90% volume growth, 50% biofuel	122	98	28	71%
Best case scenario 55% reduction, 90% volume growth, 50% biofuel	130	113	60	38%

* AFVs in the new vehicle sales are all BEVs (i.e. ZEVs with no divergence between TA and RW emissions.

Note: RW/TA factor assumed to be increasing (39.5 g/km by 2050), see Annex A.

Note: Calculations of the required target levels have been based on the design of the existing Regulation (i.e. TTW CO_2-based – type approval with no credits for biofuels).

Compatibility of the target levels for realising the 2030 reduction goal of non-ETS sectors

The target levels presented above have been estimated to result in the required RW emission reduction to meet the 2050 reduction goals for Transport. However, as already outlined in the previous section, more recently, the Council committed to a target of 30% by 2030 compared to 2005 for non-ETS sectors. Target levels for 2025 and 2030 have also been modelled with this goal as a starting point, in which case vans are likely to have to reduce their emissions with 0% to 10%:

Scenario	Target level new vans TTW NEDC in g/km		Required share AFVs* in new vehicle sales 2050
	2025	2030	
Worst case scenario 10% reduction,100% volume growth,0% biofuel	59	0	100%
Lower-mid scenario 5% reduction, 100% volume growth, 0% biofuel	66	0	100%
Mid scenario 5% reduction, 80% volume growth, 20% biofuel	100	66	32%
Upper-Mid scenario 5% reduction, 60% volume growth, 20% biofuel	121	96	1%
Best case scenario 0% reduction, 60% volume growth, 20% biofuel	131	116	0%

* AFVs in the new vehicle sales are all ZEVs with no divergence between TA and RW emissions.

The resulting target levels range from 59 to 131 g/km in 2025 and from 0 to 116 g/km in 2030, depending on the emission reduction, volume growth and biofuel share. Hence, almost the entire bandwidth resulting from the analysis with the newly agreed emission reduction goals for 2030 for non-EU ETS sectors falls within the bandwidth of targets that was estimated with 2050 reduction goals as a starting point (Table 36). Hence, the target levels required for the 2050 reduction goals are likely to be also sufficient for meeting the 2030 reduction goals.

Van targets: conclusion
Table 37 summarises the required target levels to meet the 2050 and 2030 reduction goals, respectively. As shown, the target levels for the mid scenarios are stricter for meeting the 2030 goals compared to meeting 2050 goals.
The bandwidth for 2025 ranges from 59 to 131 g/km, with mid values of 100 and 116 g/km. The bandwidth for 2030 ranges from 0 to 116 g/km, with mid values of 89 and 66.

Table 37 Summary of target levels for vans for 2025 and 2030

	Target levels of new vans in g/km	
	Mid value 2025 (bandwidth in between brackets)	Mid value 2030 (bandwidth in between brackets)
Target levels required to meet 2050 goal	**116** (59 to 130 g/km)	**89** (0 to 113 g/km)
Target levels required to meet 2030 goal	**100** (59 to 131 g/km)	**66** (0 to 116 g/km)

A.2.4 RW target levels for cars and vans
The analysis presented in Section A.2.3 resulted in TTW target levels defined in terms of TA CO_2 emissions. Figure 89 and Figure 90 summarise the target levels in terms of RW CO_2 emissions.

Figure 89 RW target levels for new passenger cars (AFVs = 100% ZEVs)

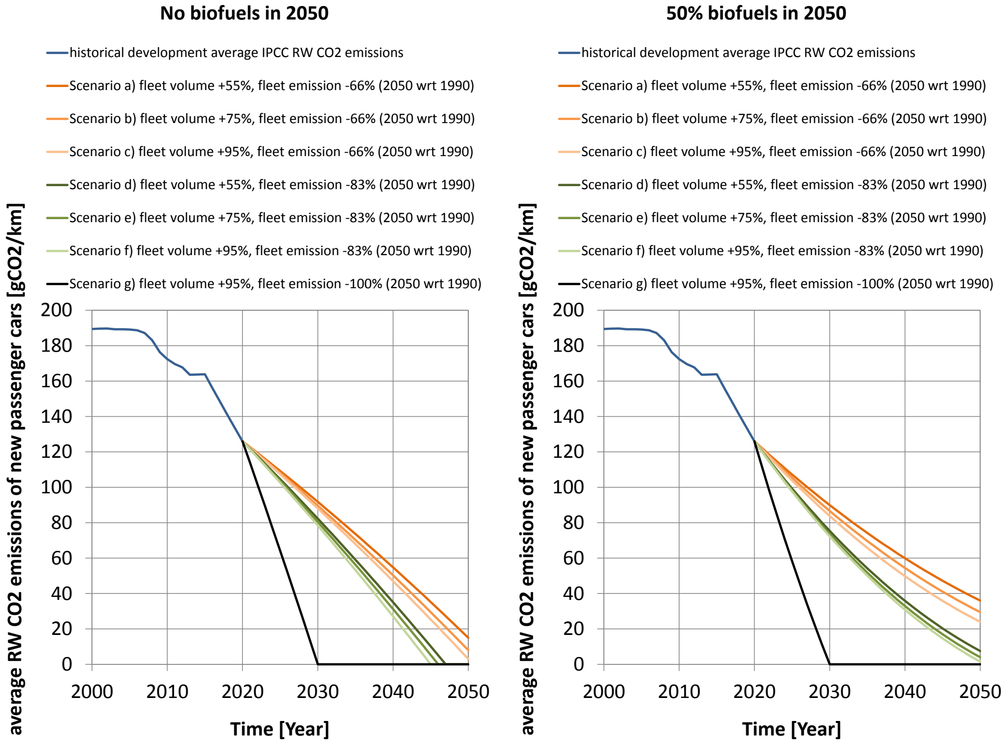


Figure 90 RW target levels for new passenger cars (AFVs = 100% PHEVs)

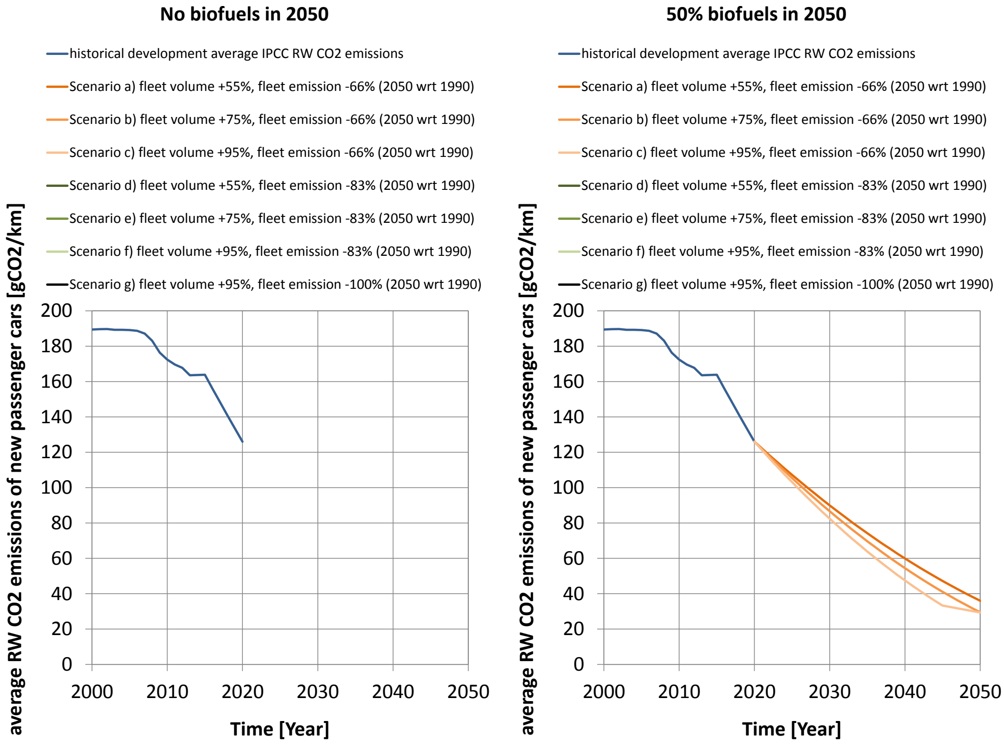
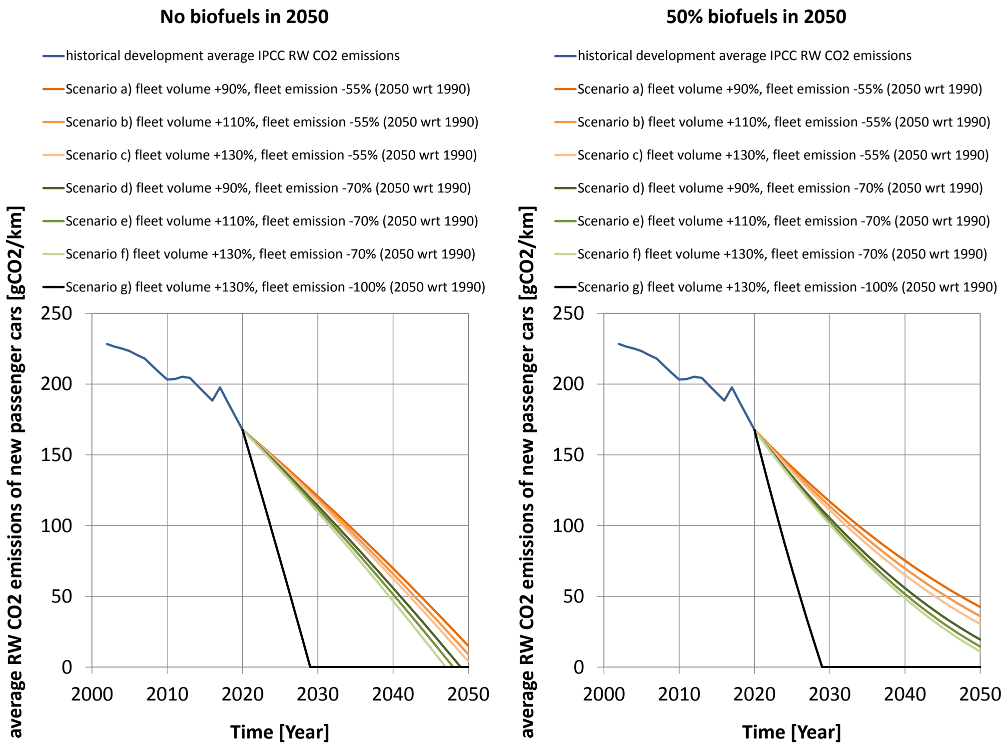


Figure 91 shows the RW TTW target levels for new vans.

Figure 91 RW target levels for new vans (AFVs = 100% ZEVs)



A.3 Comparison to historical reduction rates and other regions

In this section, the historical reduction rates in the EU and reduction rates that are required in other regions of the world are assessed and compared to the results from the top-down and bottom-up analysis.

A.3.1 Historic annual reduction rates

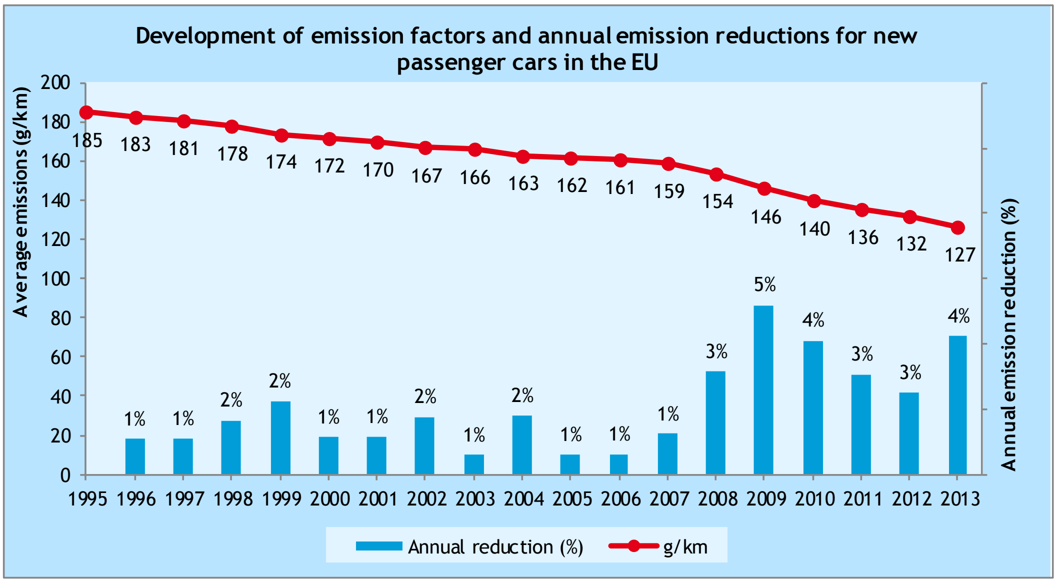
In this section, the required CO_2 emission levels to meet the long-term climate goals (top-down) and economically and technically feasible levels (bottom-up) are put in a historical perspective by comparing required annual reductions towards 2025 and 2030 to historic annual reductions (2002-2013).This gives an indication of the effort expected from OEMs in comparison to their past efforts. It should be kept in mind that close to all CO_2 reductions between 2002 and 2013 have come from ICEVs. It becomes increasingly expensive to further improve the efficiency of ICEVs, and hence, Alternative Fuel Vehicles (AFVs) with very low or zero TTW emissions are expected to gain market share. As a consequence, historic annual reductions may not provide a good indication for determining future reductions.

Figure 92 summarises the development of emission factors (red line) and annual[37] reduction (blue bars) of new passenger car sales in the EU between 1995 and 2013. Two conclusions can be drawn from this figure.

Firstly, the annual reduction rate between 1995 and 2007 was approximately 1% on average. Due to the implementation of the CO_2 regulation for cars, annual reduction rates increased from 2008 onwards to approximately 4% on average. If this average annual reduction rate of 4% is continued after 2013, the 2021 target of 95 g/km will already be achieved in 2020.

Secondly, annual reduction rates have not developed linearly; for the period between 2000-2007 reduction rates varied from 0.7 to 1.7%, and for the period between 2008-2013 they varied from 2.5 to 5.1% (EEA, 2014).

Figure 92 Historic annual reductions from passenger cars in the EU

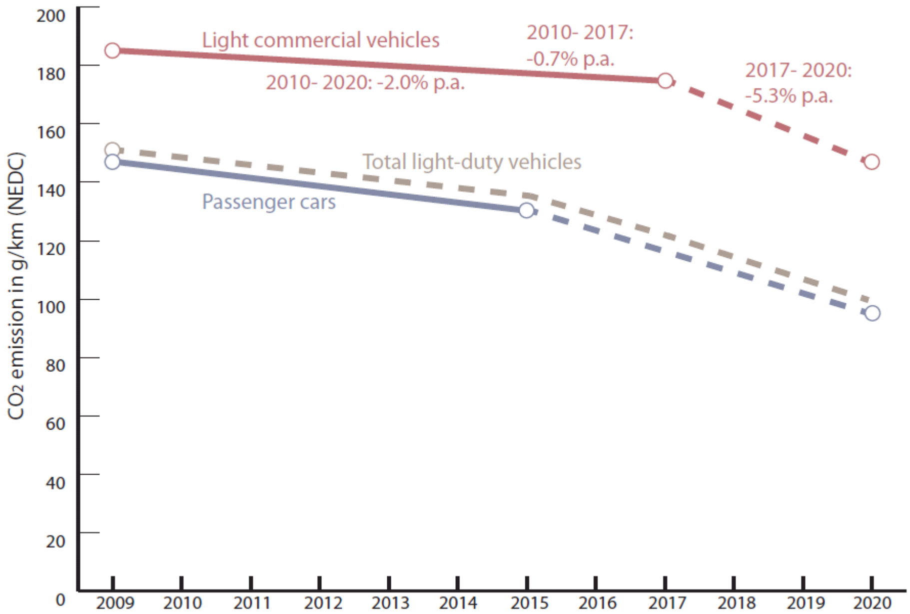


Source: I (ICCT, 2011a)(for 1995-2010); (EEA, 2014)(for 2011-2013).

[37] CO_2 reduction in a certain year compared to the previous year.

The statistics of new van sales in the EU are less well-documented. A study from the ICCT (ICCT, 2011b) does provide a rough indication of required annual reductions from vans. Their results are shown in Figure 93.

Figure 93 Historic and future annual reductions from van sales in the EU



Source: (ICCT, 2011b).

As shown above, the required reduction from 2010 to the first target in 2017 (175g/km) is 0.7% per year. Hereafter, annual reductions need to increase to 5.3% per year (ICCT, 2011b). As mentioned before, data on actual annual reductions is scarcely documented. However, EEA (2014b) shows that the annual reductions are likely to be significantly higher than the required 0.7%. Average CO_2 emissions from new vans in the EU were 180.2 g/km in 2012 and were already below the 2017 target in the year hereafter (173.3 g/km). The annual reduction between 2012-2013 was 3.8%, which is comparable to the average annual reduction of new passenger car emissions.

For comparison, the reduction targets for cars and vans for 2025 and 2030 that resulted from the top-down analysis and their corresponding annual reduction rates between 2020 (vans) or 2021 (cars) and 2025/2030 are summarised in Table 38. The table shows that mid values for cars correspond to annual reduction rates of 7-9% for 2021-2025 and 6% for 2021-2030. For vans the (mid) annual reduction rates are slightly different, but in a similar range: 5-7% for 2020-2025 and 5-8% for 2020-2030.

When interpreting these values it should be kept in mind that historic annual reductions may not provide a good indication for determining future reductions.

Table 38 Annual reduction rates for the 2025 and 2030 targets that resulted from the top-down analysis

	2025 (mid value; bandwidth in between brackets)		2030 (mid value; bandwidth in between brackets)	
	Target level in g/km	Corresponding annual reduction rate until 2025	Target level in g/km	Corresponding annual reduction rate until 2030
Cars				
Target levels required to meet 2050 goal	**70** (43* to 84 g/km)	**7%** (18% - 3%)	**55** (0 to 72 g/km)	**6%** (infinite - 3%)
Target levels required to meet 2030 goal	**65** (0 to 95 g/km)	**9%** (infinite - 0%)	**44** (0 to 95 g/km)	**6%** (infinite - 0%)
Vans				
Target levels required to meet 2050 goal	**116** (59 to 130 g/km)	**5%** (17% - 2%)	**89** (0 to 113 g/km)	**5%** (infinite - 3%)
Target levels required to meet 2030 goal	**100** (59 to 131 g/km)	**7%** (17% - 2%)	**66** (0 to 116 g/km)	**8%** (infinite - 2%)

* Assuming that all AFVs are zero-emissions; in case these are (partly) PHEVs, the lower end of the bandwidth will be lower, up to 0 g/km).

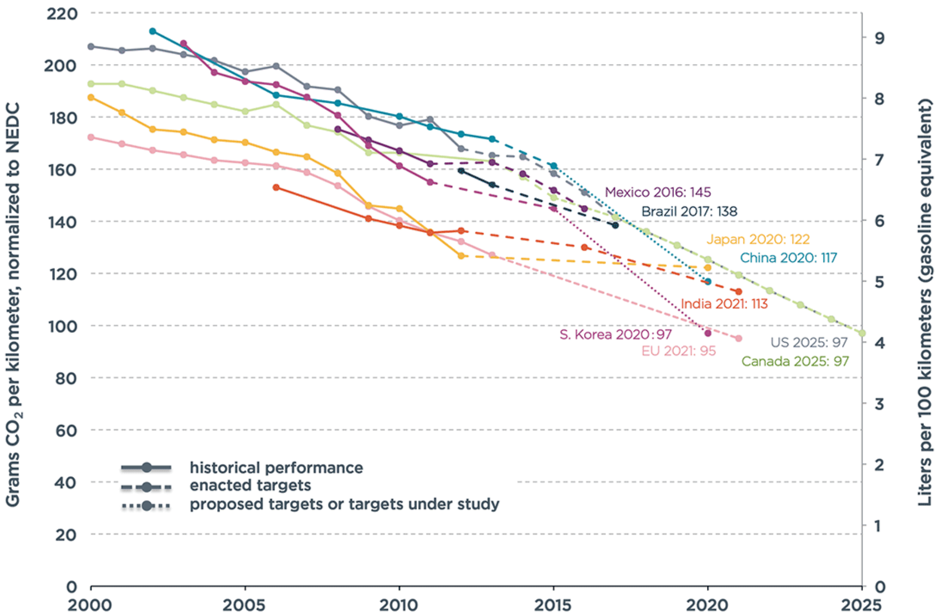
A.3.2 Expected reduction rates in other countries

Manufacturers have to comply with different legislations in different parts of the world. The larger the differences between these regulations, the lower the potential for cost reductions from economies of scales. In case a certain CO_2 reducing technology is required to meet the CO_2 emission target in one region but not in any other, this can result in relatively high additional manufacturer costs for this specific technology for example. Ambition levels and annual reduction rates in other regions of the world can therefore provide some input for the assessment of ambition levels for the EU.

There are several limiting factors reducing the usefulness of this assessment, which should be kept in mind. Firstly, the large number of optional modalities providing flexibility and/or reducing the stringency of the targets that have been implemented in different countries (e.g. super credits, eco-innovations, trading, derogations, etc.) make a comparison of the stringency of the targets inherently difficult. Secondly, most countries have not yet determined their ambition level for the period beyond 2020, which would have been the interesting part for this study at hand. Thirdly, ambition levels are a highly political decision; low ambition levels in other countries do not necessarily imply that they would be appropriate for the EU as well. Finally, car and van fleets across countries are inherently different. In the US/Canada, vehicle size and mass are much larger compared to those used in Japan/China. This has implications for the annual reductions that can be obtained.

The ICCT (ICCT, 2014a) has attempted to translate existing ambition levels for newly sold passenger cars in different countries to a comparable figure.
The results of their analysis are shown in Figure 94 and show that the EU has the relatively most ambitious target level for 2020 when compared to other regions, at least in absolute terms. However, considering that the starting positions (2000) also differ significantly between regions, a comparison of annual reductions can be considered as more relevant. The latter is shown in Figure 95 for both passenger cars and vans.

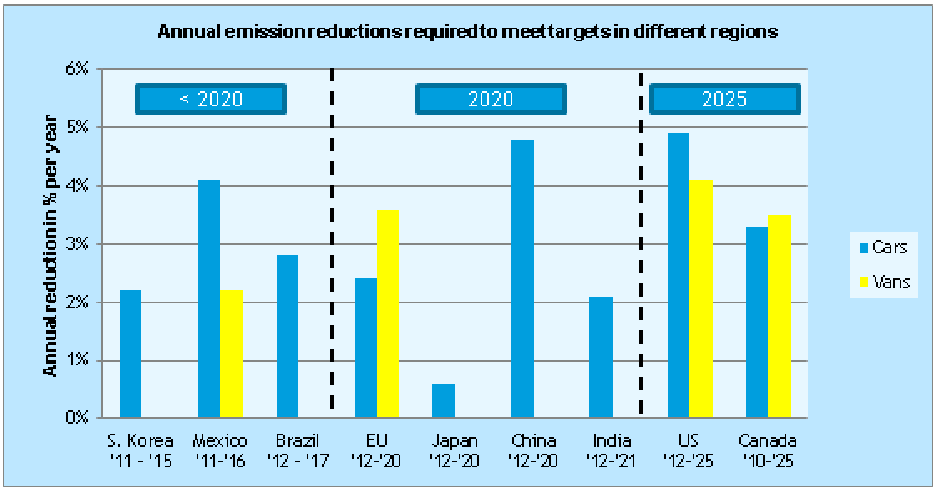
Figure 94 CO₂ emission targets for different regions normalized to NEDC test cycle



Source: (ICCT, 2011a).

Figure 95 evidences that the EU targets for passenger cars and for vans are not the most ambitious in relative terms. Although it should be noted that the annual reductions that are shown are based on different target years and hence, it would be fairest to only compare those countries that have roughly comparable implementation years and target dates.

Figure 95 Comparison of annual reductions from implementation to target (passenger cars and vans)



Source: (ICCT, 2014b), adjusted by CE Delft.

A.4 Target levels for policy variants

The target values that have been used in the assessment of the policy variants have been chosen by the client, DG CLIMA. They are also shown in Figure 96 for cars and in Figure 97 for vans (vans). For comparison also the target values resulting from the analysis in the previous sections have been indicated.

This comparison shows that targets based on a 3% annual reduction will only be sufficient for meeting the overall GHG emission reduction goals for 2030/2050 in the 'best case' scenario, i.e. when other sectors and transport modes achieve relatively high GHG emission reductions, volume growth in passenger cars is low and biofuel share increases up to 50% in 2050.

Also the targets based on a 4% annual reduction require a scenario close to these 'best case' developments and therefore carry a high risk of being insufficient for meeting the 2030/2050 overall reduction goals.

With the reduction targets based on a 6% annual reduction rate there is a higher chance of meeting the overall GHG emission reduction goals. For cars these target values are slightly above the mid-values for the targets needed for meeting the 2050 reduction goals but still about 10 g/km above the mid-estimates for meeting the 2030 reduction goal for non-ETS sectors.
For vans the targets based on 6% are just below the mid-values for the targets needed for meeting the 2050 reduction goals and also about 10 g/km above what is needed for meeting the non-ETS goal for 2030.

For a more robust reduction pathway towards meeting the long term GHG emission reduction goals, that also allow for lower shares of biofuel, higher volume growth and/or a lower GHG emission reductions in other sectors, significantly stricter targets would be needed.

Figure 96 Target values (TTW, NEDC) for cars as used in the quantitative assessment and needed for meeting long term GHG emission reduction goals

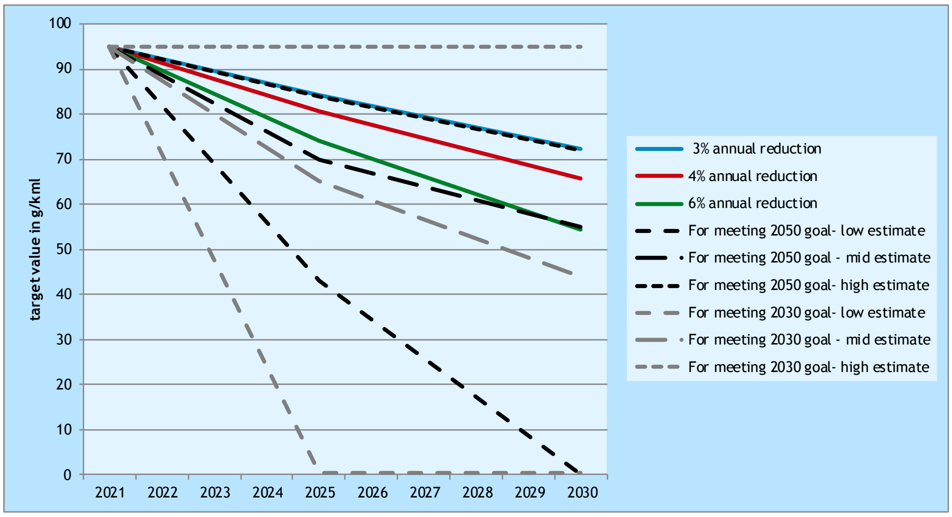
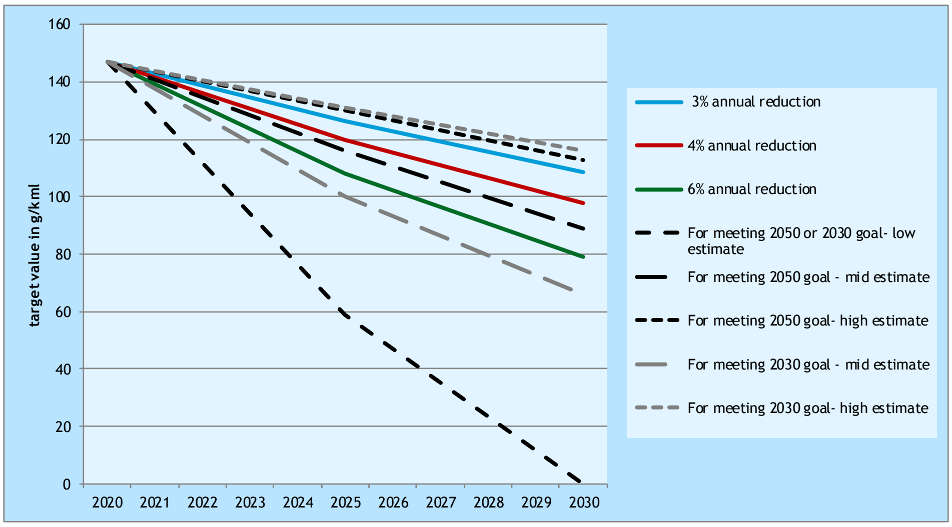


Figure 97 Target values (TTW, NEDC) for vans as used in the quantitative assessment and needed for meeting long term GHG emission reduction goals



Annex B Additional data on the level of ambition

B.1 Introduction

An important assumption made in the top-down assessment of the level of ambition is the divergence between Type Approval (TA) and Real World (RW) emissions, which impacts both TA-based and RW-based target levels for cars and vans. Annex B.2 and B.3 summarise the main assumptions made in the top-down assessment for this divergence for cars and vans, respectively.

