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COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

Accompanying the document

PROPOSAL FOR A REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on type-approval of motor vehicles and of engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009

{COM(2022) 586 final} - {SEC(2022) 397 final} - {SWD(2022) 358 final} - {SWD(2022) 360 final}

Contents

Glossary

Acronym	Meaning
AGVES	Advisory Group on Vehicle Emission Standards
AAQD	Ambient Air Quality Directive
ASC	Ammonia Slip Catalyst
BEV	Battery Electric Vehicle
CEM	Continuous Emission Monitoring
CI	Compression Ignition engine vehicles (diesel vehicles)
CNG	Compressed Natural Gas
CoP	Conformity of Production
HDV	Heavy-Duty Vehicles (lorries and buses)
DPF	Diesel Particulate Filter
EATS	Exhaust Aftertreatment System
EHC	Electrically Heated Catalyst
EGR	Exhaust Gas Recirculation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPF	Gasoline Particulate Filter
ICE	Internal Combustion Engine
ISC	In-Service Conformity
LDV	Light-Duty Vehicles (cars and vans)
LPG	Liquefied Petroleum Gas
MaS	Market Surveillance
NAO	Non Asbestos Organic (brake pads)
NECD	National Emission reduction Commitments Directive
NPV	Net Present Value
OBD	On-Board Diagnostics
OBFCM	On-Board Fuel Consumption Meters
OTA	Over-The-Air (data transmission)
PEMS	Portable Emission Measurement Systems
PFI	Port Fuel Injection
PHEV	Plug-in Hybrid Electric Vehicle
PI	Positive Ignition engine vehicles (petrol and gas vehicles)

PTI	Periodic Technical Inspections
RDE	Real Driving Emissions
RSI	Roadside Inspections
SCR	Selective Catalytic Reduction
TWC	Three-Way Catalytic converter
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organization
WHSC	Worldwide Harmonised Steady State Driving Cycle
WHTC	Worldwide Harmonised Transient Driving Cycle
WLTP	World Harmonised Light Vehicle Test Procedure

Glossary emission species

Formulae	Meaning
CH_2O / HCHO	Formaldehyde
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydrocarbon (Total hydrocarbons (THC) and Non-methane hydrocarbons (NMHC))
NH_3	Ammonia
NMOG	Non-methane organic gases
NMVOC	Non-methane volatile organic compounds
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxide (Nitrogen dioxide (NO_2) and Nitric oxide (NO))
O_3	Ozone
PM	Particulate matter
PM_{10}	Particulate matter with an aerodynamic diameter smaller than 10 micrometres (<10 µm)
$PM_{2,5}$	Particulate matter with an aerodynamic diameter smaller than 2.5 micrometres (<2,5 µm)
PN	Particle number

1 INTRODUCTION: POLITICAL AND LEGAL CONTEXT

1.1 Political context

Air pollution remains the single largest environmental and health risk in Europe.[1] While air quality has improved, a significant proportion of the EU's urban population is still exposed to pollutant concentrations above the limits defined by the Ambient Air Quality Directive[2]. Even greater proportion faces the pollution concentrations above the maximum levels recommended by the World Health Organization (WHO)[3], while even low level of pollution was recently shown[4] to be associated with increased mortality due to cardiovascular, respiratory and lung cancer. Road transport is still a major contributor to air pollution, while other sectors like residential heating, industry, energy supply or agriculture are also important source of harmful emissions. It is estimated that road transport caused about 70 000 premature deaths in the EU-28 in 2018.[5] It was on average responsible for 39% of the harmful NO_x emissions in 2018 (47% of the NO_x emissions in urban areas[6]), and 11% of total PM_{10} emissions in 2018[7]. The Dieselgate scandal[8] unveiled the widespread use of illegal defeat devices[9] in diesel vehicles, leading to abnormally high emissions on the road, compared to emissions tested in the laboratory. While the Commission has since introduced real driving emissions testing and modernised type approval procedures, the European Parliament Committee of Inquiry into Emissions Measurements in the automotive sector recommended that the Commission also proposes new technology-neutral Euro 7 emissions limits.[10]

The European Green Deal[11] (EGD) is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy. The EU should also promote and invest in the necessary digital transformation and tools as these are essential enablers of the changes. In order to reach climate neutrality by 2050 and zero-pollution ambition for a toxic-free environment, all sectors need to transform, including the road transport. EGD foresees adoption of a proposal for more stringent air pollutant emissions standards for combustion-engine vehicles (Euro 7).

[1] EEA, 2020. Air quality in Europe – 2020 report
[2] Directive 2008/50/EC on ambient air quality and cleaner air for Europe
[3] EEA, 2020. Exceedance of air quality standards in Europe
[4] Brunekreef, B. et al, 2021. Mortality and Morbidity Effects of Long-Term Exposure to Low-Level PM2.5, BC, NO2, and O3: An Analysis of European Cohorts in the ELAPSE Project
[5] See footnote 1 (EEA air quality report). This estimate is based on estimated 379 000, 54 000 and 19 400 premature deaths in the EU-28 in 2018 from fine particles pollution, NO_2 and O_3 emissions in the ambient air, respectively, and the estimated share of road transport in 2018 of 39% of the harmful NO_x emissions and of 11% of total PM_{10} emissions.
[6] JRC, 2019. Urban NO_2 Atlas
[7] EEA, 2020. Air pollutant emissions data viewer (Gothenburg Protocol, LRTAP Convention) 1990-2018
[8] The car emission scandal was set off by the revelation by the US Environmental Protection Agency (EPA) in September 2015 that the Volkswagen Group had used defeat devices in 500 000 diesel cars in the United States to comply with pollutant emission limits in laboratory conditions. Shortly after, it was confirmed by the German authorities that Volkswagen had also used defeat devices in approximately 8.5 million cars in Europe for model years 2009-2015.
[9] Defeat Devices are elements of car design that diminish the emission controls under certain circumstances. They are mostly prohibited, unless there is a specific and well justified reason for their use.
[10] EMIS, 2017. European Parliament recommendation of 4 April 2017 to the Council and the Commission following the inquiry into emission measurements in the automotive sector
[11] COM(2019) 640 final. The European Green Deal

To accelerate decarbonisation of the road transport, the Commission proposed in July 2021 legislation on CO_2 emission performance standards for cars/vans[12], to ensure a clear pathway towards zero-emission mobility.[13] Moreover, the Commission adopted in December 2020 the Sustainable and Smart Mobility Strategy[14] and in May 2021 the Zero-Pollution Action Plan[15]. According to those strategies, transport should become drastically less polluting, especially in cities and Euro 7 is considered as a vital part of the transition towards clean mobility.

Last but not least, the New Industrial Strategy for Europe[16] offers tools to address the twin challenge of the green and the digital transformation and to support the European industry in making the EGD ambition a reality. New pollutant emission framework will offer legal certainty and first-mover advantage to the EU automotive sector, avoiding the risk of falling behind other major jurisdictions setting new pollutant emission standards.

Transition towards only zero-emission vehicles fleet will however be spread across at least two decades, not least given the average lifetime of vehicles of more than 11 years. Meanwhile, in order to achieve the above policy objectives, it is imperative to ensure that the internal combustion-engine vehicles which will continue to be placed on the market are as clean as possible. This is a prerequisite for protection of human health, in particular in urban areas[17].

1.2 Legal context

Emission standards for light-duty vehicles (cars/vans), and heavy-duty vehicles (lorries/buses), were implemented in the EU since 1992 through a series of Euro emission rules which addressed one of the major sources of air quality problems, i.e. tailpipe pollutants emitted to the air. These standards are embedded in the general type-approval framework[18], based on which new vehicle models are tested, granted type-approval and verified against a minimum set of safety and emission requirements before entering into service on the EU market. Over the years, with successive Euro standards, not only the specific limits for pollutants were tightened, but also the pollutant testing procedures were gradually modernised. The current emission standards were adopted in 2007 for light-duty vehicles (LDVs-Euro 6) and in 2009 for heavy-duty vehicles (HDVs-Euro VI).[19][20] They entered into force in 2014 for LDVs and in 2013 for HDVs.[21]

[12] COM(2021) 556 final. Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition

[13] In 2022, this will be followed by a proposal on CO_2 emission performance standards for heavy-duty vehicles.

[14] COM(2020) 789 final. Sustainable and Smart Mobility Strategy – putting European transport on track for the future

[15] COM(2021) 400 final. Pathway to a Healthy Planet for All EU Action Plan: Towards Zero Pollution for Air, Water and Soil

[16] COM(2020) 102 final, A New Industrial Strategy for Europe, COM(2021) 350 final, Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery

[17] Urban areas are characterised by high volume of traffic emitting air pollutants and high population density. The population in urban areas is therefore exposed to higher concentrations of air pollutants than in rural areas and more citizens are effected.

[18] Regulation (EU) 2018/858 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles

[19] Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and its implementing Regulation (EU) 2017/1151;

The testing procedures have been adjusted by implementing Regulations over the different steps of Euro 6b-d and Euro VI A-E between 2013 and 2022 (see Annex 5, Table 36 for details)[22]. The introduction of Real Driving Emissions (RDE) testing in 2017 (footnote 24 below) required testing of pollutants in real-driving and no more only in laboratory conditions, bringing about significant reduction of harmful emissions[23]. In 2019 also more stringent verification by in-service conformity procedure (ISC), ensuring that vehicles meet the emission limits during their service, was introduced.[24]

The Euro emission standards include references to testing procedures set out in UN regulations[25]. The UN World Forum for Harmonization of Vehicle Regulations focusses on the establishment of global harmonisation of technical regulations for vehicles. The EU as a contracting party, has ensured that all relevant UN Regulations are aligned with the Euro 6/VI emission limits and testing procedures.

1.3 Interaction between Euro emission standards and other EU air pollutant policies

As shown in Figure 1, Euro emission standards for vehicles are interlinked with several other EU rules which tackle air pollutants of the road transport as well as with the CO_2 emission standards[26] which reduce air pollutants as a co-benefit.

Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and its implementing Regulation (EU) No 582/2011

[20] SEC(2005) 1745 Commission Staff Working Document, Impact Assessment on Euro 5/6 emission standards; SEC(2007) 1718 Commission Staff Working Document, Impact Assessment on Euro VI emission standards; together referred to as Euro 6/VI impact assessments in the following

[21] In 2014 for light-duty vehicles and 2013 for heavy-duty vehicles, air pollutant emission limits entered into force for NO_x (nitrogen oxide), PM (particulate matter), PN (particle number), CO (carbon monoxide), THC (total hydrocarbons) and NMHC (non-methane hydrocarbons) and, for heavy-duty vehicles only, CH_4 (methane) and NH_3 (ammonia). (See Annex 5, Table 35 for details)

[22] They also include trailers used in heavy duty vehicles for what concerns their effect on CO_2 emissions.

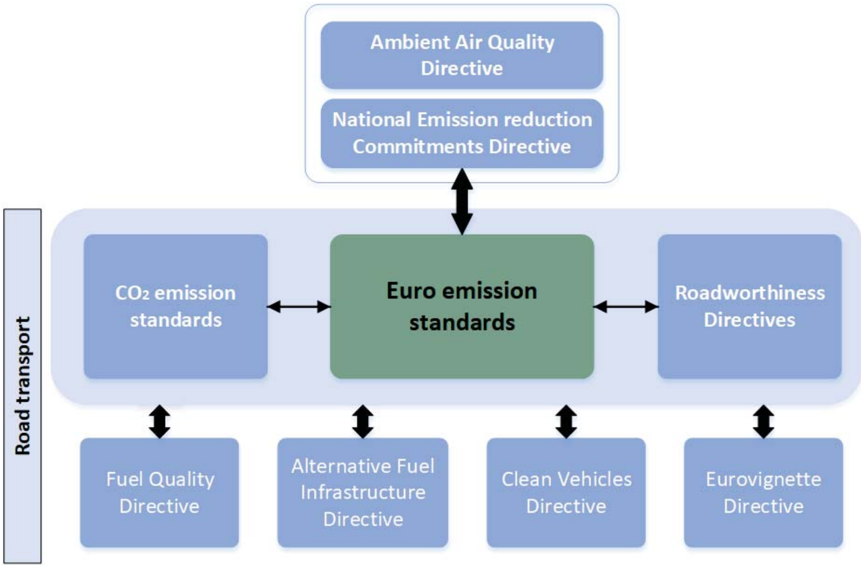
[23] Regulation (EU) 2017/1151, supplementing Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)

[24] Regulation (EU) 2018/1832 for the purpose of improving the emission type approval tests and procedures for light passenger and commercial vehicles, including those for in-service conformity and real-driving emissions and introducing devices for monitoring the consumption of fuel and electric energy

[25] Regulation No 83 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements; Regulation No 49 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles

[26] Regulation (EU) 2019/631 CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, Regulation (EU) 2019/1242 CO_2 emission performance standards for new heavy-duty vehicles

Figure 1- EU rules tackling air pollutants in the road transport sector



- The scale of policy actions undertaken in Europe to specifically address transport-related air pollution has increased over recent years, reflecting the important contribution of transport to air pollution, in particular in urban areas. Local and regional air quality management plans — including initiatives such as low- or zero-emission zones in cities and congestion charges — are now used in many areas where the level of air pollution from transport is high. The Ambient Air Quality Directive (AAQD)[27] aims at improving air quality by setting limits for the ambient air concentrations of specific air pollutants from all air pollution sources (e.g. agriculture, energy, manufacturing, etc.). The National Emission reduction Commitments Directive (NECD) aims at reducing national air pollutant emissions by setting national reduction commitments for five specific air pollutants[28], with reductions from all sectors, including road transport. The current AAQD/NECD cover ambient levels of air pollutants and emissions of road transport and the Euro emission standards for vehicles help Member States meeting their NECD reduction commitments.

  As part of the European Green Deal, the Commission announced that it will revise in 2022 EU rules on air quality proposing to strengthen provisions on monitoring, modelling and air quality plans and revising the air quality legislation to align them more closely with the new WHO recommendations[29]. It is clear from the analysis[30] carried out by one of the most authoritative air quality modelling group in Europe, i.e. the International Institute for Applied Systems Analysis (IIASA), that full compliance will not be achieved without extra measures. In 2030 more than 52

[27] Directive 2008/50/EC on ambient air quality and cleaner air for Europe
[28] Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants. The Directive establishes the emission reduction commitments for the Member States' anthropogenic atmospheric emissions of SO_2, NO_x, NMVOC, NH_3 and $PM_{2,5}$ and requires that national air pollution control programmes be drawn up, adopted and implemented and that emissions of those pollutants and the other pollutants referred to in Annex I, including CO, as well as their impacts, be monitored and reported.
[29] World Health Organization, 2021. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.
[30] European Commission, 2022. Revision of the Ambient Air Quality Directives

million EU citizens will continue to be exposed to NOx concentrations higher than the WHO recommended air quality concentration levels due to road traffic. This analysis relied on incorporating the assumptions under the Option 3a of this Impact Assessment. This demonstrates the importance of limiting emissions at the source, by setting stricter emissions standards (such as the Euro ones for road transport) and requirements for improved fuel quality. The introduction of stricter Euro emission standards for all air pollutant emissions from road transport is needed in order for Member States to achieve compliance with new targets on air quality, while limiting the need to impose vehicle circulation bans. The interactions are further explored in the next sections.

- The CO_2 emission standards support the EU's climate ambition set in European Climate Law[31], which aims at reducing EU greenhouse gas emissions by at least 55% by 2030, compared to 1990. Since the CO_2 emission standards have proven to be an effective policy tool in this respect[32], the Commission revised and strengthened the CO_2 emission standards for cars/vans in July 2021 (see 1.1). Significant positive effects on air quality can be expected from the amendment of the CO_2 standards, setting an end-date of 2035 for placing new combustion-engine cars and vans in the EU market. The revision of the CO_2 emission standards for heavy-duty vehicles is foreseen by end-2022, aiming at increasing uptake of zero- and low emission heavy-duty vehicles and enhanced fuel efficiency of conventional engines.

- The Roadworthiness Directives[33] have the objective to increase road safety in the EU and to ensure the environmental performance of vehicles, by means of regularly testing vehicles throughout their operational lifetime. As far as emissions are concerned they have as objective to contribute to the reduction of air pollutant emissions by detecting more effectively vehicles that are over-emitting due to technical defects, through periodic technical inspections (PTI) and the roadside inspections (RSI). The Euro emission standards and Roadworthiness Directives should operate in a complementary way with the aim to reduce air pollutant emissions from road vehicles.

- The Fuel Quality Directive[34] sets obligation of reduction of air pollutants from liquid transport fuels, the Eurovignette Directive[35] sets common rules on road infrastructure charges and the Clean Vehicles Directive[36] promotes clean mobility solutions through public procurement. While the Euro emission standards require clean performance of vehicles, the Alternative Fuel Infrastructure Directive (AFID)[37] promotes the use of

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[31] Regulation 2021/119 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')

[32] SWD(2021) 613 final, Commission Staff Working Document, Impact Assessment, Accompanying the document Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition

[33] Directive 2014/45/EU on periodic roadworthiness tests for motor vehicles and their trailers; Directive 2014/47/EU on the technical roadside inspection of the roadworthiness of commercial vehicles circulating in the Union

[34] Directive 2009/30/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions

[35] COM(2017) 275 final, Proposal for a Directive amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures

[36] Directive 2019/1161/EU on the promotion of clean and energy-efficient road transport vehicles

[37] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the

alternative fuels for road transport. The Eurovignette Directive and Clean Vehicles Directive may support the demand for clean vehicles by allowing Member States to vary road charges based on pollutant emissions of vehicles and by setting requirements for higher share of clean vehicles in public procurement.

2 PROBLEM DEFINITION

2.1 What are the problems?

The negative impact of road transport to air pollution has only marginally decreased over the recent years. This relative stagnation is mainly due to the ever-growing vehicle fleet[38] and increase in transport demand compared to more significant emission reductions in other sectors[39]. Also, despite improvements in the emission regulation, gaseous pollutants, in particular NO_x and exhaust particles are still emitted through tailpipes of ICE vehicles while non-exhaust particles are a result of brake and tyre wear produced by all vehicles, including zero-emission vehicles. This leads to more than 70% of ultrafine particles[40] in EU cities being attributed to road transport, either directly (primary emissions) or indirectly (secondary aerosol).[41] Furthermore, preliminary analysis done for the revision of EU air quality legislation[30] carried out by one of the most authoritative air quality modelling group in Europe, i.e. the International Institute for Applied Systems Analysis (IIASA), has shown that full compliance with NO_2 limits cannot be reached with today's vehicle emission standards.

Since the entry into force of Euro 6/VI emission limits until 2020, NO_x vehicle emissions on EU roads have decreased by 22% for cars/vans and by 36% for lorries/buses.[42] In addition, exhaust PM emissions from cars/vans have decreased by 28%, and by 14% from lorries and vans. THC emissions from lorries/buses went down by 14%, while THC and NMHC emissions from cars/vans went down by 13 and 12%.[42] Further emission reductions are expected to be made as more Euro 6d and Euro VI E vehicles enter the market[43].

In the same Euro 6/VI period, health impacts and the related external costs of medical treatment and production losses due to illness and death were reduced by €97 billion EU-wide due to reduced NO_x and PM emissions from road transport.[44] However, pollutant emissions caused by road transport still affect hundreds of thousands of European citizens and lead to significant health impacts and related external costs each year. In 2018 an EPHA study[45] estimated that any inhabitant of European cities suffered an average welfare loss of over €1 250/year due to direct and indirect health impacts of poor air quality, which is equivalent to 3.9% of income earned in cities. While these air quality problems are not exclusively caused by road transport, the same study demonstrated that

deployment of alternative fuels infrastructure

[38] ACEA, 2021. Vehicles in use Europe

[39] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-, chapter 5.1.5.3 What has been the contribution of the standards to achieving National Emission Ceilings Directive (NECD) targets?

[40] Ultrafine particles are defined here as those having less than 0.1 µm of diameter.

[41] CORDIS, 2019. Ultrafine particles and health impact: revising EU policy

[42] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3. Chapter 5.1.2.4 What was the impact of Euro 6/VI on the total level of emissions?