B.2 Assumed RW/TA divergence for cars

In 1990, the assumed RW/TA factor for cars was 1.1 (TNO, 2016). In other words, RW emissions were 10% higher than the emission level determined during the TA procedure. The TA emission level in 1990 was 180 g/km and hence, the absolute divergence was 18 g/km. It is assumed that this divergence was mainly caused by differences between:

- real world driving behaviour and the NEDC cycle;
- real world meteorological circumstances and laboratory circumstances.

Since the announcement of the first CO_2 regulation for cars, the use of flexibilities has resulted in an increased gap between TA and RW CO_2 emissions.

From TNO, 2016 it can be derived that for passenger cars the RW emissions are approximately 45 g/km higher than the type approval values and this quite independent of the actual TA CO_2 emission values and fuel type.

Based on literature and research it is assumed that for ICEVs, there are not many more flexibilities to be exploited in the type approval test. Therefore, if a business as usual scenario is assumed, this absolute divergence would apply over the entire period (i.e. from 2015 to 2050)[38].

The absolute divergence mentioned above was also found to hold for PHEVs driving on their ICE. For these PHEVs however, the difference between the share driven on the electromotor during the type approval procedure and in the real world can add significantly to the gap between TA and RW CO_2 emissions. With a 50% share of electric kilometres and a 45 g/km divergence when operated in conventional mode, the RW/TA ratio for PHEV becomes roughly 4.05. In absolute terms, the divergence is 44 g/km.

Full Electric Vehicles (BEVs) have no divergence between TA and RW TTW CO_2 emissions by definition (both 0 g/km).

38 This may also be affected by the shift from NEDC to WLTP, but the size of this is yet unclear. For that reason this analysis starts from NEDC values instead of WLTP values for the whole period until 2050.

B.3 Assumed RW/TA divergence for Vans

For vans, the relative and absolute divergence have been increasing as well over the past decade. TA emissions were 208 g/km in 1990 with a divergence of 10% (TNO, 2016). Hence, the absolute divergence was roughly 21 g/km. By now, the absolute divergence is approximately 39.5 g/km. Similar to passenger cars, it is expected that close to the full potential of flexibilities in the TA procedures have been exploited. Hence, the absolute divergence between RW and TA CO_2 emissions is assumed to be constant (39.5 g/km) between 2015 and 2050 irrespective of the emission level of the van.

Most AFVs in the van segment are Full Electric Vehicles (BEVs), which have no divergence between TA and RW TTW emissions by definition (0 g/km).

Annex C Long list of modalities and design options

This Annex summarises the long list of all identified modalities and design options for each modality.

Table 39 Long list of all identified modalities and design options

Design choice	Modalities	Design options per modality
A. What is the scope of the Regulation?	A1 Regulated vehicle categories	A1.1 Separate targets for M1 vehicles and N1 vehicles A1.2 Separate targets for M1 with smallest N1 vehicles on the one hand, and remaining N1 on the other hand A1.3 Separate targets for M1 on the one hand, and N1 and (specific segments of) N2 vehicles on the other hand A1.4 Merged Regulations (joint target in one regulation) for M1 and N1
	A2 Regulated entities	A2.1 Manufacturer groups (existing Regulations); A2.2 Brands A2.3 Importers, distributors and dealers; A2.4 Member States; A2.5 Trade associations.
	A3 Metric(s)	A3.1 TTW CO_2 emissions (as in existing Regulation) A3.2 TTW CO_2 emissions for ICEs with exclusion of Zero Emission Vehicles A3.3 TTW CO_2 emissions with notional GHG intensity for Zero Emission Vehicles A3.4 WTW CO_2 emissions A3.5 TTW energy consumption A3.6 WTW energy consumption
	A4 Embedded emissions	A4.1 Embedded emissions excluded in the metric (as in existing Regulation) A4.2 Embedded emissions included in the metric A4.3 Embedded emissions excluded in the metric but included with another approach (e.g. reporting of embedded emissions)
B. How to measure the parameters needed for determining the overall performance?	B1 Measuring TTW vehicle parameter(s)	B1.1 Type Approval test result (WLTP) B1.2 Type Approval test result + correction for real-world divergence B1.3 Type Approval test result + OEM to provide ECU data on real world fuel consumption B1.4 Real-world measurements (e.g. PEMS or monitoring of ECU data) B1.5 One of the options B1.1, B1.2 or B1.3 combined with specific test procedures for: - energy using devices - off-cycle energy saving technologies
	B2 Determining WTT parameters	B2.1 Default values for the entire EU for a single year B2.2 Default values for the entire EU projections differentiated to target year B2.3 Default values per MS for a single year B2.4 Default values per MS projections differentiated to target year *For each option it needs to be determined whether parameters are defined as marginal or average WTT values.*
	B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal	B3.1 Default values per vehicle type for the entire EU B3.2 Default values per kg of vehicle weight for the entire EU B3.3 Harmonised LCA reporting by OEMs (per vehicle or e.g. per kg of vehicle weight)

Design choice	Modalities	Design options per modality
C. How to determine the overall performance	C1 Rewarding off-cycle reductions	C1.1 Eco-innovations (as in existing Regulation) C1.2 Off-cycle technology credits (as in the US Regulation) C1.3 None
	C2 Rewarding or penalising technologies	C2.1 Super credits (as in existing Regulation) C2.2 Minimum share of advanced technologies in vehicle sales C2.3 Flexible minimum share of advanced technologies in vehicle sales C2.4 Debits or correction factors for technologies that are over-incentivised due to chosen combination of metric and test procedure C2.5 Combinations of the options listed above C2.6 None
	C3 Aggregation & weighting	C3.1 None: limit value for each vehicle C3.2 Limit based on overall sales-weighted average (as in existing Regulation) C3.3 Limit based on overall sales-weighted average per segment within categories of cars and vans C3.4 Technology specific targets: limit based on overall sales-weighted average per technology C3.5 Combining each of the options listed above with mileage weighting – Inclusion of mileage weighting with mileage values per utility/fuel type (generic) – Inclusion of mileage weighting with mileage values per utility/fuel type (manufacturer-specific) • *In addition, for all sales-weighted averages it should be determined whether this should be based on EU sales averages or MS averages of OEMs.*
D. Approach for target setting	D1 Approach for target setting	D1.1 Targets for fixed date(s) without phase-in D1.2 Targets for fixed date(s) with phase-in (as in existing Regulation) D1.3 Annually declining targets *For each option the specific target year(s)/target period(s) need to be determined and it needs to be assessed if banking and borrowing is allowed.*
E. How to fairly distribute the burden across regulated entities?	E1 Utility parameter	E1.1 No utility parameter = no differentiation E1.2 Mass as a utility parameter E1.3 Mass + correction for under-crediting of mass reduction E1.4 Footprint as a utility parameter
	E2 Shape and slope of target function	E2.1 Zero slope target function = no differentiation (this implies no utility parameter) E2.2 Linear target function with finite slope E2.3 Truncated linear target function with a floor and/or a ceiling E2.4 Non-linear target function (see e.g. US legislation)
F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?	F1 Pooling	F1.1 No pooling of targets F1.2 Pooling of targets between car or van manufacturers (as in existing Regulation) F1.3 Pooling of targets for cars and vans
	F2 Trading CO_2 credits	F2.1 No trading of credits (as in existing Regulation) F2.2 Allowing trading of credits for passenger cars F2.3 Allowing trading of credits for vans F2.4 Allowing trading of credits for vans and passenger cars separately F2.5 Allowing trading of credits for vans and passenger cars and also allowing trading of credits between cars and vans *For each option a definition of what is traded (grams, grams/km) is required and temporal aspects (banking and borrowing of credits) needs to be determined.*

Design choice	Modalities	Design options per modality
	F3 Banking/borrowing	F3.1 No banking/borrowing F3.2 Allowing only banking (maximum period and maximum banked amount to be specified) F3.3 Allowing banking and borrowing (maximum period and maximum banked/borrowed amounts to be specified)
	F4 Excess emission premiums	F4.1 Excess emission premium of €X per excess g/km, possibly with lower premium for the first few g/km exceedance F4.2 No market access when targets are exceeded
	F5 Derogations	F5.1 For manufacturers with small volume (EU) sales (as in existing Regulation) F5.2 For manufacturers with niche volume (EU) sales (as in existing Regulation) F5.3 For manufacturers with small volume (global) sales F5.4 For manufacturers with niche volume (global) sales F5.5 For certain vehicle types F5.6 Combination of the above
	F6 Correction for autonomous utility change	F6.1 Adjustment of U_0 in target function F6.2 No adjustment of U_0 in target function

Annex D Assessment of the long list of modalities and design options

D.1 Introduction

This annex summarises the results of the qualitative assessment of all modalities and design options on the long-list.

Annex D.1 contains the results of the assessment of the long list of modalities. The references used are summarised in Annex D.2. Finally, Annex D.3 contains illustrative tables and figures to clarify literature findings.

D.2 Literature synthesis per modality

Annex D.2.1 to Annex D.2.6 contain the relevant fact sheets per main design choice.

D.2.1 A. What is the scope of the Regulation?

A1	*Regulated vehicle categories*
Group of modalities	**A. What is the scope of the Regulation?**
Function in future regulation	Relates to the specific objective: Scope & choice of regulated parameter(s)
Relevant option(s)	*A1.1 Separate targets forM1 and N1 vehicles* *A1.2 Separate targets for M1 with smallest N1 vehicles on the one hand, and remaining N1 on the other hand* *A1.3 Separate targets for M1 on the one hand, and N1 and (specific segments of) N2 vehicles on the other hand* *A1.4 Merged Regulations (joint target in one regulation) for M1 and N1* Note: In the above options it is assumed that a joint target means that all vehicles of the joined categories are compared against the same target function and that the target is sales (and possibly mileage) weighted average over all vehicles in the two categories. In principle it is also possible to bring two vehicle categories under a single target while still applying different target functions (and possibly even utility parameters) to the two categories. This, however, is technically equivalent to allowing (unrestricted) pooling between the two categories. This option is discussed in factsheet F (option F1.3).
Main pros and cons of option(s)	**A1.1 Separate targets for M1 and N1 vehicles** The current situation is separate targets for M1 and N1 vehicles in separate regulations. The two vehicle categories represent different markets, with to a large extent unrelated vehicle models. Given the different characteristics and applications of passenger cars and vans, the two categories may have different CO_2 emission reduction potentials, both from a technical and from an economic perspective. An advantage of separate targets is that in defining targets, timing and other modalities account can be taken of different characteristics of the two markets. A disadvantage is that there is overlap in vehicle models and applied technologies, especially in the segment of smaller (car-derived) vans. A less stringent target for vans means that cost-effective reduction potential may remain un-utilised. Also this may create a loophole if national registrations allow small vans to be used as passenger cars. A disadvantage of separate targets in separate regulations is the greater risk of inconsistencies and incompatibilities in the regulations due to their different political processes. An advantage of separate regulations could be that controversy over one of the targets will not delay implementation of the other.

A1	*Regulated vehicle categories*
	A1.2 Separate targets for M1 with smallest N1 vehicles on the one hand, and remaining N1 on the other hand The Class I and II segments of the van market contain a large share of passenger car derived vans. And even for dedicated van platforms often engines and other powertrain components are shared with passenger car models. A joint target for cars and the smaller vans will promote technology spill-over from cars to vans. A separate target for large vans would allow a target setting and target function that does better justice to the characteristics of this segment (type of technology applied, relation between TA CO_2 and mass or footprint, and would avoid a possible trade-off in effectiveness of the legislation for cars and (large) vans that could result from a joint target for M1 and all N1 vehicles. This seems especially the case for footprint as utility parameter (see below). The disadvantage could be that controversy over one of the targets will also delay implementation of the other. **A1.3 Separate targets for M1 on the one hand, and N1 and (specific segments of) N2 vehicles on the other hand** This option has not been investigated yet. The reason for considering a target for N1 + (specific segments of) N2 vehicles is that the threshold of 3,500 kg GVW is rather artificial so that there is large overlap in vehicle configurations and technologies around this threshold. In addition, there is a large overlap in vehicle configurations and technologies around the threshold between N1 and N2. There are, however, three general problems with including N2 vehicles: – The large share of multistage vehicles in that category. Depending on the accuracy of correction measures to include the effect of the body build-up in the CO_2-value, this may be more or less of problem. – N2 have large mass and footprint. Even though numbers may be small their inclusion under a single target function makes it more difficult to define a target function that provides reasonable targets over the whole utility spectrum and generates a significant leverage with the effectiveness of the legislation for smaller vehicles. There will be limited overlap/synergy in technologies with M1 and (the smaller) N1 vehicles. It probably makes more sense to include this category in HDV/HGV policies. **A1.4 Merged Regulations (joint target in one regulation) for M1 and N1** Previous analyses have shown that a joint target for cars and all N1 vehicles would require adjustment of the TA test procedures for large vans, to make sure that CO_2 values measured for larger vans are more representative. Such an adjustment is already being done through the WLTP for M1 and N1. In the absence of WLTP-based CO_2 figures for significant numbers of cars and vans, however, it is difficult to judge whether the WLTP has sufficiently solved this problem. A joint target could in principle lead to lower costs of CO_2 reductions, as the optimal division of reduction efforts can be implemented over a larger number of vehicles. This advantage, however, is relatively small due to the fact that van sales are generally one tenth of car sales. Some distortion of competition could result from the fact that not all OEMs selling cars on the EU market are also selling vans. ***M1 + N1 + (specific segments of) N2 vehicles***
Recommendations from previous work	In case the target for passenger cars and vans would be combined, manufacturers selling both vans and passenger cars may decide to divide their effort over both vehicle types, which may delay the introduction of certain more advanced (but less cost effective) technologies. On the other hand, manufacturers of passenger cars that do not make vans would not have this advantage. Because of this competitive advantage for manufacturers selling both passenger cars and vans it is **undesirable to combine the current targets that are planned for 2020** (ref. 1). Joining car and van targets in future regulation requires careful assessments to assure that the legislation is equivalently stringent for both categories.

A1	*Regulated vehicle categories*
Relation/inter-dependencies with other modalities	The feasibility of joining targets depends on the choice of utility parameter and on the details of the test procedures used for determining CO_2 emissions of vehicles in the categories that are joined. Disadvantages of separate targets related to problems in distinguishing cars from vans relate to the details of definitions used in EU (type approval) legislation. Analysis using NEDC-based CO_2 figure (ref. 1 and 4) show that when using mass, the sales weighted least squares fits through the individual datasets (CO_2 plotted against mass for passenger cars and light commercial vehicles) are markedly different. However, the datasets have significant overlap. When using footprint, it is seen that the datasets have only little overlap. In case of a merged target using a single target function the choice of footprint as utility parameter would result in a non-optimal targets for either cars or vans. When determining the target function starting from a least squares fit through both datasets of CO_2 vs. utility value for all cars sold in the EU, the trend of the function is dominated by vans, therefore increasing the burden of reaching the target for car manufacturers. Regarding definitions, COM Regulation No 678/2011, amending Directive 2007/46 (Annex I) (EC, 2011b), includes some criteria (e.g. loading space) to more clearly distinguish the vehicle characteristics of the M1 and N1 categories. This will limit the overlap between M1 and N1 and will therefore limit potential CO_2 leakage from vehicles being accounted for in the incorrect CO_2 regulation scheme in case the two schemes do not have equivalent stringency (meaning similar (marginal) compliance costs).
Specifics for cars and vans	See above.
Main conclusions	Inclusion of N2 in the LDV Regulation is likely to go at the expense of the suitability/ effectiveness of the legislation for reducing emissions of M1 and N1 vehicles. Merging M1 and N1 could distort competition for those OEMs which only sell one category. Important pros are overall cost reduction, promoting the application of synergies in technologies, aligning the stringency of targets for cars and vans, and avoiding leakage due to ambiguities in the definition of categories. N1 might be split into two classes in order to merge the smallest class with M1. The following two options are further assessed: – A1.1 separate targets for M1 and N1; – A1.2 separate targets for M1 with smallest N1 on the one hand, and remaining N1 on the other hand.
Issues to be further assessed	It has to be checked whether N2 vehicles (specifically multi-stage) are well implemented in the WLTP test procedure.
Annex	None
Sources	(ref. 1) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (TNO, et al., 2011a) (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, 2015a)(SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 3) Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3).
	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO; AEA; CE Delft; Ricardo, 2013) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).

A2	*Regulated entity*
Group of modalities	**A. What is the scope of the Regulation?**
Function in future regulation	The legal entities to be placed under the primary obligation to take action to reduce CO_2 emissions
Relevant option(s)	– A2.1 Manufacturer groups (existing Regulations); – A2.2 Brands; – A2.3 Importers, distributors and dealers; – A2.4 Member States; – A2.5 Trade associations.
Main pros and cons of option(s)	***A2.1/A2.2 Manufacturer groups/brands*** score best on a long list of assessment criteria (e.g. practicability and enforceability). They can actually take action to reduce their emissions and they can influence their sales averages by adjusting their prices/changing their marketing. *Manufacturer groups* (A2.1) are assessed as more appropriate than *individual brands (A2.2)* as the former can share the burden of the target between their brands and hence they can implicitly pool their efforts leading to lower average costs per car for meeting the target (ref. 3). However, this is not necessarily supported in the results of the stakeholder consultation. ***A2.3 Importers, distributors and dealers*** cannot *directly* influence the CO_2 emissions of a car/van and hence, will have to rely on indirectly influencing the CO_2 emissions of sold vehicles with marketing instruments and/or adjusting prices of different vehicles. This will make it harder for them to comply than is the case for manufacturers. Thereby, forcing an obligation on one of these groups is considered as problematic when combined with targets based on sales averages (which vary significantly between MSs) (ref. 3). ***A2.4 MS governments*** have no direct control over vehicle characteristics and marketing, but can influence sales by means of fiscal instruments and information (e.g. labelling) (ref. 3). However, each MS might also need to impose obligations on manufacturers/dealers within their own territory, which is a complex system that can result in market distortions - especially if different MSs implement different instruments - which increases costs for OEMs. ***A2.5 Trade associations*** have been assessed as unsuitable regulated entities as they have been unable to comply with previous voluntary agreements/targets and as they do not have sufficient influence/power on their members to ensure that they confirm (3). Furthermore, it would be difficult to distribute the burden to account for differences in abatement costs and/or reduction potentials.
Recommendations from previous work	– **A2.1 Manufacturers (groups of connected manufacturers)** and **A2.2 Manufacturers (individual brands)** are recommended by (ref. 3). Among these, **A2.1 Manufacturers (groups of connected manufacturers)** is preferred due to lower compliance costs. – (ref. 1) and (ref. 2) adopted this recommendation and did not cover the other options.
Relation/inter-dependencies with other modalities	None.
Specifics for cars and vans	None.
Main Conclusions	– A2.1 (manufacturer groups) and A2.2. (brands) will be further investigated, as they have direct control over the emissions of new vehicles and as these are the most cost-effective options. – **A2.3 (Importers), A2.4 (Member States), A2.5 (Trade associations)** are excluded from further analysis due to their lack to control emissions with direct measures.
Issues to be further assessed	– A2.1 (manufacturer groups) is recommended by literature as the most cost-effective option, but option A2.2. (brands) is recommended by several stakeholders. It needs to be assessed in more detail what the pros and cons are of both options.
Annex	None.
Sources	(ref. 1) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (TNO, et al., 2011a) (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 3) Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3).

A3	***Metric(s)***
Group of modalities	**A. What is the scope of the Regulation?**
Function in future regulation	To determine a regulated parameter for which a target level can be set.
Relevant option(s)	– A3.1 TTW CO_2 emissions as in existing Regulation; – A3.2 TTW CO_2 emissions for ICEs with exclusion of Zero Emission Vehicles; – A3.3 TTW CO_2 emissions with notional GHG intensity for Zero Emission Vehicles; – A3.4 WTW CO_2 emissions; – A3.5 TTW energy consumption; – A3.6 WTW energy consumption.
Main pros and cons of option(s)	A wide variety of metrics has been analysed in previous studies. The main choices to be made concern: focus on CO_2 or on energy consumption, focus on TTW or on WTW, and how to deal with Ultra-Low Emission Vehicles (ULEVs)/Zero-Emission Vehicles (ZEVs). The pros and cons of each metric are discussed below. ***A3.1 TTW CO_2 emissions as in existing Regulation:*** – WTT **emissions from electricity generation** (and fuel production) **are ignored**. Consequently, it is very beneficial for OEMs to increase the share of vehicles with very low TTW emissions (e.g. zero-emission-vehicles (ZEVs)) regardless of their WTT emissions (ref. 8). However, such vehicles have significantly higher WTT emissions than vehicles with Internal Combustion Engines (ICEVs). As a result of the sales weighted average targets, manufacturers can increase the share of ZEVs to produce ICEVs with higher TTW emissions than otherwise would have been the case. The average TTW emissions will then meet the target, but the WTW emissions will increase with increasing shares of ZEVs. This can be referred to as **'WTW CO_2 leakage'** and this is illustrated graphically in Annex D.3.1. WTW CO_2 leakage is expected to be most significant in the medium term (2020-2030), as ZEVs shares increase while the WTT emissions from their energy carriers are still high (ref. 4,5,13). According to Ref 8. Excluding WTT emissions is one of the three key weakness of the existing Regulations. • Some argue that WTT emissions are covered by the EU ETS, and hence lowers the severity of this issue. Others argue that the EU ETS does not work sufficiently to ignore WTW leakage (ref. 13). – Implicitly, this metric **strongly stimulates** (some would say overstimulates) ULEVs/**ZEVs** by counting them as zero while their WTW emissions are non-zero. It is not technology neutral therefore. However, this can stimulate OEMs to produce alternative powertrains, and as such can promote innovation in such technologies. This may benefit a more rapid transition to alternative powertrains *if* consumers are willing to buy these (more expensive) vehicles. However, when combined with other policies (e.g. fiscal incentives, subsidies) to ensure these vehicles are bought, it contributes to the long-term climate goals (ref. 4; ref. 5; ref. 13). – The large difference in TTW emissions between conventional and ULEVs/ZEVs **increases risks faced by OEMs**, as it makes OEM compliance very sensitive to the penetration of ULEVs/ZEVs (ref. 5). – This **metric does not provide credits to biofuels,** both in terms of dedicated biofuel vehicles as well as the biofuel blended in petrol and diesel(ref. 4), hence the contribution of biofuels to WTW GHG impact is underestimated. – This metric provides **no incentive to improve the energy efficiency of ZEVs**, as TTW emissions are zero regardless of their energy efficiency. These vehicles are already highly efficient though because efficiency improvement are a way to increase their driving range and make them more competitive (ref. 4, 13). – **Focus on CO_2 emissions** implies that the goal of reducing CO_2 emissions is more likely to be achieved (ref. 4). – Additional manufacturer costs are comparable for the different metrics (TTW/WTW CO_2 and TTW/WTW energy-based). However, end-user costs and societal costs are slightly lower for the WTW energy-based metric. In this case, the WTW emission reduction is also lower though. At equivalent WTW reductions, **costs for manufacturers/end-users/society are comparable for option A3.1 (TTW CO_2), A3.4 (WTW CO_2), A3.5 (TTW energy) and A3.6 (WTW energy)** (ref. 5; option A3.2 and A3.3. were not covered by that study).

A3	*Metric(s)*
	– **Metric is accepted by OEMs** and automotive industry (ref. 4, 13). ***A3.2 TTW CO_2 emissions for ICEs with exclusion of Zero Emission Vehicles;*** – As ZEVs cannot be used by OEMs for internal averaging, **targets for ICEVs are not compromised** by increasing shares of ZEVs. This prevents WTW CO_2 leakage as explained in A3.1 – TTW CO_2 above (ref. 4). – **Focus on CO_2 emissions** (see A3.1 – TTW CO_2). – **It is not a fundamental long-term solution** as it ignores the upcoming market for ZEVs, which is likely to significantly grow (ref. 4). E.g. the 'most realistic scenario' of ref. 13 assumes a share of 11% in 2030 for BEVs (and a share of 41% for semi-electric vehicles). – **It does not stimulate the production of ULEVs/ZEVs** nor does it stimulate innovation in these technologies. Consequently, additional policies to incentivise consumers to buy alternatively powered vehicles may be less effective than would be the case for a TTW-CO_2 metric. (ref. 4)). ***A3.3 TTW CO_2 emissions with notional GHG intensity for Zero Emission Vehicles;*** – **Can prevent WTW CO_2 leakage** (see A3.1 above) if WTT and/or WTW/TTW factors are chosen correctly (i.e. the smaller the deviation between actual and notional WTT factors, the smaller the CO_2 leakage) (ref. 4). – In contrast to a WTW metric, **WTW and/or WTT/TTW factors used do not need to be very precise** (i.e. the true WTT factors) and as a consequence, do not need complex monitoring systems either (ref. 4). – **Focus on CO_2 emissions** (see A3.1 – TTW CO_2). – **Requires agreements and definitions of the notional GHG factors used** (ref. 4). – **OEMs may not support this metric** as they argue to have no influence on/are not responsible for WTT emissions. However, OEMs can influence WTW emissions by improving the energy efficiency of their cars and by switching to alternative energy carriers. Therefore, it does not make them responsible, but it does enforce them to take WTT emissions into account when making decisions (ref. 4, 13). Furthermore, component suppliers appear favourable due to its greater technology neutrality. – If notional factors are updated too frequently **planning by OEMs may become difficult** (ref. 4). – Relatively more technologically neutral than ignoring WTT emissions completely. – Smaller difference in TTW emissions between conventional and ULEVs/ZEVs, which **lowers risks faced by OEMs** as they are less susceptible to the ZEV share (ref. 5). ***A3.4 WTW CO_2 emissions.*** – **Fully prevents WTW CO_2 leakage** if shares of ZEVs increase, as all emissions are covered with the metric (ref. 4). – **Focus on GHG emissions** with a scope that is most relevant for world-wide climate impacts (i.e. total GHG emissions rather than TTW CO_2 emissions) (ref. 4). – **Technology neutral**; all technologies are treated equally (ICEVs, dedicated biofuel vehicles and ZEVs) (ref. 4). – **Complex monitoring systems required** to determine the actual WTT and/or WTW emission factors (ref. 4). – **OEMs may not support this metric**, but component suppliers do (see A3.3 – TTW CO_2 with notional). – Using actual WTW/WTT emissions or frequently updated emission factors makes **planning by OEMs difficult** (ref. 4). – **Costs for manufacturers/end-users/society are comparable for option A3.1, A3.4, A3.5 and A3.6** (See A3.1 – TTW CO_2, ref. 5; option A3.2 and A3.3. were not covered by that study). – **Provides incentives to improve the energy efficiency of ZEVs,** although this potential is limited considering that ZEVs already are very efficient (ref. 4, see also A3.1). – **Lowers risks faced by OEMs** (see A3.3 TTW CO_2 emissions with notional).