[43] The late introduction of RDE testing in the final Euro 6d step contributed to delayed progress in pollutant emission reduction under Euro 6, which will materialise only after 2020 (see Figure 20 in Annex 5).

[44] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.1 Effectiveness, Evaluation question 3

[45] EPHA, 2020. Health costs of air pollution in European cities and the linkage with transport

a 1% increase in the number of cars in a city is expected to lead to an overall increase in health costs by almost 0.5%.

NO_x and particles (expressed as $PM_{2.5}$) are the key air pollutants from road transport. In Figure 2, the evolution of NO_x and total (i.e. exhaust and non-exhaust) $PM_{2.5}$ emission between 2010 and 2040 is shown first for cars/vans and then for lorries/buses[46]. The fit-for-55 package of 14 July 2021, i.e. the adopted CO_2 emission standards proposing an end-date of 2035 for placing new combustion-engine cars and vans on the EU market as well as the projected fit-for-55 HDV fleet evolution to contribute to the 55% net greenhouse gas emission reduction by 2030 and the 2050 climate neutrality objective, have been factored in. The fit-for-55 package results in an expected increase of zero-emission vehicles in the vehicle fleet and, as Figure 2 shows, a decrease in both NO_x and exhaust $PM_{2.5}$ emissions. Following the proposed end-date of 2035, the emissions of NO_x and exhaust particles from cars/vans are expected to decline more steeply than those from lorries/buses. Still, combustion-engine cars and vans will continue to be part of the European fleet after 2035. In 2040, 49% of European fleet of cars and vans is still expected to consist of combustion-engine vehicles, including hybrids[47].

Moreover, increasing penetration of the latest Euro 6d/VI E vehicles in the fleet results in NO_x and exhaust $PM_{2.5}$ reduction (see Figure 2). However, Figure 2 also shows that there is no reduction of non-exhaust $PM_{2.5}$ emissions from brake and tyre wear for neither cars/vans or lorries/buses, given lack of emission control technologies in place. Controlling such non-exhaust emissions is needed, not least because they are also emitted from zero-emission vehicles. The difference between total and exhaust $PM_{2.5}$ will increase in the future for all vehicles. The projections to 2040 show that the zero-pollution ambition for a toxic-free environment, as set out in the European Green Deal, cannot be reached in the road transport sector in the near future with the current legislation in place. To improve our health and well-being in line with the Zero-Pollution Action Plan[15], air pollutants emission needs to be reduced towards zero-pollution as rapidly as possible.

The NO_x and exhaust $PM_{2.5}$ emission limits are of particular concern given that they were set as early as 2007 for cars/vans, and 2009 for lorries/buses (and assessed more than two decades ago). Furthermore, approximately 20% of current real-driving mileages in Europe are estimated to be outside the RDE testing boundaries and therefore may exceed significantly the current emission limits[63]. Significant technical evidence on this issue was gathered by major research projects, including those of the Joint Research Center (JRC), GreenNCAP and AECC[48],[49],[50],[51],[52],[53]. The test data were collected in a database

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[46] The proposed end-date of 2035 for new combustion-engine cars/vans, projected fit-for-55 HDV fleet evolution and fleet renewal with Euro 6/VI vehicles is taken into account. Additional effects from the planned revision of the Ambient Air Quality Directives in 2022, which are estimated limited compared to the effects of CO_2 emission standards, cannot be taken into account yet.

[47] SIBYL, 2021: Ready to go vehicle fleet, activity, emissions and energy consumption projections for the EU 28 member states

[48] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[49] Data provided by GreenNCAP (https://www.greenncap.com/)

[50] Real-world emission data measured on-road and on chassis-dyno of Light- and Heavy-duty demonstrator vehicles were provided by the Association for Emissions Control by Catalyst (AECC). The scientific publications can be accessed via https://www.aecc.eu/resources/scientific-publications/.

[51] JRC Market Surveillance report at https://publications.jrc.ec.europa.eu/repository/handle/JRC122035

[52] Scientific paper on "On-road emissions of passenger cars beyond the boundary conditions of the real-

run by the JRC[54]. Analysis of the data proves that when driven outside RDE testing boundaries, vehicles still emit significantly higher than when driven within RDE testing boundaries. As an example, the average of NOx emissions by diesel passenger cars outside RDE boundaries[55] is 475% higher than when driven within RDE boundaries. This means that just 1 km run outside the current RDE boundaries will pollute on average the same as 475 km run inside current RDE boundaries.

In addition, there are currently no emission limits for particles emitted by brake and tyre wear. As can be seen in Annex 4, the average tailpipe emissions of particles from a passenger car is currently much less than 1 mg/km, while the average particle emissions from the brakes is estimated to be 11 mg/km, i.e. more than 11 times higher.

Moreover, there is urgent need to address pollutants emission from heavy-duty vehicles. The projected fit-for-55 share of new combustion-engine heavy-duty vehicles including hybrids, placed on the EU market is expected to be 53% in 2040 (see Figure 7 in section 5.1), while the overall share of combustion-engine heavy-duty vehicles in the EU fleet would still be 86%[47]. At the same time, the NO_x and exhaust $PM_{2.5}$ emission limits for these vehicles were set in 2009, on the basis of engine testing only. Emission limits should be set on the basis of the emissions of the entire heavy-duty vehicle, as it is the case for light-duty vehicles.

Conclusion: Despite proposed end-date of 2035 for placing new combustion-engine cars and vans on the EU market, increasing share of zero- and low-emission heavy-duty vehicles and new Euro 6d/VI E vehicles entering the market, a zero-pollution level cannot be reached for NO_x and total $PM_{2.5}$ emissions from road transport. The main reasons are obsolete vehicle emission limits adopted over a decade ago, unaccounted real-driving emissions from cars and vans, not regulated vehicle brake emissions and the slower transition of lorries to zero-emission powertrains.

As shown in the evaluation of the Euro 6/VI emission standards, cost-effective pollutants emission reduction from road transport stems from the mandatory Euro standards introduced at EU level, which also support Member States improving their local air quality in line with current rules and in view of the proposed revision of the Ambient Air Quality Directives and meeting their emission reduction commitments under the National Emission reduction Commitments Directive.

Figure 2 – Magnitude and evolution of the problem of air pollutants related to road transport in EU-27 **split up for cars/vans (a) and lorries/buses (b)**, with end-date of 2035 for new combustion-engine cars/vans and fleet renewal with Euro 6/VI vehicles[56]

driving emissions test" in https://www.sciencedirect.com/science/article/pii/S001393511930369X

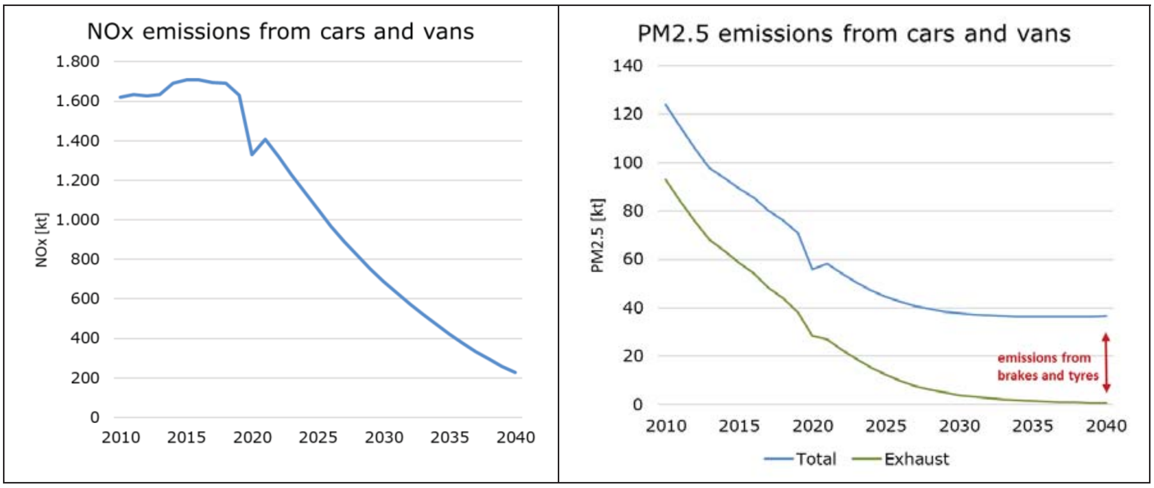
[53] Scientific papers on "Assessment of Gaseous and Particulate Emissions of a Euro 6d-Temp Diesel Vehicle Driven >1300 km Including Six Diesel Particulate Filter Regenerations", https://www.mdpi.com/2073-4433/11/6/645/htm

[54] JRC link to database when available

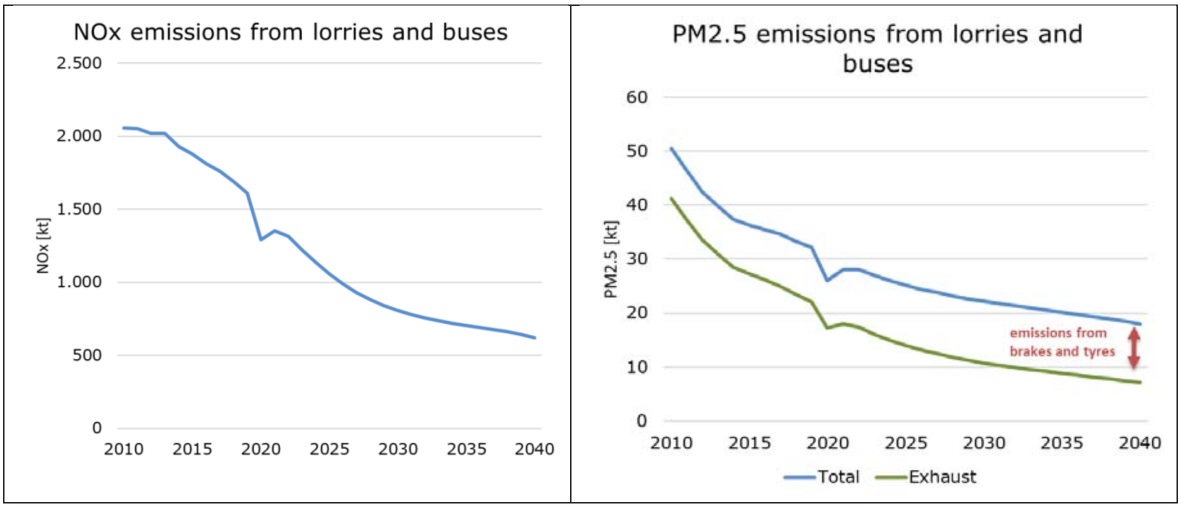
[55] Number quoted are the average of 172 tests on 54 diesel vehicles for trips outside the RDE boundaries, and 144 tests on 64 diesel vehicles for trips inside the RDE boundaries.

[56] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, Figure 4-3: Evolution of (a) NOx and (b) PM2.5 emissions from road transport after "EU fit-for-55" package. NO_x emissions are harmful nitrogen oxide emissions (nitrogen dioxide (NO_2) and nitric oxide (NO)). $PM_{2.5}$ are harmful particles with an aerodynamic diameter smaller than 2.5 micrometres.

a) Cars and vans



b) Lorries and buses



The evaluation of the Euro 6/VI emission standards identified three main problems, relevant for the cars/vans as well as the lorries/buses segment, and the related problem drivers limiting their effectiveness (see Figure 4). The problems: complexity of vehicle emission standards, obsolete vehicle pollutant limits and insufficient control of vehicle real-world emissions, explain why the current Euro 6/VI emission standards insufficiently contribute to the necessary reduction of pollutant emissions from road transport. This is of particular concern when considering the zero-pollution ambition of the European Green Deal.

Next to the negative impacts on human health and on environment, other consequences of the current Euro standards shortcomings have been identified. Firstly, the emergence of national and local measures aiming at addressing significant pollutant emissions from road transport. City or driving bans of vehicles with internal combustion engine put at risk the functioning of the single market[57] and could result in undermining consumer confidence in the automotive products.[58] Several Member States[59] request an end date for the sales/registration of new petrol and diesel cars or announced national initiatives to

[57] More information on internal market can be found in 6.1.1.3 Single market.
[58] More information on consumer trust can be found in 6.1.3.4 Consumer trust.
[59] Austria, Belgium, Denmark, France, Greece, Ireland, Lithuania, Luxembourg, Malta, Netherlands, Spain, Sweden

ban diesel or all combustion engines or to introduce zero-emission zones[60] in order to limit health impact of air pollution and address climate change concerns. In October 2021, there are already multiple Urban Vehicle Access Restrictions (UVARs) in the EU in place or in planning: 328 Low-Emission Zone (LEZ), 130 emergency pollution schemes, 36 zero-emission zones and 6 urban tolls[61]. There is a risk that uncoordinated action at national or local level could endanger the free movement of persons and goods in the single market.

Secondly, global pressure to reduce transport emissions intensifies as key markets, in particular China and the United States, plan more demanding vehicle emission standards.

China is progressing with an ambitious China 7 emission standards[62]. The China 6b emission standards for cars/vans (applicable in 2023), are already fuel-neutral and 40 to 50% more stringent than Euro 6/VI limits.[63] The emission limits in the US (Tier 3 Bin 30) are already well below the limits for almost all Euro 6 pollutants.[64] The US currently works on proposals for more stringent emission rules to improve the US competitive position on clean and efficient cars and trucks[65,66]. Furthermore, both China and the US have increased durability requirements up to 240 000 km or 15 years. In comparison, the current European requirements reach only 100 000 km or 5 years for the complete vehicle and 160 000 km for the emission control systems. These developments are especially important when considering that in 2019 the US was next to the United Kingdom the leading destination of EU exports of vehicles, with 19% of EU-27 motor vehicles[67] being exported to US (by value). With 12% of EU-27 motor vehicle exports, China is the second most important trade partner for the EU automotive industry (see Figure 13 Annex 4).[68]

Since Brexit, the United Kingdom has become the EU's most important trade partner. In 2018, roughly one fourth of EU-27 exports was destined to the UK.[68] It is assumed that any future mutual agreement will have the ambition to continue the implementation of Euro emission standards in the UK. Switzerland, Japan and South Korea are other main destinations for exports of EU vehicles. In 2019, Switzerland was the destination of 5% of EU motor vehicle exports. Since Switzerland participates in the EU Single Market for motor vehicles, Switzerland also follows the Euro emission standards. Japan, who is the destination of 5% of all EU exports of motor vehicles, employs emission control requirements for vehicles which are close to EU ones. South Korea is the destination of

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[60] Politico, 2021. Nine EU countries demand an end date for petrol and diesel cars; Ministère de la transition écologique (FR), 2020. Développer l'automobile propre et les voitures électriques; EURACTIV, 2021. Denmark to ban petrol and diesel car sales by 2030; BBC, 2019. Ireland to ban new petrol and diesel vehicles from 2030; Reuters, 2018. Spain to propose ban on sale of petrol, diesel cars from 2040

[61] Source: https://urbanaccessregulations.eu/

[62] European Commission – JRC, 2021. Sino-EU Workshop on New Emissions Standards and Regulations for Motor Vehicles

[63] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[64] ICCT, 2019. Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union

[65] The Wall Street Journal, 2021. Biden Administration Moves to Unwind Trump Auto-Emissions Policy

[66] The White House Briefing Room, 2021. Executive Order on Strengthening American Leadership in Clean Cars and Trucks (August 05 2021)

[67] Includes next to cars also commercial vehicles such as vans, lorries and buses. In value, the EU export of cars presented approximately 92% of the EU export of all motor vehicles. For more information, see section 1.4.1. in Annex 4.

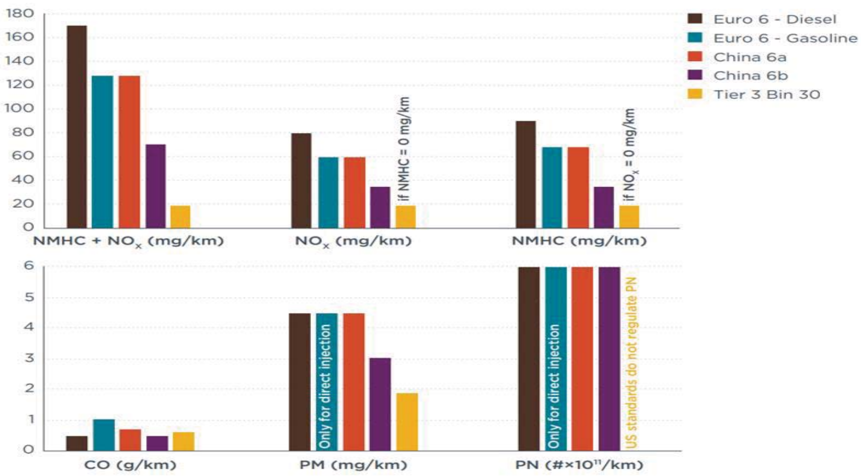
[68] ACEA, 2020. EU passenger car exports, top 10 destinations (by value); ACEA, 2020. EU motor vehicle exports, top 10 destinations (by value)

4% of EU motor vehicle exports and has been following the European rules for diesel vehicle emission standards since 2002 with the Euro 6-level standard entering into force in 2020.[69]

At the same time, the EU automotive industry could maintain its competitive position on the global market of internal combustion technologies that will still play a role in several third markets for which a slower transition to zero-emission cars/vans is expected[70], such as India, South-East Asia, Brazil or South Africa, and in the lorries/buses segment, where internal combustion engines will prevail for longer. By accelerating investments in zero-emission technologies, the EU automotive value chain should not put at risk its know-how on more traditional technologies that will continue to be important for countries with slower transitions.

In conclusion, key markets for EU export of vehicles, US and China, are developing more stringent standards and other main markets are following the Euro standards. Manufacturers can adapt the manufacturing of the vehicles' emission control systems themselves to keep their export market share in key markets that are not supposed to follow the Euro emission standards, i.e. China and US. However, less regulatory entrance costs to these markets are expected with an ambitious Euro emission standards matching global developments. Without action, there is the risk that access to key markets could be hampered for EU manufacturers as it would become more costly to meet emission requirements in different markets.

Figure 3 – Comparison of latest emission limits in the EU, United States (Tier 3 Bin 30) and China for light-duty vehicles, Source: ICCT, 2019*[71]*



The problem analysis shows that there are differences in the problems and need to act between cars/vans and lorries/buses segments (see Box 1).

[69] See Annex 4, section 1.4.1. Competitiveness: Export of EU motor vehicles to key destinations
[70] See Annex 4, section 1.5.4. Cumulative impacts on industry
[71] ICCT, 2019. Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union. Differences in testing procedures not taken into account.

Box 1 – Differences of the problems and need to act between cars/vans and lorries/buses segment

In 2022, electric powertrains are a widely accepted solution for urban and personal mobility with a large number of pure electric vehicle types in the market and the numbers of sales growing fast. However, for the long-haul transport of goods electrification is significantly slower with only a few pure electric models currently available.

Due to the planned phasing out of cars/vans with an internal combustion engine by 2035, and the technology-readiness of electric cars/vans, the emissions of traditional pollutants from cars/vans are expected to decline more steeply than those from lorries/buses (see Figure 2). Therefore, in the future there will be a higher contribution from lorries/buses segment to the problem of pollutant emissions from road transport and therefore a higher need to take measures to reduce pollutant emissions from this sector.

Figure 2 also shows that without action, non-exhaust particles emissions for both cars/vans and lorries/buses will not be reduced, given the lack of emission control technologies in place.

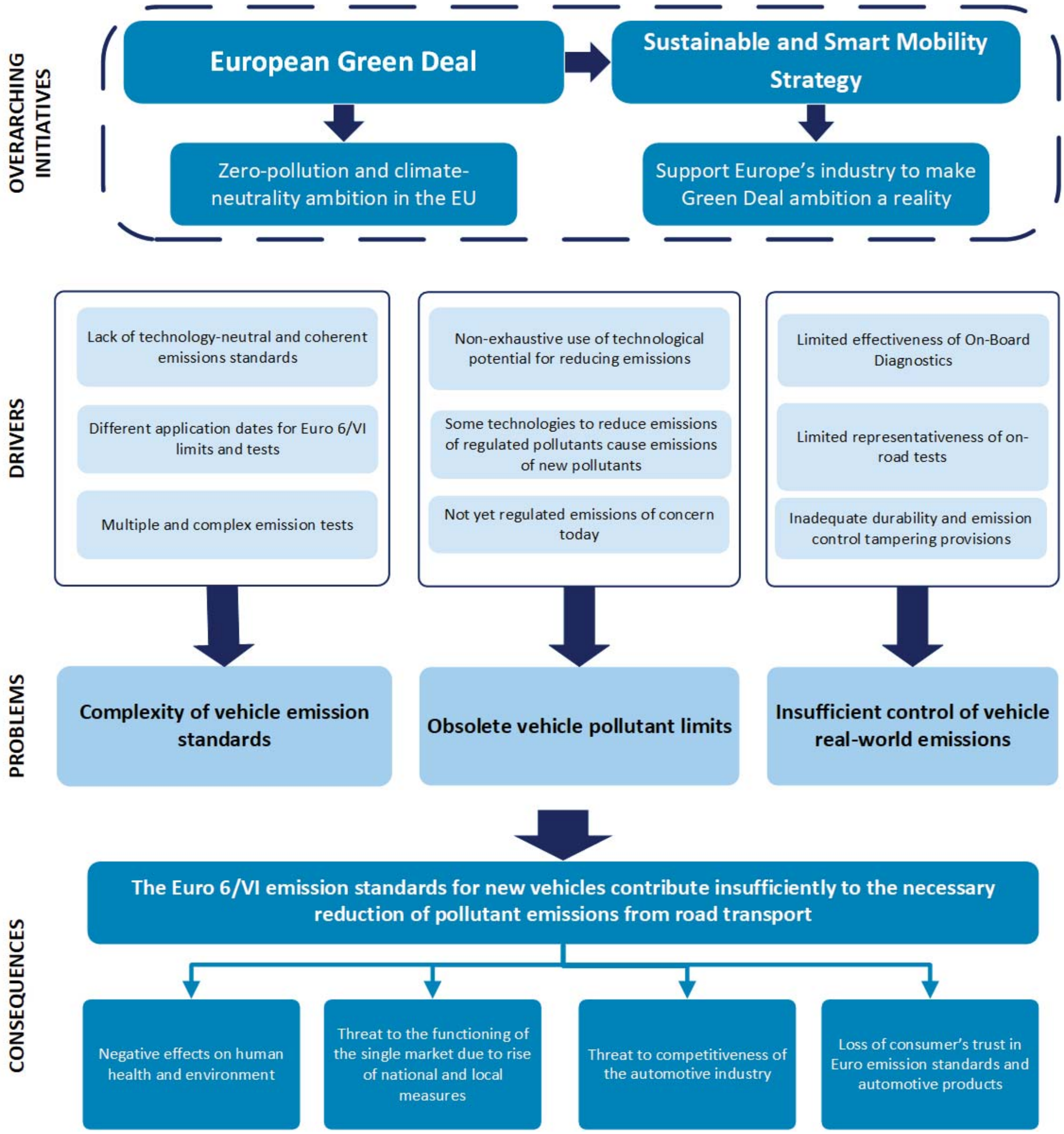
Hence there is need to act in both vehicle segments to improve our health and well-being in line with the Zero-Pollution Action Plan[15]. Moreover, the new EU Urban Mobility Framework from December 2021[72] underlines the overall importance of getting transport drastically less polluting in cities and that the majority of urban vehicle access regulations concern low (and zero) emission zones to address local air quality problems, in particular in the cars/vans segment.

The need to act towards zero-pollution needs to consider the limited time remaining to recoup the necessary investments for internal combustion engines in the cars/vans segment as well as the limited number of heavy-duty vehicles sold each year to recoup the necessary investment costs in the lorries/buses segment. For both vehicle segments, the design of policy options needs to consider options that are achievable with existing technologies and in a timely manner for introduction into vehicles by 2025.

By accelerating investments in going beyond exhaust emissions, as the Euro standards need also cover particles emissions from brakes and tyres and battery durability, the EU automotive value chain can continue to build up its competitive position in the fast growing new market of zero-emission vehicles.

[72] COM(2021) 811 final. The New EU Urban Mobility Framework

Figure 4 – Problem tree



2.1.1 Problem 1: Complexity of vehicle emission standards

The overwhelming majority of the respondents (98 of the 128) to the public consultation[73] from all stakeholder groups consider the Euro 6/VI emission standards to be complex or even very complex, for the cars/vans as well as the lorries/buses segment[74]. While some stakeholders from industry consider this complexity to be justified to ensure that vehicles are clean, the majority of stakeholders from Member

[73] See Annex 2: Stakeholder consultation, Public Consultation, Question 8

[74] Arabic numerals refer to Euro emission standards for cars and vans, Roman numerals refer to Euro emission standards for lorries and buses.

States, civil society and citizens see complexity as a factor hampering the necessary reduction of pollutant emissions from road transport.[75]

While the overall architecture of the Euro emission standards is complicated, the evaluation of the efficiency of the Euro 6/VI rules has shown that in particular shift from Euro 5/V to Euro 6/VI increased such complexity.[76] A full overview of the Euro 6/VI emission standards, including the multiple dates of introduction of different requirements, clearly demonstrates it.[77] Euro 6/VI rules were built on the legislative text of their predecessors, adding new requirements on top of the already existing ones while not always referencing the UN international harmonised testing procedures or eliminating obsolete tests. As a result, the Euro 6/VI implementing Regulations span a total of more than 1.300 pages to define properly laboratory testing and on-road testing procedures for granting type-approval, Conformity of Production and In-Service Conformity.[78]

The evaluation showed that moving from Euro 5/V to Euro 6/VI emission standards has resulted in significant increase of costs during implementation phase for vehicle manufacturers, consisting of testing and witnessing costs[79], type-approval fees[80] and administrative costs[81]. The increase of these costs was mainly caused by more robust on-road tests, however this was not accompanied by the removal of tests that became obsolete. The costs of testing of pollutant emissions and of witnessing those tests by type-approval authorities in the facilities of the manufacturers are estimated to have increased about 50% per engine family[82] for lorries/buses. Also for cars/vans, the manufacturers' effort related to the testing have doubled with the introduction of Euro 6 and quintupled with the introduction of RDE testing. The administrative costs increased up to 50%, due to the additional manufacturers' time and effort needed to meet the obligations to provide information. These costs are expected to stay rather stable over time, until new testing requirements are included.[76]

The complex matrix of Euro 6/VI rules is particularly burdensome for the type-approval authorities and technical services. Both have experienced considerable increase of costs in terms of human resources to perform additional testing and witnessing and in terms of time it takes to complete a type-approval process. [76]

[75] See Annex 2: Stakeholder consultation, Public Consultation, Question 10

[76] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.2 Efficiency, Evaluation question 4

[77] CLOVE, 2022. Technical studies for the development of Euro 7: Simplification. ISBN 978-92-76-56405-8.

[78] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 2.1 Description of Euro 6/VI emission standards and its objectives

[79] Testing and witnessing costs: Recurrent costs for testing in the context of type-approval, in-service conformity and conformity of production performed or witnessed by type-approval authorities in the facilities of the manufacturers.

[80] Type-approval fees: Recurrent costs including the fees for granting type-approval paid to type-approval authorities, excluding the witnessing costs.

[81] Administrative costs: Recurrent costs including costs for reporting and to fulfil other information provision obligations as part of the process for granting type-approval, CoP and ISC.

[82] Manufacturers are allowed to group cars/vans to model families, and lorries/buses, for which engines are tested, to engine families. All members of the family shall comply with the applicable emission limit values.

2.1.2 Problem 2: Obsolete vehicle pollutant limits

The second problem identified in the evaluation of the Euro 6/VI emission standards are obsolete vehicle pollutant limits, for the cars/vans as well as the lorries/buses segment.[83] The limits are of particular concern given that they were adopted over a decade ago (and assessed more than two decades ago). While the testing procedures for cars, vans, lorries/buses have been adjusted over the different steps of Euro 6b-d and Euro VI A-E, the emission limits were set as early as 2007 for cars/vans, and 2009 for lorries/buses.

The evaluation of the Euro 6/VI effectiveness made clear that the emission limits have achieved reductions for regulated NO_x, PM, CO, CH_4, THC and NHMC pollutants (see Table 1). However, these emission reductions would have been much higher if more pollutants than only NOx and PN were measured on the road and if state-of-the-art emission control technologies had been used.[84]

In addition, the evaluation of the Euro 6/VI has made clear that new harmful pollutants are emitted by road transport.[85] The use of new engine types, emission control systems, fuels and additives has led to worrying levels of pollutant emission not regulated by Euro 6/VI that cause significant harm to the environment and human health (ultrafine particles, N_2O, HCHO, non-exhaust brake- and tyre wear emissions and, for cars/vans, CH_4 and NH_3). Table 1 shows that much lower emission reduction for unregulated pollutants compared to regulated pollutants is observed. N_2O emissions even increased by 160% between 2010 and 2018 due to the use of catalysts.[86]

Table 1 – Pollutant emissions from road transport in 2018 compared to 2010, Source: SIBYL 2021[87]

Pollutant	Regulated under Euro 6/VI?	Air pollutant or GHG?	2010	2018	
NO_x	yes	Air pollutant	3 674 kt	3 381 kt	-8%
$PM_{2,5,total}$	no	Air pollutant	174 kt	109 kt	-37%
$PM_{2,5,exhaust}$	yes	Air pollutant	134 kt	67 kt	-50%
PN_{10}	PN_{23}	Air pollutant	$2,1x10^{26}$	$1,0x10^{26}$	-51%
CO	yes	Air pollutant	4 941 kt	3 210 kt	-35%
THC	yes	Air pollutant	795 kt	455 kt	-43%
NMHC	yes	Air pollutant	738 kt	406 kt	-45%
NH_3	HDV only	Air pollutant	75 kt	45 kt	-40%
CH_4	HDV only	GHG & air pollutant	57 kt	50 kt	-12%
N_2O	no	GHG & air pollutant	28 kt	73 kt	+160%

While many technologies to further limit the emissions of regulated or unregulated pollutants have been developed since the adoption of Euro 6/VI and are mostly available on the market, only some high-end manufacturers adopted them proactively. Even more

[83] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 6 Conclusions
[84] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.1 Effectiveness, Evaluation question 1
[85] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.3 Relevance, Evaluation question 6
[86] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7.
[87] SIBYL, 2021: Ready to go vehicle fleet, activity, emissions and energy consumption projections for the EU 28 member states

advanced technologies that allow additional emission reductions are already under development and will become available in the near future. These developments demonstrate a significant untapped past and future potential of road transport emission reductions that could have been achieved and can be achieved if such advanced emission control technologies are used.

2.1.3 Problem 3: Insufficient control of vehicle real-world emissions

It is eye-catching that a majority of stakeholders from all groups consider that real-world emissions are not adequately monitored (72 out of 124) over the lifetime of vehicles, for the cars/vans as well as the lorries/buses segment.[88] More than half of the respondents from Member States and civil society[89] are not convinced that RDE testing ensure that vehicles are compliant with the pollutant limits in "all driving conditions" (while RDE addresses only "normal conditions of use").[88] This is reinforced by the scientific assessment performed during the supporting studies which estimates the distribution of the actual driving mileages in the EU. Approximately 20% of current driving mileages in Europe are estimated to be outside the RDE legal boundaries and therefore may exceed significantly the current emission limits[63]. Driving conditions or trips that are excluded from RDE testing are usually characterized by too low (less than -7°C) or too high ambient temperatures (more than 35°C), too aggressive driving, high altitude, etc. In addition, too short (i.e. less than 15 000 km) or too long car mileage (more than 100 000 km) are also not part of RDE.

In 2017 real-world emissions of NOx were still several times above the allowed Euro 6 limit. Even though the latest Euro 6d step, adopted in the wake of Dieselgate, has endeavoured to close this gap between real-world and type-approved emissions, evidence from the evaluation of Euro 6/VI shows that this step only partially achieved it.[90] Such partial success is at least to a certain extent result of the regulatory choices made at the time of adoption of the first Real Driving Emissions Regulation[91].

Moreover, Euro 6/VI durability requirements are significantly below the actual lifetime of vehicles in the EU. While the average age of cars on EU roads is around 10.8 years, the Euro 6 emission standards take into account a lifetime of only 5 years. Similar discrepancies in the durability requirements are found for vans, lorries/buses (see Annex 5, Table 46). Since in-service conformity of vehicles and durability of their pollution control devices is checked only for the prescribed 5 years, emissions are not properly controlled over the entire lifetime of vehicles.[92]

An additional issue that was identified in the recent proposal of a Battery Regulation[93], relates to the lack of control of the durability of the propulsion batteries in plugin hybrid and battery electric vehicles. This problem may lead to lack of consumer trust in such

[88] See Annex 2: Stakeholder consultation, Public Consultation, Question 14

[89] 7 of the 12 Member State respondents disagreed that RDE testing ensures that cars/vans are compliant with the pollutant limits in all driving conditions (10 of the 18 respondents from civil society), and 6 of the 11 Member State respondents disagreed that that lorries/buses are compliant with the pollutant limits in all driving conditions (8 of the 15 respondents from civil society).

[90] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.1 Effectiveness, Evaluation question 2

[91] In regards the scope of RDE testing boundary conditions and introduction of a conformity factor.

[92] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.3 Relevance, Evaluation question 6

[93] Proposal for a Regulation of the European Parliament and of the Council concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020, COM(2020) 798/3.

new technologies but also higher emissions in the case of plugin hybrids, where deterioration in the battery capacity will result in higher emissions from the internal combustion engine.

2.2 What are the problem drivers?

2.2.1 Drivers behind the complexity of vehicle emission standards

- *Lack of technology-neutral and coherent emissions standards*

The Euro 6/VI emission standards lack technology-neutrality. Different combustion engine technologies, spark-ignition (petrol), compression-ignition (diesel), used in the same vehicle category – cars, vans or heavy-duty vehicles – have to comply with different emission limits. Such differences of limits stringency and implementation dates result from the intention, at the time of their setting, to provide more flexibility for diesel technology. This distinction can no longer be supported.

Such technology preference limited the effectiveness and internal coherence of the standards in reducing pollutants emissions from road transport.[94] While diesel cars are allowed to emit 80 milligrams of $NO_{x/}$km, petrol cars have to comply with a more stringent limit of 60 milligram NO_x/km. Hence, sufficient NO_x emission reduction is not achieved by diesel cars despite availability of appropriate emission control systems. Moreover, the PN limits do not apply to all petrol vehicles as the rules exclude port fuel injection (PFI) vehicles, which have an estimated share of 30% of new petrol vehicle registrations in 2020[95].

89 out of 128 stakeholders from all groups participating in the public consultation confirm that different limits based on fuel and technology are complex – with Member States being relatively more convinced of this than industry.[96]

According to Member States and civil society, separate regulatory frameworks between LDVs, and HDVs, are not coherent and contribute to complexity.[96] While the obligations for emissions testing for LDVs and HDVs set out in the implementing Regulations[97] are relatively different, the architecture of the basic acts of Euro 6 and Euro VI[98] is almost identical. This calls for a single basic act for both vehicle categories.

- *Different application dates of Euro 6/VI limits and tests*

Another driver of complexity for Euro 6/VI emission standards is the gradual phase- in of different steps of Euro 6b-d and of Euro VI A-E, in combination with different application dates for different vehicle categories and, additionally, for new types of vehicles and for all new vehicles. Different emission limits due to different technologies (see above) required different application dates and specific testing procedures, which moreover continued to be improved.

[94] See footnote 84; see Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.4 Coherence, Evaluation question 7
[95] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 2.1 What is/are the problem(s)?
[96] See Annex 2: Stakeholder consultation, Public Consultation, Question 9
[97] Regulation (EU) 2017/1151 and Regulation (EU) No 582/2011
[98] Regulation (EC) No 715/2007 and Regulation (EC) No 595/2009

119 out of 128 respondents to the public consultation from all stakeholder groups indicated that different application dates for Euro 6/VI steps are complex.[96] Industry indicated that it would have been better to define the steps of Euro 6 b-d and Euro VI A-E at the time of Euro 6/VI adoption, instead of continuous addition of the steps, with no sufficient lead-time to industry.[84]

- *Multiple and complex emission tests*

The procedures and, to a lesser extent, the number of emission tests were pointed out by stakeholders from all groups as complex or even very complex features of Euro 6/VI.[99] In the targeted consultation, industry stakeholders pointed to the complexity of the test procedures as resulting in errors in performing of emission tests and calculations. Testing complexity required additional costly capacity-building by manufacturers in order to comply with the legislation. This significantly increased the overall costs during implementation phase (see 2.1.1).[100] Moreover, the evaluation identified various technical inconsistencies in the legislation.[101]

2.2.2 Drivers behind obsolete vehicle pollutant limits

- *Non-exhaustive use of technological potential for reducing emissions*

Technological potential exists for reducing emissions by using best available emission control technology. There are advances in thermal management, engine controls, filters and catalyst technology in petrol and diesel powertrains available on the market that allow vehicles to achieve emission significantly lower than the Euro 6/VI levels.[102] In addition, existing sensor technologies may contribute to the digital transformation and allow keeping emissions under well under control throughout the lifetime of a vehicle.

Therefore obsolete vehicle emission limits for regulated pollutants may be corrected, i.a. by introducing updated emission limits that lead to the use of available technology. In the public consultation, the large majority of respondents (55 out of 67) from Member States, civil society and citizens indicated that current technology offers room for additional emissions reductions. Industry had different views on the matter[103].[104]

- *Some technologies to reduce emissions of regulated pollutants cause emissions of new pollutants*

Reduction of a given pollutant may result in higher emissions of another unregulated pollutant. This is for example the case for NH_3 emissions resulting from cars/vans. The emission control technologies that are necessary to comply with NO_x emission limits may cause a so-called ammonia slip due to excess dosing of urea.[64] To tackle such collateral emissions, additional technologies are already used on a voluntary basis.

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[99] See Annex 2: Stakeholder consultation, 2.2.1. Evaluation Euro 6/VI emission standards

[100] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.3.1 Costs for vehicle manufacturers

[101] Such inconsistencies include differences in the provisions for type-approval and In-Service Conformity for specific vehicles or obsolete smoke opacity tests. (See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.4 Coherence, Evaluation question 7)

[102] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[103] 19 of the 59 industry respondents agreed that the current emission control technology creates room for additional reductions in emissions, while 20 disagreed to the statement and 20 neither agreed nor disagreed.

[104] See Annex 2: Stakeholder consultation, Public Consultation, Question 12

- *Not yet regulated emissions of concern today*

The introduction of new technologies in the vehicle fleet over the last decade, such as gas-fuelled heavy-duty vehicles that are expected to reach 5% market share by 2025[95], emit new pollutants. They are currently not covered by Euro 6/VI standards, although they are of concern, as confirmed in the evaluation of Euro 6/VI and the public consultation by all stakeholders[105][106].

The current PN limits take into account particles larger than approximately 23 nm. As research shows, particles smaller than 23 nm, may have detrimental health effects as they can enter the bloodstream, thus reaching all organs. However, they are not yet covered in Euro 6/VI[107].

CH_4 emissions are up till now only regulated for lorries/buses. Natural gas lorries are expected to play a role in decarbonisation agenda, especially if blended with bio-methane or if full bio-methane is used. As CH_4 fuel use is projected to increase (e.g. new registrations of CNG cars[108]), limiting this greenhouse gas and ozone precursor also for cars/vans becomes important.

Brake and tyre emissions have become increasingly relevant sources of particles, especially since the exhaust particles were drastically diminished with the use of particle filters. This is due mainly to the number of vehicles on the road and km travelled leading to an increase of road transport activity from 3 200 Gvkm in 2010 to 3 500 Gvkm in 2018 (see Figure 6 in section 5.1) but also due to the increasing share of heavier and fast-accelerating vehicles such as SUVs and electric vehicles, although the later somewhat reduce such emissions by regenerative braking. In 2018, PM_{10} emissions from tyre and brake wear were equivalent to the PM_{10} levels of emissions that originate from the tailpipe of light- and heavy-duty vehicles[6]. According to the existing literature, it is expected that the non-exhaust contribution to vehicle-related PM_{10} emissions will reach 90% of total PM_{10} emissions in 2040 (see Figure 2). This is mainly due to the drop of exhaust emissions and the fact that brake- and tyre-wear is emitted by all types of vehicles, including zero-emission vehicles. In particular brake wear is recognized as the leading source of non-exhaust particles, harmful to human health due to its smaller size and composition and is emitted also by zero CO_2 emission vehicles. A method for measuring brake wear emissions is under validation in the Particle Measurement Programme of the UNECE[109].