A3	Metric(s)
	A3.5 TTW energy consumption – **Reduces the (risk of) overstimulation of ZEVs** as the gap between energy consumption of ICEVs and ZEVs is relatively smaller than the gap in TTW CO_2 emissions (ref. 4,5). Consequently, it also **reduces the WTW CO_2 leakage**. It does not fully solve the latter issue though; if WTT emissions factors are high, WTW emissions will still increase with increasing shares of ZEVs. However, WTW emissions can decrease with increasing shares of ZEVs if the WTT emissions of energy carriers are sufficiently low (ref. 4). – If the goal of the Regulation is to improve TTW energy efficiency it is technology neutral, but if it is to reduce WTW GHG emissions it is **not technology neutral**; the energy efficiency of ICEVs and ZEVs not necessarily reflects WTW emissions. ZEVs are about 3 times more efficient than ICEVs (in terms of final energy consumption of the vehicle), but their WTW emissions are highly dependent on the WTT emissions of the energy carriers (ref. 4). The latter can be an argument to choose for a WTW energy-based metric (ref. 13). – **Focus on energy efficiency instead of on emissions** may reduce the effectiveness of achieving the goals set by the Regulation in terms of achieving emission reduction (ref. 4). – **Provides incentives to improve the energy efficiency of ZEVs,** although this potential is limited considering that ZEVs already are very efficient (ref. 4). – **Costs for manufacturers/end-users/society are comparable for option A3.1, A3.4, A3.5 and A3.6** (See A3.1 – TTW CO_2, ref. 5; option A3.2 and A3.3. were not covered by that study). *A3.6 WTW energy consumption* – **Reduces the (risk of) overstimulation of ZEVs** and **WTW CO_2 leakage** (see A3.5. TTW energy – all vehicles), even more significantly than in case of a TTW energy metric, as the main energy losses for ZEVs are during the electric power generation (ref 13). – **Focus on energy efficiency instead of on emissions** may reduce the effectiveness of achieving the goals set by the Regulation in terms of achieving emission reduction (ref. 4). – **Provides incentives to improve the energy efficiency of ZEVs** although this potential is limited considering that ZEVs already are very efficient (ref. 4). – **OEMs may not support this metric** (see A3.3 – TTW CO_2 with notional). – **Costs for manufacturers/end-users/society are comparable for option A3.1, A3.4, A3.5 and A3.6** (See A3.1 – TTW CO_2, ref. 5; option A3.2 and A3.3. were not covered by that study). – **Promotes overall resource efficiency.**
Recommendations from previous work	– General agreement on the fact that the existing metric (TTW CO_2-based metric) carries that risk of overall increased WTW fleet emissions due to zero counting of ZEVs (i.e. WTW leakage), particularly in the medium term in scenarios when the share of ZEVs can already be high while WTT emissions of power (or hydrogen) generation are still significant (ref. 4; ref. 5; ref. 13; ref. 8). – Each (alternative) metric has different advantages and disadvantages and no metric is superior to other metrics on all aspects (ref. 5). The authors of ref. 5 conclude “the WTW CO_2-based metric appears to be the one with which the desired WTW CO_2 reduction is likely to be achieved in the most cost effective way in 2030”. – The authors of ref. 4 do not recommend a particular metric. However, their summary table does show that the WTW CO_2 metric is least sensitive to the GHG intensity of electricity and the ZEV share (see Annex D.3.1). – Ref 8. Recommends that for the future Regulations, “it will be important to consider how best to take account of WTT as well as TTW CO_2 emissions”. – Finally, ref. 13 recommends an “extension of the current CO_2 Regulation for cars and vans to a system covering well-to-wheel GHG emissions for both ICEVs and EVs”. This could be realised with a WTW energy consumption, TTW with notional GHG intensity for ZEVs or the WTW CO_2-based metric.
Relation/inter-dependencies	– The decision to in- or exclude WTT emissions in the metric influences the need to

A3	Metric(s)
with other modalities	determine parameter(s) to measure these emissions. It therefore influences the modality “Determining WTT parameter(s)”. – The WTW CO_2-based metric and energy consumption metrics are closely related to ‘Aggregation & weighting’, as for these metrics there is the choice for one target or for multiple targets (i.e. technology-specific targets). – TTW with exclusion of ZEVs might be desirable to combine with a minimum share of ZEVs in sales or other measures for stimulating ZEVs.
Specifics for cars and vans	none
Main conclusions	– A3.1 (TTW), A.3.2 (TTW exclusion ZEVs) and A3.4 (WTW) are included for further assessment. In case a TTW metric is chosen it can be IPCC-based or tailpipe-based. – **A3.3 (TTW notional)** is excluded from further analysis, as it is an inaccurate measurement of WTW emissions, so a WTW metric is preferable in this case as all other effects of these metrics are comparable. Thereby, it is a technology-specific solution and not a scientifically sound approach. – **A3.5 TTW energy consumption and A3.6 WTW energy consumption** are also excluded from further analysis as they do not have any significant benefits over the CO_2 design options: energy consumption is poorly related to GHG emissions and primary energy consumption is an irrelevant parameter when comparing renewables with fossil energy sources.
Issues to be further assessed	– Ref. 4 and ref.5 have explored the different options with a high level of detail, although the GHG values used for power generation where too low. The impact hereof on the results may benefit further analyses. – Ref. 5 recommends a broad stakeholder consultation to assess the appropriateness of replacing the TTW CO_2-based metric with the WTW CO_2-based metric. – The metric in the current Regulation is based on tailpipe TTW emissions which deviate from the TTW emissions as defined by IPCC. The main difference is that biofuels count as zero in the TTW emissions with an IPPC definition. A metric based on this might be considered as another alternative for the current tailpipe TTW emissions-based metric. – Potential impacts of the significantly higher estimates for WTT emissions of fossil fuels (as recently proposed by the Commission) on previous assessments of the various metrics and electricity. – Pros and cons of TTW vs. WTW in a short essay.
Annex	Annex D.3.1
Sources	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO; AEA; CE Delft; Ricardo, 2013) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 5) Analysis of the influence of metrics for future CO_2 legislation for Light Duty Vehicles on deployment of technologies and GHG abatement costs (TNO; CE Delft, 2013). (SR#8 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 13) Impacts of Electric Vehicles (Deliverable 1-5 (CE Delft; ICF; Ecologic, 2011).

A4	*Embedded emissions*
Group of modalities	**A. What is the scope of the Regulation?**
Function in future regulation	Determines whether the GHG-emissions related to vehicle manufacturing, maintenance and disposal are covered with the Regulation.
Relevant option(s)	– A4.1 Embedded emissions excluded in the metric – A4.2 Embedded emissions included in the metric – A4.3. Embedded emissions excluded in the metric but included with another approach (e.g. reporting of embedded emissions)
Main pros and cons of option(s)	The emissions from vehicle manufacture, maintenance and disposal can either be in- or excluded from the scope of the Regulation. Currently (2015), embedded emissions from manufacturing and maintaining cars are only 16% on average, while the remainder (84%) of the lifecycle emissions result from vehicle operation. Therefore, excluding embedded emissions has been appropriate to date, but with increasing shares of alternative powertrains, for which embedded emissions have a larger share in total lifetime emissions, it is likely to become less appropriate and is identified as one of the three key weaknesses of the current Regulations (ref. 8). This is also shown in Figure 100 in Annex D.3.1: embedded emissions are expected to increase to 20% in 2025, 23% in 2030 and 47% in 2050 (ref. 12). This increasing share is caused by two factors. First, more efficient technologies, particularly hybrid and electric powertrains, result in additional embedded emissions of approximately 5-20 g/km (ref. 2) to 27-31 g/km (ref. 31) compared to ICEs. This is shown graphically in Figure 100 of Annex D.3.1. Second, vehicle energy consumption and the GHG intensity of the consumed energy are expected to reduce at a faster rate than the embedded emissions of materials used in the vehicle (ref. 2; ref. 12). ***A4.1. Embedded emission excluded in the metric***. Up to 2030 the relevance of embedded emissions in overall life cycle emissions increases only moderately (from 16% in 2015 to 23% in 2030) (ref. 12). Therefore, in the short- to medium- term, the bulk of the emissions would still be covered by the Regulation if embedded emissions are excluded (ref. 8). Within this timeframe, the total benefits of alternative powertrains still outweigh the higher emissions from production and disposal significantly (ref. 12). Thereby, OEMs do not have full control over embedded emissions, especially over those resulting from components bought from suppliers (ref. 4). Excluding embedded emissions does result in unfair competition in favour of alternative powertrains and will erode some of the overall GHG benefits (ref. 12). Other studies also recognise this issue of eroding GHG benefits and its growing importance (e.g. the low CVP project in the UK). ***A4.2. Embedded emissions included in the metric***. When taking a medium to long-term perspective, the share of embedded emissions in the total life cycle emissions is expected to triple within the next 40 years (from 16% in 2015 to 47% in 2050) (ref. 12). Therefore, embedded emissions cannot be ignored in the long-term as the Regulation would then only cover half of the total life-cycle emissions. Thereby, the inclusion of embedded emissions results in a fairer competition between ICEs and alternative powertrains and avoids possible undesired rebound effects of increasing shares of alternative powertrains (ref. 4). Finally, it ensures that OEMs take into account any differences in embedded emissions of the different technologies in their planning product portfolio (ref. 4). Including embedded emissions will be challenging though, as the measurement of embedded emissions can be difficult. This issue is further discussed with the modality 'Determining parameter(s) w.r.t. vehicle manufacturing & disposal'. In addition, OEMs can only partially control embedded emissions and hence, may not support the inclusion of these emissions in the metric (ref. 4). ***A4.3. Embedded emissions excluded in the metric but included with another approach*** (e.g. reporting of embedded emissions). Some argue that including embedded emissions in the metric in a meaningful way (i.e. with LCA reporting rather than with default values) is too complex at the moment. However, other approaches could try to promote harmonised LCA methodologies and data sets, for example by a requirement to publish an embedded CO_2 figure for all models. Consequently, OEMs and consumers are still stimulated to take embedded emissions into account. It will be relatively less effective in reducing embedded

A4	***Embedded emissions***
	emissions compared to when it is included in the metric (and hence in the compliance target).
Recommendations from previous work	– Ref 12. does not make an explicit recommendation to in- or exclude embedded emissions in the CO_2 Regulation for cars and vans. However, the authors of this study and of other studies do conclude that "policy action should be taken to minimise the degree to which future GHG emissions from these [production, maintenance, and disposal] elements erode the GHG savings due to reductions in the operational energy use (and its GHG intensity) of vehicles."
Relation/inter-dependencies with other modalities	– The decision to in- or exclude embedded emissions in the metric influences the need to determine parameter(s) to measure these emissions. It therefore influences the modality 'Determining parameter(s) w.r.t. vehicle manufacturing & disposal'. – Secondly, it influences the exact definition of the 'Metric(s)'.
Specifics for cars and vans	None.
Main conclusions	– **A4.2. (embedded emissions in metric with defaults)** is not included for further analysis. It discourages particular technologies as defaults need to be based on the current embedded emissions of vehicle production, while these emissions may be completely different in the longer term. However, it is very difficult to already make such projections. Thereby, it does not provide incentives to improve performance (as it is based on defaults). – **A4.1. (embedded emissions excluded)** and **A4.3 (embedded emissions included but not in the metric)** are included for further analysis, but for the remainder of this project the analysis is identical (both are not included in the metric).
Issues to be further assessed	– A LCA reporting approach would need to be further investigated in case embedded emissions are included. However, as we have assessed this to be only feasible in case it is voluntary (e.g. for reporting), it will fall outside the scope of this Regulations, and hence, of this project.
Annex	Annex D.3.1
Sources	(ref. 2). Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (CE Delft; ICF; Ecologic, 2011) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO; AEA; CE Delft; Ricardo, 2013) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 12) EU Transport GHG: Routes to 2050? Developing a better understanding of the secondary impacts and key sensitivities for the decarbonisation of the EU's transport sector by 2050 (AEA ; TNO; CE Delft ; TEPR, 2012).
	(ref. 31) 'Indirecte en directe CO_2-uitstoot van elektrische personenauto's.' (TNO; CE Delft, 2014).

D.2.2 B. How to measure the parameters needed for determining the overall performance?

B1.	*Measuring TTW vehicle parameters*
Group of modalities	**B. How to measure the parameters needed for determining the overall performance?**
Function in future regulation	Specification of direct CO_2 emissions and/or energy consumption of vehicles that are subject to the regulation as well as of other vehicle parameters that are needed for determining the manufacturer-specific target and monitoring progress.
Relevant option(s)	– B1.1 Type Approval test procedure (WLTP) – B1.2 Type Approval test result + correction for real-world divergence – B1.3 Type Approval test result + OEM to provide ECU data on real world fuel consumption – B1.4 Real-world measurements (e.g. PEMS or monitoring of ECU data) – B1.5 One of the options B1.1, B1.2 or B1.3 combined with specific test procedures for: • Energy using devices • off-cycle energy saving technologies In addition, unambiguous specifications are needed on how to define the utility value (mass of footprint) of each vehicle. These need to be included in the Type Approval regulation.
Main pros and cons of option(s)	The evaluation of the existing regulations (ref 8.) has identified the test cycle as the key weakness in the regulations, as the increasing discrepancy between test cycle and real world performance has eroded a significant share of the CO_2 (and fuel saving expenditures) benefits of the regulation. Ref 8. estimates that real word emission savings of the last few years were 48% (cars) to 73% (vans) lower than the savings which should have been realised according to improvements in the test-cycle. This partially results from the increasing use of more energy consuming devices which are not measured in the test cycle (ref. 8). Therefore, they recommend that this weakness "may need to be addressed in future policy proposals". **B1.1 Type Approval test procedure (WLTP)** Pro: existing and legally binding procedures. Con: reductions measured on the TA test do not translate into similar reductions in real-world driving. The WLTP will provide some improvements but will not fully resolve the issues described above. **B1.2 Type Approval test result + correction for real-world divergence** Pro: Provides CO_2/fuel consumption numbers that are more representative for real-world and therefore more reliable information for consumers. Con: Correction factors need to be generic and may not be correct for specific technologies. Also they may not do justice to OEMs that make efforts in reducing the gap between TA and RW values. **B1.3 Type Approval test result + OEM to provide ECU data on real world fuel consumption** Pro: Provides vehicle specific CO_2/fuel consumption numbers that are more representative for real-world and therefore more reliable information for consumers). Con: Procedure for determining correction based on ECU data still to be developed. Complex task to develop appropriate methodology. **B1.4 Real-world measurements (e.g. PEMS or ECU monitoring)** Pro: Provides vehicle specific CO_2/fuel consumption numbers that are more representative for real-world and therefore more reliable information for consumers. Con: Procedure for determining RW CO_2-based on ECU data still to be developed. Complex task to develop appropriate methodology. Replacing values from the TA test by RW testing poses much higher demands on the accuracy and comparability of test results, compared to when RW data are used for a correction factor. **B1.5 One of the options B1.1, B1.2 or B1.3 combined with specific test procedures for energy using devices and off-cycle energy saving technologies** This is an alternative for the current eco-innovations, which are voluntary and allow OEMs to

B1.	*Measuring TTW vehicle parameters*
	define their own procedure for assessing the impact of off-cycle CO_2 reducing technologies. Instead it is made mandatory to include the impact of energy using devices and off-cycle energy saving technologies using prescribed specific test procedures. Pro: If vehicles become more efficient, the share of energy using devices in total energy consumption/emissions becomes larger. This option provides an incentive for improving the energy efficiency of these devices. Also it stimulates the application of energy-saving technologies that do not contribute to CO_2 reduction on the TA test. Con: Appropriate specific test procedures need to be developed. The work to develop procedures for mobile air conditioners (MAC) has shown that this is can be a complex task.
Recommendations from previous work	These options have not been previously assessed.
Relation/inter-dependencies with other modalities	In principle the metric and the utility parameter determine the minimum requirements for what needs to be known of vehicles.
Specifics for cars and vans	None.
Main conclusions	– All options will be included for further assessment (see below).
Issues to be further assessed	– Feasibility of using PEMS or ECU monitoring to determine RW correction factors/performance. In-use emissions study may provide useful insights.
Annex	None.
Sources	ref. 10) Supporting Analysis on Test Cycle and Technology Deployment for Reviews of Light Duty Vehicle CO_2 Regulations (AEA; Ricardo; IHS Global Insight; TNO , 2012) (SR#6 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 11) Support for preparing correlation of WLTP and NEDC (SR#9 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 17) Travelcard Nederland BV data source document: Fuel consumption of Dutch passengers cars in business use 2004-2012. (TNO, 2013a).
	(ref. 18) Real-world fuel consumption of passenger cars for business use and plug-in hybrid vehicles (Praktijkverbruik van zakelijke personenauto's en plug-in voertuigen) (TNO, 2013b).

B2	Determining WTT parameter(s)
Group of modalities	**B. How to measure the parameters needed for determining the overall performance?**
Function in future regulation	To measure the WTT performance of the different energy carriers in case a WTW CO_2 or energy-based metric is used.
Relevant option(s)	– B2.1 Default values for the entire EU for a single year – B2.2 Default values for the entire EU projections differentiated to target year – B2.3 Default values per MS for a single year – B2.4 Default values per MS projections differentiated to target year *For each option it needs to be determined whether parameters are defined as marginal or average WTT values.*
Main pros and cons of option(s)	The two main choices to be made for this modality concern the geographical scope (EU wide vs. Member State level) and the timeframe (single year vs. projections) of the WTT parameters. **B2.1/B2.2.Default values for the entire EU** may be more appropriate as car manufacturers operate transnationally (ref. 13) and as it is consistent with the scope of the Regulation. Thereby, the predictability of the targets is improved if WTT parameters (which OEMs cannot influence) are the same for all manufacturers (ref. 4). However, an advantage of **B2.3/B2.4 Default values per Member State** (and disadvantage of EU values) is that it may better present real-world WTW emissions. If electric cars are mainly sold in European countries with cleaner energy mixes (average or marginal, depending on what is calculated with in the Regulation; see below), using average EU values could overestimate the WTT emissions caused by these electric cars. OEMs will try to sell ZEVs in countries with lowest electricity emissions factors, as vehicles contribute most in these countries. However, export of second hand vehicles may partly off-set this better accuracy of the default values per MS. Both EU and MS default values can be based on a single year (e.g. actually monitored in that year, or recent past) or on projections (to determine the average WTT emissions over the vehicle's lifetime). **B2.2/B2.4 Projections** may be more appropriate as the Regulation regulates cars that are sold and used in the future, and hence, will use the future energy mix (ref. 13). It also has the advantage over actually monitored emissions that it enhances the predictability of the target if projections are determined well in advance (ref. 4). Ref. 21 has projected the WTT emissions from different energy carriers for the period between 2020 for example. It will be necessary to update such projections regularly (to account for unexpected changes in the energy mix) though. The frequency of doing so influences the predictability of the target (ref. 4). The advantage of default values that are based on **a (B2.1/B2.3) single year** is that it may better represent the real-world impact. In case this is based on actually monitored emissions this could be based on the monitoring and reporting that is in place for the EU ETS (refining and electricity) (ref. 13). However, this does compromise the predictability of the targets for OEMs. For each of the above explained options it should be determined whether the WTT value should reflect ***marginal*** or ***average*** GHG emissions. **Average** WTT parameters are easier to determine and more transparent, which is why ref. 13 recommends this option. With marginal WTT parameters there are multiple options. Marginal WTT parameters can be determined with the emissions resulting from all *additional* electricity that needs to be generated due to (PH)EVs, or as marginal to the EU ETS. As emissions from electricity are covered by the EU ETS, some argue that the marginal emissions are zero. This does assume a perfectly functioning EU ETS, which is currently not the case. Thereby this logic implies that it does not matter whether a transport user buys an energy efficient or inefficient electric car, while in reality it does matter.
Recommendations from previous work	– Ref. 13 recommends EU wide values that are based on projections.
Relation/inter-dependencies with other modalities	– Highly dependent on the modality 'metric(s)'. Determining WTT parameters is only necessary in case a CO_2 or energy-based metric is chosen which takes into account WTT emissions or energy consumption.
Specifics for cars and vans	None.

B2	*Determining WTT parameter(s)*
Main conclusions	– **Single year options (B2.1 - EU and B2.3 - MS)** are excluded as this is not accurate (esp. if emission reduction of electricity starts to go very rapidly). – Both **projections options (B2.2 - EU and B2.4 - MS)** are included as both have pros and cons, although B2.2 is overall recommended as the preferred option. – **Marginal** default values will be excluded from further analysis, as this is not transparent, difficult to determine and provides wrong signals to transport users.
Issues to be further assessed	– Frequency of updating the WTT parameters for the projections. – Which values to choose for the WTT parameters for conventional fuels and biofuels. – Estimation of the share of biofuels in various conventional fuels (gasoline, diesel, LPG and CNG).
Annex	None.
Sources	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO; AEA; CE Delft; Ricardo, 2013) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 13) Impacts of Electric Vehicles (Deliverable 1-5), (CE Delft; ICF; Ecologic, 2011).
	(ref. 21) WELL-TO-TANK Appendix 2 - Version 4.a. Summary of energy and GHG balance of individual pathways. (EC, JRC, 2014b) WELL-TO-WHEELS ANALYSIS OF FUTURE AUTOMOTIVE. FUELS AND POWERTRAINS IN THE EUROPEAN CONTEXT.

B3	*Determining parameter(s) w.r.t. vehicle manufacturing & disposal*
Group of modalities	**B. How to measure the parameters needed for determining the overall performance?**
Function in future regulation	To determine the embedded emissions resulting from vehicle manufacturing, maintenance and disposal.
Relevant option(s)	– B3.1. Default values per vehicle type for the entire EU – B3.2. Default values per kg of vehicle weight for the entire EU – B3.3. Harmonised LCA reporting by OEMs (per vehicle or e.g. per kg of vehicle weight)
Main pros and cons of option(s)	Measuring the actual performance with respect to embedded emissions requires highly complex Life Cycle Assessments (LCAs), as thousands of components are used in the EU that are sourced from all over the world (ref. 2). There are two main options for determining such embedded emissions; using **Default values (B3.1 per vehicle types or 3B.2 per kg weight)** or with **harmonised LCA reporting by the OEMs** (B3.3). With the former, the administrative burden to OEMs is kept low. However, using default values also implies that any efforts from OEMs to reduce their embedded emissions are not acknowledged/rewarded, as each vehicle type or kg is given the same parameter. In case the default values are based on vehicle weight, light-weighting would be incentivised and captured in the measurement, which can be considered an advantage over default values per vehicle type. Note that this is only the case when reducing the use of existing materials. If OEMs start using new light-weight materials, the real-world embedded emissions may deviate significantly from the default. The main advantage of **B3.3. Harmonised LCA reporting by OEMs** on the other hand is that it captures the real-world embedded emissions better, and hence, OEMs are rewarded for their effort to reduce embedded emissions. It does enforce OEMs to adopt relatively complex LCA reporting, which can be time consuming. If **default values** are chosen, these can be determined with recent studies, for example with the LCA work of the World Auto Steel and the European Aluminium Association or the high level analysis in the 'EU transport GHG: Routes to 2050' work (ref. 12). However, as pointed out in ref. 2., values mentioned in literature vary significantly. If **Harmonised LCA reporting** is chosen on the other hand, a harmonised methodology is required and needs to be monitored, to ensure a fair and comparable representation of embedded emissions. The monitoring and verification of the LCA values provided by OEMs can be difficult.
Recommendations from previous work	– There is limited literature available on how parameters for embedded emissions should be determined in case embedded emissions would be included in the metric.
Relation/inter-dependencies with other modalities	– Highly dependent on the modality 'embedded emissions'. It is only necessary to determine parameters for embedded emissions if these emissions are included in the scope. The reliability and/or accuracy would be less crucial if the embedded emission are excluded from the metric (B3.2) but included by means of another approach (B3.3).

B3	*Determining parameter(s) w.r.t. vehicle manufacturing & disposal*
Specifics for cars and vans	None.
Main conclusions	– **Default values (B3.1 and B3.2)** are excluded from further assessments as it is not accurate and provides no incentives for improvements – **LCA values (B3.3)** are desirable
Issues to be further assessed	– A LCA reporting approach would need to be further investigated. However, as we have assessed this to be only feasible in case it is voluntary (e.g. for reporting), it will fall outside the scope of this Regulations, and hence, of this project.
Annex	None.
Sources	(Ref. 2). Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(Ref. 12). EU Transport GHG: Routes to 2050? Developing a better understanding of the secondary impacts and key sensitivities for the decarbonisation of the EU's transport sector by 2050 (AEA ; TNO; CE Delft ; TEPR, 2012).

D.2.3 C. How to determine the overall performance?

C1	*Rewarding off-cycle reductions*
Group of modalities	**C. How to determine the overall performance?**
Function in future regulation	To incentivise innovations which can reduce CO_2 emissions, but which cannot be (accurately) measured with the chosen test procedure.
Relevant option(s)	– C1.1 Eco-innovations (as in existing Regulation) – C1.2 Off-cycle technology credits (as in the US Regulation) – C1.3 None
Main pros and cons of option(s)	There are several new and innovative (meaning not in widespread use) technologies for which the (full) CO_2 benefits do not result from the official test procedures to measure compliance with the standard (Ref. 33). Both **C1.1. Eco-innovations** (existing EU Regulation) and **C1.2 off-cycle technology credits** (existing US Regulation), are design options that have been implemented in existing Regulations to take such innovations into account. However, while off-cycle technology credits only provide credits (i.e. reduce the target of OEMs) for devices that are *not switched on* during the test cycle, eco-innovations are broader and *also* take into account devices that are switched on in the test procedure, but for which the total real-world reduction potential is *not accurately measured, (except for comfort features including air conditioning)*(ref. 32; ref. 30). Despite this difference, both options will **increase the cost-effectiveness** of reaching targets, as manufacturers will only develop these innovations and apply for a reward of their off-cycle reduction if this is less costly than improving elements that are captured with the test procedure or paying an excess emissions premium (ref. 29). Thereby, both options **incentivise the adoption and the future innovation in such 'off-cycle' (and/or not accurately measured) technologies** (ibid). It should be noted that with the new WLTP test procedure real-world driving conditions are better reflected, which **reduces the need for rewarding off-cycle reductions/eco-innovations** (ref. 29). However, (ref. 29) states that the introduction of the WLTP test procedure will not ensure that *all* energy-using devices will be switched on and accurately measured in the test. Thereby, the definition of eco-innovations/off-cycle technology credits ensures that *only* those energy using devices *not* taken (accurately) into account in the test-procedure are eligible for credits. Therefore, (ref. 29) argues that these design options could still be implemented together with the new test procedure. However, if the WLTP test-procedure indeed accurately represents real-world driving conditions, the emission reduction benefits of those energy-using devices that are switched on in the test should be better measured. In this case, (C1.2) off-cycle technology credits may be more appropriate compared to (C1.1) eco-innovations. Both options have the disadvantage that the CO_2 emission reduction of **eligible technologies needs to be accurately measured, verified and approved**. Previous experience with mobile air conditioners (MACs) has shown that this may be very difficult.

C1	Rewarding off-cycle reductions
	C1.3. Does not provide any credits for off-cycle energy using/saving devices, which can be combined in case mandatory measurements (B1.5) are chosen for these devices. If B1.5. is not chosen, it would reduce the cost-effectiveness of the Regulation.
Recommendations from previous work	– Ref. 29 recommends to continue with eco-innovations (even if the new test procedure is adopted) as it reduces CO_2 while increasing cost-efficiency.
Relation/inter-dependencies with other modalities	– Off-cycle reductions are closely related to the measurement procedures of TTW parameters, as this (partially) determines which technologies are eligible for being rewarded (ref. 33). – C1.1 Eco-innovations and C1.2 (Off-cycle credits) cannot be combined with mandatory test procedures which add the performance of these devices to the vehicles' performance (B1.5). Hence, in case B1.5. is chosen, C1.3 (none) must be chosen for this modality.
Specifics for cars and vans	None.
Main conclusions	– All options are included as each has pros and cons
Issues to be further assessed	– The implication of a WLTP TTW measurement on the necessity for rewarding off-cycle reductions, especially for those devices that are switched on but were not accurately measured with NEDC. – The (cost-effective) CO_2 reduction potential of off-cycle technologies.
Annex	None.
Sources	(ref. 29) Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles (EC, 2012b).
	(ref. 30) Epa and NHTSA Set standards to reduce GHGs and improve fuel economy for model years 2017-2025 cars and light trucks (EPA, 2012a).
	(ref. 32) 'Regulation (EC) no. 443/2009 of the European Parliament and of the Council of April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles' (EC, 2009).
	(ref. 33) 'Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule'. (EPA, 2010) Published in the Federal Register 75/88, 2010.

C2	*Rewarding or penalising technologies*
Group of modalities	**C. How to determine the overall performance?**
Function in future regulation	To provide incentives and/or disincentives for particular technologies.
Relevant option(s)	– C2.1 Super credits (as defined in the current Regulation) – C2.2 Minimum share of advanced technologies in vehicle sales – C2.3 Flexible minimum share of advanced technologies in vehicle sales – C2.4 Debits or correction factors for technologies that are over-incentivised due to chosen combination of metric and test procedure – C2.5 Combinations of the options listed above – C2.6 None
Main pros and cons of option(s)	**C2.1 Super credits.** Super credits create an incentive to OEMs to increase their sales of vehicles with low tailpipe (e.g. <50 g/km) emissions as the increased weight given to these technologies allows them to produce **more less-efficient ICEVs** (ref. 1). As was described in the metrics factsheet, this is also the case for a TTW metric without super credits due to zero counting of ZEVs; a 10% share of EVs implies that emissions from ICEVs can be 10% above the target on average (ref. 1). However, super credits further enhance this effect; emissions from ICEVs emissions can then be 15% (1,5 credit per ZEV sale) up to 40% above target (3,5 super credits per ZEV sale) (ref. 1). This is shown in Figure 101 in Annex D.3.2. As a consequence, super credits **increase overall WTW fleet emissions**, especially if combined with a TTW metric due to the WTW leakage that will result (ref. 2; ref. 3; ref. 29). The more vehicles become eligible for super credits, the larger this effect will be (ref. 2). In principle, super credits therefore **reduce the stringency of the target** and are **not technology neutral** (ref. 29; ref 8). However, the evaluation of the existing regulation (ref. 8) concludes that super credits "have not resulted in any practical weakening of the Regulatory targets", as they have not been needed yet. However, if they would have been needed, super credits would have resulted in an additional gCO_2/km reduction ranging from 0 to 7.4 for larger OEMs in the EU (ref. 8). Furthermore, as ZEVs are a relatively expensive strategy for reducing CO_2 emissions (esp. for vans), super credits **reduce the overall cost-effectiveness** of meeting the target (ref. 29; ref. 1), which is illustrated in Table 40 of Annex D.3.2. On the positive side, super credits **do stimulate ZEVs research and production** (ref. 13), although with more stringent targets, the incentive for ZEVs will be significantly large, even without super credits (ref. 2). The negative effects above could be reduced if the multiplier is kept low, if the threshold for super credits (i.e. the 50g/km) is lowered, and/or if the cumulative number of super credits per manufacturer is capped (as in the existing van Regulation (ref. 29). In any case super credits have no impact on consumer willingness to buy ULEVs. That can only be influenced by measures affecting their value to the purchaser. **C2.2 Minimum share of advanced technologies in vehicle sales** With this design option, manufacturers are required to have an minimum share of x% of advanced technologies (to be defined) in their vehicle sales. This option has been implemented in California. Evaluations of this Regulation show that it turns out to be **difficult to define the 'x' share**; if the share is an underestimation, potential environmental benefits are not fully exploited, while if potential is overestimated this option results in unacceptably high compliance costs compared to the environment benefits gained(ref. 34). Hence, it can be a **risky** design option, especially if a suboptimal technology pathway is stimulated. However, if set correctly, it can contribute to overcoming initial barriers to the widespread diffusion of new technologies, which in turn increases economies of scale and learning effects and hence reduce costs (ref. 34). However, this is dependent on consumers actually buying such vehicles. This could also be realised if overall performance standards are strict enough though. Thereby, this would be less costly as OEMs have more flexibility in this case (ref. 34). **C2.3 Flexible minimum share of advanced technologies in vehicle sales** With this design option, the minimum share of advanced technologies in vehicles sales is not fixed, but flexible. An example is a flexible ZEV or ULEV mandate, which allows OEMs some

C2	*Rewarding or penalising technologies*
	flexibility: a higher share of ZEVs is translated into a less stringent CO_2 target for their ICEVs while a lower share results in a stricter CO_2 target for the ICEVs. **C2.4 Debits or correction factors for technologies that are over-incentivised due to chosen combination of metric and test procedure.** Some technologies may be over-incentivised due to the metric and test procedure that are chosen. This is for example the case for (semi-)electric cars and vans when a TTW CO_2-based metric is chosen (as was explained in the Metric factsheet). Correction factors may reduce such effects, which will enhance the technical neutrality of the Regulation. However, whether this is desirable and for which technologies this should be implemented has not been investigated in existing literature.
Recommendations from previous work	– Ref 2, ref 13 and ref. 29 recommend not to continue with super credits in future Regulations due to the negative effects described above. If continued, it is advised to at least combine it with a WTW metric. – Some evidence that mandate minimum share of advanced technologies may not be most effective approach.
Relation/inter-dependencies with other modalities	– (C2.1) Super credits are related to 'Metric', as the WTW leakage with a TTW-based (CO_2) metric is enlarged with super credits. – C2.4 (debits) is especially useful if a TTW metric is chosen. – C2.2 or C2.3 (minimal share of technologies) are especially useful if a WTW metric is chosen.
Specifics for cars and vans	– The negative impacts of super credits may be somewhat lower for vans compared to cars, as there are fewer van options with emissions lower than 50 (or other amount) g/km (ref. 29). – Also the impact on cost-effectiveness may be different, due to the different additional costs of producing a ZE van vs. car.
Main conclusions	– C2.1, C2.2, C2.3 and C2.6 will be further investigated. – C2.3 (Debits) are excluded from further analysis as this option increases WTW emissions and reduces cost-effectiveness.
Issues to be further assessed	– Impacts of a minimum share of advanced technologies and an assessment of which technologies this should concern. – Impacts of debits/correction factors for certain technologies and an assessment of which technologies this should concern and how this debit should be determined.
Annex	Annex D.3.2.
Sources	(ref. 1) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (TNO, et al., 2011a) (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 13) Impacts of Electric Vehicles (Deliverable 1-5), (CE Delft; ICF; Ecologic, 2011).
	(ref. 29) Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles (EC, 2012b).

C3	*Aggregation & weighting*
Group of modalities	**C. How to determine the overall performance?**
Function in future regulation	To determine how the performance of individual vehicles is aggregated into one (or multiple) target(s).
Relevant option(s)	– C3.1 None: limit value for each vehicle – C3.2 Limit based on overall sales-weighted average – C3.3 Limit based on overall sales-weighted average per segment within categories of cars and vans – C3.4 Technology specific targets: limit based on overall sales-weighted average per technology – C3.5 Combining each of the options listed above with mileage weighting • Inclusion of mileage weighting with mileage values per utility/fuel type (generic) • Inclusion of mileage weighting with mileage values per utility/fuel type (manufacturer-specific) *In addition, for all sales-weighted averages it should be determined whether this should be based on EU sales averages or MS averages of OEMs.*
Main pros and cons of option(s)	Once it has been determined how the performance of each vehicle can be measured, it should be decided how the performance of each vehicle is aggregated into an overall performance per regulated entity that can be compared to a (or multiple) target(s). One option would be not to aggregate (**C3.1 None: Limit value for each vehicle**), which implies that all vehicles must meet the target that is set. This could be one target that is the same for all vehicles (i.e. flat limit curve) or different targets for each vehicle (e.g. linear/curved limit curves) (ref. 29). In both cases, it is **ensured that all vehicles meet a certain level of performance.** Furthermore, it ensures that emission reductions are also realised for high emission vehicles as OEMs cannot rely on low emission vehicles for compensation (ref. 2). However, there is no room for internal averaging. Therefore, it is a **very inflexible** option and is likely to result in **very high compliance costs** and **market disruptions** or distortions if no flexibility mechanisms are implemented simultaneously (ref. 3; ref. 29; ref. 2). This option does not take into account differences between OEMs in terms of vehicle size and/or type (e.g. sportive cars vs. SUVs, etc.). A **(C3.2) Limit based on overall sales-weighted average** provides the relatively highest level of flexibility to OEMs as it provides most room for internal averaging (ref. 3). Hence, they can compensate underachieving vehicles with overachieving others (ibid.). It does have several disadvantages. Firstly, it can result in more inefficient ICEVs than would be the case for technology specific targets for example. As any additional g/km in ICEVs can be compensated with increasing the shares of Low TTW emission vehicles emissions if a TTW metric is chosen. Hence this drawback of **WTW leakage** can occur when this design option is combined with a TTW metric(see also factsheet on Metric(s)) (ref. 4). Also the **real-world emissions** of the fleet can be impacted due to differences in mileage of different vehicle types. If the OEM chooses to let a small car overachieve the target and a large car to underachieve, this will increase real-world fleet emissions as small cars have on average lower mileages than large cars (ref. 2; ref. 4). Finally, **setting only one target for all vehicles is complex as it limits the target setting to feasible market shares of ZEVs** if the target is set at a level that cannot be met by ICEVs alone. Again this is mainly a problem if combined with a TTW metric, as in this case the difference between the performance of an ICEV and of a Low TTW emission vehicle is highest. Hence, if the share of Low TTW emission vehicles is lower than what was expected with setting the target, this needs to be compensated by improving the efficiency of ICEVs or with a flexibility mechanism (e.g. excess emission premiums or banking and borrowing). The potential of doing so may be limited and it may even not be technically feasible (ref. 4). As was the case for C3.1 Limit value for each vehicle, targets can either be the same for all OEMs or can be differentiated with a utility function. The **relative impact of mileage differences** between different vehicles can be somewhat **lowered** with option **C3.3 Limit based on overall sales-weighted average per segment**, as vehicles within one size segment will have a more comparable mileages than all vehicles in

C3	Aggregation & weighting
	the fleet. Hence, this option does not have to be combined with mileage weighting (C3.5.). However, still, it does not fully eliminate the risk of real-world CO_2 increases, as mileages within size segments can still differ significantly. The **flexibility of OEMs is** also **reduced**, although they can still vary with different vehicles within one car/van size segment. It will therefore increase costs compared to one overall sales-weighted average limit (C3.2) (ref. 3). This is especially the case for vans, which have fewer sales and models in each size segment for internal averaging (ref.3). When combined with a TTW metric, this option may also allow higher emitting ICEVs (and **WTW leakage)** as within one segment, an OEM can compensate his underachieving ICEs with higher shares of Low TTW emission vehicles in that segment. Thereby, the shares of alternatives in different size segments will vary, which is important to take into account when setting targets for each size segment. Furthermore, competition between OEMs is fairer as they mostly compete within one segment. It also prevents waterbed effects for national policies. The latter issue is not applicable to the fourth option (**C3.4 Technology specific targets: limit based on overall sales-weighted average per technology**) even when combined with a TTW metric. Setting a limit for each main technology (ICEV, BEV, PHEV/REEV, etc.) ensures **that ICEV targets are not compromised** by increasing shares of Low TTW emission vehicles as OEMs cannot use internal averaging between Low TTW emission vehicles and ICEVs (ref. 4). Hence, it provides incentives to improve all main powertrains and **prevents WTW CO_2 leakage**. Another advantage of setting separate targets is that it results in a **less complex target setting process**, as it is not necessary to assume feasible market shares of Low TTW emission vehicles when determining targets; each target is assessed separately on feasibility and cost effectiveness. This option has some disadvantages. Firstly, it **reduces the flexibility of OEMs** compared to a situation with one target for total fleet sales, although OEMs can still vary their efforts between different vehicles within one technology. Secondly, it **does not promote a transition to technologies with the lowest WTW performance** (if the separate targets are equalling challenging), although this can also be considered an advantage as it is technology neutral (ref. 4). Thirdly, differences in mileage can still impact **real-world emissions**. Within one technology segment (e.g. diesel ICEs), there can be significant differences in mileage. While keeping the (other dis)advantages of the sales-weighted average options described above, the **Option C3.5 Combining each of the options listed above with mileage weighting** corrects for differences in mileage and captures that a g/km reduction in a particular segment will have a smaller or larger impact on the total emissions than a reduction in another segment (ref. 4). The difference in lifetime mileage between petrol and diesel cars is roughly 70,000 km according to ref 9. Within the segment of petrol cars, mileage increases with mass/footprint. Within the segment of diesel cars and vans, lifetime mileage is relatively constant (ref 9.). By including mileage weighting the **real-world GHG emission reduction becomes thus less sensitive to an OEM's distribution of efforts** over different vehicles (note that leakage due to mileage differences is something different than WTW leakage with a TTW metric) (ref. 2; ref. 4; ref. 2). Thereby, this option can **reduce compliance costs,** as CO_2 reductions applied to larger vehicles pays-off more (due to their higher mileage) and because emission reduction technologies for diesel cars (with higher mileages) are more expensive than is the case for petrol cars; hence, with including mileage-weighting a lower reduction per km is needed for diesel vehicles (ref. 2). According to ref 9. a reduction of 1.75% (combined with mass as utility) to 1.62% (combined with footprint as utility) in overall fleet-wide marginal costs to OEMs of achieving similar CO_2 emission reduction results from applying mileage weighting. Including mileage in the sales-weighted averages does require estimated **mileage values** for each vehicle, which can be based on a categorisation using various vehicle characteristics, such as fuel type and utility (e.g. mass or footprint). Furthermore, this could be a general function or (at least in theory in) a manufacturer-specific function. According to ref. 2, working with general fleet average mileage values is sufficient if mileage values are based

C3	*Aggregation & weighting*
	on both utility and on energy carrier, as for the latter mileages differ significantly. It may be difficult to determine mileage values for immature technologies that have not yet been applied at large scales (ref. 4). Moreover, mileages may differ between manufacturers, countries and vary over time, which may make it difficult to reach consensus (ref. 4). Thereby, OEMs may not accept this option, as they can argue to have no control over how their vehicles are used (ibid.). However, completely ignoring the different mileages may be considered worse than approximating them. For each of the sales-(and mileage) weighted options mentioned above it is also necessary to decide whether the sales-(and mileage) weighted target applies to ***EU-wide sales*** or to ***national sales in each Member State***. Considering that the Regulation also has an EU wide scope and OEMs operate transnationally, it seems more appropriate to focus on EU-wide sales, except if Member States are chosen as the regulated entity. This is also recommended by ref. 3.
Recommendations from previous work	– Ref. 3 recommends target levels that are based on **EU sales averages** rather than on national averages. – Ref. 29 recommends *not* to implement **C3.1. None: limits for each vehicle.** – Ref. 2. states that it is sufficient to work with **general mileage values** which differentiate both energy carriers and utility.
Relation/inter-dependencies with other modalities	– Related to the metric. If a TTW CO_2-based metric is chosen the necessity to set different targets for different technologies is higher than for an energy-based or WTW CO_2-based metric. – Related to the regulated entity: in case Member States are regulated, National sales averages are more appropriate. For other entities, EU-wide sales are more appropriate. – Interdependency with 'utility parameter' and 'Shape and slope of target function'; The limits can be the same for all OEMs/vehicles/segments/, etc. (no utility) or can vary according to their utility. – Related to the approach for target setting; sales-weighted averages can either be defined as annual sales, but could also be based on periodic sales (e.g. average of three subsequent years).
Specifics for cars and vans	– For cars a larger size does on average not lead to a significantly higher transport utility while this is usually the case for vans: larger vans provide more loading space and therefore may reduce the number of vans needed (and reduce the emissions per tkm). Therefore, applying **C3.1. None: limits for each vehicle** to vans can reduce transport efficiency (ref. 29). – For vans a **(C3.3) limit to overall sales-weighted average** per segment may lead to unwanted distributional impacts (i.e. it will impact the competitiveness of individual manufacturers), due to the relatively small sales volumes and limited number of models in each segment which in turn limit the scope for internal averaging (ref. 3).
Main conclusions	– **C3.1 None: Limit value for each vehicle** is excluded from further analysis as it reduces flexibility of OEMs, increases compliance costs and may result in market distortions. – **C3.3 (per segment)** is excluded from further analysis as it has a lower cost-effectiveness and is a relatively complex approach. Moreover, an unambiguous definition of segments is very difficult and perverse effects around the boundaries between segments can be expected. – **Sales averages based on MSs** will be excluded. – All other options will be further investigated.
Issues to be further assessed	– Impact of setting technology specific targets on overall fleet emissions (due to possibly lower shares of low TTW emission vehicles compared to one overall target). – According to ref. 2 "more analysis is needed to assess the full effects of mileage weighting as well as to further determine practical implications". – How to deal with mileage values for immature technologies which are likely to gain market share in the near future (e.g. PHEVs, BEVs).
Annex	None
Sources	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).

C3	Aggregation & weighting
	(ref. 3) Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3).
	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO; AEA; CE Delft; Ricardo, 2013) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 5). Analysis of the influence of metrics for future CO_2 legislation for Light Duty Vehicles on deployment of technologies and GHG abatement costs. (TNO; CE Delft, 2013) (SR#8 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 29) Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles (EC, 2012b).

D.2.4 D. Approach for target setting

D1	*Approach for target setting*
Group of modalities	**D. Approach for target setting**
Function in future regulation	To determine when the regulated entity must have met the target level that has been set.
Relevant option(s)	– D1.1 Targets for fixed date(s) without phase-in – D1.2 Targets for fixed date(s) with phase-in (as in existing Regulation) – D1.3 Annually declining targets *For each option the specific target year(s)/target period(s) need to be determined.*
Main pros and cons of option(s)	Three options have been distinguished for the target setting approach. To clarify the differences between these approaches, they are illustrated graphically in Figure 102 in Annex D.3.3. With option **D1.1 Targets for fixed date(s) without phase-in and D1.2 Targets for fixed date(s) with phase-in**, targets are determined for a (number of) fixed year(s) and have to be met from this (these) year(s) onwards. According to ref 2. the main advantage of these options is that they **align well with product development cycles**, which, on average, vary from 2.5 (for an existing technology with new application) to 5 (for a new technology) years. This is why target dates would ideally be implemented 5 years in advance, to not conflict with these development cycles and to give OEMs sufficient time to respond (ibid). In practice this argument may not necessarily apply; OEMs will comply with the targets through a range of technologies across their vehicle range and will not redesign each vehicle in accordance with the Regulation. Targets for fixed dates can be implemented with or without phase-in. Without phase-in (option D1.1), OEMs are completely free in deciding how to meet the target in a particular year. However, in theory this can result in OEMs delaying the introduction of more fuel-efficient technologies to the last years before the target year (ref. 2). As is shown in Figure 103 in Annex D.3.3, this would result in relatively **higher fleet-wide CO_2 emissions** than would otherwise have been the case. According to ref. 2, this results in additional emissions that are approximately 3g/km higher (for the period 2015-2040) compared to annually declining targets. In practice this behaviour has not yet been seen. Phase-in of the target (option D1.2), requires an increasing x% share of the fleet to meet the target in the years prior to the target and is argued to reduce the risks of delays in introducing new technologies (ref. 29). However, it is also argued to reduce the flexibility of OEMs as they have to comply with (part of) the target in multiple years instead of only in the target year (ref. 29). Ref. 8 concludes that phasing-in in the existing Regulations have weakened the Regulation with 1.7% 2012 for cars. However, this “needs to be balanced with the benefits to manufacturers of easing the transition in relation to the application of the Regulation”. Flexibility of OEMs is further reduced with **D1.3 Annually declining targets,** which sets yearly declining intermediate targets (e.g. with constant yearly reductions) between two or

D1	*Approach for target setting*
	more main target years (e.g. 2025 and 2030). Despite the fact that it reduces OEMs' flexibility (although this depends on other flexibility mechanisms available) and may - at least in theory - conflict with product development cycles (ref. 29; ref. 2), it has three main advantages. Firstly, it can avoid that OEMs postpone the introduction of more fuel-efficient technologies and new efficient models to the last years before the target has to be met (ref. 2). As was shown in Figure 103 of Annex D.3.3, this will reduce fleet-wide CO_2 emissions relatively more compared to the situation without separate target (option D1.1 in particular and option D1.2). Secondly, this option will increase the likelihood that OEMs will actually meet their targets in the main target years (ref. 2). Manufacturers may not support this option though, due to the fact that the loose the flexibility in determining their yearly reduction pace. Thirdly, it enables banking and borrowing. Ref. 2 recommends to implement this option together with the modality 'banking and borrowing' (see Section D.2.6), as with yearly targets OEMs have little room to steer for the targets and in addition unexpected changes in their sales distribution can otherwise result in high compliance costs (if combined with excess emission premiums). In this case, it may be desirable to implement a maximum level of CO_2 credits, to prevent that OEMs are unable to balance out borrowed CO_2 credits (ref. 2). It does increase the burden of the Commission.
Recommendations from previous work	– In case **D1.3 annually declining targets** are chosen, ref 2. recommends to also implement the banking and borrowing modality with a maximum level of CO_2 credits (see Section D.2.6). – Ref. 8 concludes that if targets are set sufficiently in advance, there is no added value (with respect to the objectives of the regulation) to implement phase-in (D1.1).
Relation/inter-dependencies with other modalities	– Related to 'Banking and borrowing'; some of the options for target setting (particularly annually declining targets) would best be combined with banking and borrowing, while others (e.g. targets for fixed periods) are less appropriate to combine.
Specifics for cars and vans	– Risks of overshooting/undershooting annually declining targets may be higher for vans than for cars, due to smaller sales volumes.
Main conclusions	– All options will be further investigated.
Issues to be further assessed	– To what extent the benefits of annually declining targets indeed outweigh the drawbacks.
Annex	Annex D.3.3
Sources	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 29) Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles. (EC, 2012b).

D.2.5 E. How to fairly distribute the burden across regulated entities?

<table>
<tr><th>E1</th><th>Utility parameter</th></tr>
<tr><td>Group of modalities</td><td>E. How to fairly distribute the burden across regulated entities?</td></tr>
<tr><td>Function in future regulation</td><td>Provides a basis for differentiating the overall target into specific targets for individual legislated entities</td></tr>
<tr><td>Relevant option(s)</td><td>– E1.1 No utility parameter = no differentiation
– E1.2 Mass as a utility parameter
– E1.3 Mass + correction for under-crediting of mass reduction
– E1.4 Footprint as a utility parameter</td></tr>
<tr><td>Main pros and cons of option(s)</td><td>
E1.1 No utility parameter = no differentiation
This option corresponds to flat limit function, i.e. a constant limit CO_2 value which is not dependent of other variables such as vehicle weight and footprint.

E1.2 Mass as a utility parameter (ref.2)
Table 1 Pros and cons of reference mass as utility parameter
<table>
<tr><th colspan="2">Reference mass</th></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>Easily / objectively measured</td><td>Not a direct measure of utility</td></tr>
<tr><td>Accepted by industry (continuity with current legislation)</td><td>Possibilities for gaming depend on slope of limit function</td></tr>
<tr><td>Good correlation with CO_2 emissions</td><td>Easy options for gaming: “Brick in the boot”</td></tr>
<tr><td></td><td>Makes weight reduction as CO_2 reduction measure much less attractive</td></tr>
</table>

E1.3 Mass + correction for under-crediting of mass reduction
This option has been assessed in the down-weighting study. A correction based on the density of the vehicle (mass/footprint) could be used.

E1.4 Footprint as a utility parameter (ref.2)
Table 2 Pros and cons of footprint as utility parameter
<table>
<tr><th colspan="2">Footprint</th></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>Easily / objectively measured</td><td>Relatively tough on compact / high cars (e.g. MPVs)</td></tr>
<tr><td>Gaming is considered relatively difficult due to required changes in structural design of vehicle and associated consequences for mass and vehicle CO_2 emissions</td><td>May promote tendency towards larger cars unless compensated for such autonomous footprint increase</td></tr>
<tr><td>Better proxy for utility than mass</td><td></td></tr>
<tr><td>Used in US legislation</td><td></td></tr>
<tr><td>Good correlation with CO_2 emissions</td><td></td></tr>
</table>
</td></tr>
<tr><td>Recommendations from previous work</td><td>
For cars (ref.2)
– Comparing the different pros and cons for mass and footprint the conclusion is that there is no clear favourite. The main arguments for maintaining mass as utility parameter would be its acceptance by industry and the general desire to keep definitions for the 2020 as much as possible the same as for the 2015 target. The main arguments in favour of footprint are that it is a better proxy for the true utility of the vehicle and that it fully rewards the benefits of weight reduction as a CO_2 reducing option. The latter is relevant as advanced levels of weight reduction will be an increasingly important option for meeting targets for 2020 and beyond.
– […], footprint seems to be the favourable utility parameter.
For vans (ref.1)
– Compared to footprint, using mass as the utility parameter leads to slightly higher additional manufacturer costs for steeper limit functions.
– The additional manufacturer costs are distributed more evenly for mass than for the footprint-based limit function.
– It should also be noted that the time between the short term target of 175 g/km based on mass (2017) and the longer term 147 g/km target (2020) is only three years. In case footprint is deemed favourable for the 2020 target manufacturers with deviant mass-footprint ratios, might have to severely adapt their CO_2 reduction strategies in a relatively short period.

Competitiveness impacts (ref. 6)
– Shape and slope of the target function, together with sales distributions of EU and
</td></tr>
</table>

E1	*Utility parameter*
	non-EU OEMs, determine possible impacts on competitiveness of EU car manufacturers. For footprint as utility parameter choices with respect to the shape and slope of the target function are less likely to lead to impacts on competitiveness of EU vs. non-EU manufacturers.
Relation/inter-dependencies with other modalities	Regulated vehicle categories: see above. No utility parameter = no differentiation = target function with zero slope.
Specifics for cars and vans	None.
Main conclusions	There is basically no valid argument for keeping mass as a utility parameter, as clearly pointed out in the presentation of the study on mass reduction (ref. 7). In addition to arguments already given in previous assessments this new study also shows that the costs for meeting the target are significantly lower when footprint is used. However, mass has the preference of some stakeholders, and therefore, both are included for further assessment.
Issues to be further assessed	The methodology for 'Mass + correction for under-crediting of mass reduction' needs to be checked in the down weighting study. Conclusions with respect to mass and footprint for vans are influenced by specifics of the current TA test procedure which result in relative low CO_2 values for large vans. It needs to be assessed to what extent that the previously identified issues are solved in the WLTP.
Annex	None
Sources	(ref. 1) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (TNO, et al., 2011a) (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 3) Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3).
	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO; AEA; CE Delft; Ricardo, 2013) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 6) Assessment of competitiveness impacts of post-2020 LDV CO_2 regulation, Project for DG CLIMA under the Multiple framework contract for the procurement of studies and other supporting services on impact assessments and evaluations (Valdani Vicari & Associati (VVA); Technopolis Group (TG); TNO, as part of Joint Institute for Innovation Policy (JIIP), 2015) (ENTR/172/PP/2012/FC) (ongoing).
	(ref. 7) study on mass reduction (ICCT, 2010).