2.2.3 Drivers behind insufficient control of vehicle real-world emissions

- *Limited effectiveness of On-Board Diagnostics*

On-Board Diagnostics (OBD) monitor the functioning of powertrain systems and emission control technologies, in order to identify possible areas of malfunction during the life of the vehicle and inform the user of the need to carry out vehicle maintenance.

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[105] See Annex 2: Stakeholder consultation, Public Consultation, Question 12.2

[106] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.4 Do the standards properly cover all relevant/important types of pollutant emissions from vehicles that pose a concern to air quality and human health? Are there important types of pollutant emissions that are not covered?

[107] Giechaskiel, B. & Martini, G., 2014. Review on engine exhaust sub-23 nm solid particles

[108] European Alternative Fuels Observatory, 2020. Vehicles and fleet

[109] UNECE, 2021. UNECE to develop global methodology to measure particle emissions from vehicles' braking systems

The OBD is verified during In-Service Conformity (ISC) checks, Periodic Technical Inspections (PTI) – which take place at fixed intervals – and Roadside Inspections (RSI) – for which commercial vehicles are selected on the road.[33]

However, 78 of the 120 respondents to the public consultation from all stakeholder groups indicated that the limited effect of OBD measurement at least somewhat contributes to maintaining high levels of pollutant emissions[110]. In addition, 17 out of 28 respondents from Member States and environmental NGOs to the public consultation indicated that OBD does not ensure that new vehicles are compliant with the pollutants limits over their entire lifetime, while industry respondents are generally less sceptical on the functionality of OBD[111].[88] Evidence provided to the Euro 6/VI evaluation study by four key stakeholders – one from industry, one type-approval authority, one research institution and one environmental NGO – and the relevant JRC report revealed that the current OBD systems have only limited capacity to address durability and are ineffective in detecting and diagnosing degradation, failure or tampering of pollution-control devices.[112],[113] In addition, today's developments in the field of continuous emission monitoring allow for more comprehensive monitoring which is so far not properly reflected in the Euro 6/VI durability requirements.[114]

This shows that despite the enhancement of the OBD thresholds in Euro 6/VI, the current OBD requirements do not allow for proper checks of emissions during the lifetime of vehicles or emission testing during ISC, PTI and RSI. [101]

- *Limited representativeness of on-road tests*

Another driver of insufficient control of vehicle real-world emissions is the limited representativeness of the on-road tests. The shift towards RDE and PEMS testing in Euro 6/VI emission standards introduced a wide range of load, speed, temperature and altitude conditions to make sure that the emission limits are respected under a broad range of real-world driving conditions. However, not all driving conditions are covered by RDE and PEMS testing. Emissions tend to be higher outside the coverage of RDE and PEMS and important emissions remain therefore unaccounted for in the current testing[115]. NO_x emissions, for example, were found to increase by 1.6 to 1.7 times in low ambient temperatures.[116],[102]

- *Inadequate durability and emission control tampering provisions*

A final driver for insufficient control of vehicle real-world emissions is the risk of ageing, lacking maintenance and tampering[117] of vehicles and their emission control

[110] See Annex 2: Public Consultation, Question 15

[111] 40 of 58 industry stakeholders that answered the question agreed that OBD ensures that new vehicles are compliant with the pollutant limits over their entire lifetime.

[112] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.4.2.1.3 Vehicle roadworthiness legislation

[113] JRC 2021 Technical Report: "Vehicles Odometer and Emission Control Systems - Digital Tampering and Countermeasures", Jose Luis Hernandez Ramos (JRC), L. Sportiello (JRC).

[114] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.3 Relevance, Evaluation question 6

[115] This is the case for short trips, idle times, low speed, strong acceleration, high loads, high altitude circuits and severe temperature conditions in which emissions are usually considerably higher.

[116] As another example, low speed driving, which is not covered in the current RDE tests, has been linked to high pollutant emissions (See Annex 5: Evaluation Euro 6/VI emission standards, Figure 22 – Emission performance of Euro 6d vehicles for NO_x for different average speeds, based on CLOVE, 2022)

[117] Regulation (EC) No 595/2009 defines tampering as "inactivation, adjustment or modification of the

technologies. The evaluation of Euro 6/VI emission standards emphasised that the current durability requirements cover only the first half of the vehicle life (see 2.1.3). Considering this and the increasing complexity of pollution-control devices, there is a need for a more complete demonstration of durability in order to provide effective emission control over the lifetime. [84]

The replies from stakeholders from all groups to the public consultation have proven that tampering (117 of the 124 replies), vehicle ageing (114 of the 127 replies) and the cost of vehicle maintenance (101 of the 123 replies) have contributed to an increase in real-world pollutant emissions. These results indicate that Euro 6/VI rules are not effective to prevent tampering and to control effectively emissions throughout the vehicle lifetime.[110]

2.3 How will the problem evolve?

When considering the negative effects of air pollutant emissions from vehicles on human health and environment, improvements are expected over time in the absence of new action, for the cars/vans as well as the lorries/buses segment (see Figure 2 in section 2.1).

Fleet renewal will lead to an increased share of Euro 6/VI vehicles in the vehicle mix. As only 20% of cars/vans, and 34% of lorries/buses in the fleet are of Euro 6/VI standards in 2020, including RDE testing, the benefits of cleaner Euro 6/VI vehicles compared to previous Euro vehicles will continue to be felt in the coming years on EU road as older vehicles are replaced by these new cleaner Euro 6/VI vehicles.[84]

In addition, significant positive effects on air quality can be expected from the adoption of the package of proposals to make EU's climate policies fit for reducing net greenhouse gas emissions by at least 55% by 2030 ('fit-for-55 package') in July 2021[118]. The proposed amendment of the CO_2 emission performance standards for new cars and vans sets an end-date of 2035 for placing new combustion-engine cars and vans in the EU market[12]. Additional effects from the planned revision of Ambient Air Quality Directive in 2022, which are estimated to be limited compared to the effects of CO_2 emission standards, cannot be taken into account yet, but as explained earlier compliance with air quality standards cannot be achieved without more stringent emission limits for motor vehicles. See details in section 5.1.

At the same time, Figure 2 shows that there is need to act towards zero-pollution in the cars/vans as well as the lorries/buses segment to improve our health and well-being in line with the Zero-Pollution Action Plan and in particular in cities. See details in Box 1 in section 2.1.

3 WHY SHOULD THE EU ACT?

3.1 Legal basis

The Euro emission standards are based on Article 114 of the Treaty of the Functioning of the European Union. According to this Article, the European Parliament and the Council shall adopt measures which have as their object the establishment and functioning of the

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vehicle emissions control or propulsion system, including any software or other logical control elements of those systems, that has the effect, whether intended or not, of worsening the emissions performance of the vehicle"

[118] Press release 14 July 2021. European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions

single market. Furthermore, the Euro emission standards have the objective to ensure a high level of environmental and health protection.

3.2 Subsidiarity: necessity and added value of EU action

The evaluation of Euro 6/VI emission standards emphasized the necessity and added value of EU action in this policy domain by illustrating that both action at national or international level are unlikely to lead to optimal outcomes[119] since both air pollution and road transport have a transboundary nature. Secondly, the development and governance of emission standards at EU level is key to ensure properly functioning single market. Differences in air quality policy ambitions among Member States could easily lead to a patchwork of different national measures (e.g. to measures limiting access to certain areas) that would create considerable obstacles for industry and pose great risk to the single market. Hence, continued harmonised EU action to further reduce vehicle emission is fully justified. In conclusion, the objectives of the proposed action cannot be achieved sufficiently by the Member States acting alone and can be better achieved at Union level by reason of scale or effects of that action.

4 OBJECTIVES: WHAT IS TO BE ACHIEVED?

4.1 General objectives

The general objective of the initiative is twofold: (1) to ensure the proper functioning of the single market by setting more adequate, cost-effective and future-proof rules for vehicle emissions; and (2) to ensure a high level of environmental and health protection in the EU by further reducing air pollutants emission from road transport towards zero-pollution, as required by the Zero Pollution Action Plan, as rapidly as possible.

4.2 Specific objectives

This initiative will contribute to achieving the general objective by pursuing the following three specific objectives in line with the identified problems, relevant for the cars/vans as well as the lorries/buses segment (see chapter 2). It will:

1) *Reduce complexity of the current Euro emission standards.* This specific objective directly addresses the defined problem of complexity in the standards. Tackling complexities would allow for reduced administrative costs and costs during implementation phase and would facilitate efficient implementation of the Euro standards.

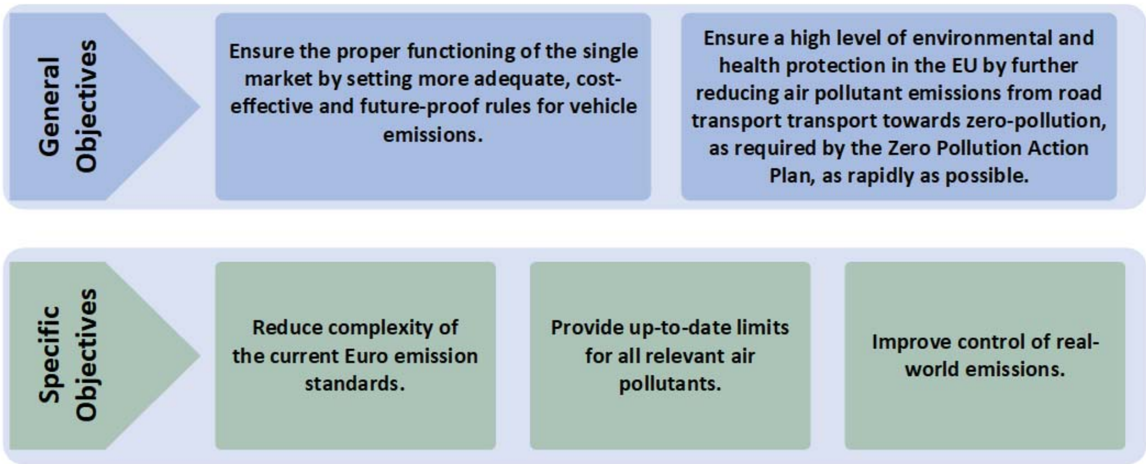
2) *Provide up-to-date limits for all relevant air pollutants*. This specific objective addresses the problem of obsolete vehicle pollutant limits in the Euro 6/VI emission legislation which prevent further reduction of air pollutants emission from road transport. Up-to-date limits based on best available technology and today's knowledge on emission controls will allow to curb harmful emissions. That way, the functioning of the single market could be ensured, together with high level environmental and health protection in the EU.

3) *Improve control of real-world emissions.* This specific objective is a direct response to the problem of current RDE boundaries that do not cover all conditions of use

[119] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 5.5 EU-added value

throughout the lifetime of the vehicle which prevent further reduction of air pollutants emission from road transport. Achieving this objective would reduce vehicle emissions in a more systematic manner and improve environmental and health protection in the EU. It could also help guarantee the functioning of the single market by addressing challenges associated with urban vehicle access restrictions.

Figure 5 – Euro 7 objectives



5 WHAT ARE THE AVAILABLE POLICY OPTIONS?

5.1 What is the baseline from which options are assessed?

The baseline to assess impacts of the policy options takes the following into account: a) the Euro 6/VI emission standards, b) the impact of COVID-19 on road transport activity[120] and c) the impact of the new 55% (cars) and 50% (vans) CO_2 targets by 2030 and 100% CO_2 targets for cars and vans by 2035[121] and the projected fit-for-55 HDV fleet evolution to contribute to the 55% net greenhouse gas emission reduction by 2030 and the 2050 climate neutrality objective[122] .

The baseline cannot take into account the effect of future potentially more stringent air quality targets which may lead to more cities banning combustion-engine vehicles and therefore modify road transport activity or vehicle sales, in the absence of more stringent emission standards for motor vehicles. Such possible effect of future air quality targets would be difficult to quantify since it will depend on local actions taken at Member States level and will not be uniformly applied throughout the EU. However, this additional effect from the planned revision of Ambient Air Quality Directive in 2022 is estimated limited compared to the effects of CO_2 emission standards.

[120] Road transport activity is the volume-km driven by vehicles on EU roads and is projected by the estimated evolution of vehicle sales.
[121] A linear interpolation was used for the year 2030 for both the activity and shares of vehicles between the two existing scenarios in the CO_2 Impact Assessment (TL_Med and TL_High), while the TL_High scenario was used for the year 2035. This approach is the estimated representation of the impact of the Commission proposal for CO_2 targets for cars/vans.
[122] For heavy–duty vehicles, the activity and fleet shares of vehicles are based on the SWD(2020) 176 final, Impact Assessment on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people (part 1) and SWD(2020) 176 final (part 2), supplemented for buses by CLOVE, 2022.

The baseline is a "no policy change" scenario which implies that the relevant EU-level legislation, addressing air pollutant emissions resulting from road transport will continue to apply without change. That means that Euro 6/VI applies, taking into account impact of the CO_2 targets for vehicles, including the aforementioned new CO_2 targets for cars/vans, and COVID-19 on road transport activity. It is referred to in chapter 6 as the baseline.

a) Euro 6/VI emission standards

The Euro 6/VI emissions standards[19] and in particular the air pollutant emission limits and real-driving testing conditions set out therein are summarised in Annex 5, Table 34 and Table 35. They are assumed to remain in force. Moreover, as shown in Annex 5, Figure 19, the baseline assumes that fleet renewal would lead to a higher share of Euro 6/VI vehicles in the vehicles mix, mostly with cars/vans introduced under Euro 6 d step. The benefits of cleaner Euro 6/VI vehicles compared to previous Euro norms will increase in the next years as older vehicles are replaced with clean ones.[84]

b) Impact of COVID-19 on road transport activity

The COVID-19 pandemic continues to have significant impacts on the automotive sector, which will shape the sector for years to come. First, various lockdown measures had significant impact on sales. Following the 6,1% decrease of the EU GDP in 2020[123], demand for new passenger and light commercial vehicles dropped by respectively 23.7% (to 9.9 million units) and 18.9% (to 1.7 million units) in 2020 as a direct result of the pandemic.[124] The full long-term effects on the industry will only become clear after the pandemic has come to an end and will largely depend on the pace of the economic recovery[125]. Over the first half of 2021, passenger car sales increased by 25.2% to almost reach 5.4 million units registered in total. However, this is still 1.5 million units below the 2019 pre-crisis level for the same period.[126] In addition, industry is facing shortages of semi-conductors. This shortage limits the capacity of industry to satisfy demand which is already at historically low levels. Demand is only expected to return to the pre-pandemic levels by 2023.[127] This may affect the capacity of the industry to invest in new technologies. See Annex 7 for more details on the impact of COVID-19 on automotive industry.

The baseline takes into account the indirect impact of the COVID-19 pandemic on vehicle emissions, mostly through its effect on transport activity and fuel consumption. Estimations from the impact assessment on the 2030 climate target plan[128] indicate that the projected decrease of total fuel consumption of road transport was about 17% in 2020 compared to 2019. In addition, the JRC estimated that between February and April 2020 a total drop in vehicle activity of 60-90% for passenger cars compared to a 15% drop for freight transport.[129]

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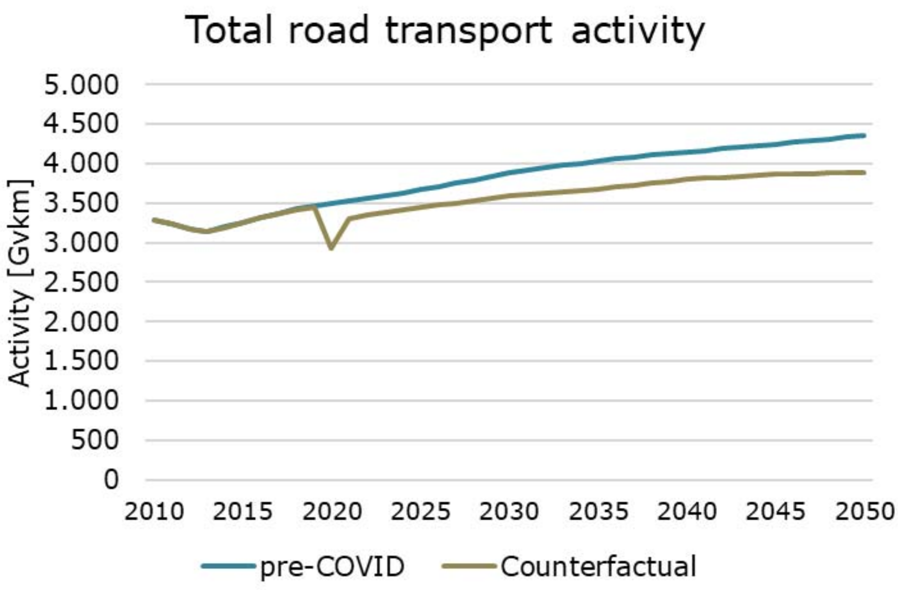
[123] Eurostat, 2021. Real GDP growth rate - volume
[124] ACEA, 2021. Press release: Passenger car registrations: -23.7% in 2020; -3.3% in December 2020; ACEA, 2021. Press release: Commercial vehicle registrations: -18.9% in 2020; -4.2% in December 2020
[125] European Commission, 2021. Spring 2021 Economic Forecast: Rolling up sleves
[126] ACEA, 2021. Passenger car registrations: +25.2% first half of 2021; +10.4% in June
[127] BCG, 2020. COVID-19's Impact on the Automotive Industry
[128] SWD(2020) 176 final, Impact Assessment on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people (part 1) and SWD(2020) 176 final (part 2)
[129] JRC, 2020. Future of Transport: Update on the economic impacts of COVID-19

Based on this evidence and taking into account the impacts of COVID-19 on GDP, the impact of the pandemic on road transport activity in various vehicle segments has been estimated. The short-term estimates point to a sharp activity drop of 15% in 2020, followed by significant recovery in 2021. Nevertheless, by 2030 the pandemic and following crisis are projected to result to a permanent loss in total road transport activity of 6% compared to the pre-COVID levels. Figure 6 presents the projected evolution of transport activity taking into account the COVID-19 drop as counterfactual. In addition, reduced private transport activity is assumed due to promotion of public means of transport and advancing modal shifts to other than road transport means, especially when it comes to passenger transport.[128] The total activity for passenger transport in 2050 is projected to 6.4% lower, whereas the activity levels for freight transport are not assumed to differ. The counterfactual evolution of road transport activity is taken into account in the baseline.

Figure 6 – Evolution of total road transport activity in EU-27 considered in the baseline (in volume-km)[130]



c) CO_2 emission performance standards

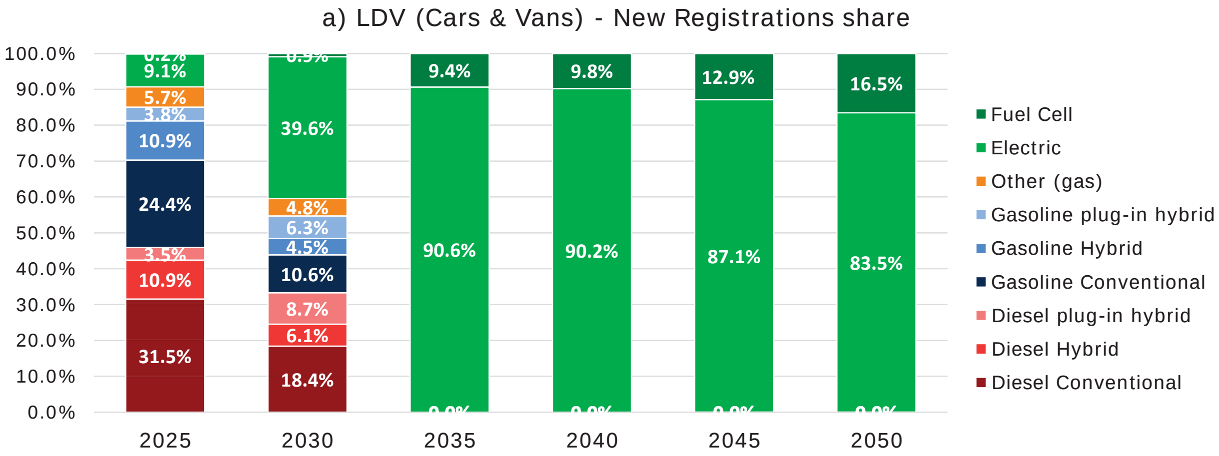
The CO_2 targets for vehicles laid down in the CO_2 Regulation, including the new CO_2 targets for cars/vans proposed in July 2021[12], also contribute to reduction of air pollutant emission from road transport. This is due to the increased sales of zero- and low-emission vehicles that are triggered by stringent CO_2 targets for light- and heavy-duty vehicles, scaling up towards an end-date of 2035 for placing new combustion-engine cars and vans in the EU market. Electric and fuel cells powered vehicles do not have tailpipe emissions but do emit particles from brakes and tyres. Low-emission vehicles, such as plugin hybrids, also have less tailpipe air pollutant emissions. The CO_2 targets, including the new CO_2 targets proposed for cars/vans and the projections for heavy-duty vehicles, and their impact on the vehicle fleet, are included in the Euro 7 baseline.