E2	*Shape and slope of the target function*
Group of modalities	**E. How to fairly distribute the burden across regulated entities?**
Function in future regulation	A utility-based target function is used to specify emission targets per vehicle depending on its utility value. Manufacturer targets are defined by sales-weighted averaging over the emission targets for all vehicles (models and variants) sold in the EU27.
Relevant option(s)	– E2.1 Zero slope target function = no differentiation (this implies no utility parameter) – E2.2 Linear target function with finite slope – E2.3 Truncated linear target function with a floor and/or a ceiling – E2.4 Non-linear target function (see e.g. US legislation)
Main pros and cons of option(s)	**E2.1 Zero slope target function = no differentiation (this implies no utility parameter)** (ref. 2) A constant CO_2 target value which is not dependent of other variables such as vehicle weight and footprint. A flat limit curve will result in significantly higher compliance cost than a linearly limit function with finite slope. Due to the non-linear cost curves the additional costs for OEMs who manufacture large vehicles will more than outweigh the reduced costs for manufacturers of on average smaller cars (ref. 29). According to ref. 29 both sub-options should be discarded for vans and cars. **E2.2 Linear target function with finite slope: $CO_2 = b + a \times (U - U_0)$** (ref. 1) A linear target function with finite slope does justice to the fact that larger cars, due to their inherently larger mass, can on average not reach the same CO_2 emission levels as smaller cars at comparable cost levels. The current regulations have a linear limit function and provide a reasonable correlation with the scatter of CO_2 data as function of mass. Switching would mean a break with historical regulations and could conflict with strategic choices made by OEMs with respect to selection of CO_2 reduction options in view of the shape and slope of the target function. A linear target function (with correction for trends in U_0)provides certainty of meeting the overall target if all manufacturers meet their individual target. **E2.3 Truncated linear target function with a floor and/or a ceiling** (ref. 2) i.e. linear sloped line targets with horizontal cut-offs at the upper and/or the lower end. The motivation for truncating the limit function would be e.g. to reflect possible flattening of the correlation between utility and CO_2 or to reduce the burden for small vehicles resp. limit the credits that large vehicles get for increasing utility. If a floor or ceiling is to affect a significant number of vehicles it has to intercept the linear limit function at a utility value that is well within the bandwidth defined by the cloud of data points (utility value and CO_2 per model). From analysing the position of the limit function with 100% slope relative to the cloud of data points it has become apparent that in the European market situation floors and ceilings of non-linear limit functions do not have significant impacts unless they are set at unreasonable levels (> 80 g/km for the floor and < 140 g/km for the ceiling in order for each to affect 5% of the new vehicle fleet). **E2.4 Non-linear target function (see e.g. US legislation)** (ref. 2) i.e. quadratics, cubic or higher order polynomials. Since the non-linear curves ought to be based on the linear curves with cut-off, the same conclusions were drawn for the continuous limit functions with floors and/or ceilings. Conclusively, these types of limit functions can be considered to be interesting theoretical concepts, but are proven to provide no practical benefits in the European situation.
Recommendations from previous work	**Linear target function with finite slope: $CO_2 = b + a \times (U - U_0)$** are recommended by (ref. 1) (ref. 2).
Relation/inter-dependencies with other modalities	Utility parameter.
Specifics for cars and vans	For vans the current test procedures lead to CO_2 as function of mass and particularly footprint that fit less well with a linear target line than for passenger cars. It needs to be reviewed whether that is still the case for the WLTP.
Main conclusions	Option **E2.2** is preferable if the distribution of sales remains comparable as in 2009. In that case, **E2.3** and **E2.4** are excluded.

E2	***Shape and slope of the target function***
	Depending on the sales database for 2014, **E2.3** and **E2.4** are still included for further assessment (see below).
Issues to be further assessed	The impact of the WLTP impact on the correlation between vehicle CO_2 and mass resp. footprint has to be assessed. In previous analyses, **E2.3** and **E2.4** were excluded for further investigation. A comparison between the sales databases 2009 and 2014 will have to show whether this is still the case.
Annex	None.
Sources	(ref. 1) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (TNO, et al., 2011a) (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 3) Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3).
	(ref. 29) Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles. (EC, 2012b).

D.2.6 F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?

F1	*Pooling*
Group of modalities	**F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?**
Function in future regulation	To reduce the compliance costs of manufacturers through providing flexibility
Relevant option(s)	– F1.1 No pooling of targets – F1.2 Pooling of targets between car or van manufacturers (as in existing Regulation) – F1.3 Pooling of targets for cars and vans
Main pros and cons of option(s)	**F1.1. No pooling of targets.** The main disadvantage of not allowing pooling are **suboptimal compliance costs**, as each manufacturer group/brand name (also those with relatively high marginal abatement costs) *has* to reduce emissions of their cars/vans. It does ensure however, that the **energy efficiency of all vehicle types and sizes is improved**. **F1.2 Pooling of targets between manufacturer groups** can be applied to provide more flexibility to car and to van manufacturers for meeting their targets. The larger possibilities for internal pooling **reduce compliance costs** as reductions can be applied by those manufacturers which have lowest marginal costs or greatest ability to sell lower CO_2 vehicles. From previous studies it is clear that pooling of manufacturer targets does not have negative consequences on a range of criteria. If targets are based on sales-weighted averages, pooling can **negatively impact the net real-world emission reduction** if the g/km reduction is shifted from larger cars (with high annual mileage) to smaller cars (with low annual mileage (ref. 2; ref. 4). This would not be the case if targets are sales-and-mileage based and hence pooling is as well. **F1.3 Pooling of the targets for passenger cars and vans** would mean that manufacturers can compensate underachievement in one category by an equivalent overachievement in the other category. The main advantage hereof is that they enhance OEMs' flexibility in meeting both targets (internal averaging), which can **reduce their compliance costs.** As a result it can occur that either the van or passenger car target is not met though. The **deviation from the target** (in g/km) is likely to be larger for vans, which can be explained by the fact that the sales of vans are much smaller than car sales; a small deviation from the g/km target for cars has a much larger impact on the total under-/overachievement (g/km times total mileage and/or sales) than would be the case for vans. Hence, it is much easier to compensate the over- under achievement for vans with cars than the other way around. The extent to which pooling of the car and van targets is applied depends on the marginal costs of reducing CO_2 for both vehicle types (ref. 2; ref. 4). In case marginal costs are roughly the same, undesired consequences are avoided. For the 2020 targets, marginal costs for vans are much lower than for cars. If pooling of targets would be allowed for the 2020 targets, this would thus result in much lower CO_2 emissions per kilometre for vans and slightly higher emissions per kilometre for passenger cars (due to the sales-volume effect described above). This is shown graphically in Annex D.3.4. The marginal costs for targets beyond 2020 have not been assessed. A disadvantage of both options for pooling targets is that it **negatively impacts competitiveness of OEMs that only sell cars or vans**, and hence, cannot reduce their compliance costs by applying internal averaging (ref. 4). Therefore, these two options do not comply with the objective of competitive neutrality. If the target and hence pooling is based on sales-weighted averages shifting a g/km reduction from vans to cars has a negative impact on the **real-world fleet wide CO_2 emissions**, as vans have significantly higher mileages (ref. 2; ref. 4). If targets and pooling are based on sales-and mileage weighted averages this risk is avoided (ref. 4).
Recommendations from previous work	None.
Relation/inter-dependencies with other modalities	– F1.3 (pooling of car and van targets) is related to the target level that is set for vans and cars, as this determines the marginal cost difference of achieving both targets. This in turn will determine whether pooling of these targets will have negative consequences.

F1	Pooling
	– Whether pooling (F1.2. and F1.3) is based on sales or sales-and-mileage averages, is dependent on Aggregation & Weighting; if the overall performance is determined with sales-weighted targets, pooling should also be sales-based and the other way around.
Specifics for cars and vans	None.
Main conclusions	– F1.1 No pooling of targets is included for further analysis, but only in combination with trading of CO_2 credits. – F1.2 (pooling targets OEM groups) is included for further analysis as it is a no regret option (with linear target functions). – F1.3 Pooling of targets for cars and vans is excluded from further analysis as it can result in unfair competition to those who do not produce both vehicle types.
Issues to be further assessed	None.
Annex	Annex D.3.4.
Sources	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 4) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (TNO, et al., 2011a) (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043).

F2	*Trading CO_2 credits*
Group of modalities	**F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?**
Function in future regulation	To reduce the compliance costs of manufacturers through providing flexibility
Relevant option(s)	– F2.1 No trading of credits – F2.2 Allowing trading of credits for passenger cars – F2.3 Allowing trading of credits for vans – F2.4 Allowing trading of credits for vans and passenger cars separately – F2.5 Allowing trading of credits for vans and passenger cars and also allowing trading of credits between cars and vans *For each option a definition of what is traded (grams, grams/km) is required and temporal aspects (banking and borrowing of credits) needs to be determined.*
Main pros and cons of option(s)	If **(F2.1) no trading of credits** is chosen, each regulatory entity will *have* to meet its own target. Considering that the marginal abatement costs of reducing CO_2 will differ between different car manufacturers and van manufacturers (and especially between cars and vans), this is likely to result in relatively **higher total compliance costs** (ref. 3). However, if pooling is allowed, the additional benefits of trading reduce. **Allowing trading (F2.2 – F2.5)** on the other hand, is likely to **reduce overall compliance costs**, as relatively larger CO_2 emission reductions can be realised by those OEMs that have relatively lower abatement costs. This will mainly reduce the burden of OEMs with sales distributions and/or vehicle portfolios that deviate most from the average in the market. Ref 3. modelled the 130 g/km target for passenger cars for example and found that traded amounts would be quite small (1-3%). However, the monetary value of these traded credits represented 10-20% of the total modelled costs of reaching the target, resulting in an overall cost reduction (for the market and for each OEM) of approximately 10%. Trading is also beneficial for the distributional impact, although it does increase administrative complexity for OEMs (ref. 3). Four trading options can be thought of, which are allowing trading of credits for: – Passenger cars only (F2.2); – Vans only (F2.3); – Vans and for passenger cars separately (F2.4); – Vans and for passenger cars and also between vans and passenger cars (F2.5). For each option, a trading system needs to set up which increases the administrative burden of the Commission compared to pooling. However, it provides some additional flexibility as it also allows small amounts to be (anonymously) traded. The first three design options share the benefits mentioned above. However, with **(F2.5) trading between vans and cars**, some additional (dis)advantages can be pointed out. As the difference of marginal abatement costs is likely to be relatively larger between an average car and an average van compared to the differences between different cars or between different vans (see also Figure 104 in Annex D), the benefits of trading credits between cars and vans in terms of lowering overall compliance costs can also be significant. However, this in turn also result in the risk of not achieving both the car and van target, as relatively more effort will be assigned to improving the vehicle category with lowest abatement costs. Obviously, this disadvantage is only relevant in case separate targets are set for vans and cars. Additionally, allowing trading between cars and vans can have an impact on the real-world fleet emissions, as the divergence between test-cycle and real-world emissions is likely to be differ for cars and vans (ref. 3). These effects are comparable to the effects that may result if sales-weighted pooling of cars and vans target is allowed (see 'Pooling' in Section D.2.6). In case one of the options allowing trading (F2.2 – F2.5) is chosen, a definition of what is traded is required, which can be g/km (sales average) or grams (g/km times the average mileage of the OEM who's trading) for example. In case the traded amount is not corrected for mileage (g/km), the real-world fleet emission reduction can be (negatively or positively) impacted, due to differences in average mileages between OEMs. This can be especially

F2	*Trading CO_2 credits*
	significant if car emission credits are traded with vans, the latter having a significantly higher mileage (see 'Pooling' in Section D.2.6). Additionally, it should be determined if the credits that are traded can be banked and/or borrowed or not. Banking and borrowing does increase OEMs' flexibility and hence reduces compliance costs further (ref. 2).
Recommendations from previous work	– No explicit recommendation from previous work, although Ref. 3 seems to point out fewer negative aspects of trading within one category compared to trading between cars and vans.
Relation/inter-dependencies with other modalities	– The negative consequences that may be expected with option F2.5 (trading between cars and vans) depend on whether separate targets are set or not (modality 'Regulated vehicle categories'). – Trading would eliminate the need for pooling.
Specifics for cars and vans	None.
Main conclusions	– F2.1 (No trading) is included in further analyses, but only if pooling is allowed or with a non-linear target function. Allowing no trading nor pooling would result in reduced cost-effectiveness. – **F2.2 (Trading passenger cars) and F2.3 (Trading vans**) are excluded for further analysis, as it is unfair to only allow trading for one group and not for the other. – F2.4 (trading passenger cars and trading vans) is included for further analysis. – **F2.5 (trading between cars and vans)** is excluded from further analysis as it may result in higher real world emissions due to the higher mileages of vans.
Issues to be further assessed	– The impact of different definitions of what is traded on the real-world fleet emissions.
Annex	None.
Sources	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 3). Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3.

F3	*Banking and/or borrowing*
Group of modalities	**F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?**
Function in future regulation	Banking and/or borrowing is a scheme that allows manufacturers to have more flexibility in the compliance with a specific emission target for a specific year. When the average CO_2 emission of the new vehicle sales is below the specific emission target for that year, the manufacturer or group of manufacturers can bank the difference as emission allowances. When the average CO_2 emission value exceeds the specific emissions target in another year, the manufacturer can offset these excess emissions with 'banked' emission allowances from preceding year(s) or 'borrow' emission allowances, which have to be 'paid back' in subsequent years. This mechanism allows manufacturers to flexibly deal with the introduction of new technologies, decreasing the risk of paying excess emissions premiums, while maintaining the overall reduction trajectory.
Relevant option(s)	– F3.1 No banking/borrowing – F3.2 Allowing only banking (maximum period and maximum banked amount to be specified) – F3.3 Allowing banking and borrowing (maximum period and maximum banked/borrowed amounts to be specified)
Main pros and cons of option(s)	**F3.1 No banking/borrowing** --- **F3.2 Allowing only banking (maximum period and maximum banked amount to be specified)** This option only really makes sense in combination with annually decreasing targets. In the current situation, with a target valid from a given year onwards, it is highly unlikely that a manufacturer's average is below target in the target year and above target in later years. The opposite is more probable. **F3.3 Allowing banking and borrowing (maximum period and maximum banked/borrowed amounts to be specified)** (ref. 2) The possible effect on fleet-wide CO_2 emissions of the introduction of banking and borrowing in addition to annual decreasing targets is small as long as the banked or borrowed emission allowances balance is neutralised by the end of the banking and borrowing period and this period is sufficiently short. Banking and borrowing does not provide an incentive for manufacturers to postpone the application of CO_2 reducing technologies. Due to the strong non-linearity of the cost curves for CO_2 reduction, borrowing CO_2 credits prior to banking increases the net costs of meeting the target averaged over a longer time period. Therefore manufacturers will only delay their CO_2 emissions reduction if the costs of changing their model cycles are higher than the additional costs of compensating for their borrowed CO_2 credits. The other way around it could provide an incentive for manufacturers to over comply in earlier years. Hence it is safe to allow banking and borrowing. In order to manage the risk of manufacturers not being able to balance out a negative amount of CO_2 credits, a maximum amount of borrowed CO_2 credits can be considered.
Recommendations from previous work	**Banking and borrowing** is a recommendable flexibility mechanism in addition to a trajectory of declining annual target values since such short periods between targets leave relatively little headroom for manufacturers to steer for these annual targets. This relates to their possibilities to adjust R&D programmes and model development cycles, but also to exterior developments (e.g. unexpected changes in sales distribution) that can influence a manufacturer's average CO_2 emission levels. Allowing banking and borrowing offers manufacturers the opportunity to compensate for possible overshooting or undershooting the targets in certain years as a result of these control limitations (ref. 2).
Relation/inter-dependencies with other modalities	Banking an borrowing needs to be combined with a **trajectory of declining annual target values** (ref. 2). When combined with targets that are only adjusted every 3-5 years (as in the current regulation, a sloped approach towards the next target generates a lot of free credits ('hot air') which will be used to postpone meeting that next target.

Specifics for cars and vans	None.
Main conclusions	All options are included for further analysis.
Issues to be further assessed	No specifics, there seems to be general consensus on the fact that banking/borrowing in combination with a trajectory of declining annual target values is a recommendable flexibility mechanism. It should be considered whether banking and borrowing without mileage weighting can lead to a overall CO_2 savings.
Annex	None.
Sources	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043)

F4	*Excess emission premiums*
Group of modalities	**F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?**
Function in future regulation	Excess emission premiums of a penalty per g/km can be used to sanction manufacturers that exceed their-specific target.
Relevant option(s)	– F4.1 Excess emission premium of €X per excess g/km, possibly with lower premium for the first few g/km exceedance – F4.2 No market access when targets are exceeded
Main pros and cons of option(s)	**F4.1 Excess emission premium of €X per excess g/km** (ref.1) If the average CO_2 emissions of a manufacturer's fleet exceed its limit value, the manufacturer has to pay an excess emission premium for each vehicle registered that is proportionate to the level of exceedance of the target. According to the current Regulations, this premium amounts to € 95 for every g/km of exceedance from 2019 onwards. This is the same for passenger cars and vans. According to (ref. 1) the excess premium level from 2019 onwards is significantly higher than the average marginal costs for meeting the 2020 target for every manufacturer (which on average is just below € 30 g/km for all slopes analysed). Between 2015 and 2020 the excess emission, for which manufacturer groups have to pay a penalty, is determined relative to their 2015 target, determined per manufacturer group using the mass-based limit function. Besides as a penalty the excess premium can also be seen to act as a safety valve. Manufacturers are never forced to implement measures with higher marginal costs than the excess emission premium. Also it allows OEMs to continue selling cars on the EU market even if they temporarily do not meet the requirements of the CO_2 legislation. To assure that this does not lead to significant deviations from the overall target the excess premium needs to be higher than the highest marginal costs of each of the OEMs. **F4.2 No market access when targets are exceeded** As far as we are aware, this was not studied previously. It could be considered an alternative for excess premiums, but as it would be an extremely far reaching measure to block market access, the cost are clearly higher than excess premiums.
Recommendations from previous work	**The level of excess emission premium** must be re-evaluated for 2025 and beyond in order to establish whether the penalty is high enough to incentivise all manufacturers to reduce CO_2 levels of their vehicle fleet to the target level.
Relation/inter-dependencies with other modalities	According to (ref. 1) the excess premium levels from 2025+ must be larger than the highest **marginal costs for realising the final 1 g/km CO_2 emission reduction** for any OEM to meet the target. Allowing trading between OEMs would provide an OEM that does not meet its target an the possibility to avoid having to pay a penalty. The price of traded credits will always be lower than the excess premium.
Specifics for cars and vans	None.
Main conclusions	No options are excluded for further analysis. There is no reason not to have excess premiums as a modality of post 2020 CO_2 legislation for cars and vans. Insight in the marginal costs of meeting the targets can serve as a basis for determining the height of the premium.
Issues to be further assessed	None.
Annex	None.
Sources	(ref. 1) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (TNO, et al., 2011a) (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 3) Possible regulatory approaches to reducing CO_2 emissions from cars (IEEP; CE Delft; TNO, 2007) (070402/2006/452236/MAR/C3).

F5	*Derogations*
Group of modalities	**F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?**
Function in future regulation	To reduce compliance costs for specific regulated entities and/or regulated vehicles
Relevant option(s)	– F5.1 For manufacturers with small volume (EU) sales – F5.2 For manufacturers with niche volume (EU) sales – F5.3 For manufacturers with small volume (global) sales – F5.4 For manufacturers with niche volume (global) sales – F5.5 For certain vehicle types – F5.6 Combination of the above
Main pros and cons of option(s)	Marginal abatement costs will differ between different regulated entities. Consequently, meeting the targets that are set, for example with limit value curves (see Section D.2.5), can be more challenging and costly for some OEMs than for others. This is likely to be especially the case for OEMs with small volumes and a specialised portfolio (ref. 29). It can therefore be considered as inappropriate to force the method for determining the target for **F5.1/F5.3 OEMs with small (EU and/or global) volume sales** as is used for large OEMs and more appropriate to determine the reduction potential on a case-by-case basis (ref. 32). This is especially appropriate when taking into account that the vehicles of these manufacturers are often used for shorter distances (e.g. sport cars) than vehicles sold by large OEMs. Consequently, the contribution of Small volume OEMs is estimated below 0.01% of the total CO_2 emissions (ref. 29). With the current threshold for this derogation (<10,000 cars), the market distortion impact is likely to be limited even when the derogation is based on EU sales (ref. 30; ref. 8). In the US Regulation this threshold is set even tighter (<5,000 vehicles) (ref. 30). Derogations could also be applied to OEMs with **(F5.2/F5.4) niche (EU and/or global) volume sales**, as their sales mix may not be in line with the overall EU fleet. In the existing Regulation, the threshold is 10,000–300,000 (ref. 32). In the existing Regulations niche derogation thresholds are based on EU-sales volume. Consequently, some major global manufacturers with relatively small sales in the EU, fit the niche derogation criterion currently defined (ref. 29). This in turn may result in a distortion of the market and may provide new entrants in the EU market a competitive advantage. If the upper threshold (currently 300,000 for cars) would be lowered, the market distortions would be lowered as well. Alternatively, derogations could be based on global sales rather than EU sales, which would solve this issue as well. According to ref. 8 niche derogations provide a larger source of potential weakness in the Regulation compared to derogations for small OEMs. If small and niche OEMs which use derogations would miss their original target (without the derogation) with 50 g/km, the regulation would be weakened with 0.3% (small) and 1.4% (niche), respectively. However, only one-third of the niche OEMs uses derogations at the moment. Hence, if all these OEMs would use derogations, the impact on the CO_2 reduction realised with the Regulation may become larger (ref. 8). The four options described above each require the definition of a threshold for the derogation and a method for determining alternative targets. This could be a specific emissions target that is consistent with the reduction potential of the manufacturer (case-by case) or a X% reduction on the average specific emissions of CO_2 in year Y for example (ref. 2). The method chosen will impact the benefits and drawbacks of the derogations described above. Rather than providing derogations to the regulated entity, derogations could also be given to **certain vehicle types (F5.5)**, such as dedicated passenger vans. This has not been assessed in existing literature, but it may share the same advantages and disadvantages as small volume OEMs.
Recommendations from previous work	– Ref. 29 recommends to continue with the small volume derogations (EU sales), at least up to 2020, and to adjust the niche derogations as defined in 443/2009 to prevent unfair competition. This could be realised either by adjusting the upper threshold or by taking into account global sales.

F5	*Derogations*
Relation/inter-dependencies with other modalities	– The approach for target setting modalities may differ for these derogated OEMs.
Specifics for cars and vans	– As the sales volumes differ significantly between cars and vans, separate thresholds need to be determined for the derogations. In the existing Regulations, niche derogations have only been adopted for the car Regulation, not for vans.
Main conclusions	– All options included for further analysis.
Issues to be further assessed	– Exploration of justification for continuing niche derogation. – Appropriate thresholds and target levels for the different derogations and impacts on emissions and compliance costs. – Assessment on whether global sales volumes can be measured objectively to be made legally binding in case the derogation is determined with global sales volumes. – Pros and cons of derogations to vehicle types.
Annex	None.
Sources	(ref. 2) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (TNO, et al., 2011b) (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043).
	(ref. 29) Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles (EC, 2012b).
	(ref. 30) Epa and NHTSA Set standards to reduce GHGs and improve fuel economy for model years 2017-2025 cars and light trucks (EPA, 2012a).
	(ref. 32) 'Regulation (EC) no. 443/2009 of the European Parliament and of the Council of April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles' (EC, 2009).

F6	*Adjusting U_0 in target function*
Group of modalities	**F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?**
Function in future regulation	Adjustment of the target function for trends in average vehicle utility factor leading to either the target not being met or an effectively more stringent target.
Relevant option(s)	– F6.1 Adjustment of U_0 in target function – F6.2 No adjustment of U_0 in target function
Main pros and cons of option(s)	**F6.1 Adjustment of U_0 in target function** If a linear target function is used, a shift in the average utility of all vehicles sold in the EU27 leads to a deviation of the average CO_2 value from the target value. If the utility increases (e.g. by sales shifts towards larger or heavier vehicles, vehicles gaining weight/size by added features, or by selling battery electric vehicles) the target is not met even if all OEMs meeting their specific target. If the utility decreases (e.g. by sales shifts towards smaller/lighter vehicles or application of weight/size reduction measures) OEMs are penalised by a lower target. Adjusting U_0 allows the Commission to compensate for such trends. **F6.2 No adjustment of U_0 in target function** The importance of weight/size reduction as a means to make LDVs more efficient increases with increasingly stringent targets. Mass as utility parameter provides a disincentive to OEMs to reduce weight. This is further enhanced if there is no provision for adjusting m0. The need for a possibility to adjust U_0 obviously decreases with a decreasing slope of the target function.
Recommendations from previous work	--
Relation/inter-dependencies with other modalities	Utility parameter. Shape and slope of target function.
Specifics for cars and vans	None.
Main conclusions	**F6.2** is not included for further assessment as it may cause the target not being met.
Issues to be further assessed	None.
Annex	None.
Sources	-

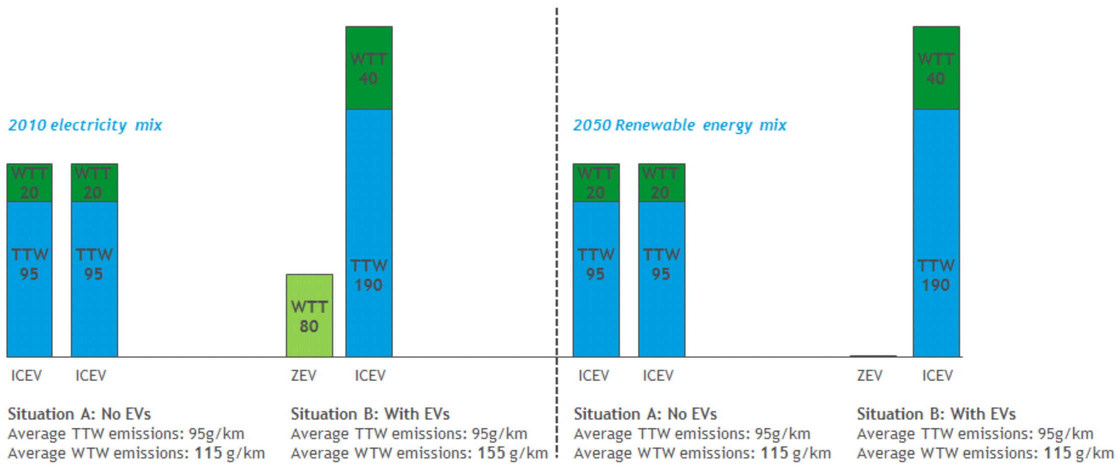
D.3 Figures and tables to illustrate some findings from literature

D.3.1 A. What is the scope of the regulation?

Metric(s)

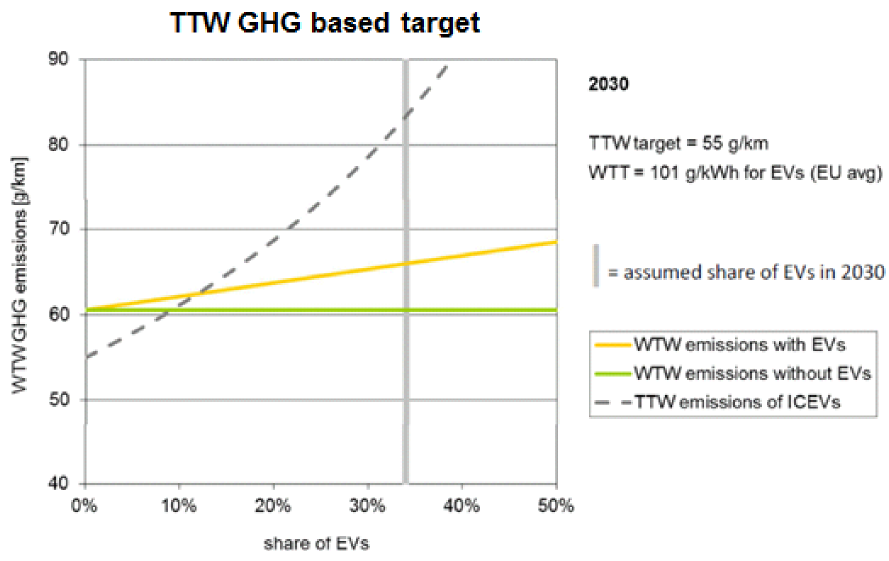
Figure 98 illustrates the effect of a TTW-based metric for the case of an OEM selling two cars and having a target of 95 g/km.
In Situation A, the OEM meets the target with ICE-vehicles only, while in Situation B a combination of an EV and ICE-vehicle is used. As can be seen, the TTW target is met in both situations. However, when increasing its share of EVs, the OEM can produce an ICE-vehicle that does not meet the target.
For the current limit, each ZEV that is sold allows ICEVs to emit 1 g/km more than the target for example (TNO et al., 2013). This has no impact on the average TTW emissions, but may increase the WTW emissions significantly in case the electricity mix still causes significant emissions (figure a). This is also depicted in Figure 99 for different EV shares. In case the electricity mix would be completely generated with renewable energy sources (0 g/kWh), the WTW emissions are comparable to the situation without ZEVs (figure b) and no WTW leakage occurs.