[130] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 4.2 The impact of COVID-19 on the baseline development.

As can be seen in Figure 7, the share of new zero- and low-emission vehicles in the European vehicle fleet is projected to increase substantially over time, for LDVs much faster than for HDVs. The share of new zero-emission cars/vans is expected to increase from 9% in 2025 to 100% in 2035, whereas the share of hybrid and low-emission vehicles is expected to decrease from 35% in 2025 to 0% in 2035. The share of ICE cars/vans is expected to decrease from 56% in 2025 to 0% in 2035.

The projected vehicle fleet evolution is different for HDVs[131]. In particular long-haul lorries are not projected to shift swiftly to zero- and low-emission performance due to their need for high powered engines and long trips, while the electrification of buses is expected to happen faster due to their predominant use in urban areas. The share of ICE HDVs is expected to decrease from 70% in 2025 to 6% in 2050, whereas share of hybrid and other low-emission lorries is expected to increase from 26% in 2025 to 33% in 2050. New zero-emission lorries are expected to constitute 61% of the total in 2050.

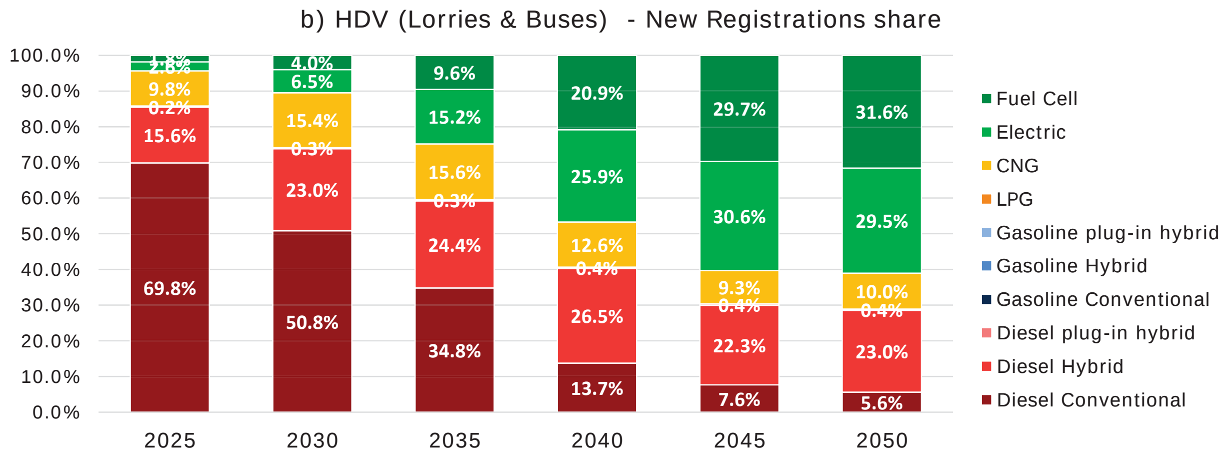
Figure 7 – Projected powertrain changes in the vehicle fleet in EU-27 of new registration of (a) cars/vans, (b) lorries and (c) buses in the baseline until 2050[132],[133]



[131] The projected vehicle fleet evolution is consistent with the overall 55% net greenhouse gas emission reduction by 2030 to achieve the 2050 climate neutrality objective.

[132] A linear interpolation was used for the year 2030 for both the activity and shares of vehicles between the two existing scenarios in the CO_2 Impact Assessment (TL_Med and TL_High), while the TL_High scenario was used for the year 2035. This approach is the estimated representation of the impact of the Commission proposal for CO_2 targets for cars/vans.

[133] For heavy–duty vehicles, the activity and fleet shares of vehicles are based on the SWD(2020) 176 final, Impact Assessment on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people (part 1) and SWD(2020) 176 final (part 2), supplemented for buses by CLOVE, 2022.



The contribution of a) Euro 6/VI vehicles, b) road transport activity and c) CO_2-related powertrain changes in the fleet to the evolution of NO_x and $PM_{2.5}$ emissions are shown in Figure 2 in section 2.1. The NO_x emissions are expected to decrease by 87% between 2015 and 2050. Exhaust $PM_{2.5}$ coming from combustion-engine vehicles decrease steadily over the next 30 years, while total $PM_{2.5}$, include tyre- and brake emissions come from all types of vehicles and therefore remain significant.

5.2 Description of the policy options

Table 2 gives a schematic overview of the policy options developed for this impact assessment, while a detailed description of the policy options is available in Annex 6.

In light of creating an adequate, cost-effective and future-proof Euro 7 regulation ensuring a high level of environmental and health protection in the EU, the policy options consider the green and digital transformation required by the European Green Deal. The transformation provides opportunities for more advanced solutions in terms of pollutant emission reductions, such as the use of low emission technology and continuous emission monitoring with advanced sensors and vehicle connectivity. The policy options take also into account the shift to electrified powertrains requiring cost-effective and adequate solutions for reducing pollutant emissions in the combustion-engine segment. All options are relevant for the cars/vans as well as the lorries/buses segment, whereas the impacts of the policy options are calculated separately for each segment in chapter 6.

All options presented in the tables require implementing legislation, with adequate lead time for the industry. Elements such as measurement methodologies, procedures and equipment, accuracy and repeatability of measurements, selection of vehicles and statistical procedures will be part of the implementing legislation. Most of these elements are either already available or under development both in the EU and in UNECE framework. The work for the implementing legislation will start in 2022.

Table 2 - Description of the policy options

	Baseline	**PO1 – Low Green Ambition**	**PO2a – Medium Green Ambition**	**PO2b – High Green Ambition**	**PO3a – PO2a and Medium Digital Ambition[1]**
Simplification	-	Simplification measures	Simplification measures	Simplification measures	Simplification measures
Emission limits	Euro 6/VI	Euro 6/VI but technology-neutral (60	Medium Ambition (30 mg/km	High Ambition (20 mg/km NO_X,..)	Medium Ambition (30 mg/km

		mg/km NO_X,..)	NO_X,..)		NO_X,..)
Real-driving boundaries	Euro 6/VI	Low ambition of boundaries (low/high temperature…)	Medium ambition of boundaries (+short trips…)	High ambition of boundaries (+high speed, high altitude…)	Medium ambition of boundaries (+short trips….)
Durability	Euro 6/VI	Euro 6/VI (160 000 km or 8 years)	Average Increase (200 000 km or 10 years[2])	Full Increase (240 000 km or 15 years[3])	Average Increase (200 000 km or 10 years[2])
Continuous Emission Monitoring	-	-	-	-	With available sensors

[1] A second sub-option in policy option 3 (i.e. PO3b – PO2a and High Digital Ambition) which added to PO2a high ambitious continuous emission monitoring, i.e. the development of new sensors that would require several years before they can be implemented, was discarded following the proposed end-date of combustion engine cars/vans by 2035 (see 5.3).
[2] For lorries < 16t, buses < 7.5t: 375 000 km and for lorries > 16t, buses > 7.5t: 875 000 km
[3] For lorries < 16t, buses < 7.5t: 450 000 km and for lorries > 16t, buses > 7.5t: 1 050 000 km

In line with the specific objectives, all options aim at reducing complexity of the current Euro emission standards by introducing simplification measures. Up-to-date emission limits for all relevant air pollutants should be provided in PO1 with low ambition, in PO2a and PO3a with medium ambition and in PO2b with high ambition. Control of real-world emissions should be improved in PO1 by low ambitious real-driving testing boundaries, in PO2a by medium ambitious real-driving testing boundaries and durability requirements, in PO2b by high ambitious real-driving testing boundaries and durability requirements and in PO3a by medium ambitious real-driving testing boundaries, durability requirements and continuous emission monitoring. That means, the completely new digital ambition of continuous emission monitoring to control real-world emissions is considered in PO3 only.

As the policy options are built on existing emission control and sensor technology, it is possible to introduce an application date of 1 January 2025 for all new registrations. As adequate lead time is needed for the industry to implement new rules, all secondary rules need to be finalised soon after entry into force of the Regulation.

The possibility for Member States to apply financial incentives at national level for early implementation of Euro 7 (i.e. between its entry into force date and its application date, i.e. the date by which all vehicles entering the market need to be Euro 7) are assumed in the policy options.

The modular approach of the policy options was proposed in the inception impact assessment and confirmed in the stakeholder consultations.

The simplification measures, emission limits, real driving boundaries, durability and sensor requirements have been elaborated in the supporting studies[63,77,134] and discussed with stakeholders in the AGVES meetings.

[134] CLOVE, 2022. Technical studies for the development of Euro 7: Durability of light-duty vehicle emissions. ISBN 978-92-76-56405-8

5.2.1 Policy option 1 (PO1): Low Green Ambition

PO1 implies a narrow revision of Euro 6/VI emissions standards to tackle complexity of the legislation (problem 1) somewhat addressing obsolete vehicle pollutant limits (problem 2) and insufficient control of vehicle real-world emissions (problem 3) with a low green ambition. This policy option was developed as a less intrusive approach.[135]

PO1 addresses key simplification and consistency challenges through refining the architecture of the Euro 6/VI emission standards. It assumes that a single framework for cars, vans, lorries/buses is developed, multiple application dates of Euro 6/VI steps are avoided and the multitude and complexity of emissions tests is reduced. To ensure technology-neutrality, this option foresees making the Euro 6/VI emissions limits consistent across different ICE technologies (see Annex 6, Table 48). This improves only marginally emission from diesel cars and vans, but all other emission remain the same, so especially for lorries/buses there is no significant change. NH_3 limit is extended for cars and vans for the same reason it was already introduced for lorries and buses in Euro VI, i.e. to control ammonia slip from the current generation of catalysts.

The measures aiming at refining and simplifying Euro 6/VI emissions testing (see Annex 6, Table 47) remove obsolete testing and other obsolete provisions. PO1 allows testing of vehicles beyond the Euro 6d RDE and Euro VI E PEMS conditions (see Annex 6, Table 49). Both actions address the problem of insufficient control of vehicles' real-driving emissions with a low ambition. PO1 explicitly refrains from digital control of vehicles' real-driving emissions, i.e. continuous emission monitoring that would be a completely new element in the Euro standards and worldwide.

In light of creating a future-proof regulation, low-ambitious PO1 refrain from a green and digital transformation in view of the shift to electrified powertrains.

5.2.2 Policy option 2 (PO2a and PO2b): Medium and High Green Ambition

PO2 implies a wider revision of Euro 6/VI emissions standards in order to tackle the complexity of the legislation (problem 1), to address obsolete vehicle pollutant limits (problem 2) and to partly address insufficient control of vehicle real-driving emissions (problem 3). While a PO2a will tackle the last two problems with a medium green ambition level, PO2b will address them with a high green ambition level.

PO2 builds on the same simplification measures as PO1. In addition, two ambition levels (medium and high ambition) of pollutant emission limits and boundary conditions are considered, to ensure up-to-date limits for all relevant air pollutants including some unregulated ones (see Annex 6, Table 50 and Table 51). The new pollutants added are HCHO, N_2O, and particles from brakes[136]. HCHO, CH_4 and N_2O emission limits are set at the level of today's emissions (i.e. a simple cap on emissions) to ensure that these emissions do not disproportionately increase in future vehicles or with new fuels.

[135] See Annex 2 Stakeholder consultation, Section 2.2 Analysis of responses

[136] Next to brake emissions, tyre emissions are found to be a source of non-exhaust emissions as they contribute to the formation of particles. As it is not yet technologically feasible to develop limits or tests for tyre emissions, they cannot be assessed in this impact assessment and it is suggested to include a review clause in Euro 7 proposal.

In addition, PO2 will cover comprehensive real-driving testing conditions with medium or high ambition, to account for broader conditions than Euro 6d/VI E emission tests, e.g. low ambient temperatures or low speed driving (see Annex 6, Table 52 and 53).

PO2 also considers the need to address inadequate durability provisions. PO2 extends the requirements to comply with the emission limits for vehicles in use, i.e. the durability provisions, over the current inadequate period in Euro 6/VI. While PO2a introduces a medium ambition of durability provisions, e.g. 200 000 km for LDV; PO2b considers a high ambition, e.g. 240 000 km for LDV (see Annex 6, Table 54). Durability requirements will also cover propulsion batteries in PHEVs and BEVs, according to the developments at international level[137].

In light of creating a future-proof regulation, PO2a considers a medium-ambitious and PO2b a high-ambitious green transformation towards zero-emission vehicles. Both sub-options refrain from a digital transformation, i.e. continuous emission monitoring that would be a new element in the Euro standards and world-wide.

In the stakeholder consultations, automotive industry and civil society representatives raised concerns, often having conflicting opinions, regarding the level of emission limits, length of durability requirements and the technological potential for reducing emissions over the lifetime of the vehicles. In addition to the different emission limits and durability in the policy options for low, medium and high green ambition (see Table 2), an alternative set of assumptions on emission limits and durability was therefore assessed to address remaining uncertainty in the medium green ambition (see Annex 8).

5.2.3 Policy option 3 (PO3a): PO2a and Medium Digital Ambition

PO3 implies a profound revision of Euro 6/VI emission standards to tackle complexity of the legislation (problem 1), to address obsolete vehicle pollutant limits (problem 2) and to address insufficient control of vehicle real-driving emissions (problem 3) with a medium green and digital ambition.

PO3 builds on the same simplification measures as PO1, on the medium ambitious air pollutant emission limits, real-driving testing conditions and durability provisions of PO2a given that the high ambitious emission limits of PO2b cannot be reliably measured with either current or future sensor technology as was elaborated in the supporting technical studies (see Annex 6, Table 50, 52 and 54).

In addition, new continuous emission monitoring of pollutants over the whole lifetime of the vehicle is added in PO3. PO3a on Medium Digital Ambition is based on improved versions of available sensor technologies for NO_x, NH_3 and partly PM (see Annex 6, Table 55). Synergies with the on-board fuel consumption meters (OBFCM) introduced under the CO_2 emission performance standards[138] will be exploited. PO3 would also

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[137] UNECE, 2021. UN GTR No 22 on In-Vehicle Battery Durability for Electrified Vehicles in https://unece.org/transport/documents/2022/04/standards/un-gtr-no22-vehicle-battery-durability-electrified-vehicles

[138] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles and Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles both require in Article 12 that the Commission shall regularly collect data on the real-world CO_2 emissions and fuel or energy consumption of passenger cars, light commercial vehicles and heavy-duty vehicles using on-board fuel and/or energy consumption monitoring devices.

facilitate the implementation of geo-fencing that puts a vehicle automatically into zero-emission mode when entering zero-emission zones.

New continuous emission monitoring is only part of PO3 because it adds a completely new digital dimension to the Euro standards making PO3 overall the most profound policy option. Such an approach has not been introduced up to now in any other emission regulation world-wide. While this new measure was highly praised by stakeholders from some Member States, component suppliers, civil society and citizens during the consultation activities, vehicle manufacturers took a more sceptical position on the matter.[139] Taking the above into account, it was decided to not add new continuous emission monitoring in PO1 to allow the assessment of lower ambition and less intrusive policy option.

In light of creating a future-proof regulation, PO3a considers a medium-ambitious green and digital transformation. Available pollutant sensors and the rise of connected vehicles provide the opportunity for increased enforcement, by continuously monitoring the state of the emission control systems. High emitting vehicles will thus be fixed earlier, or tampering[117] of vehicles will be avoided. Additional cost gains, which are not included in this impact assessment, can be expected for the revision of the Roadworthiness Directives by replacing costly inspection mechanisms with over-the-air control of emissions.

A second sub-option, PO3b on High Digital Ambition, which would have been based on future sensor technologies, such as PM/PN and NMOG, was discarded following the proposed end-date of combustion-engine cars and vans by 2035 (see 5.3).

5.3 Options discarded at an early stage

During the technical work in support to the Euro 7 proposal, a variety of technology driven policy option packages were evaluated both for light- and heavy-duty vehicles. Such technology-driven policy option packages would lead to varying stringencies of the emission limits. For light-duty vehicles 16 such variations were analysed (12 for gasoline and 4 for diesel) both in terms of technology readiness as well as for their potential for emission reduction. For heavy-duty vehicles 6 technology-driven policy option packages were evaluated for diesel and gaseous fuelled engines. From these technology packages only three levels were considered as compatible with the expected timeline of Euro 7 and technically feasible without restricting driving habits and were therefore retained in the policy options further analysed.[140]

Stakeholders' responses to the different consultation areas (see Annex 2), make clear that all three policy options initially developed for the inception impact assessment, i.e. PO1, PO2 and PO3, presented for public and targeted consultation and discussed in AGVES meetings received some support, although some simplification measures have been rejected - see list after consultation in Annex 6, Table 47. No stakeholder group required different ambition level and therefore policy options for the cars/vans and lorries/buses segment.

[139] See Annex 2 Stakeholder consultation, Section 2.2.5. Continuous emission monitoring

[140] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

A second sub-option of PO3 (i.e. PO3b – PO2a and High Digital Ambition) was discarded following the proposed end-date of 2035 for placing new combustion-engine cars and vans on the EU market. PO3b added to PO2a high ambitious continuous emission monitoring, i.e. more advanced sensors such as PN/PM or NMOG sensors that are not yet available in the market and would require a few years of development before being employed (see 5.2). This would require high investment costs for vehicle manufacturers and component suppliers which would not be recuperated until 2035. Sensors for vehicles are designed for application in all vehicles, light and heavy-duty ones. With the planned end-date for combustion engines for cars and vans, the market for such sensors diminishes significantly. Even though such sensors could eventually be implemented in the heavy-duty sector for a longer period, such an investment for the limited number of heavy-duty vehicles sold each year would not allow to recuperate the high investment costs. Hence, PO3b was discarded, for light-duty as well as heavy-duty vehicles, to only include policy options that are achievable with existing technologies and in a timely manner for introduction into vehicles by 2025.

PO1 to PO3 are built in a modular approach by combining several policy measures with increasing ambition levels. Hence, one could in principle build variations of these policy options by making different combinations of measures. By changing the comprehensive real-driving conditions from medium to high ambition in both PO2a and PO3a, all else being equal, two other combinations of measures were assessed.[141] Since neither of these alternative combinations outperformed the effectiveness and efficiency of PO2a and PO3a with medium ambition comprehensive real-driving conditions, these combinations of measures were discarded at an earlier stage.

Next to the stakeholder support for building upon the Euro 6/VI emission standards with PO1 to PO3, one could also think of solving the problems discussed in chapter 2 through voluntary measures, especially considering that many technologies for further reducing vehicle emissions are already available on the market. Nevertheless, their adoption is not likely to happen using voluntary measures, as was already shown by the scarce propensity of the industry to introduce any additional measures linked with emissions. This was demonstrated clearly in the antitrust case of the Commission against three major car manufacturers for restricting competition in emission after treatment systems for new diesel cars.[142] In particular, the manufacturers did not use better available technology (AdBlue tanks), as this was not explicitly required by the type-approval legislation. As discussed in section 2.3, this follows from the fact that emission control technologies do result in costs and subsequently higher vehicle prices, while perceived value of improved pollutant emissions performance by customers is often limited.

6 WHAT ARE THE IMPACTS OF THE POLICY OPTIONS?

The quantification of the impacts of the three policy options, for the cars/vans as well as the lorries/buses segments, relies on a number of models which use input of regulatory costs and the emissions reduction performance of available or future technologies necessary to comply with the different policy options. The models used, i.e. COPERT and SIBYL, are amongst the most advanced in the field and are used widely both in

[141] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 4.3 Description of the policy options.

[142] European Commission, 2021. Press release: Antitrust: Commission fines car manufacturers €875 million for restricting competition in emission cleaning for new diesel passenger cars

Europe and around the world for the estimation of emissions from road transport. They are at the basis of the national and EU submission of emission inventories to Intergovernmental Panel on Climate Change (IPCC) and have been developed over the years with input from numerous projects. A network of experts from 57 leading EU institutions has been directing their development in Europe for the past decades[143].

Such detailed models are needed in order to provide adequate detail both on the technological choices, mileage covered, vehicle age and other details which are crucial for estimating the emissions from the European fleet now and in the future. Models often used for other impact assessments assessing the fleet level (e.g. PRIMES, GAINS etc.) are less suitable for detailed modelling at vehicle level required for estimating the effects of changes in the type-approval legislation. Detailed information on the methodological approach can be found in Annex 4.

Industry strongly opposes disproportionate burden which may eventually trigger a decision to stop ICE production. They support in-between PO1 and PO2a solution. On the other hand, there is a pressure from environmental and consumer organisations and some Member States to set more ambitious requirements as in PO3a and PO2b to support further improvement in air quality and thus contribute to protecting public health and the environment, while it may be expected that such digital solution as proposed in PO3a may raise concerns of social acceptability of continuous monitoring. However, such potential concern of making pollutant data from vehicles available was not raised by consumer organisations or citizens in the stakeholder consultations.

The aforementioned stakeholders were encouraged to verify or contest any result or assumptions in the extensive public and targeted stakeholder consultations, including interviews and confidential data sharing, and various AGVES meetings (see Annex 2). In total, more than 200 experts were participating in each meeting. Feedback and differences in stakeholders' views received through these channels were carefully analysed and taken into account. **In the assessment of the impacts of the policy options, in particular on industry competitiveness, consumer affordability and employment, qualitative stakeholder data has been triangulated with quantitative estimates and/or literary evidence depending on the specific impact** (see each section below). A detailed overview of the stakeholder views and the use of the consultation results is included in Annex 2.

To ensure **robustness of the analysis**, the estimated impacts and their underlying assumptions have been cross-checked with independent experts and the concerned stakeholders, separately for the cars/vans and the lorries/buses segments. To address any remaining uncertainty, the level of confidence for each regulatory cost category and the health and environmental benefits was assessed. Based on the availability and quality of information, data and shared input by stakeholders, the administrative costs and costs during implementation phase (including testing and witnessing cost and type-approval fees) are characterised by a high level of confidence, the equipment costs by medium (R&D and related calibration costs) or medium-high (hardware costs for emission control technology) confidence. Medium-high confidence is also assumed for the health and environmental benefits that are calculated based on the models above and the Commission's Handbook on the external costs of transport.[144] This medium to high level of confidence of the cost and benefit estimates valid for the cars/vans as well as the

[143] See Leading EU Models | ERMES GROUP (ermes-group.eu)
[144] European Commission, 2019. Handbook on the external costs of transport

lorries/buses segments and verified by stakeholders and experts is considered sufficiently robust to present in chapter 6 average values for the cost and benefit elements. Nevertheless, the cost-benefit analysis in chapter 7 is complemented by providing ranges of expected costs and benefits, separately for the cars/vans and the lorries/buses segments, to make political choices based on the net benefits of the policy options. More information can be found in Annex 4 section 1.3.2.1. Uncertainty.

6.1 PO1: Low Green Ambition

6.1.1 Economic impacts

6.1.1.1 Regulatory costs for automotive industry

The regulatory costs for automotive industry consist of substantive compliance costs (equipment costs for emission control technologies and the related R&D and calibration costs including facilities and tooling costs as well as costs during implementation phase for testing, witnessing of tests by type-approval authorities and type-approval fees) and administrative costs (reporting and other information obligations as part of the type-approval procedures). A detailed description of the cost categories is available in Annex 5, Table 39.

The simplification measures introduced in PO1 aim at reducing complexity, eliminating inconsistencies and improving effectiveness of the legislation. This policy option is expected to result in some cost reductions, especially of costs during implementation phase and administrative costs, largely due to the streamlined testing procedures or removal of obsolete ones. However, these cost savings would be offset by the expected increase in R&D, hardware and related calibration costs linked with technology-neutral limits and extended real-driving testing for all vehicle categories except for petrol/compressed natural gas (CNG) lorries/buses. For these vehicles, a small total regulatory cost saving of €2 per vehicle is expected. For diesel lorries/buses, the implementation of the simplification measures are expected to reduce costs during the implementation phase and administrative costs by €49 per vehicle. However, such cost savings would be offset by an increase in R&D and related calibration costs of €103 per vehicle. The total regulatory cost for lorries/buses are estimated at €44 per vehicle.[145]

Also for cars/vans, no total regulatory cost savings are expected. While cost savings during implementation phase and administrative cost savings are expected with the simplification measures, these will likely be exceeded by hardware, R&D and related calibration costs. The largest share of the latter costs follow from the need to ensure that emission are also controlled in enhanced real-driving testing outside the current RDE boundaries, while a smaller share is linked to introducing technology-neutral limits. In all, the total regulatory cost for cars/vans for industry are estimated at €60 per vehicle.

To ensure that no administrative burden is added, administrative costs[146] are assessed

[145] The cost per vehicle is calculated by dividing the regulatory cost over the period 2025-2050 by the total number of vehicles per vehicle category. This total cost is calculated by adding up all the different cost categories (which include one-off and recurrent costs) (see Annex 5 Table 39) over their specific unit. These units do not only include the number of new vehicle registrations per category, but also the number of engine/model families, type-approvals, manufacturers and calibrations. Hence, the cost per vehicle and regulatory cost is affected by changes in the fleet and in the specific unit.

[146] Administrative costs are those costs incurred by stakeholders to comply with information obligations, such as reporting or registration and include requirements for information documents, type-approval

separately. Euro emission standards trigger recurrent administrative costs, including costs for reporting and compliance with other relevant information obligations as part of the process for granting type-approval, Conformity of Production (CoP) and In-Service Conformity (ISC).[147]

Since PO1 allows for reduction of the number of type-approvals and tests with reporting requirements, the simplification measures translate into significant administrative cost savings in all vehicle categories. For cars/vans, administrative cost savings are estimated at €97 thousand per type approval for petrol cars/vans (€18 per vehicle) and at €126 thousand per type approval for diesel cars/vans (€17 per vehicle). For lorries/buses, savings of €30 thousand are expected per diesel type-approval (€14 per vehicle) and of €31 thousand per petrol type-approval (€31 per vehicle).

A detailed description of the total regulatory costs for automotive industry in PO1 compared to the baseline is available in Annex 4, section 1.3.1.1.

Table 3 presents the total regulatory costs in 5-year intervals over the period of implementation of PO1. It shows that the largest share of the costs occur in the first five years after 2025. Since PO1 does only introduce changes in the requirements and emission testing for combustion-engine vehicles, the regulatory costs become zero after the proposed end-date of combustion-engine cars and vans in 2035.

Table 3 – Expected distribution of total regulatory costs in PO1 compared to the baseline, in billion € and 2025 NPV[148]

	2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total
Cars and vans	2.00	2.51	0.53	0.00	0.00	0.00	5.04
Lorries and buses	0.38	0.10	-0.09	-0.06	-0.04	-0.03	0.27

These costs consist of both recurrent costs (e.g. for hardware) – that increase with the number of produced vehicles or type-approvals – and one-off costs (e.g. related to the development of new emission control systems) that are expected to be similar for the manufacturers, irrespective of size.[149] Taking into account the market share of car/van manufacturers in the EU[150], the two largest manufacturing groups[151], which together had 46% of the car market in 2019, would have to invest a maximum of €0.7 billion each for the whole period 2025-2035. For all other car/van manufacturers, PO1 would only require a total investment between €0.2 and €0.3 billion for the same period. The total regulatory costs for the industry divided by the 12 main manufacturers of lorries/buses mean that each lorries/buses manufacturer would have to invest €0.02 billion. This a very

certificates, result sheet, test reports, certificates of conformity and vehicle registration.

147 Commission Implementing Regulation (EU) 2020/683 implementing Regulation (EU) 2018/858 with regards to the administrative requirements for the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles

148 CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 5.1.2. Economic impacts, Policy Option 1.

149 CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2 Efficiency, evaluation question 4; CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 5.1.3.; 5.2.3.; 5.3.3. Cost-benefit analysis.

150 Car Sales Statistics, 2020. 2019 Europe: Best-Selling Car Manufacturers and Brands (based on ACEA)

151 Volkswagen Group and Stellantis Group (formed in 2021 through a merger between Fiat Chrysler Automobiles and PSA)

small additional amount to the €59 billion each car manufacturer is estimated to invest for the shift to automation, connectivity and electrification.[152]

With the end-date of combustion-engine cars/vans by 2035, the cumulative annual investment of PO1 and proposed CO_2 emission standards for cars/vans[32,153,32] over 2021-2040 amounts to €19.2 billion, out of which €19 billion is due to the proposed CO_2 target and €0.2 billion due to PO1 (see Annex 4, Table 33). Hence, the investment attributable to PO1 is with 1% increase in annual investments not high. See detailed analysis on the cumulative impacts on industry in Annex 4 section 1.5.4.

Table 5 (II.A) in Annex 3 presents an overview of these regulatory costs for manufacturers split up in one-off and recurrent costs linked to the different policy measures, including simplification measures and technology-neutral limits and extended real-driving conditions.

6.1.1.2 Competitiveness

The views of **stakeholders from industry, civil society and Member States** on competitiveness were collected as part of the targeted stakeholder consultation. No specific views were expressed regarding PO1.

While the European automotive industry is considered to hold a strong position in international trade, in recent years Europe has been overshadowed by other emerging markets. In 2019, about 20% of motor vehicles produced globally was produced in Europe[154], in comparison with 32% in the year 2000[155]. The positive trade balance of EU cars have continued to decrease since 2015 with imports rising while exports of EU cars remained more stable.[156] In 2018, EU exports of cars to main trade partners the United States and China still amounted up to €37 and €22 billion, in comparison to imports worth €6 and €0.5 billion respectively.[157] A detailed description of EU export of motor vehicles to key destinations is available in Annex 4, section 1.4.1., for EU-27 passenger car exports as well as EU-27 motor vehicles (i.e. cars, vans, lorries and buses).

The evaluation of the Euro 6/VI showed that global pressure to reduce transport emissions intensifies, not least because other key players, in particular China and the United States, have introduced or are planning to introduce more demanding vehicle emission standards.[44] Despite the fact that the Euro 6/VI legislation have set the stage for real-driving testing worldwide, today EU is found to be lagging behind when it comes to i.a. pollutants coverage and emission limits.[158]

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[152] McKinsey Center for Future Mobility, 2020. Estimation of the level of investment from car manufacturers to gain a defensible position in new technologies

[153] Since the recently proposed CO_2 emission standards only have implications for cars and vans and a revision of the CO_2 emission standards for heavy-duty vehicles is only planned for 2022, the cumulative impact assessment focuses only on the cumulative impacts in the cars and vans segments. The scenario TL_High in the CO_2 impact assessment, which is the closest scenario to the final adopted CO_2 proposal, was used to calculate the cumulative impacts.

[154] ACEA, 2021. Production

[155] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 5.2.2. Economic impacts.

[156] Eurostat, 2020. International trade in cars.

[157] ACEA, 2019. EU-US automobile trade: facts and figures; ACEA, 2019. EU-China automobile trade: facts and figures

[158] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission

Nevertheless, PO1 is only expected to have a very limited effect in aligning the EU with emission regulatory developments in the United States and China. Only the extended RDE testing is expected to slightly improve the EU's competitive position in real-driving testing. PO1 is not expected to change the **access to international markets** of EU's automotive industry, given that other countries develop more ambitious emission standards.

PO1 requires almost no R&D efforts for development of emission control systems, neither for the cars/vans nor for the lorries/buses segments. Therefore, **innovation** of European companies in the supply-chain will not be encouraged nor will their competitive position improve in comparison to what is expected in the baseline. In all, positive effects on the mobility ecosystem as a whole are expected to be limited.[159]

The assessment of access to international key markets, innovation and cumulative investments with CO_2 emission standards (see 6.1.1.1) leads to the conclusion that no impacts are expected from PO1 on industry competitiveness.

6.1.1.3 Single market

PO1 is expected not to affect the intentions of Member States with regard to national initiatives aiming at tackling significant pollutant emission from road transport, such as bans for diesel or all combustion engines and the introduction of zero-emission zones (see chapter 2), putting at risk the functioning of the single market.

6.1.1.4 SMEs

The European automotive industry mostly comprises of large manufacturers active in vehicle assembly and component production. However, SMEs are present among the suppliers of equipment. They may be indirectly affected by newly required emission control technologies or other equipment.

Some SMEs manufacture vehicles or systems that require an EU emission type-approval. 35 SMEs[160] were identified in the cars/vans segment[161], which are mostly small companies (i.e. staff headcount < 50 and either turnover or balance sheet total ≤ €10m). These 35 SMEs are building specialised vehicles on the basis of powertrains produced by larger manufacturers[162]. Nevertheless, these SMEs rarely carry out calibration of the specific powertrains in order to make them comply with new emission standards. Since no significant changes to the emission control technologies and calibration of engines are expected in PO1, the impact on SME manufacturers is expected to be negligible.

A higher number of SMEs is expected to be indirectly affected by new vehicle emission standards as users (e.g. transport or logistics services, vehicle rental or leasing companies, companies using vehicles) due to price and affordability of light- or heavy duty vehicles. Assuming that costs translate into vehicle prices as demonstrated in the

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Limits. ISBN 978-92-76-56406-5, chapter 3.2 Emission standards outside of the EU.

[159] Industrial ecosystems encompass all players operating in a value chain: from the smallest start-ups to the largest companies, from academia to research, service providers to suppliers. For more information see footnote 16 (industrial strategy).

[160] SME definition (europa.eu)

[161] No SMEs were identified in the lorries/bus segment.

[162] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 5.1.2 Economic impacts.

Euro 6/VI evaluation[76], the total regulatory costs in PO1 are expected to be less than 0.5% of the estimated light- or heavy-duty vehicle price (see Annex 4, Table 17). Hence, only negligible impact is expected on the affordability of vehicles by SME users in comparison to the baseline.

6.1.2 Environmental impacts

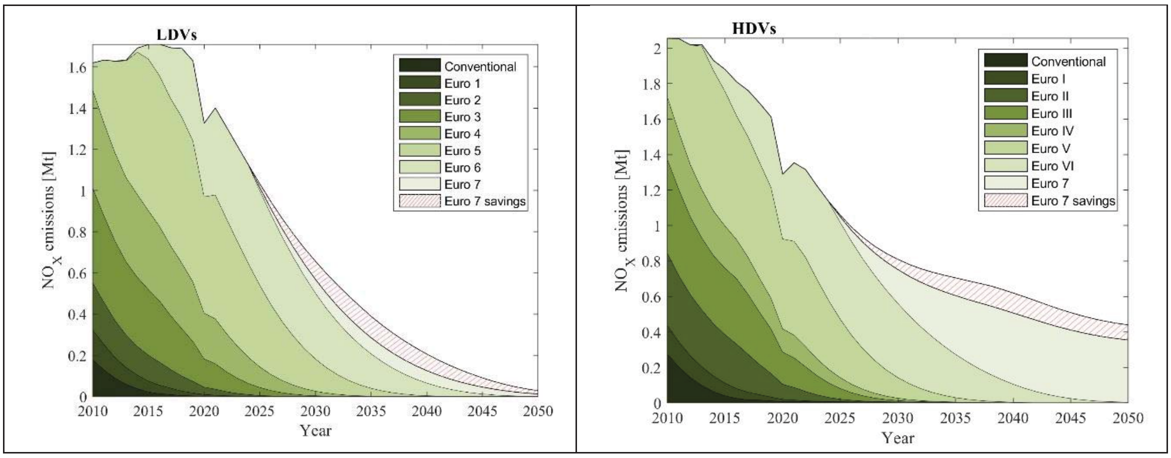
Air pollutant emission reductions are expected to increase with time even with Euro 6/VI vehicle fleet renewal in combination with the impact of the new CO_2 standards (see chapter 5.1).

As illustrated for key pollutant NO_x in Figure 8 and all pollutants in Annex 4, Table 11, the emission reductions that can be expected in PO1 are rather limited. This is due to maintaining the current emission limits (only ensuring technology neutrality). Broader RDE testing conditions and improved OBD allowing for more effective ISC and MaS over the lifetime of vehicles do not change this conclusion.

For cars/vans, NO_x emissions are expected to further decrease by 13% in 2030 to 55% in 2050, compared to the baseline. This significant decrease follows from the introduction of low ambition extended real-driving testing covering conditions outside the current RDE boundaries and a technology-neutral NO_x emission limit. Some reductions can be expected for particles, NH_3 and CO emissions from cars/vans compared to the baseline.

For lorries/buses, NO_x emission reductions are the only reductions expected in PO1. The Euro VI limits are already technology-neutral. The reduction of NO_x emission, 7% in 2030 to 19% in 2050, derive from extended real-driving testing covering conditions outside the current PEMS boundaries and assumed increased frequency of ISC and MaS testing.[163]

Figure 8 – NO_x reductions from light- and heavy-duty vehicles in PO1 compared to the baseline, Source: SIBYL/COPERT 2021



[163] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 5.1.1 Environmental impacts

6.1.3 Social impacts

6.1.3.1 Monetised health and environmental benefits

By reducing harmful pollutants, a new vehicle emissions standard benefits citizens by curbing negative health impacts from road transport that cause respiratory and cardiovascular diseases upon inhalation e.g. bronchitis, asthma or lung cancer. This health benefit can be monetised using the concept of external costs developed for the Commission's Handbook on the external costs of transport. It reflects the damage costs by air pollution from transport to health and environment. While benefits of reducing emission are independent of the absolute emission levels, the differences in exposure for metropolitan, urban and rural areas are taken into account. Combatting health impacts is expected to result in a reduction of medical treatment costs, productivity losses due to illnesses and even deaths.[164][165]

Although the damage costs by air pollution from transport take into account predominantly the impact on health, they also reflect impact on the environment such as crop losses, material and building damage and biodiversity loss due to particulate matter formation, photochemical oxidant formation, acidification, eutrophication and ecotoxicity of air, water and soil (see Annex 4, Box 3 and Figure 10 and 11). Hence, Table 4, in which the monetised health and environmental benefits are presented, also reflects all relevant environmental Sustainable Development Goals (SDGs)[166] of the 2030 UN Agenda for Sustainable Development. With monetary benefits estimated for these parameters in all policy options (see 6.2.3 and 6.3.3), PO1, 2 and 3 are not expected to do significant harm to any of the environmental SDGs.

Table 4 shows the monetised health and environmental benefits in PO1 compared to the baseline. Since PO1 considers technology-neutral emission limits and some improvements regarding extended real-driving testing, benefits are only expected to be achieved through reductions of NO_x, exhaust PM and NH_3 emissions. Through the reduction of NO_x emissions from cars/vans, PO1 is expected to result in a €20.6 billion reduction of external costs up to 2050. With a total reduction of €21.1 billion for lorries/buses, reduction of NO_x emissions from these vehicles is expected to have a slightly larger benefit. Additional health and environmental benefits are expected from the reduction of the particle number threshold from 23 nm to 10 nm in PO1. Lastly, the emission reductions for NH_3 for cars/vans are expected to result in benefits up to €0.9 billion.