Figure 98 Implications of a TTW CO_2 target when OEMs use electric vehicles



a) with 2010 electricity mix b) with renewable electricity mix

Figure 99 WTW leakage with TTW GHG-based target

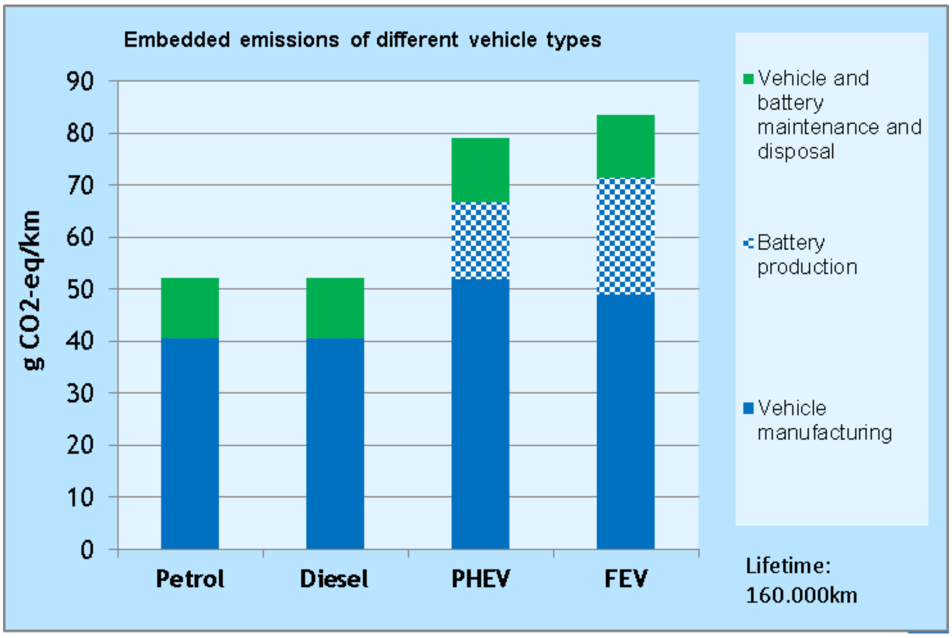


With a TTW metric based on energy consumption (MJ/km), the relative impact of increasing the share of ZEVs on WTW emissions becomes smaller. The increase in TTW emissions of ICEVs is smaller as the TTW energy consumption of ZEVs is larger than 0. However, as the electricity mix becomes cleaner (i.e. more renewable sources), the increase in WTW emission becomes smaller. With a fully renewable mix, the WTW emissions can even decrease when applying ZEVs, even though the metric only covers TTW energy consumption.

Embedded emissions

Figure 100 shows the embedded emissions of conventional vehicle configurations and of PHEVs and EVs when used for 160,000 km. As shown in the figure, PHEVs/REEVs and BEVs have significantly higher embedded emissions compared to conventional vehicles (+50% and +60%, respectively). Although this study focused on passenger cars only, it can be assumed that a similar picture would result for vans, as in this case as well at least the battery production and more complex drivetrain results in additional emissions.

Figure 100 Embedded emissions of different vehicle configurations (2014)



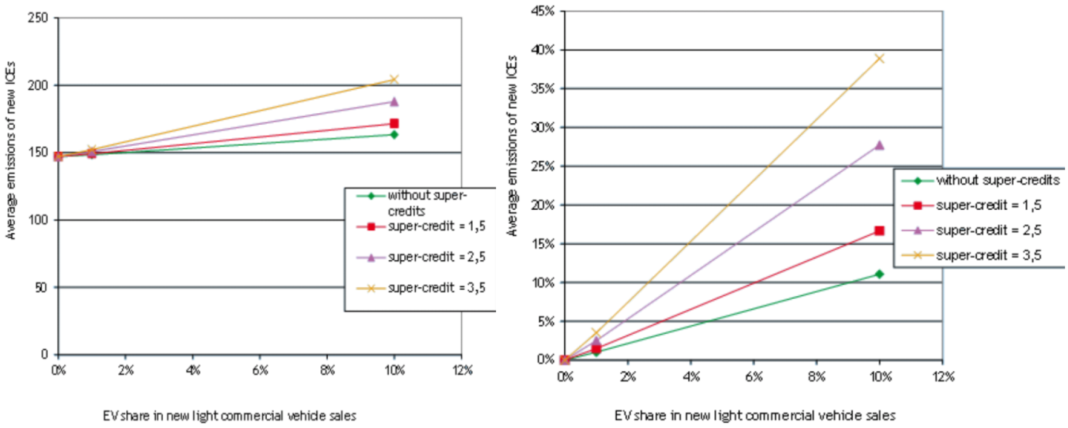
Source: (TNO; CE Delft, 2014) (ref 31).

D.3.2 C. How to determine overall performance?

Super credits

Figure 101 shows the impact of super credits for different EV penetration scenarios on the average emissions of new ICEs (left hand side) and on the average deviation from the target (right hand side). As can be seen, for vans, a 10% penetration rate results in ICE emissions that are 10% above the target. Super credits worsen this effect en can result in ICE emissions that are 15% (1.5 super credit per EV) up to 40% (3.5 super credits per EV) higher than the target if EVs obtain a market share of 10%.

Figure 101 Impact of super credits on the emissions of ICEVs (for vans)



Source: (TNO, et al., 2011a) ref 1.

Table 40 shows the impact of super credits and increasing (PH)EV shares on the compliance costs of van OEMs. The baseline scenario (no EVs) results in compliance costs of € 545. In case the shares of EVs increase (with or without super credits) compliance costs increase with there are no super credits (super credit = 1), increases the compliance costs with 58% to 346%. As can be seen when comparing the situation without (super credits = 1) and with (super credits = 3,5) super credits compliance costs increase further due to larger shares of BEVs.

Table 40 **Impact of super credits on the compliance costs for van OEMs**

Utility parameter = mass Slope = 100% Super credits = 1	Baseline scenario	Scenario 1	Scenario 2	Scenario 3
Scenario characteristics				
Sales share PHEVs	0.0%	5.6%	3.5%	8.5%
Sales share EREVs	0.0%	2.0%	1.0%	3.0%
Sales share FEVs	0.0%	1.7%	0.7%	2.5%
Total sales share EVs	0.0%	9.3%	5.2%	14.0%
Average CO_2 emissions per EV [g/km]	-	87	93	83
Scenario impact on ICEVs				
Sales share of ICEVs	100%	90.7%	94.8%	86.0%
Average ICEV emissions to reach 147 g/km [g/km]	147	153.1	150.0	157.5
Results				
Average additional manufacturer cost per EV [€]	-	9794	8094	9540
Average ICEV costs to meet target ICEV [€]	545	384	462	286
Average overall costs to meet 147 g/km target [€]	**545**	**1259**	**859**	**1582**

Utility parameter = mass Slope = 100% Super credits = 3.5	Baseline scenario	Scenario 1	Scenario 2	Scenario 4 (TNO)
Scenario characteristics				
Sales share FEVs	0.0%	5.4%	3.5%	8.1%
Sales share PHEVs	0.0%	1.9%	1.0%	2.9%
Sales share EREVs	0.0%	4.9%	2.1%	7.1%
Total sales share EVs	0.0%	12.3%	6.5%	18.1%
Average CO_2 emissions per EV [g/km]	-	87.5	93.1	82.6
Scenario impact on ICEVs				
Sales share of ICEVs	100%	87.7%	93.5%	81.9%
Maximum ICEV emissions to reach 95 g/km [g/km]	147	155.3	150.8	161.2
Results				
Average additional manufacturer cost per EV [€]	-	9794	8094	9540
Average ICEV costs to meet target ICEV [€]	545	320	438	198
Average overall costs to meet 95 g/km target [€]	**545**	**1483**	**937**	**1888**

D.3.3 D. Approach for target setting

Figure 102 illustrates the four approaches for target setting that have been distinguished in this study. With all options, the target dates/periods (dark blue) can also be set for different target years/periods. Option D1.1. sets a target for a fixed date. From this date onwards, the target must be met by the entire fleet. Option D1.2. is comparable, except that the new (dark blue) targets are phased-in in previous years. I.e. from X years prior to the new target an increasing share of the new vehicle fleet must meet the new target. During these intermediate years, emissions must be at least equal to the previous target. With option D1.3. annually declining targets are set.

Figure 102 Illustration of the different approaches for target setting

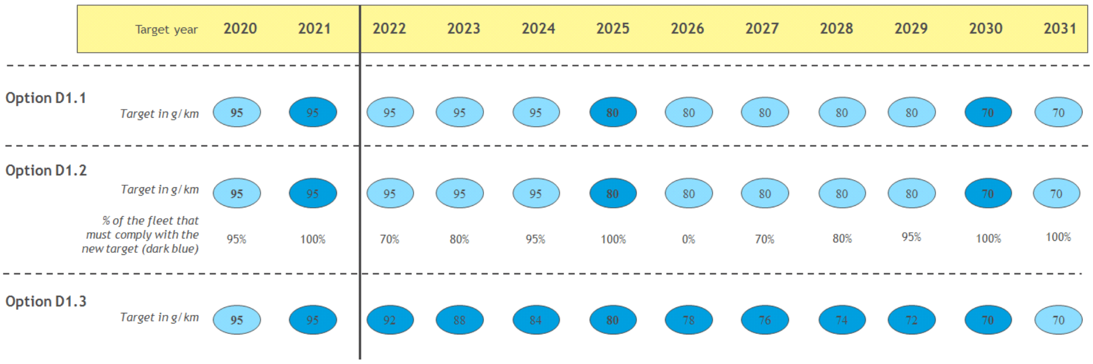
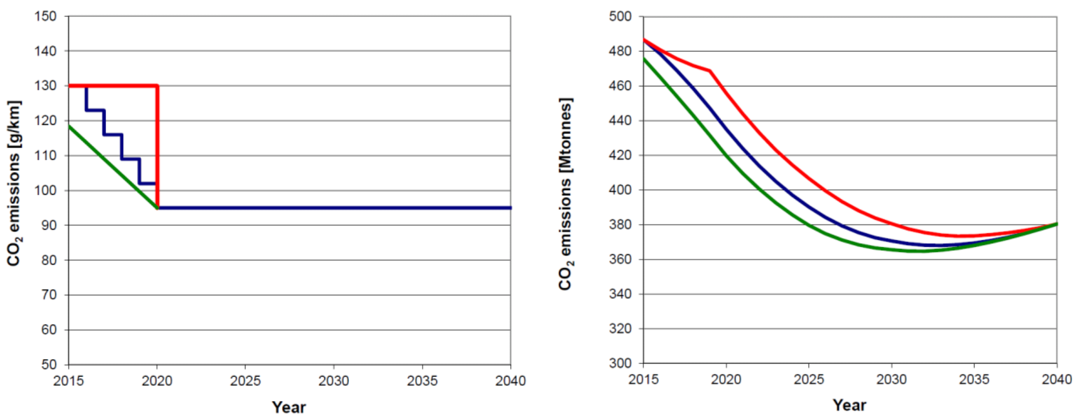


Figure 103 shows the implications of different target setting approaches (shown in the left hand side of the figure; comparable to option D1.1 and D1.3) for the overall fleet emissions that result between 2015 and 2040. As can be seen, setting only two targets with no targets for intermediate years results in relatively highest CO_2 emissions. In case targets are set for intermediate years as well (either step-based or linearly decreasing targets) emission savings are approximately 3 gCO_2/km.

Figure 103 Implications of different target setting approaches for total CO_2 emissions of fleet



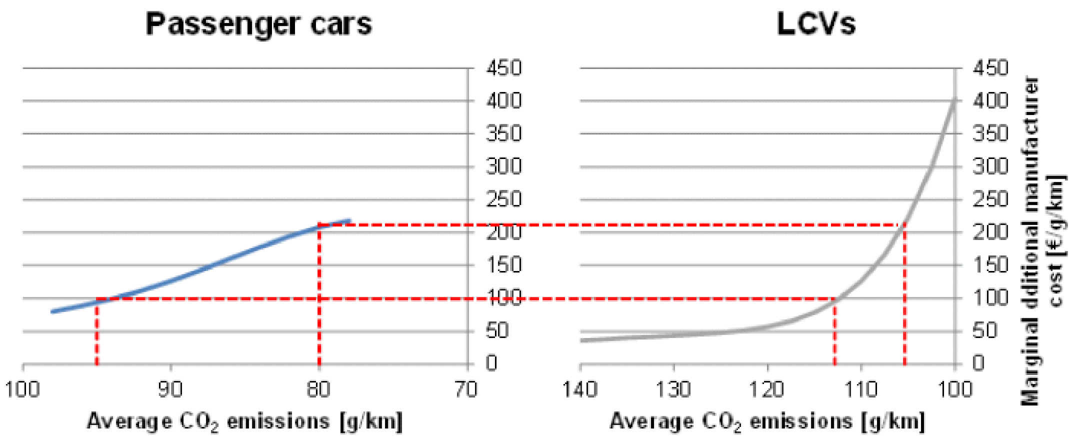
Note that the red line is comparable to option D1.1 (targets set for fixed year(s)) and the green and blue lines to Option D1.3 (step-wise/continuous) annually declining targets).

D.3.4 F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?

Pooling/Trading

Figure 104 shows the marginal costs for meeting different targets for cars and for vans. As can be seen, reaching the 2021 car target (95 g/km) is much more expensive for cars than for vans (147 g/km). In case pooling/trading is allowed between cars and vans, it will be cheaper for OEMs to overachieve the van target therefore. The marginal costs are lower up to approximately 117 g/km, which is 30 g/km more efficient than the target. It should be pointed out that this does not imply that cars will be 30 g/km under target, as the target is sales-weighted and car sales are much larger than van sales.

Figure 104 Marginal costs of emission reduction for cars and vans



Source: (TNO; CE Delft, 2012). Assessment of alternative targets and modalities for the CO_2 regulation for light commercial vehicles.

D.4 References

Ref. #	Study
1	(TNO, et al., 2011a) Support for the revision of Regulation on CO_2 emissions from light commercial vehicles (SR#3 of Framework Contract No ENV.C.3./FRA/2009/0043)
2	(TNO, et al., 2011b) Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars (SR#1 of Framework Contract No ENV.C.3./FRA/2009/0043)
3	(IEEP; CE Delft; TNO, 2007) Possible regulatory approaches to reducing CO_2 emissions from cars (070402/2006/452236/MAR/C3)
4	(TNO; AEA; CE Delft; Ricardo, 2013) Consideration of alternative approaches to regulating CO_2 emissions from light duty road vehicles for the period after 2020 (SR#4 of Framework Contract No ENV.C.3./FRA/2009/0043)
5	(TNO; CE Delft, 2013) Analysis of the influence of metrics for future CO_2 legislation for Light Duty Vehicles on deployment of technologies and GHG abatement costs. (SR#8 of Framework Contract No ENV.C.3./FRA/2009/0043)
6	(Valdani Vicari & Associati (VVA); Technopolis Group (TG); TNO, as part of Joint Institute for Innovation Policy (JIIP), 2015) Assessment of competitiveness impacts of post-2020 LDV CO_2 regulation, Project for DG CLIMA under the Multiple framework contract for the procurement of studies and other supporting services on impact assessments and evaluations (ENTR/172/PP/2012/FC)
7	Technical support to the correlation of CO_2 emissions measured under NEDC and WLTP. (Framework contract CLIMA.C.2/FRA/2013/0006) (to be published)
8	(Ricardo-AEA; TEPR, 2015) Evaluation of Regulations 443/2009 and 510/2011 on the reduction of CO2 emissions from light duty vehicles
9	(Ricardo-AEA, 2014) Data gathering and analysis to improve understanding of the impact of mileage on the cost-effectiveness of Light-Duty vehicles CO_2 Regulations (Framework contract CLIMA.C.2/FRA/2013/0006)
10	(AEA; Ricardo; IHS Global Insight; TNO , 2012) Supporting Analysis on Test Cycle and Technology Deployment for Reviews of Light Duty Vehicle CO_2 Regulations (SR#6 of Framework Contract No. ENV.C.3./FRA/2009/0043).
11	Support for preparing correlation of WLTP and NEDC (SR#9 of Framework Contract No ENV.C.3./FRA/2009/0043)
12	(AEA ; TNO; CE Delft ; TEPR, 2012) EU Transport GHG: Routes to 2050? Developing a better understanding of the secondary impacts and key sensitivities for the decarbonisation of the EU's transport sector by 2050.
13	(CE Delft; ICF; Ecologic, 2011) Impact of Electric Vehicles (Deliverable 1-5), CE Delft, 2011
14	(Ricardo-AEA; TEPR; TU Graz; Cardiff Business School, 2015) The potential for weight reduction of passenger cars and light commercial vehicles in relation to future CO_2 regulatory requirements: Ricardo-AEA
15	(Ricardo-AEA, 2016) Supporting Analysis on improving understanding of technology and costs for CO_2 reductions from cars and LCVs in the period to 2030 and development of cost curves (Framework Contract no. CLIMA.C.2/FRA/2012/0006 (February, 2016))
16	(National Research Council (US), 2013) Transitions to alternative vehicles and fuels
17	(TNO, 2013a) Travelcard Nederland BV data source document: Fuel consumption of Dutch passengers cars in business use 2004-2012. TNO 2013 R11165
18	(TNO, 2013b) Real-world fuel consumption of passenger cars for business use and plug-in hybrid vehicles (Praktijkverbruik van zakelijke personenauto's en plug-in voertuigen) TNO, 2013 R10703. 31 May 2013
19	(ICCT, 2014b) Global Comparison of Passenger Car and Light-commercial Vehicle Fuel Economy/GHG Emissions Standards. Update: February 2014. The ICCT
20	(ICCT, 2013a) European Vehicle Market Statistics Pocketbook 2013. The ICCT
21	(EC, JRC, 2014b) WELL-TO-TANK Appendix 2 - Version 4.0. Summary of energy and GHG balance of individual pathways. WELL-TO-WHEELS ANALYSIS OF FUTURE AUTOMOTIVE. FUELS AND POWERTRAINS IN THE EUROPEAN CONTEXT

Ref. #	Study
22	(EMISIA; INFRAS; IVL, 2013)Transport data collection supporting the quantitative analysis of measures relating to transport and climate change. Project acronym: TRACCS. Final Report. EMISIA SA Report No:13.RE.025.V1. http://traccs.emisia.com/
23	(EPA, 2012b) Light-Duty Vehicle Mass Reduction and Cost Analysis - Midsize Crossover Utility Vehicle. Assessment and Standards Division. Office of Transportation and Air Quality. U.S. Environmental Protection Agency. Prepared for EPA by FEV EPA. Contract No. EP-C-12-014. Work Assignment No. 0-3
24	(ICCT, 2013b) 'Summary of mass reduction impacts on EU cost curves', Working paper 2013-1, January 2013, ICCT
25	(ICCT, 2010) 'An assessment of mass reduction opportunities for a 2017 – 2020 model year vehicle programme', March 2010, conducted by Lotus Engineering for ICCT
26	SuperLIGHT-CAR
27	(Scenaria, 2012) 'Weight reduction with aluminium: part of all cost-effective fuel economy strategies', September 2012, conducted by Scenaria for The Aluminium Association
28	(Koffler & Rohde-Brandenburger, 2010) 'On the calculation of fuel savings through lightweight design in automotive life cycle assessments', Volkswagen, International Journal of Life Cycle Assessment, 2010, Vol. 15
29	(EC, 2012a) (EC, 2012b) 'Impact assessment Accompanying the documents Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No. 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars and Proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) No 510/2011 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new light commercial vehicles'. European Commission, 2012
30	(EPA, 2012a) 'EPA and NHTSA Set standards to reduce GHGs and improve fuel economy for model years 2017-2025 cars and light trucks'. EPA, 2012
31	(TNO; CE Delft, 2013) 'Indirecte en directe CO_2-uitstoot van elektrische personenauto's.' TNO & CE Delft, 2014
32	(EC, 2009) 'Regulation (EC) no. 443/2009 of the European Parliament and of the Council of April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles'. EC, 2009
33	(EPA, 2010) 'Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule'. EPA, 2010. Published in the Federal Register 75/88, 2010
34	(Bedsworth & Taylor, 2007) 'Learning from California's Zero-Emission Vehicle Program'. Bedsworth & Taylor, 2007. Published in the California Economic Policy, vol. 3, no. 4, 2007

Annex E Results of the stakeholder consultation

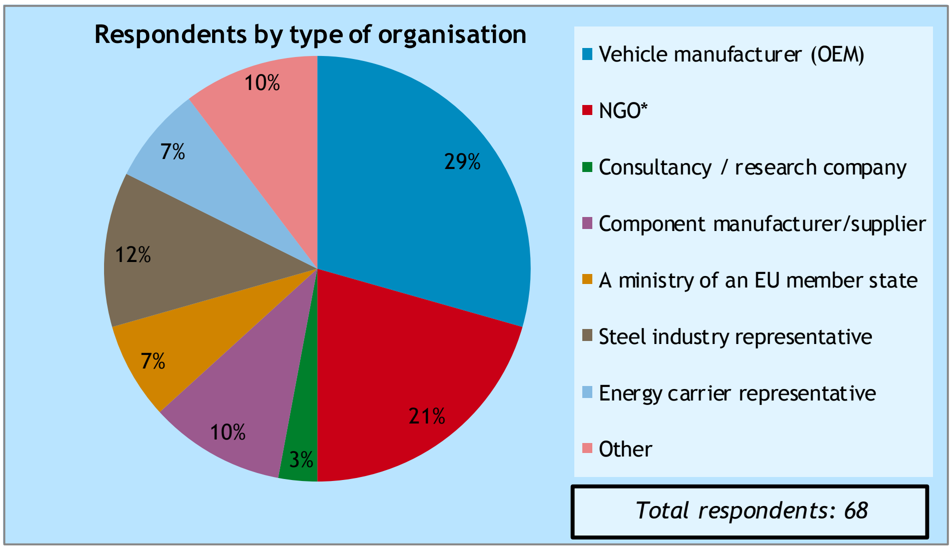
E.1 Introduction

This annex summarises the results from the stakeholder consultation. Section E.2 summarises the key results and Section E.3 and E.4 summarise the results of each question in more detail.

E.2 Summary of key results online questionnaire

The online questionnaire generated 68 responses from different stakeholder groups. The represented organisations are summarised in Figure 105.

Figure 105 Overview of respondents of the online questionnaire



* The NGO group consists mainly of environmental NGOs.

The questionnaire contained 30 statements with different design options for the future LDV Regulations, which have been categorised in six main topics. The remainder of this chapter summarises the main results per topic and per modality.

Disclaimer:
As the participating stakeholders are highly diverse and have significantly different opinions, results are presented per main participating stakeholder group. Although this is better than presenting only results for the overall sample, it does not completely solve the issue. Especially the group of component manufacturers (excl. steel) and energy representatives consist of very diverse companies (e.g. focus on different type of materials/fuels, both incumbents vs. new entrants, etc.). This should be kept in mind when interpreting the results.

The most important results are presented per main stakeholder group in this sub-section. However, Annex E.3 and E.4 contain more detailed results of the multiple choice and open questions for each of these groups, respectively.

Table 41 provides a summary of the design options (maximum of 6 for) each stakeholder group highlighted in the open questions as the most important design options to adjust or adopt for the post 2020 Regulations. These issues were those mentioned most frequently, but the level of agreement in each group was very high.

Table 41 Most important issues for different stakeholder groups for the future Regulation

Design option:	Vehicle OEM	Component OEM	NGO	Steel industry	Energy carrier repr.	MS
Inclusion embedded emissions		X		X		
Inclusion of WTT emissions		X		X	X	
Real world measurements			X			
Broaden Eco-innovations	X	X		X		
Extend Super credits	X					
Eliminate super credits			X			X
Flexible mandate for ULEVs			X			
Lifetime mileage weighting			X			
Footprint as utility parameter			X			
More flexibilities	X					
Banking and borrowing	X	X	X			
Lower excess emissions premium	X					

E.2.1 A. What is the scope of the Regulation?

A1 Regulated vehicle categories

The majority of vehicle OEMs (and ACEA) do not prefer N2 vehicles being brought into the scope of the regulations, nor do they want to bring overlapping N vehicles in the car regulation. NGOs on the other hand have a strong preference for the exact opposite. Both groups have a preference for separated regulatory frameworks for cars (M) and vans (N).

A2 Regulated entities

The majority of the vehicle OEMs and ACEA would prefer brands being regulated rather than manufacturer groups. NGOs do not have a strong preference, while all other groups (i.e. component OEMs, energy representatives and Member States) prefer manufacturer groups to be regulated.

A3 Metric(s)

The majority of both vehicle OEMs and NGOs prefer the continuation of the current TTW CO_2-based metric, both groups argue that it is preferable to align the scope of the metric with the activities of the regulated entity; i.e. OEMs have direct control over TTW emissions.

However, the majority of the component manufactures, the steel industry, energy representatives and Member States would like to broaden the scope of the metric to cover WTT emissions as well. They argue that TTW-based metrics are not technology neutral. With the exception of energy representatives, each of these groups prefers a CO_2-based metric over an energy-based metric.

A4 Embedded emissions
The majority of both vehicle OEMs and NGOs prefer not to include embedded emissions in the metric.

The majority of the component manufactures, the steel industry, energy representatives and Member States would like to broaden the scope of the metric to cover embedded emissions. Their main argument is that a TTW metric shifts emissions from the use phase to the production and recycling phase, which in turn is not effectively regulated. Also exclusion of embedded emissions is not technology neutral (in terms of materials and production processes with lower embedded emissions).

E.2.2 B. How to measure the parameters needed for determining the overall performance?

B1 Measuring TTW vehicle parameter(s)
Vehicle OEMs and ACEA strongly disagree with any correction for or measurement of real-world performance. NGOs and Member States on the other hand, strongly prefer a shift to real world measurements, or at least would like to see a correction for the real world divergence. Their main argument is that almost half of the emission reduction since 2008 has not been delivered in the real world due to the possibility to exploit test cycle flexibilities. WLTP tests will reduce this problem they argue, but will still contain loopholes that will be exploited.

With the exception of vehicle OEMs, all main stakeholder groups opt to introduce obligatory measurements for energy using devices and off-cycle energy saving technologies that can be added to the TTW performance.

B2 Determining WTT parameters
There is not much agreement on the measurement method of WTT emissions within the stakeholder groups. OEMs. For WTT emissions, ACEA prefers default values for a single year, while a small majority (55%) of the vehicle OEMs prefers EU-wide projections. Energy representatives vary in their preference as well, a small majority (60%) prefers default values for a single year.

B3 Determining parameter(s) w.r.t. vehicle manufacturing & disposal
There is also not much agreement on the measurement method of embedded within the stakeholder groups. Most vehicle OEMs prefer LCA reporting, although opinions vary (40% agrees, 30% disagrees). There is no majority preference in the group of component OEMs and steel industry, although 40% of the former group prefers default values (14% disagrees).

E.2.3 C. How to determine the overall performance?

C1 Rewarding off-cycle reductions
All main stakeholder groups strongly agree that it should be possible to receive credits for technologies that result in off-cycle emission reductions or that are not measured adequately with the test procedure. However, many stakeholders argue that the scope should be broadened and the application procedures simplified.

C2 Rewarding or penalising technologies
All groups – except vehicle OEMs - also prefer debits for technologies that are over-incentivised due to the TTW test procedure/metric.

Vehicle OEMs, NGOs and Member States prefer extra incentives for ULEVs although the arguments provided in the answers to open questions do highlight important differences between these three groups. Vehicle OEMs want to extend super credits (i.e. to receive more support for ULEVs), while NGOs and Ministries want to eliminate the concept of super credits. Whereas OEMs argue that these vehicles should be supported as meeting the target is highly dependent on the share of ULEVs, NGOs and Member States argue that it weakens the stringency of the Regulation and is not technology neutral. NGOs suggest to replace it with a flexible mandate, which obligates each OEM to achieve a x% of their vehicle sales with vehicles emitting x g/km or less. In case the OEM overachieves the mandate, this could be rewarded by raising the OEM's overall g/km target. Underachieving the sub-target could be penalised by reducing the g/km target. The other three main groups (component OEMs, energy representatives and the steel industry) prefer to eliminate the extra incentives for ULEVs all together. Finally, the majority of all main groups, except NGOs, disagree with demanding a minimum share of ZEVs.

C3 Aggregation & weighting
All main groups, except NGOs, support the continuation of one overall sales-based target as is currently implemented in the Regulations. NGOs do agree with setting one fleet wide target, but they do prefer that mileage weighting is included when determining performance. They argue that this stimulates OEMs to focus their attention on achieving CO_2 reductions in the vehicles that produce the most CO_2 over their lifetime.

E.2.4 D. Approach for target setting
Not included in the online questionnaire.

E.2.5 E. How to fairly distribute the burden across regulated entities?

E1 Utility parameter
The Majority of vehicle and component OEMs would like to continue with the current system of differentiated targets (i.e. not the same target for all OEMs). The differentiated targets should then result in an equal CO_2 reduction for each OEM they argue. NGOs prefer the exact opposite; they prefer the same target for all OEMs, or if targets are differentiated this should result in an equal retail price increase.

Also with respect to the utility parameter, preferences vary; vehicle and component OEMs prefer mass, while NGOs prefer footprint. NGOs argue that mass discriminates light-weighting options and has higher compliance costs. The steel industry prefers mass rather than footprint.

E2 Shape and slope of target function
Not included in the online questionnaire.

E.2.6 F. How to provide flexibility to facilitate compliance and to correct for undesired side-effects?

F1 Pooling and F2 Trading CO_2 credits
Vehicle OEMs prefer most flexibilities to be implemented. With respect to trading and pooling, they have a small preference to pool and trade also between car and van OEMs. In contrast, NGOs prefer trading and pooling only within one segment. Member states prefer not to implement trading and to only pool between car manufacturers and between van manufactures.

F3 Banking/borrowing
Most stakeholder groups (except component OEMs) have a strong preference for banking and borrowing, as it better aligns with different investment timing. However, vehicle OEMs do not prefer this flexibility mechanism to be implemented in combination with annual targets, while NGOs prefer to *only* implement banking and borrowing in combination with annually declining targets and not in combination with intermediate targets.

F4 Excess emission premiums
Finally, all groups prefer the implementation of a buy-out option.
However, vehicle OEMs argue that the premium is too high and should be lowered (e.g. the same carbon price as in other sectors).

F5 Derogations
Vehicle and component OEMs have a preference for derogations for both small volume and niche manufacturers, while NGOs would like to eliminate niche manufacturers from derogations. NGOs and vehicle OEMs prefer derogations to be defined with EU rather than global sales.

F6 Correction for autonomous utility
Not included in the online questionnaire.

E.3 Results of the multiple choice questions

This section summarises the results per statement and per stakeholder group.

E.3.1 Detailed results: What is the scope of the Regulation?

1 What should the Regulation cover?	Vehicle manufacturer		Component manufacturer		NGO		Steel industry		Energy representative		A ministry of an EU member state	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
1.1 Inclusion of both N1 and N2 vehicles in van Regulation instead of only N1	0%	**85%**	14%	29%	**86%**	7%	0%	0%	0%	60%	**60%**	0%
1.2 One Regulation for M and N vehicles instead of two separate ones	0%	**90%**	14%	**57%**	0%	**79%**	0%	0%	0%	0%	40%	**60%**
1.3 Overlapping vehicles in car Regulation	0%	**85%**	29%	14%	**86%**	7%	0%	0%	40%	0%	**80%**	20%
1.4 Regulate Manufacturer groups not brands	20%	**70%**	**57%**	0%	21%	7%	0%	0%	**60%**	0%	**60%**	0%

2 What is being regulated?	Vehicle manufacturer		Component manufacturer		NGO		Steel industry		Energy representative		A ministry of an EU member state	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
2.1 Energy-based approach instead of CO_2-based	15%	**70%**	14%	**71%**	7%	**86%**	0%	**100%**	**60%**	40%	40%	**60%**
2.2 Cover WTT in addition to TTW	10%	**75%**	**86%**	0%	7%	**93%**	**100%**	0%	**60%**	40%	**80%**	20%
2.3 Cover embedded emissions	5%	**85%**	43%	29%	14%	**79%**	**100%**	0%	**60%**	40%	**60%**	40%

E.3.2 Detailed results: How to measure the parameters needed for determining the overall performance

3. Measuring performance	**Vehicle manufacturer**		**Component manufacturer**		**NGO**		**Steel industry**		**Energy representative**		**A ministry of an EU member state**	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
3.1 TTW emissions should be measured with ECU data instead of NEDC/WLTP	0%	**95%**	14%	29%	**86%**	14%	0%	13%	20%	0%	**60%**	40%
3.2 NEDC/WLTP should be complemented with ECU data	5%	**90%**	29%	14%	14%	7%	0%	13%	40%	0%	**60%**	40%
3.3 Test cycle emissions should be corrected for real world divergence	5%	**90%**	29%	43%	**93%**	7%	0%	0%	40%	0%	20%	40%
3.4 Additional specific test procedures for energy using devices/off-cycle savings which are added to TTW performance	10%	**85%**	**71%**	0%	**93%**	7%	**100%**	0%	**100%**	0%	**80%**	0%
3.5 WTT factors based on projections instead of single years	**55%**	25%	**57%**	0%	14%	**86%**	13%	0%	40%	**60%**	40%	20%
3.6 Embedded emissions measured with defaults instead of LCA	30%	40%	**43%**	14%	14%	**86%**	13%	0%	**100%**	0%	0%	40%

E.3.3 Detailed results: How to determine the overall performance?

4. Target Setting	**Vehicle manufacturer**		**Component manufacturer**		**NGO**		**Steel industry**		**Energy representative**		**A ministry of an EU member state**	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
4.1 Provision of credits to off-cycle emission reductions	**95%**	0%	**100%**	0%	**93%**	0%	**88%**	0%	**80%**	0%	40%	20%
4.2 Provision of extra incentives for ULEVs/ZEVs	**85%**	5%	0%	**71%**	**86%**	7%	0%	**100%**	40%	**60%**	**60%**	40%
4.3 Requirement of minimum share of ZEVs	0%	**85%**	29%	**57%**	**93%**	7%	0%	**100%**	40%	**60%**	20%	**80%**
4.4 Debits for over-incentivised technologies	10%	**75%**	29%	14%	**79%**	14%	**100%**	0%	**80%**	20%	40%	40%
4.5 Sales-weighted targets for each technology instead of one target	0%	**95%**	0%	**100%**	0%	**93%**	0%	**100%**	0%	20%	20%	**80%**
4.6 Sales and mileage weighted targets instead of sales-weighted targets	10%	**85%**	0%	**71%**	**64%**	21%	0%	0%	0%	20%	20%	40%

E.3.4 Detailed results: How to fairly distribute the burden across regulated entities?

5. Distributing the burden	Vehicle manufacturer		Component manufacturer		NGO		Steel industry		Energy representative		A ministry of an EU member state	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
5.1 Distribution of the burden based on equal % retail price increase instead of $\%CO_2$ decrease	5%	**85%**	0%	29%	**71%**	7%	0%	0%	0%	20%	0%	40%
5.2 Target should be the same for all OEMs	5%	**90%**	14%	29%	**71%**	14%	0%	0%	20%	0%	40%	40%
5.3 Footprint as utility parameter instead of mass	10%	**75%**	29%	**57%**	**86%**	7%	0%	**88%**	20%	0%	40%	40%

E.3.5 Detailed results: How to provide flexibility to facilitate compliance and to correct for undesired side-effects?

6. Providing flexibility to OEMs	Vehicle manufacturer		Component manufacturer		NGO		Steel industry		Energy representative		A ministry of an EU member state	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
6.1 Allow pooling between cars and between vans	**50%**	0%	**57%**	0%	**86%**	0%	0%	0%	20%	**60%**	**100%**	0%
6.2 Allow pooling between cars, between vans, and between cars and vans	**65%**	15%	0%	43%	7%	**86%**	0%	0%	**60%**	20%	20%	**60%**
6.3 Allow trading between cars and between vans	40%	10%	0%	29%	**71%**	14%	0%	0%	**60%**	0%	20%	**80%**
6.4 Allow trading between cars, between vans, and between cars and vans	**65%**	10%	0%	29%	7%	**86%**	0%	0%	**60%**	0%	0%	**100%**
6.5 Allow OEMs to bank and borrow credits	**70%**	0%	14%	29%	**64%**	29%	0%	0%	**60%**	20%	40%	40%
6.6 Derogations for both small volume and niche OEMs	**50%**	10%	43%	14%	7%	**79%**	0%	0%	**60%**	0%	40%	20%
6.7 Derogations based on global instead of EU sales	20%	**50%**	29%	14%	14%	**79%**	0%	0%	**80%**	0%	**60%**	20%
6.8 Implementation of a buyout option (excess emission premiums)	**55%**	10%	43%	14%	**79%**	7%	0%	0%	**60%**	20%	**60%**	40%

E.4 Results of the open questions

This section provides detailed responses to the open questions.

E.4.1 Elements of the existing Regulation that should be adjusted and/or eliminated

Element	#	Main arguments made
Super credits	25	*NGOs and Member States* suggest to **eliminate super credits** in the future Regulations. Their arguments for doing so are: – It **weakens the stringency** of the Regulation and reduces the incentives to improve the efficiency of ICEs. Therefore, most NGOs suggest a flexible mandate instead. – Super credits are **too complicated**. – Super credits are **not technology neutral**. – Super credits are **not necessary** as the TTW metric already overcompensates EVs. If continued, some respondents suggest to implement a higher multiplier for BEVs than for PHEVs (as is the case in the US), e.g. by determining the allowance with an energy efficiency metric. *Vehicle OEMs* would like to **enhance** (and hence continue with) **super credits** because: – New **targets** heavily **depend** on the market **uptake of EVs**. – Super-credits **enhance market introduction** of innovations.
Eco-innovations	17	*Vehicle and component OEMs (OEMs)* would like to **continue with eco-innovations** in future Regulations, but argue that they should be **adjusted**. Their main arguments include: – **Expand the scope of eligible technologies.** E.g. Air-conditioning technologies (cooler and heater) have a certain share in the off-cycle CO_2 emissions but are excluded from the current scope of eco-innovations. Some respondents suggest two criteria: a) efficiency not regulated with other EU laws and b) Necessity; intrinsic to the vehicle's operation. – The application procedures for eco-innovations are complex and should be **simplified.** – The **1 g threshold** and **maximum amount of eco-innovation credits** should be eliminated. Continuation of eco-innovations could for example be made more comparable to the US system. Either way, an appropriate test cycle for the evaluation of the off-cycle CO_2 reduction needs to be determined.
Utility parameter	17	*NGOs* generally prefer **footprint instead of mass** as a utility parameter, because: – The mass-based utility system **discriminates light-weighting options**, which is not the case with footprint. – Footprint results in **lower compliance costs.** – The mass-based utility is **unsustainable** as new alternative powertrains (EVs) are introduced. – Footprint makes it harder for OEMs to **'game'** the system.
TTW Measurement method	14	*NGOs* like to **eliminate a measurement method that is fully based on type approval data**, as a large share of the emission reductions since 2008 have not been delivered in the real world due to the possibility to **exploit test cycle flexibilities**. Respondents do mention that the **WLTP test** will reduce this problem, but expect that it will still contain loopholes that will be exploited. Whereas some respondents would like

Element	#	Main arguments made
		to see a measurement that is fully based on **real-world driving tests (PEMS)**, others opt for a **combination of on-road tests and laboratory tests**. The former requires an assessment of the available technologies for measuring real-world fuel consumption/CO_2 emissions. Some suggest that the method used in the US is better than the one of the EU, e.g. due to a higher level of independency
Metric	13	Both *component manufactures and the steel industry representatives* would like to broaden the **scope of the metric** to cover **embedded emissions** and **WTT emissions**. The main arguments made are: – With a TTW metric, OEMs focus on measures to reduce emissions from the use phase (e.g. light weighting, alternative powertrains), however, some of these measures cause higher embedded emissions (e.g. carbon fibre, BEVs) and/or have emissions from the production of electricity. Thereby, some of these measures cause challenges in the recycling/ disposal phase. Consequently, a TTW metric **shifts emissions from the use phase to the production and recycling phase**, which is not effectively regulated. – TTW metrics are **not technology neutral** as it ignores technical innovations such as more efficient production processes and the use of materials with lower embedded emissions. Furthermore, BEVs and FCEVs are treated as zero emissions while the emissions from electricity production are ignored.
Excess emissions premium	7	*Vehicle OEMs (OEMs)* argue that the **excess emission premium is too high** and should be lowered. E.g. a penalty that is in line with the price of carbon for other sectors (CO_2 price in the EU ETS, rather than on technology costs).

E.4.2 Design options that are not included in the existing Regulations but which should be implemented beyond 2020

Element	#	Main arguments made
Banking and borrowing	24	Many respondents suggest to **implement banking and borrowing** in the future Regulation. However, respondents can be categorised in two groups; those who would like to implement banking and borrowing with annual targets (mainly *NGOs*) and those who would like to implement banking and borrowing with 5-year targets (mainly *vehicle OEMs*). Arguments made include: – The targets will become more stringent, and hence, this can only be met with additional flexibility. – OEMs have **different investment timing,** banking and borrowing takes this into account. – It **reduces compliance costs.** – For **small OEMs**, model changes do not occur every year and therefore emissions drop with the years of model changes. These OEMs would therefore benefit from banking and borrowing.
Inclusion of WTT emissions	18	*Component OEMs*, *steel industry representatives* and *energy carrier representatives* would like to see **WTT Emissions to be included** in the scope, due to the **large diversity of powertrains and the diversity in WTT emissions** of these different powertrains. Some stakeholder suggest an energy-based metric if WTT emissions continue to be ignored.
Inclusion of embedded emissions	13	*Component OEMs* and *Steel industry representatives* argue that the **inclusion of embedded emissions** prevents a shift from emissions in the use phase of the vehicle to the manufacturing/disposal phase. These respondents argue that many OEMs already implement LCA reporting for their decision making and that this is a comprehensive

Element	#	Main arguments made
		methodology for measuring automotive GHG emissions. Including embedded emissions can: – **Open up a new field of competition** between OEMs, shifting from light-weighting to more efficient and less polluting production processes, choice for materials with lower embedded emissions, and solutions to improve the recyclability of their vehicles. – **Result in cross-sectorial collaboration** between carmakers and suppliers and value chains to ensure a 'real' CO_2 reduction.
Implementation of more flexibilities	13	*Vehicle OEMs* indicate that **more flexibilities need to be implemented** with the future targets. Most respondents do not specify which flexibilities should be implemented. Those that do mostly mention trading as an example. Banking and borrowing was mentioned separately (see above), which is also a flexibility mechanism.
Lifetime mileage weighting	10	*NGOs* argue that the current regulation favours diesel cars, while diesel cars have **higher lifetime emissions**. Mileage weighting could correct for this effect. Thereby, existing research indicates that under a mileage based weighting system OEMs would focus their attention on achieving CO_2 reductions in the vehicles that produce the most CO_2 over their lifetime. This would abide by the **polluter pays principle** and ensure that car's with the greatest lifetime CO_2 emissions/fuel consumption would be targeted. Research also indicates this might be a **lower cost option** for car OEMs.
Flexible mandate for ULEVs	9	*NGOs* suggest to implement a **flexible mandate on ULEVs** as a replacement for super credits. The mandate obligates each OEM to achieve a x% of ULEVs in the total sales, which will **drive the market** for ULEVs for each OEM. In case the OEM overachieves the mandate, this could be rewarded by raising the OEM's overall g/km target. Underachieving the sub-target on ULEVs could be penalised by reducing the g/km target.
Reward off-cycle reductions	7	*Steel industry representatives* would like to include (more) off-cycle reductions, but included no arguments in their explanations.

Annex F Approach for assessment of policy variants

F.1 Introduction

Several mathematical models are used to determine certain parameters that can be used to assess the suitability of the various policy variants. In this sections these models are described in more detail.

F.2 Cost assessment model

F.2.1 Introduction

A core element in the quantitative assessment is the cost analysis by the cost assessment model. This mathematical model was developed by TNO to determine the required CO_2 reduction and costs for individual OEMs to achieve a certain target at the lowest possible costs. This model was later refined in (TNO, 2006) again in (TNO, 2011) and (TNO, 2012).

The output of the cost assessment model includes the required technologies for manufacturers to meet the CO_2 targets as well as insights in the (average) additional manufacturer costs for manufacturers to apply these technologies. Moreover the effects of these additional costs and CO_2 reduction, resulting from fuel consumption reduction or the use of alternative energy carriers, on the total cost of ownership for end users and societal costs are determined.

In order to determine the cost optimal CO_2 reduction per segment per OEM, cost curves are used that define the relation between CO_2 reduction and additional manufacturer costs. Based on these curves, the model finds the CO_2 reductions for all segments meeting a pre-defined sales-weighted average CO_2-based target at the lowest possible costs. The developed search algorithm is based on the principle that for the cost optimal solution, the marginal costs of CO_2 reduction are equal in all segments. In other words, the additional manufacturer costs of reducing the last g/km are equally expensive for all segments.

The cost assessment model does not calculate the share of ZEVs. The impact of the share of ZEVs on the cost is significant. It is assessed by running the cost assessment model for various technology scenarios, for each policy variant. For each policy variant, only the technology scenario with the lowest cost for society will be used for the assessment with the other models, which calculate other impacts.

F.2.2 How the model is used

The assessment of the costs to reach a given type approval CO_2 target are determined in the following way:

1. Quantification of the baseline situation per manufacturer in terms of the sales and average TA CO_2 emissions per segment.
2. Quantification of assumptions on autonomous trends between baseline year and the target year regarding sales shifts between drivetrain technologies.

3. Assessment of the target year situation:
   - The target applicable to the legal entity (in regulations up to 2020 these are manufacturer groups) in the target year are based on the entity's average utility value and the selected utility function.
   - For calculating every manufacturer group's cost optimal CO_2 or energy use reductions per segment between the base year and the target year to meet their target, it is assumed that the target set will be reached in such a way that the total costs for individual manufacturer groups are minimal. This way the manufacturer group's costs in a given segment are the same for all cars. The reductions per car for each segment are found using a solver-function which minimises the total costs (costs for realising the target year, starting from the base year) for the manufacturer group by varying the reductions per car for the different segments. When this minimum is reached, the reductions per car per segment are such that the marginal costs are equal for all segments.
   - The effort required between the current situation can be derived from extracting the required effort (additional manufacturer costs) between the base year and the current situation from the required effort between the base year and the target year.
4. As explained above, in the situation where the required CO_2 reductions per manufacturer group are achieved at the lowest possible costs, the marginal costs for reducing CO_2 emissions are equal in all segments in which the manufacturer group sells vehicles. This principle is used to find the cost optimal solution per manufacturer group.

F.2.3 Model updates made

In the four studies mentioned above, the development of cost curves (step 1 in methodology described above) and the assessment of the potential impact of CO_2 regulation (step 2 in methodology described above) were part of the same study. In this case however, cost curves for the 2025 to 2030 period, that will be used to assess the impact of the 2025 and 2030 CO_2 targets, were developed in a separate study. Since these new cost curves differ from the previously developed cost curves on parameters such as the baseline year, reference vehicles and segmentation a further adaptations of the TNO cost assessment model have been made, i.e.:

- *The current situation*: As explained above, the model uses 'the current situation' to determine the reductions that OEMs have already applied and the effort that is still required to meet a certain CO_2 average in the target year. In order to use the model to assess possible post 2020 regulations, the current situation will have to be assessed. In previous assessments vehicle sales databases were acquired to determine manufacturer segment average mass, CO_2 emissions, footprint, price, etc. However for this study the EU monitoring database will be used instead. The model has been updated to be able to assess the current situation based on this database.
- *Translation from NEDC-based values to WLTP-based values*: Until now the effects of required CO_2 targets on manufacturer costs were based on NEDC values. For the post 2020 regulation, targets and resulting efforts of OEMs will be based on WLTP CO_2 emissions. As the cost curves will be based on WLTP-based CO_2 reductions, the baseline situation and the current situation have been translated to WLTP-based values (see Annex G).
- *Segments to be included*: As explained above, the cost optimal CO_2 reductions are determined for every manufacturer group's per segment. For the assessment of the 2020 targets, six segments were included (two fuel types and three size segments). Since cost curves are being constructed for more segments than previously, the model has been adapted to include more segments.

- *Inclusion of more drivetrain technologies*: In the previous assessments only two energy carriers were included, i.e. petrol and diesel. Since the shares of alternative energy carriers and alternative drivetrain types, e.g. BEVs, PHEVs, REEVs and FCEVs are expected to have a significant market share beyond 2020, the effect increased shares of these 'xEVs' have now been accounted for in the model.
- *Modalities not yet included in the model*: Certain modalities, such as the utility function are already included in the model. Based on the favorable modalities to be included in the regulation (based on Chapter 2), additional modalities have been included in the model, i.e. the use of different regulatory metrics, mileage weighting.

F.3 MOVEET

The outputs of the cost assessment model are used as input for the MOVEET model. This model is used to:
- Assess 1st and 2nd order impacts on fleet composition and use.
  It calculates the fleet shares, based on a vintage module. In this module, the current fleet composition is established per country from the balance of added, retired and remaining vehicles. The actual usage of these vehicles is also computed. The calculations are all based on transport demand computation and vehicle costs from the cost assessment model.
- Assess achievement of GHG emission targets for the transport sector at European as well as at the world level.

MOVEET is a system dynamic based analytical tool to address the policy problems related to transport and climate change. The model has been developed at Transport & Mobility Leuven.

The tool is capable of estimating transport demand and emissions, as well as forecasting the impacts of policy and technological measures in transport-related sectors, covering all transport modes from the different regions in the world up to 2050.

The model consists of 57 regions of the world, many of them representing single countries, i.e. all the European countries and other world major economies. In the model, we consider all transportation modes (road, air, rail, and maritime) that interact through four interrelated modules: Transport Demand, Fleet, Environmental, and Welfare.

European Commission TRACCS database project results[39] published on December 2014 have been used to feed the historical conventional (internal combustion engine) passenger car fleet stock and sale database of MOVEET. MOVEET was used as the main transport model in the EEA report[40] to assess the status of electrification of the road transport passenger vehicles whose report was published on September 20, 20016.

39 www.eea.europa.eu/data-and-maps/data/external/traccs as accessed 2/12/2016

40 www.oeko.de/fileadmin/oekodoc/Assessing-the-status-of-electrification-of-the-road-transport-passenger-vehicles.pdf as accessed 2/12/2016

In this project, MOVEET was used to assess the implication of the different penetration rates of electric powered light duty vehicles (LDVs) represented in the different scenarios. In each scenario, exogenous sale shares and estimated purchase prices of the different LDVs propulsion types for the years 2013, 2020 and 2030 are given. MOVEET assess the effect of these scenarios on transport demand, vehicle fleet dynamics, average generalized costs, energy consumption and CO_2 emissions.

F.4 EDIP

The output of MOVEET is used as input for EDIP model. This model is used to determine the effects of CO_2 regulation of LDVs on social equity. Using this model relevant economic effects of proposed CO_2 regulation variants are estimated. The outcome will be firstly a change in household consumption, with a distinction between a number of income groups.

The EDIP-model (Distribution and Inequality Effects of Economic Policies) is constructed using the Computable General Equilibrium (CGE) framework. CGE models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. A model consists of (a) equations describing model variables and (b) a database (usually very detailed) consistent with the model equations. The EDIP model is based on the most recent publically available social, economic, environmental transport and energy data and the public version of the WIOD database. The EDIP database covers EU 28 countries, Norway, Switzerland, and Turkey.

One of the indicators that is calculated by EDIP is the Gini-index or Gini-coefficient, which is one of the most commonly used indices for inequality. It is a measure of statistical dispersion that can be applied to measure the inequality of an income or wealth distribution. The Gini-coefficient takes a value between 0 and 1, where 1 is complete inequality and 0 of complete equality. Its actual calculation can be done in a number of different ways and can also be based on the Lorenz curve.

Its general formula for a discrete distribution of incomes is

$$G = \frac{1}{2n^2\mu} \cdot \sum_i \sum_j \left| x_i - x_j \right|$$

In the case of the EDIP model, where we have different groups (5 income quintiles) with a representative income we can express the Gini-coefficient as

$$G = \frac{1}{2\mu} \cdot \sum_i f_i \sum_j f_j \left| x_i - x_j \right|$$

Where

f_i is a fraction of the population of which we assume that it gets the same income

x_i the representative income for a certain fraction of the population

μ is the mean income of the population, calculated as

$$\mu = \sum_i f_i \cdot x_i$$

The Gini-coefficient differs from other indices, as it is essentially based on the relative ranking of each income in the income distribution. It is especially sensitive for changes around the middle of the income distribution

F.5 E3ME

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used globally for policy assessment, for forecasting and for research purposes.

E3ME has several important features which make it particularly suitable for carrying out the economic assessment in this project:
- it has a highly disaggregated sectoral classification (69 sectors in Europe), allowing for a detailed analysis of sectoral (e.g. competitiveness) impacts;
- it fully integrates the economy with energy consumption and greenhouse gas emissions;
- it covers Europe by Member State but also has global coverage, which is a major advantage when considering competitiveness effects;
- its econometric specification, which provides a strong empirical foundation and also means that the model is not limited by some of the assumptions common to CGE models.

This model description provides a short summary of the E3ME model. Forfurther details, the reader is referred to the full model manual available online from www.e3me.com.

F.5.1 E3ME's basic structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2014 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

F.5.2 The main dimensions of the model

The main dimensions of E3ME are:
- 59 countries – all major world economies, the EU28 and candidate countries plus other countries' economies grouped;
- 69 industry sectors (for European countries), based on standard international classifications;
- 43 categories of household expenditure (for European countries)
- 22 different users of 12 different fuel types;
- 14 types of air-borne emission (where data are available) including the six greenhouse gases monitored under the Kyoto protocol.

The countries and sectors covered by the model are listed at the end of this document.

F.5.3 Standard outputs from the model

As a general model of the economy, based on the full structure of the national accounts, E3ME is capable of producing a broad range of economic indicators. In addition there is range of energy and environment indicators. The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade);
- sectoral output and GVA, prices, trade and competitiveness effects;
- international trade by sector, origin and destination;
- consumer prices and expenditures;
- sectoral employment, unemployment, sectoral wage rates and labour supply;
- energy demand, by sector and by fuel, energy prices;
- CO_2 emissions by sector and by fuel;
- other air-borne emissions;
- material demands.

This list is by no means exhaustive and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national and regional level and annually over the period up to 2050.