Table 4 – Monetised health and environmental benefits for PO1 compared to the baseline, Source: SIBYL/COPERT 2021

	Monetised health and environmental benefits until 2050 (billion €)				
	NO_x	$PM_{exhaust}$	$PM_{non-exhaust}$	NH_3	NMHC
Cars and vans	20.63	0.33	0.00	0.94	0.01
Lorries and buses	21.14	0.00	0.00	0.00	0.00

[164] European Commission, 2019. Handbook on the external costs of transport, Version 2019 -1.1
[165] See Annex 4: Analytical methods, section 1.2.3 Damage costs
[166] Goal 3: Good health and well-being, Goal 6: Clean water and sanitation, Goal 13: Climate action, Goal 14: Life below water and Goal 15: Life on land from United Nations, 2021. The 17 Goals

6.1.3.2 Employment and skills

The Euro 6/VI evaluation found no compelling evidence that emission regulations have a negative effect on employment. On the other hand, Euro 6/VI may positively impact employment through creation of new jobs in R&D domain or those related to production of emission control systems at the suppliers.[44]

Almost half of the **suppliers** in the targeted consultation stressed that new limits will create new business opportunities and quality jobs. Since PO1 only aligns the emission limits for different vehicle technologies, no impact on employment is expected in PO1, neither in the cars/vans nor the lorries/buses segments. Reason for this being that there is no need for new workforce for the continued use of current emission control technologies or to control emission outside the current RDE boundaries.

Nevertheless, resources for type-approval and testing services may slightly decrease following the introduction of simplification measures and the expected lower number of emission type-approvals in PO1, and subsequently also policy options 2 and 3.

Since PO1 does not require new emission control or ICT technologies, no up- or re-skilling should be needed compared to the baseline.

6.1.3.3 Consumer affordability

It is expected that total regulatory costs following new policy measures for vehicles initially borne by manufacturers are eventually passed on to the consumers, at least in the longer term. It is difficult to establish a clear correlation between regulatory costs and vehicle prices.[167] The Euro 6/VI evaluation could not demonstrate if a price increase of cars since 2014 is associated with regulatory costs stemming from the Euro 6/VI, since the observed increase could also result from other factors affecting prices, e.g. installation of comfort equipment or changes in fleet composition towards more heavy and expensive vehicles.[44] However, 121 out of 139 respondents to the public consultation from **all stakeholder groups, including citizens**, considered that Euro 6/VI has led to an increase in the prices of cars, vans, lorries and buses.[168] The regulatory cost increase could lead in the most relevant segment for low income consumers, i.e. small cars/vans, to 0.1% vehicle price increase for petrol vehicles and 0.5% for diesel vehicles, which is considered not significant. See detailed comparison of total regulatory costs per vehicle segment in Annex 4, Table 17.

Private users are not considered relevant for heavy-duty vehicles. The impact on SME users of heavy-duty vehicles are discussed in section 6.1.1.4.

While Euro emission standards are expected to increase costs for consumers, the newly proposed CO_2 emission standards for cars/vans[32] are expected to decrease the total cost of ownership (TCO)-first user[169] of new cars/vans. This is explained by the fuel and

[167] Mamakos, A. et al., 2013. Cost effectiveness of particulate filter installation on Direct Injection Gasoline vehicles

[168] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 3.1)

[169] While the CO_2 impact assessment also inspects the impacts on the total cost of ownership from the second user perspective, for this assessment an analysis of the first user perspective is deemed sufficient. The Euro emission standards mostly affect consumer affordability and the cost of ownership through the impact on the price of vehicles for first users. Impacts on the second users market will be limited since the increase is expected to be only a fraction of the price for first users, for all options.

electricity savings that are expected to outweigh the high upfront costs of zero- and low-emission vehicles. In 2030, PO1 is estimated to slightly decrease the net saving in TCO of €600 per vehicle achieved through the proposed CO_2 targets by €13 for cars and by €74 for vans. Overall, the net savings in the TCO are still found to be highly positive. See detailed analysis on the cumulative impacts on consumers in Annex 4 section 1.5.2.

6.1.3.4 Consumer trust

While consumer trust was severely affected by Dieselgate in 2015, the last Euro 6d step for cars/vans introducing RDE testing and the changes to the EU type-approval rules with strengthened and independent testing, market surveillance and new enforcement procedures had positive impact on consumer trust[170]. PO1 is expected to have low positive impact on consumer trust. Some positive impact is expected due to introduction of technology-neutral limits, while real-driving testing is slightly enhanced in PO1.

6.2 PO2: Medium and High Green Ambition

6.2.1 Economic impacts

6.2.1.1 Regulatory costs for automotive industry

The total regulatory costs are expected to be higher in PO2 in order to meet medium ambitious emission limits and testing boundaries of PO2a and high ambitious emission limits and testing boundaries of PO2b, compared to PO1. The increase of hardware costs, caused by the new emission control technologies available in the market today, and of some R&D costs for technology system integration and calibration, raises the total regulatory cost compared to the baseline for all vehicle categories. Total regulatory costs per vehicle are higher for lorries/buses than for cars/vans due to the more robust emission control systems required for such vehicles.

While the simplification measures lead to cost savings during the implementation phase and administrative cost savings (€41 per vehicle), the new requirements for tailpipe, evaporative and brake emission are expected to result in additional R&D, hardware and calibration costs. The hardware cost per vehicle are calculated using the cost of different technology packages weighted over the development of the fleet in the assessed period. The different technology packages to achieve the requirements of PO2a and PO2b and their costs were verified by **stakeholders from automotive industry, civil society and some Member States** and are presented in Table 21 in Annex 4.

For diesel cars and vans, in PO2a regulatory costs linked to the requirements for tailpipe and evaporative emissions are estimated at €399 per vehicle and in PO2b at €463 euro per vehicle. For petrol cars and vans, these costs are expected to be lower estimated at €144 per vehicle in PO2a and at €327 per vehicle in PO2b. In addition, the introduced limits for brake emissions lead to additional hardware costs that differ between combustion-engine and electric vehicles due to differences in technologies and braking patterns. For combustion-engine cars and vans, in PO2a additional regulatory costs linked to the requirements for brake emissions are estimated at €23 per vehicle and in PO2b at €100 per vehicle. For electric cars and vans, these additional regulatory costs are estimated at €13 per vehicle in PO2a and at €60 per vehicle in PO2b.

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[170] See Annex 2: Stakeholder consultation, 2.2.1 Evaluation Euro 6/VI emission standards

Overall, this would result in total regulatory costs for cars/vans of €297 per vehicle in PO2a and of €475 per vehicle in PO2b.[144171] This cost estimate for cars/vans in PO2a is below the total regulatory costs associated with introduction of Euro 6 for diesel cars/vans, but exceeds the total regulatory costs associated with the introduction of Euro 6 for petrol cars/vans. In case of PO2b, the total regulatory costs per vehicle for cars/vans are in the range of the total regulatory costs of Euro 6 for diesel cars/vans.[172]

For lorries/buses (mainly diesel), in PO2a the cost per vehicle is estimated to increase by €2 601 and in PO2b this cost is estimated to increase by €4 059 for internal combustion engine vehicles. Similar to PO1, the cost savings following the simplification measures (€60 per vehicle) are expected to be exceeded by the hardware, R&D and calibration costs linked to the new limits, testing and durability requirements (€2 661 per vehicle in 2a and €4 119 per vehicle in 2b). For these vehicles, the total regulatory costs are found below the total regulatory costs of the introduction of Euro 6/VI for PO2a and in the range for PO2b.[171]

Following the same reasoning as in PO1, PO2 is also expected to result in savings in administrative costs. Since PO2 includes the simplification measures introduced in PO1, the administrative costs savings are estimated at the same levels.

A detailed description of the total regulatory costs for automotive industry in PO2 compared to the baseline is available in Annex 4, section 1.3.1.2.

Table 5 presents the total regulatory costs in 5-year intervals over the period of implementation of stricter emission limits in PO2, including tailpipe, evaporative and brake emissions. It shows that the largest share of the costs occur in the first ten years after 2025. Subsequently, the costs will decrease with a **small share of the costs remaining after 2035**, mainly resulting from the **requirements regarding brake emissions for all cars/vans, including zero-emission vehicles**, and combustion-engine lorries/buses. They will also be due to the need to continue market surveillance and in-service conformity checks throughout the lifetime of vehicles (i.e. at least for another 10-15 years after the first registration). For all categories, the five year costs decrease over time as a consequence of the decreasing number of combustion engine vehicles.

Table 5 – Expected distribution of total regulatory costs in PO2 compared to the baseline, in billion € and 2025 NPV

	2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total
PO2a – Medium Green Ambition							
Cars and vans	8.62	14.77	4.26	1.03	0.86	0.72	30.27
Lorries and buses	5.72	5.82	2.22	1.35	0.76	0.57	16.44
PO2b – High Green Ambition							

[171] For cars/vans, this cost per vehicle in PO2a corresponds to €280 per ICE vehicle for costs linked to requirements for tailpipe and evaporative emissions and €17 per vehicle for all powertrains linked to requirements for brake emissions. For cars/vans in PO2b, this is €399 per ICE vehicle and €76 per vehicle for all powertrains.

[172] See Annex 5: Evaluation Euro 6/VI emission standards, chapter 6 Conclusions: For Euro 6 cars/vans, the total regulatory cost for the period up to 2020 increased by €357-€929 per CI vehicle and €80-€181 per PI vehicle. For Euro VI lorries/buses, the total regulatory costs increased by €3 717-€4 326 per vehicle.

Cars and vans	12.99	28.62	10.33	4.70	3.93	3.27	63.84
Lorries and buses	6.50	9.07	4.57	2.78	1.56	1.17	25.65

Taking into account the market share of car/van manufacturers in the EU[149], the two largest manufacturing groups, would have to invest between €5.1 and €5.7 billion each in PO2a and between €12 and €13.6 billion in PO2b for the whole period between 2025 and 2050, i.e. over 25 years. For all other car/van manufacturers, PO2a would only require a total investment between €0.5 and €2.7 billion, while PO2b would require a total investment between €0.5 and €6.1 billion for the same period depending on the size of the manufacturer. The investment costs for PO2a can be translated €1.4 billion per manufacturer of lorries/buses while for option 2b the costs increase to €2.1 billion respectively. This is still expected to have a low impact on the estimated investment need for car makers of €59 billion to address automation, connectivity and electrification challenges[151], costs are still considered low for the automotive industry in particular those for PO2a.

Especially **automotive industry** has raised concerns regarding too high cumulative impacts in view of the CO_2 investments and the technological potential for reducing emissions. With the end-date of combustion-engine cars/vans by 2035, the cumulative annual investment of PO2a/PO2b and proposed CO_2 emission standards[32] over 2021-2040 amounts to €20.2/€21.4 billion, out of which €19 billion is due to the proposed CO_2 target and €1.2/€2.4 billion due to PO2a/PO2b (see Annex 4, Table 33). The investment attributable to PO2a is considered with 7% increase in annual investments not too high, while the investment attributable to PO2b is considered with 13% high. See detailed analysis on the cumulative impacts on industry in Annex 4 section 1.5.4.

Table 5 (II.B) in Annex 3 presents an overview of these total regulatory costs for manufacturers split up in one-off and recurrent costs linked to the different policy measures, including simplification measures, medium and high ambition emission limits, real-driving testing boundaries and durability.

6.2.1.2 Competitiveness

The views of stakeholders on competitiveness were collected as part of the targeted stakeholder consultation. While **Member States and civil society** generally expect a positive relationship between stricter standards and competitiveness, differing views were found amongst **industry stakeholders** with suppliers anticipating positive impacts and manufacturers negative impacts (see Annex 2, Figure 7). Stakeholders did not express different views on the cars/vans and lorries/buses segments.

Through the Euro standards, the EU has traditionally been the global emission standard setter, and the EU automotive industry has traditionally been the technological leader for internal combustion engines. PO2 would put the EU in the forefront of vehicle emission reductions worldwide, overtaking the actual regulatory developments in other key market such as China and the US for tailpipe pollutants except durability (see 6.1.1.2) as well as for new ones that will be there irrespectively of the engine: from brakes and, in the future, from tyres. This would maintain **access to international markets**.

In addition, over recent years EU export of cars has followed a downwards trend, while import has known a steady increase. In 2019, car exports amounted up to €140 billion, while imports to €63 billion.[155] This downward trend is also visible for the export of all motor vehicles, including all light-duty as well as heavy-duty vehicles. In 2019, EU exports of motor vehicles added up to €157 billion and imports to €71 billion.[173] The stricter emission limits for internal combustion engines in PO2 should support EU automotive industry to seize opportunities for further cleaning of internal combustion engines that will still play a role in several third markets for which a slower transition to zero-emission cars/vans is expected, such as in India, South-East Asia, Brazil or South Africa, and in the lorries/buses segment[174]. Choice of PO2 is expected to increase export of EU goods compared to the baseline values, reversing current trends, thus positively affecting the global market share of the EU.[154]

These findings for PO2 are also supported by the majority of component suppliers participating in the targeted consultation, indicating that new emission limits will encourage **innovation** in the supply-chain and increase the competitiveness of the EU automotive industry on the global stage. Vehicle manufacturers, on the other hand, tend to be more reserved on this point.[175] For the whole mobility ecosystem the effects of PO2 are expected to be positive, given the strong competitive position of EU suppliers of emission control systems.

Despite the total regulatory costs for industry and cumulative investments with CO_2 emission standards for cars/vans (see 6.2.1.1), PO2a and PO2b are expected to have a low to moderate positive effect on competitiveness in terms of access to international markets and innovation. Stimulating innovation in zero-emission technologies by CO_2 emission standards as well as in pollutant emission control technology, access to international markets can be maintained while improving the competitive position of the EU automotive sector over the baseline.

However, the assessment also shows that some of the concerns of **automotive industry** regarding stricter Euro emission standards are justified, such as high investments in the cars/vans segment with emission limits lower than 30 mg/km for NO_x and high ambitious real-world testing in all driving conditions in PO2b.

6.2.1.3 Single market

It is expected that PO2 will increase confidence in vehicles, in particular cars, being clean in all conditions of use and may encourage Member States to reconsider announcements for vehicle bans and local or regional vehicle access limitations, in particular as those have to be notified as potential barriers of internal EU trade of vehicles under Directive 2015/1535[176]. PO2, by increasing confidence in clean vehicles under extended conditions of use and subsequently making Member States reconsider need for unilateral measures, positively affects the functioning of the single market through setting more adequate, future proof rules for vehicles emission. Higher positive impact is expected in PO2b than in PO2a as the former introduces high ambition emission limits and testing boundaries.

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[173] ACEA, 2022. EU motor vehicle exports, main destinations (by value). ACEA, 2022. EU motor vehicle imports, main countries of origin (by value).
[174] Zhao, Fuquan et al, 2020. Challenges, Potential and Opportunities for Internal Combustion Engines in China
[175] See Annex 2: Stakeholder consultation, section 2.2.6. Impacts of a stricter emission standard
[176] Directive (EU) 2015/1535 laying down a procedure for the provision of information in the field of technical regulations and of rules on Information Society services; see also 2015/1535 notification procedure

6.2.1.4 SMEs

The new requirements considered in PO2 could potentially be more difficult and costly to implement for the 35 SME cars/vans manufacturers[177] (see 6.1.1.4). Most of those SMEs are specialised in sporty and lightweight cars that are predominantly equipped with petrol engines, whose emission control systems present the lowest total regulatory costs in the vehicle categories. Furthermore, several of these SMEs are supported by the research facilities of larger manufacturers to whom they are linked in the supply chain. In the targeted stakeholder consultation, differing views on the effect of PO2 on SME manufacturers were found. While **large manufacturers** were pessimistic, **suppliers** were uncertain or slightly positive considering that SMEs would not be significantly affected in a positive or negative manner by the proposed measures in PO2.[174]

The SME users of motor vehicles, such as transport services, etc., are mostly concerned about the effect of new requirements on the price and affordability of vehicles. When fully passed on to SME users, the total regulatory costs in PO2a amount up to 2.1% for small cars/vans and up to 3.1% for small lorries of the vehicle price, and in PO2b up to 2.8% for small cars/vans and up to 4.9% for small lorries (see Annex 4, Table 22). Hence, the strictest emission limits are expected to have medium negative impact on the affordability for SME users.

6.2.2 Environmental impacts

As illustrated for key pollutant NO_x in Figure 9 and all pollutants in Annex 4, Table 12, the emission reductions compared to the baseline that can be expected by introducing strict emission limits (PO2a) are significant, in particular for lorries/buses. The reduction of emissions for cars/vans is also important, as those vehicles are predominantly used in densely populated urban areas where more citizens are exposed.

For cars/vans, NO_x emission are expected to decrease significantly and rapidly compared to the baseline, by 21% in 2030, 42% in 2035, 62% in 2040 to 88% in 2050. This significant reduction follows from the introduction of medium ambition extended real-driving testing covering almost all conditions outside the current RDE boundaries and a technology-neutral NO_x emission limit of 30 mg/km for cars. This replaces the diverging NO_x limits of Euro 6 of 60 mg/km for petrol cars and 80 mg/km for diesel cars. The decrease in Figure 9 illustrates that cars/vans progress more rapidly toward zero-pollution levels (about 0.08 Mt NO_x/a) in 2040, compared to similar levels reached in 2050 in the baseline.

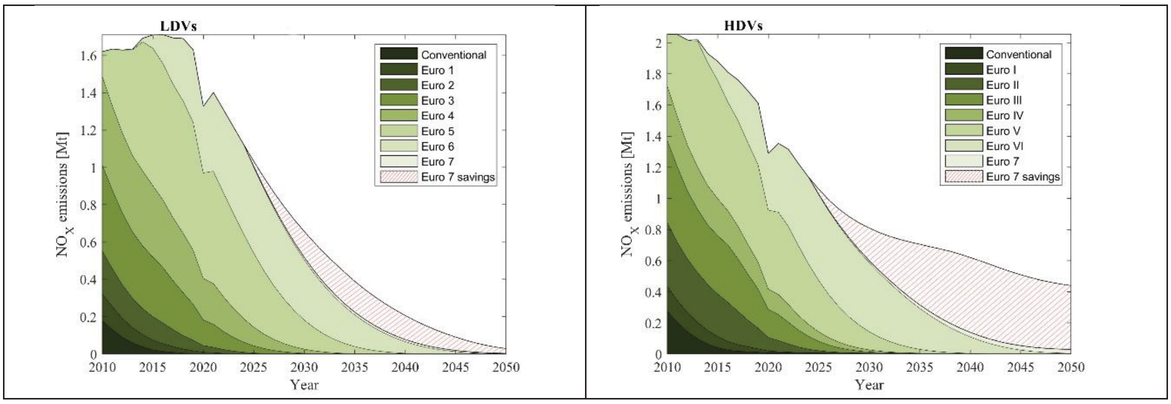
Additional significant reductions can also be expected due to the stricter air pollutant emission limits and increased durability requirements (see details in Annex 4, section 1.2.3.2). Brake emissions, an example for stricter emission limits, have become increasingly relevant sources of non-exhaust particles and are assumed to go down by 16% in 2030 to 36% in 2050 through the use of improved brake pads[178].

For lorries/buses, the highest emission reductions can be expected under PO2a due to the more stringent air pollutant emission limits for NO_x, particles, hydrocarbons, CO, NH_3

[177] No SMEs were identified in the lorries/bus segment.
[178] As there are no testing methods for brake emissions from lorries and buses and for tyre emissions from all vehicle categories developed so far, the environmental impact of those non-exhaust particles cannot be determined and subsequently assessed.

and N_2O emission. NO_x emission are assumed to decrease by 0.2 Mt in 2030 to 0.4 Mt in 2050. This high reduction comes from the fact that in the EU fleet a significant number of HDVs, in particular diesel lorries, is still expected to be equipped with a combustion engine vehicle until 2050 (see Figure 7).