F.5.4 E3ME as an E3 model

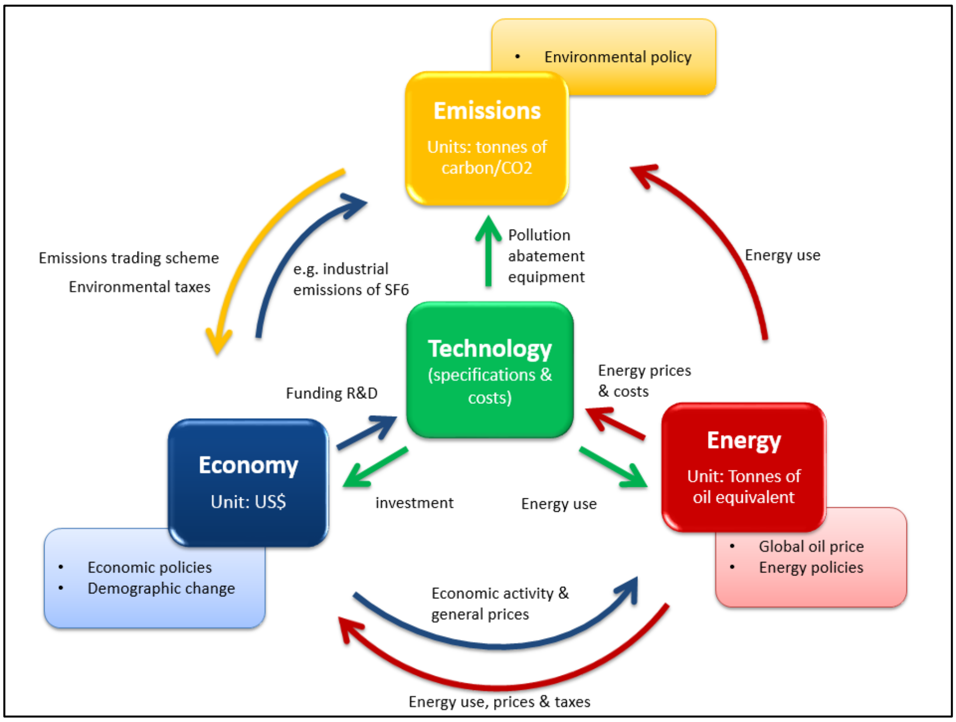
Figure 106 shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For each region's economy the exogenous factors are economic policies (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of the energy industries). For the environment component, exogenous factors include policies such as reduction in SO_2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn can give measures of damage to health and buildings. The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

Technological progress plays an important role in the E3ME model, affecting all three Es: economy, energy and environment. The model's endogenous technical progress indicators (TPIs), a function of R&D and gross investment, appear in nine of E3ME's econometric equation sets including trade, the labour market and prices. Investment and R&D in new technologies also appears in the E3ME's energy and material demand equations to capture energy/resource savings technologies as well as pollution abatement equipment. In addition, E3ME also captures low carbon technologies in the power sector through the FTT power sector model[41].

41 See Mercure (2012).

Figure 106 E3 linkages in the E3ME model



F.5.5 Treatment of international trade

An important part of the modelling concerns international trade. E3ME solves for detailed bilateral trade between regions (similar to a two-tier Armington model). Trade is modelled in three stages:

- econometric estimation of regions' sectoral import demand;
- econometric estimation of regions' bilateral imports from each partner;
- forming exports from other regions' import demands.

Trade volumes are determined by a combination of economic activity indicators, relative prices and technology.

F.5.6 The labour market

Treatment of the labour market is an area that distinguishes E3ME from other macroeconomic models. E3ME includes econometric equation sets for employment, average working hours, wage rates and participation rates. The first three of these are disaggregated by economic sector while participation rates are disaggregated by gender and five-year age band.

The labour force is determined by multiplying labour market participation rates by population. Unemployment (including both voluntary and involuntary unemployment) is determined by taking the difference between the labour force and employment. This is typically a key variable of interest for policy makers.

F.5.7 Comparison with CGE models and econometric specification

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimal behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian framework and it is possible to have spare capacity. The model is more demand-driven and it is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity. This is described in more detail in the model manual.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend.
The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects[42], which are included as standard in the model's results.

F.5.8 Applications of E3ME

E3ME is commonly used for evaluating the impacts of an input shock through a scenario-based analysis. The shock may be either a change in policy, a change in economic assumptions or another change to a model variable. The analysis can be either forward looking (ex-ante) or evaluating previous developments in an ex-post manner. Scenarios may be used either to assess policy, or to assess sensitivities to key inputs (e.g. international energy prices).

For ex-ante analysis a baseline forecast up to 2050 is required; E3ME is calibrated to match a set of projections that are published by the European Commission and the IEA but alternative projections may be used.
The scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the change in inputs can be determined.

It is possible to set up a scenario in which any of the model's inputs or variables are changed. In the case of exogenous inputs, such as population or energy prices, this is straight forward. However, it is also possible to add shocks to other model variables. For example, investment is endogenously determined by E3ME, but additional exogenous investment (e.g. through an increase in public investment expenditure) can also be modelled as part of a scenario input.

For the scenarios in this report, an increase in vehicle fuel-efficiency was assessed in the model with an assumption about how efficient vehicles become, and the cost of these measures. This was entered into the model as a higher price for cars and a reduction in fuel consumption (all other things being equal). E3ME could was then used to determine:
– secondary effects, for example on fuel suppliers;
– rebound effects;
– overall macroeconomic impacts.

[42] Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al. (2009).

Table 42 Main dimensions of the E3ME model

	Regions	Industries (Europe)
1	Belgium	Crops, animals, etc.
2	Denmark	Forestry & logging
3	Germany	Fishing
4	Greece	Coal
5	Spain	Oil and Gas
6	France	Other mining
7	Ireland	Food, drink & tobacco
8	Italy	Textiles & leather
9	Luxembourg	Wood & wood prods
10	Netherlands	Paper & paper prods
11	Austria	Printing & reproduction
12	Portugal	Coke & ref petroleum
13	Finland	Other chemicals
14	Sweden	Pharmaceuticals
15	UK	Rubber & plastic products
16	Czech Rep.	Non-metallic mineral prods
17	Estonia	Basic metals
18	Cyprus	Fabricated metal prods
19	Latvia	Computers, etc.
20	Lithuania	Electrical equipment
21	Hungary	Other machinery/equipment
22	Malta	Motor vehicles
23	Poland	Other transport equip
24	Slovenia	Furniture; other manufacture
25	Slovakia	Machinery repair/installation
26	Bulgaria	Electricity
27	Romania	Gas, steam & air cond.
28	Norway	Water, treatment & supply
29	Switzerland	Sewerage & waste
30	Iceland	Construction
31	Croatia	Wholesale & retail MV
32	Turkey	Wholesale excl. MV
33	Macedonia	Retail excl. MV
34	USA	Land transport, pipelines
35	Japan	Water transport
36	Canada	Air transport
37	Australia	Warehousing
38	New Zealand	Postal & courier activities
39	Russian Fed.	Accommodation & food serv.
40	Rest of Annex I	Publishing activities
41	China	Motion pic, video, television
42	India	Telecommunications
43	Mexico	Computer programming, etc.
44	Brazil	Financial services
45	Argentina	Insurance
46	Colombia	Aux to financial services

47	Rest Latin Am.	Real estate
48	Korea	Imputed rents
49	Taiwan	Legal, account, consult
50	Indonesia	Architectural & engineering
51	Rest of ASEAN	R&D
52	Rest of OPEC	Advertising
53	Rest of world	Other professional
54	Ukraine	Rental & leasing
55	Saudi Arabia	Employment activities
56	Nigeria	Travel agency
57	South Africa	Security & investigation, etc.
58	Rest of Africa	Public admin & defence
59	Africa OPEC	Education
60		Human health activities
61		Residential care
62		Creative, arts, recreational
63		Sports activities
64		Membership orgs
65		Repair comp. & pers. goods
66		Other personal serv.
67		Holds as employers
68		Extraterritorial orgs
69		Unallocated/Dwellings

Source(s): Cambridge Econometrics.

Annex G Equivalent targets

G.1 Introduction

Assessing the impact of the choice of metric in which the CO_2 target is defined, requires defining 'equivalent targets' in order to decouple the effects of the metric from effects related to the stringency of the target. Starting point is a target defined in the TTW CO_2-based metric used in the existing legislation and from this equivalent targets for the other metrics are derived.

Since the potential TTW targets to be assessed are NEDC-based, while the cost curves are WLTP-based, the targets first have to be converted into WLTP targets. Hereafter the TTW targets can be translated into 'equivalent' WTW targets. This translation is based on the principle of equally contributing to the policy goal, i.e. overall RW WTW CO_2 emission reduction.

G.2 Converting NEDC-based TTW CO_2 targets to WLTP-based TTW CO_2 targets

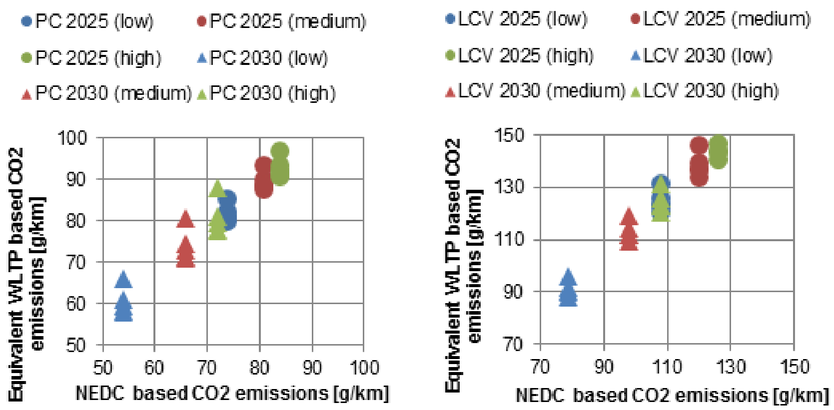
For the conversion of NEDC-based TTW CO_2 emission levels into WLTP-based TTW CO_2 emission levels, the used conversion factors (Table 43) are taken from (Ricardo, 2016). These factors have been used in this study as no 'official' or broadly supported correlation factors to determine the equivalent WLTP emission levels were (yet) available.

Since the factors are different for every powertrain and segment, the resulting WLTP-based target depends on the shares of the different drivetrain types and segments in the new fleet composition. Since five different fleet compositions (known as 'technology scenarios') are assessed in this study (i.e. 1) *Mixed xEV*, 2) *Ultra efficient ICEV*, 3) *BEV extreme*, 4) *PHEV/REEV extreme* and 5) *FCEV extreme*), five WLTP-based targets result from every NEDC-based TTW CO_2 target proposed.

Table 43 WLTP/NEDC conversion factors for TTW CO_2 emissions

		SI+Hybrid	CI+Hybrid	SI PHEV	CI PHEV	SI REEV	CI REEV	BEV	FCEV
Passenger cars	Small	1.063	1.088	1.34	1.267	1.511	1.499	1	1
	Lower medium	1.066	1.092	1.388	1.324	1.504	1.489	1	1
	Upper medium	1.096	1.104	1.406	1.35	1.508	1.496	1	1
	Large	1.127	1.156	1.436	1.376	1.556	1.532	1	0
LCVs	Small	1.042	1.096	1.436	1.332	1.599	1.596	1	1
	Medium	1.091	1.124	1.509	1.418	1.668	1.666	1	1
	Large	1.176	1.138	1.584	1.506	1.706	1.708	1	1

Figure 107 Several potential NEDC-based targets and their WLTP equivalents based on several possible future fleet compositions (or 'technology scenarios')



Given the fleet compositions in the target years and the factors from Table 43, the resulting WLTP-based potential targets are shown in Table 44 and Figure 107. As can be seen in Figure 107, a range or WLTP-based equivalent targets is found for every NEDC-based TTW target. This range is rather narrow apart from some 'technology scenarios'. For deriving the WLTP target equivalent to the NEDC target, the technology scenario 'Mixed xEV' is used, as this is a mix of all other technology scenarios.

N.B. the correlation factors used are based on 2013 vehicles. These vehicles were very likely optimised to have low CO_2 emissions on the NEDC cycle. After this cycle is replaced by the WLTP, it is very likely that manufacturers will optimise their vehicles on this new cycle. Relative to the 2013 situation the difference between the NEDC- and WLTP-based emissions is likely to become smaller. These correlation factors are not only used to determine equivalent emission values in 2013, but also to determine the equivalent WLTP targets of the selected NEDC-based targets. As a result the 2025 and 2030 equivalent WLTP-based target levels could be lower than what is derived based on the 2013 correlation factors. However, three different target levels are assessed for both 2025 and 2030. Although it may not be the actual equivalent of the NEDC target, the most suitable WLTP target level can be selected based on criteria such as the ones mentioned in Section 2.5.1, e.g. cost effectiveness.

Table 44 Equivalent WLTP target levels based on the Mixed xEV fleet development scenario

Target year	Target scenario	NEDC (gCO_2/km)	WLTP (gCO_2/km)					
			Mixed xEV	Ultra-efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme	Equivalent WLTP target
2025	Low	74	82.0	80.9	79.6	85	80.3	**82.0**
	medium	81	89.8	88.5	87.2	93	87.9	**89.8**
	High	84	93.1	91.8	90.4	96.5	91.2	**93.1**
2030	Low	54	60.7	59.4	57.9	65.8	58.2	**60.7**
	medium	66	74.2	72.6	70.8	80.5	71.2	**74.2**
	High	72	80.9	79.2	77.2	87.8	77.6	**80.9**
2025	Low	108	125	123	120	131	123	**125**
	medium	120	139	137	134	146	137	**139**
	High	126	146	143	140	153	143	**146**

Target year	Target scenario	NEDC (gCO_2/km)	WLTP (gCO_2/km)					
			Mixed xEV	Ultra-efficient ICEV	BEV extreme	PHEV REEV extreme	FCEV extreme	Equivalent WLTP target
2030	Low	79	91.7	89.9	88	96	89.9	**91.7**
	medium	98	114	112	109	119	111	**114**
	High	108	125	123	120	131	123	**125**

G.3 Converting WLTP TTW CO_2 emissions to equivalent WLTP WTW emissions

For the purpose of this study, WTW targets are considered equivalent with TTW targets if the resulting overall WTW GHG emission reduction is equal in both cases (equal effectiveness). This way of defining the 'equivalence' was agreed upon with the European Commission.

Given the cost curves for every drivetrain technology and the technology scenario in the target year, the cost assessment model can be used to determine the cost optimal solution from manufacturers' point of view for any TTW target level. This model also determines the WTW emissions, additional manufacturer costs and overall GHG emission reduction at this cost optimal solution. By running the 'cost assessment model' for many different TTW target levels, relations can be defined between

- the sales weighted average TTW emissions and the overall GHG emission reduction; and
- the sales weighted average WTW emissions and the overall GHG emission reduction.

Using these relations, it can be determined for any TTW target level which WTW-based target would result in the same overall WTW GHG emission reduction and would therefore be the 'equivalent' WTW target level. This is shown in Figure 108 to Figure 111.

As can be seen in these figures, for a certain TTW target level the overall WTW GHG emission reductions are different for the different fleet compositions assessed. Therefore also the 'equivalent' WTW target levels depend on the fleet composition. The CO_2 reductions per distinguished drivetrain type to meet a certain TTW target at the lowest possible cost depend on the fleet composition. As a result also the overall WTW GHG emission reductions depend on the fleet composition, after all, the WWT factors and lifetime mileage differ per drivetrain type.

From these relations, the average WTW emissions can be determined at which the overall GHG emission reduction is equal to the overall GHG emission reduction at a certain TTW target. For this, the 'Mixed xEV' scenario is used as it is a combination of all other technology scenarios considered. (This explains why the TTW and WTW targets may not be 100% equivalent under the other technology scenarios.)

The way in which the equivalent WTW targets are derived is shown by the red dotted lines in Figure 108, Figure 109, Figure 110 and Figure 111.
The 'equivalent' WTW target can then be selected from the relation between the WTW CO_2 emissions and the required manufacturer's effort.

Figure 108 Approach for calculating equivalent targets for passenger cars 2025

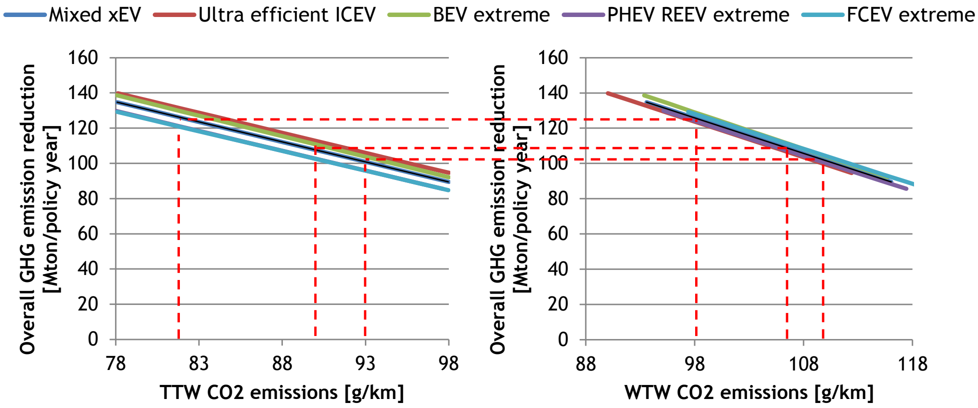


Figure 109 Approach for calculating equivalent for targets for passenger cars 2030

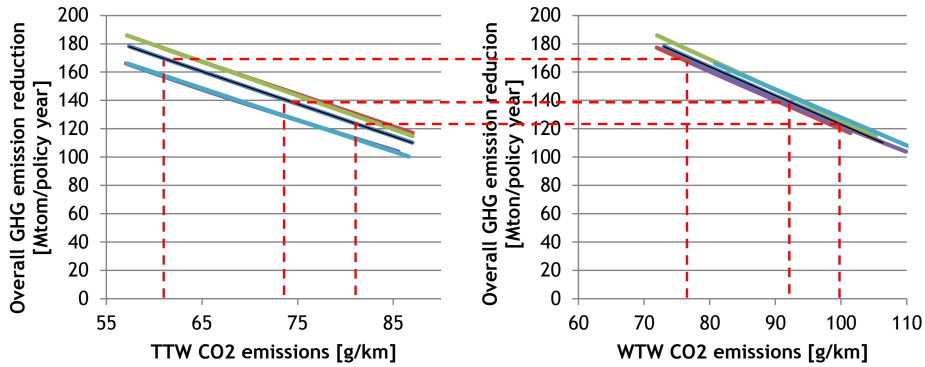


Figure 110 Approach for calculating equivalent for targets for vans 2025

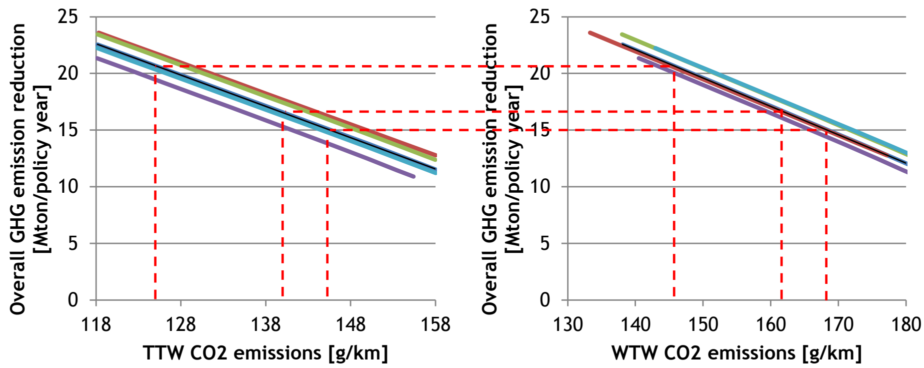
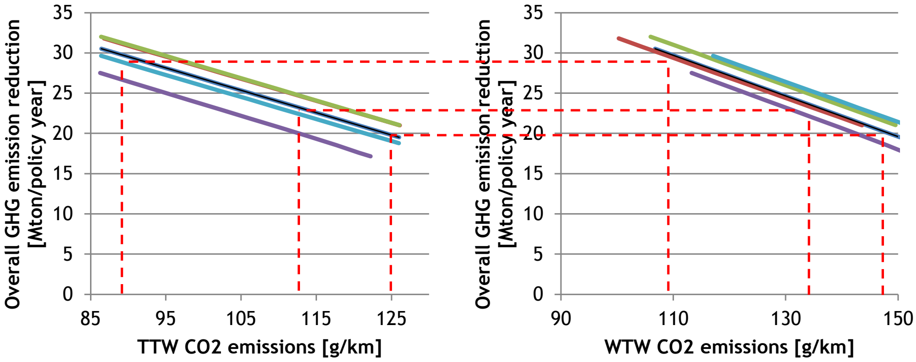


Figure 111 Approach for calculating equivalent for targets for vans 2030



G.4 Overview of equivalent targets

The equivalent targets for passenger cars and for vans for both 2025 and 2030 are shown in Table 45.

Table 45 Equivalent targets for passenger cars and for vans (2025 and 2030)

Vehicle type	Target year	Target scenario	NEDC targets	Equivalent TTW WLTP target	Equivalent WTW WLTP target
Passenger car	2025	6% annual reduction	74	82.0	98
		4% annual reduction	81	89.8	107
		3% annual reduction	84	93.1	110
	2030	6% annual reduction	54	60.7	77
		4% annual reduction	66	74.2	92
		3% annual reduction	72	80.9	100
Vans	2025	6% annual reduction	108	125	146
		4% annual reduction	120	139	161
		3% annual reduction	126	146	169
	2030	6% annual reduction	79	91.7	113
		4% annual reduction	98	114	137
		3% annual reduction	108	125	150

Annex H Explanation of modalities: mileage weighting and regulatory metric

In this annex, the modalities (1) mileage weighting and (2) the regulatory metric are defined in more detail.

H.1 Regulatory metric

Based on g/km WTW emissions for all technologies/energy carriers.
In general WTW emissions of vehicles can be written in different ways which are all equivalent:

$$G_i^{WTW} = g_i^{WTW} \cdot E_i^{TTW} = G_i^{TTW} + g_i^{WTT} \cdot E_i^{TTW} = (g_i^{WTT} + g_i^{TTW}) \cdot E_i^{TTW}$$

with:

G_i^{WTW}	the WTW GHG emissions in g/km of vehicles with energy carrier i
g_i^{WTW}	the WTW GHG emission factor in g/MJ of energy carrier i
g_i^{WTT}	the WTT GHG emission factor in g/MJ of energy carrier i
g_i^{TTW}	the TTW GHG emission factor in g/MJ of energy carrier i
E_i^{TTW}	the TTW energy consumption in MJ/km of vehicles with energy carrier i

- WTW or WTT emission factors can be based on actual monitoring or can be set as default values which are regularly updated on the basis of less frequent monitoring.
  - Emission factors can be defined as EU averages, or per Member State (MS).
  - Emission factors cannot be manufacturer specific, unless based on weighted average of MS specific values.
  - Using actual data requires a complex and fast monitoring system to have up-to-date information of EU or MS averages.
  - The relation with monitoring of GHG intensity of energy carriers as foreseen under the FQD should be noted.
  - Main methodological issues relate to:
    - using average vs. marginal emissions;
    - impact of EU ETS on emission values for e.g. electricity and hydrogen.
  - WTT emission factors may need to take into account estimated future progress to represent expected average values over vehicle lifetime, rather than values representative for the year in which the vehicle is sold.
- In general for this WTW GHG-based metric the target can be defined as:

$$G_{target}^{WTW} = \sum_{i=1}^{m} \eta_i \sum_{j=1}^{n} g_j^{WTW} \cdot E_{i,j}^{TTW}$$

with:

G_{target}^{WTW} the WTW GHG emission target in g/km
η_i the share of vehicles with technology i in the new vehicle sales

g_j^{WTW} the WTW GHG emission factor in g/MJ of energy carrier j
$E_{i,j}^{TTW}$ the sales-weighted average TTW consumption of energy carrier j in MJ/km by vehicles with technology i

- Making an explicit distinction between conventional vehicles, plug-in hybrids and various ZEV technologies, the above equation can also be written as:

$$G_{target}^{WTW} = \sum_{i=1}^{l} \eta_{ICEV-i} \cdot (G_{ICEV-i}^{TTW} + g_i^{WTT} \cdot E_{ICEV-i}^{TTW}) + \sum_{j=1}^{m} \eta_{PHEV-j} \cdot (G_{PHEV-j}^{TTW} + g_j^{WTT} \cdot E_{PHEV-j}^{TTW} + g_{elec}^{WTT} \cdot E_{PHEV-j-elec}^{TTW}) + \sum_{k=1}^{n} \eta_{ZEV-k} \cdot g_{ZEV-k}^{WTT} \cdot E_{ZEV-k}^{TTW}$$

with:

η_{ICEV-i} the share of ICEVs with fuel i in the new vehicle sales

G_i^{TTW} the sales-weighted average TTW GHG emissions in g/km of ICEVs with fuel i

g_i^{WTT} the WTT GHG emission factor in g/MJ of fuel i

E_i^{TTW} the sales-weighted average TTW electricity consumption in MJ/km of ICEVs with fuel i

η_{PHEV-j} the share of PHEVs with fuel j in the new vehicle sales

G_{PHEV-j}^{TTW} the sales-weighted average TTW GHG emissions in g/km of PHEVs with fuel j

E_{PHEV-j}^{TTW} the sales-weighted average TTW fuel consumption in MJ/km of PHEVs with fuel j

g_{elec}^{WTT} the WTT GHG emission factor of electricity in g/MJ

$E_{PHEV-j-elec}^{TTW}$ the sales-weighted average TTW electricity consumption in MJ/km of PHEVs with fuel j

η_{ZEV-k} the share of ZEVs with energy carrier k in the new vehicle sales

g_{ZEV-k}^{WTT} the WTT GHG emission factor in g/MJ of energy carrier $ZEV-k$

E_{ZEV-k}^{TTW} the sales-weighted average TTW energy consumption in MJ/km of ZEVs with energy carrier $ZEV-k$

H.2 Mileage weighting

- For a given vehicle lifetime GHG emissions = gCO_2/km x lifetime mileage, either on a TTW or WTW basis.
- As actual mileages cannot be used, default lifetime mileage values must be defined.
- Mileage weighting only affects the metric if the mileage is different for different vehicles. Mileage therefore needs to be correlated with one or more objectively identifiable vehicle attributes.
- The utility parameter used in the legislation is an obvious candidate for a size dependent mileage weighting.
  - The most obvious implementations are in the form of a size- or mass-based mileage. The former is preferred as vehicle mass will be strongly affected by weight reduction measures in the next decades. Size could e.g. be parameterised as pan area (length x width) or footprint (wheelbase x track width).
- Besides size-dependent the mileage could also be technology dependent. EVs may be assumed to be used in applications with lower annual mileages, while e.g. diesel vehicles are and FCEVs on hydrogen may be used in applications with longer annual mileages.
- For mileage weighting the type approval emission value of every vehicle sold is multiplied by the lifetime mileage assume for that vehicle. Dividing the sum of all lifetime GHG emissions of all vehicle sold by the sum of the lifetime mileages of all vehicles sold, yields the lifetime-mileage weighted average emissions.
  - This can be applied per manufacturer as well as to all vehicles sold in Europe.
- Mileage weighting can be included in the metrics as developed under a), b), and e).
  - Mileage weighting is already included in option d).

Mileage weighting has already been indicatively explored as part of Service Request 1 (TNO, 2011). The main conclusions drawn in that study are as follows:

- Mileage weighting will help to reach the intended overall GHG emission reduction in a more cost-effective manner by taking account of the fact that CO_2 emission reduction technologies have more impact in cars that drive more. Lifetime emissions total for all vehicles sold in 2020 can be achieved 2% less expensively (equivalent to € 600 million) when mileage is taken on board as weighting parameter in addition to sales. This is due to two reasons: i) larger vehicles with higher emissions generally cover longer distances, thus increasing the emission reductions that can be captured with CO_2 reduction technologies applied to these vehicles; and ii) diesel vehicles also drive more than petrol vehicles and emission reduction in diesels is more expensive than for petrol.
- Mileage weighting requires the establishment of robust and accepted mileage values, which at least should be recorded in function of an appropriate utility parameter and the fuel type, but possibly also specific for each manufacturer. This can be done through surveys or improved inspection/reporting procedures, for which discussions with the relevant sectors will be needed.
- Mileage weighting makes the achieved net GHG emission reduction insensitive to the way in which manufacturers choose to distribute their reduction efforts over different market segments/models.
- More analysis is needed to assess the full effects of mileage weighting as well as to further determine practical implications.