Figure 9 – NO_x reductions from light- and heavy-duty vehicles in PO2a compared to the baseline, Source: SIBYL/COPERT 2021



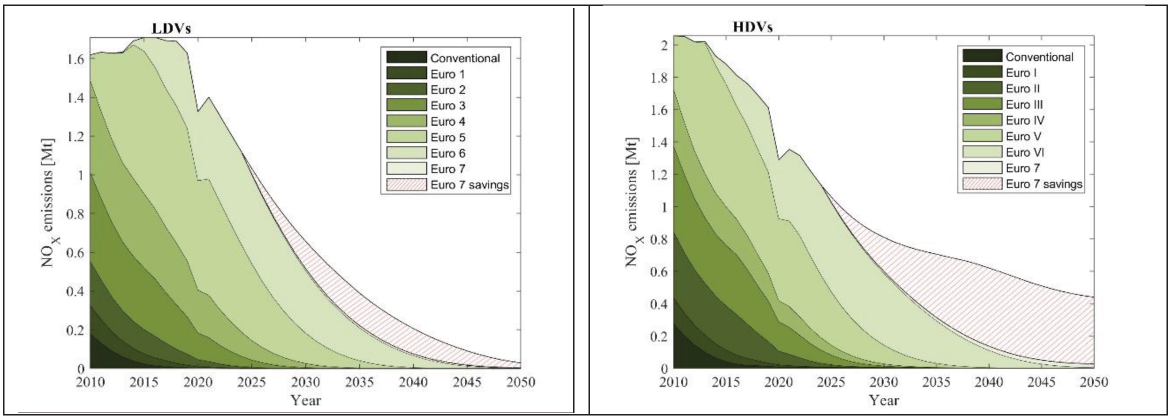
As illustrated for key pollutant NO_x in Figure 10 and for all pollutants in Annex 4, Table 13, the emission reductions compared to the baseline that can be expected by PO2b are significant, in particular for lorries/buses. However, PO2b is expected to lead only to marginal additional emission reductions compared to PO2a for all categories of vehicles (compare Figure 9 and Figure 10).

For cars/vans, the small difference in emission savings between PO2a and PO2b is explained by the small emissions levels. The only major difference are emissions during cold start, which are more effectively controlled under the stricter emission limits under PO2b, rather than under the medium ones in PO2a.

For lorries/buses, the marginal NO_x effect is explained by the fact that the testing conditions are already extended in PO2a leading to the major positive effect on the emission performance. The additional reduction of the NO_x limit from 150 mg/kWh to 100 mg/kWh in PO2b offers a low total emission reductions.[87]

On the other hand, additional reductions are expected for non-exhaust $PM_{2.5}$ emissions from cars/vans. PO2b includes more stringent limits for brake emissions which require improved brake pads and the installation of brake dust particle filter.

Figure 10 – NO_x reductions from light- and heavy-duty vehicles in PO2b compared to the baseline, Source: SIBYL/COPERT 2021



6.2.3 *Social impacts*

6.2.3.1 Monetised health and environmental benefits

Table 6 shows the monetised health and environmental benefits for PO2 compared to the baseline. The two different ambition levels for stricter emission limits, extended real-driving testing boundaries and durability requirements have high health and environmental benefits exceeding significantly the low benefit of PO1.

In PO2a, the reduction of NO_x emissions for cars/vans until 2050 is expected to result in health and environmental benefits of €32.7 billion, while the reduction for lorries/buses is expected to result in benefits of €88.8 billion. For cars/vans, PO2 is also expected to generate health and environmental benefits through a reduction in non-exhaust PM emissions through the inclusion of a new brake emission limit. For all vehicles, PO2 is additionally supposed to result in a reduction of N_2O and CH_4 emissions, of which health and environmental benefits are monetised as climate change cost[163,164].

While the health and environmental benefits related to NO_x, NMHC, N_2O, CH_4 and brake emissions are marginally higher in PO2b, there are no changes for exhaust PM and NH_3 as their emission limits remain the same in both sub-options.

Hence, the impact assessment shows that some of the concerns are justified, such as the marginal gains of PO2b with emission limits lower than 30 mg/km for NO_x and high ambitious real-world testing in all driving condition, resulting from high costs and marginal additional health and environmental benefits compared to PO2a.

Table 6 – Monetised health and environmental benefits for PO2 compared to the baseline, Source: SIBYL/COPERT 2021

	Monetised health and environmental benefits until 2050 (billion €)					
	NO_x	$PM_{exhaust}$	$PM_{non\text{-}exhaust}$	NH_3	NMHC	N_2O+CH_4
PO2a – Medium Green Ambition						
Cars and vans	32.67	0.37	9.90	1.45	0.63	9.77
Lorries and buses	88.80	6.22	0.00	0.79	0.10	36.63
PO2b – High Green Ambition						
Cars and vans	33.24	0.44	14.85	1.46	0.70	14.46
Lorries and buses	89.32	6.29	0.00	0.80	0.11	37.49

6.2.3.2 Employment and skills

A low positive impact on employment at vehicle manufacturers is expected in PO2. Stricter emission limits in both stringency levels and comprehensive real-driving testing will require some additional workforces in the cars/vans as well as the lorries/buses segment due to the related R&D and manufacturing of new components in the vehicles' emission control systems.

In the targeted consultation, **automotive industry** expressed concerns that stringent emission limits and testing in all driving conditions may accelerate the shift to electric cars. While this possible shift has not been assessed quantitatively (as the model takes as a given the fleet of vehicles as projected in the high target level scenario of the impact assessment on CO_2 standards for cars and vans), no compelling reason was found to justify such an accelerated shift due to PO2.[174] The main driver to the electro-mobility transition is, and is expected to remain, climate policies. In fact, stricter emission limits and comprehensive real-driving testing are expected to result in small increase of regulatory costs. This increase does not amount to more than 2.1% of the current cars/vans prices in medium ambitious PO2a and 2.8% in the high ambitious PO2b (see Annex 4, Table 22).

In the targeted consultation, almost half of the component and equipment **suppliers** stressed that new emission limits will create new business opportunities and quality jobs, particularly in relation to technologies required in the emission control systems, engine optimisation and powertrain hybridisation components.[174]

Similarly, a low to moderate positive impact on skills at vehicle manufacturers and suppliers is expected in PO2 compared to the baseline. Stricter emission limits, new limits for brake emissions and extended coverage of pollutants and real-driving testing will require some re- and up-skilling of the workforce in the automotive supply chain of light- and heavy-duty vehicles to address the related R&D and manufacturing of new components in the vehicles' emission control systems. This is in line with the targeted consultation where a large share of industry, Member States and civil society stakeholders indicated that a higher-level education (38 out of 66) and new skills (47 out of 66) will be required for the majority of the personnel in the entire automotive supply chain to successfully apply the measures in PO2.[174] For type-approval authorities, no significant changes are expected in the required skills set. Stakeholders did not express different views on the cars/vans and lorries/buses segments.

The overall contribution of PO2 to the cumulative impact with CO_2 emission standards[32] on employment is not significant, since the sub-options are based in general on existing technologies not requiring a sector transformation. While the CO_2 emission standards for cars/vans are expected to result in the number of jobs increasing by 39 000 in 2030 and even by 588 000 in 2040, the low positive impact of PO2b could indicatively still lead to an additional increase of about 15 thousand jobs in 2030 in the cars/vans segment. On the other hand, PO2a is expected to have a no impact on employment (i.e. also no cumulative employment impact attributable to PO2a). See detailed analysis on the cumulative impacts on employment in Annex 4 chapter 1.5.3.

6.2.3.3 Consumer affordability

The total regulatory costs for industry introduced by PO2 are expected to be passed on to consumers, at least in the longer term. For PO2a and PO2b respectively, this leads in the most relevant segment for low-income consumers, i.e. small cars/vans, to 0.8-2.2% vehicle price increase for petrol vehicles and 2.1-2.8% for diesel vehicles (see Annex 4, Table 22). Impact on consumers' affordability will be low to moderate since diesel engine, where the additional measures are most expensive, is no longer technology of choice for this segment, especially in PO2a.

Private users are not considered as relevant for heavy-duty vehicles. The impact on SME users of heavy-duty vehicles are discussed in section 6.2.1.4.

While **automotive industry** has indicated that more stringent limits would lead to more costly vehicles and a slower fleet turn-over, the expected low impact on consumer affordability in PO2 is more in line with the views of the other stakeholder groups. In the targeted consultation, a **consumer organisation** stated that the previous Euro standards illustrate that an appropriate level of ambition can make vehicles significantly cleaner while not making them disproportionately more expensive.

Looking into the cumulative impact with the newly proposed CO_2 emission standards for cars/vans[32], PO2 is estimated to decrease the net saving in total cost of ownership (TCO) for combustion-engine cars/vans until 2035, but also after this date for zero-emission cars/vans through the proposed brake emission limits. For new cars and vans in 2030, the net TCO savings-first user of €600 achieved through the proposed CO_2 targets are expected to decrease by €114 per car and €258 per van in PO2a compared to €244 per car and €364 per van in PO2b. See detailed analysis on the cumulative impacts on consumers in Annex 4 section 1.5.2.

6.2.3.4 Consumer trust

PO2 with stricter emission limits and comprehensive real-driving testing conditions positively impact the consumer trust in automotive products as it ensures systematic clean vehicles performance.

Also the responses to the targeted consultation suggest that **stakeholders from all groups, except from vehicle manufacturers**,[179] believe that there is potential for a new Euro legislation to further improve consumer trust in emission performance of vehicles and automotive products.[180]

6.3 PO3a: PO2a and Medium Digital Ambition

6.3.1 Economic impacts

6.3.1.1 Regulatory costs for automotive industry

The total regulatory costs for PO3a, adding medium digital ambition to PO2a by introducing Continuous Emission Monitoring (CEM) based on available sensor technology, are estimated in the range of PO2a.[181] The main reason for this is that the cost for available sensor technology is counterbalanced by higher costs savings due to simplified type-approval using CEM data. This finding should support the buy-in of industry stakeholders who raised concerns that the introduction of continuous emission monitoring in combination with stricter emission limits could be too burdensome for European car manufacturers. For cars/vans, total regulatory costs are estimated €304 per vehicle in PO3a.[182][144] Similar to PO2a, these total regulatory cost estimate is below the total regulatory cost associated with introduction of Euro 6 for diesel cars/vans, but exceeds the costs associated with the introduction of Euro 6 for petrol cars/vans.[171] Although PO3a requires the installation of available sensors to allow for CEM, the respective increase in hardware, R&D and calibration costs (€21 per vehicle) is partly cancelled out by reduced costs during implementation phase and administrative costs (€14 per vehicle).

For lorries/buses, total regulatory costs are estimated at €2 681 per vehicle in PO3a. Thus, the increase in hardware, R&D and calibration costs linked to the introduction of CEM (€112 per vehicle) is partly offset by the increase in cost savings during

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[179] Automotive industry, Member States and civil society

[180] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 5.1.4. Social impacts

[181] PO3b on PO2a and High Digital Ambition has been discarded at an early stage (see 5.3).

[182] For cars/vans, this cost per vehicle corresponds to €287 per ICE vehicle for costs linked to requirements for tailpipe and evaporative emissions and €17 per vehicle for all powertrains linked to requirements for brake emissions.

implementation phase and administrative costs (€31 per vehicle). The total regulatory costs that came with the introduction of the Euro VI standards for lorries/buses are still found to be in a higher range (€3 717-€4 326 per vehicle).

In PO3, the administrative burden is further decreased as the new CEM requirements are expected to further simplify the reporting and other information provision obligations[146] for granting type-approval and verification procedures through reduced number of type-approvals. This leads to additional cost savings for all vehicle categories. In PO3a, administrative cost savings are estimated at €224 thousand per type-approval (€22 per vehicle) for diesel cars/vans and at €204 thousand per type approval for petrol cars/vans (€26 per vehicle).

For lorries/buses, the administrative cost savings in PO3a amount up to €66 thousand per diesel type-approval (€22 per vehicle) and €67 thousand per petrol type-approval (€47 per vehicle).

A detailed description of the total regulatory costs for automotive industry in PO3 compared to the baseline is available in Annex 4, section 1.3.1.3.

Table 7 presents the total regulatory costs in 5-year intervals over the period of implementation of medium ambition emission limits and introduction of available CEM in PO3, including tailpipe, evaporative and brake emissions. It shows that the largest share of the costs occur in the first ten years after 2025. After that, the costs will decrease with a **small share of the costs remaining after 2035**, mainly resulting from **brake emissions requirements for all cars and vans, including zero-emission vehicles**, and **combustion-engine lorries/buses.** They will also be due to the need to continue market surveillance and in-service conformity checks throughout the lifetime to vehicles (i.e. at least for another 10-15 years after the first registration).

Table 7 – Expected distribution of total regulatory costs in PO3a compared to the baseline, in billion € and 2025 NPV

	2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total
Cars and vans	8.91	15.05	4.23	1.03	0.86	0.72	30.80
Lorries and buses	6.11	6.01	2.18	1.33	0.74	0.56	16.94

Taking into account the market share of car/van manufacturers in the EU[149], over the 25-year period the two largest manufacturing groups, would have to invest between €5.1 and €5.7 billion each in PO3a for the whole period 2025 to 2050. For all other car/van manufacturers, PO3a would only require a total investment between €0.6 and €2.8 billion depending on the size for the whole period. This a small additional amount to the €59 billion each car manufacturer is expected to invest for the shift to automation, connectivity and electrification. [151]

The total regulatory costs for the industry divided by 12 main manufacturers of lorries/buses translate to investment of €1.4 billion per lorries/bus manufacturer for PO3a.

Especially **automotive industry** has raised concerns regarding too high cumulative impacts in view of the CO_2 investments. With the end-date of combustion-engine cars/vans by 2035, the cumulative annual investment of PO3a and proposed CO_2 emission standards[32] over 2021-2040 amounts to €20.2 billion, out of which €19 billion is due to the proposed CO_2 target and €1.2 billion due to PO3a (see Annex 4, Table 33).

The investment attributable to PO3a is considered with 7% increase in annual investments not too high. See detailed analysis on the cumulative impacts on industry in Annex 4 section 1.5.4.

Table 5 (II.C) in Annex 3 presents an overview of these regulatory costs for manufacturers split up in one-off and recurrent costs linked to the different policy measures, including simplification measures, medium ambition emission limits, real driving testing boundaries and durability and medium ambition continuous emission monitoring.

6.3.1.2 Competitiveness

Since the medium ambition stricter emission limits and real driving testing boundaries of PO2a are also part of PO3a, the arguments relevant for PO2 are also applicable for both vehicle segments in this policy option. While the majority of component **suppliers** participating in the targeted consultation indicated that continuous emission monitoring in combination with stricter emission limits would positively affect the competitive position of the EU automotive industry, **vehicle manufacturers** consider it too burdensome.

Next to a medium green ambition, PO3a also introduced a medium digital ambition by introducing requirements regarding continuous emission monitoring systems. PO3a is expected to have a moderate positive effect on competitiveness in terms of innovation and access to international markets. Continuous emission monitoring systems are relevant in several third markets for which cleaner ICE vehicles are still needed in view of an expected higher age of the vehicle fleet than the up to 19 years in the EU cars/vans fleet and up to 21 years in the EU lorries/buses fleet[183].

The introduction of CEM with modern IT functionalities in PO3a is considered as an element of digital **innovation** in the automotive sector. In addition, the development of sensors and digital communication systems creates opportunities, some of them beyond the automotive supply-chain i.a. in cybersecurity area[184]. European suppliers of communication systems are expected to develop secure protocols for the transmission of information and other IT solution to protect the emission control systems from tampering under PO3 and to facilitate the secure transmission of data. Further synergies with the access to data regulations are also expected, ensuring adequate protection of personal data which are not needed for checking compliance of a vehicle type. It is also worthwhile mentioning that the introduction of CEM is expected to be of high interest for periodic technical inspections and roadside checks of vehicles.

Similar developments in other key markets in the field of continuous emission monitoring (US with REAL initiative, China with remote on-board diagnostics for heavy-duty vehicles) demonstrate that PO3a could further close the gap between the EU and other countries emission standards.

Lastly, PO3a will also facilitate the implementation of geo-fencing. As a consequence, new business models using the information collected can be developed to support the

[183] ACEA, 2021. Average age of the EU vehicle fleet, by country.
[184] UC Riverside, 2020. How to create a paradigm shift in vehicle emission regulation

concept of Smart Cities[185] and to offer new solutions regarding the improvement of air quality.

Despite the regulatory costs for industry and cumulative investments with CO_2 emission standards (see 6.3.1.1), stimulating digital, green and electric innovation would allow the EU automotive sector to maintain access to international markets which would improve its competitive position over the baseline. Since cost for available sensor technology, as assumed in PO3a, is counterbalanced by costs savings due to simplified type-approval (see 6.3.1.1), the investment for PO3a is not higher than for PO2a and not considered too burdensome for vehicle manufacturers.

6.3.1.3 Single market

PO3 would significantly improve and simplify compliance of motor vehicles with emission rules and therefore improve the trust on the automotive sector. The possibility to introduce geo-fencing possibilities could allow a wider range of powertrains in zero-emission zones (i.e. zero-emission enabled PHEVs). That way, PO3a could counter the national measures (e.g. zero-emissions zones or phasing-out combustion engines, see section 2.3) and preserve the single market.

6.3.1.4 SMEs

The CEM requirements could be more difficult and costly to implement for the 35 SME cars/vans manufacturers[186] (see 6.1.1.4). Considering that those SMEs use engines equipped with on-board fuel consumption meters (OBFCM)[137] from larger manufacturers, the implementation of available sensor technologies based on the OBFCM communication platform is not expected to be a challenge.

As the total regulatory costs related to PO3 are expected to be passed on to SME users, they are mostly concerned about the affordability of vehicles. Similar to PO2a, the total regulatory costs in PO3a amount up to 2.2% for small cars/vans and up to 3.2% for small lorries of the vehicle price (see Annex 4, Table 25). Hence, the introduction of CEM is expected to have medium negative impact on the affordability for SME users.

6.3.2 Environmental impacts

As illustrated for key pollutant NO_x in Figure 11 and all pollutants in Annex 4, Table 14, the emission reductions that can be expected in PO3a compared to the baseline are significant, in particular for lorries/buses. Also for cars/vans, very low NO_x emission levels are reached in 2040, compared to 2050 in the baseline (see 6.2.2).

Through the introduction of continuous emission monitoring for NO_x and NH_3 emissions, some additional emission reductions are expected compared to the introduction of strict emission limits only (PO2a). This is due to improved compliance with emission limits and improved protection against tampering with the emission control systems.

Figure 11 – NO_x reductions from light- and heavy-duty vehicles in PO3a compared to the baseline, Source: SIBYL/COPERT 2021

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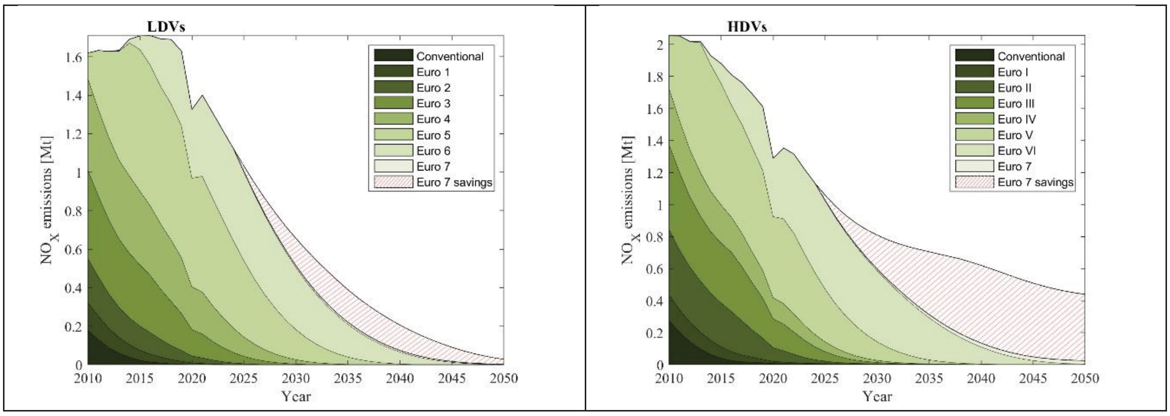
185 European Commission, 2022. Smart cities

186 No SMEs were identified in the lorries/bus segment.



6.3.3 Social impacts

6.3.3.1 Monetised health and environmental benefits

Table 8 shows the monetised health and environmental benefits for PO3a compared to the baseline. New CEM requirements in a Medium Digital Ambition, in addition to the medium ambition stricter emission limits and extended real-driving testing boundaries in PO2a, are expected to result in additional benefits for nearly all pollutants.

In PO3a, some additional health and environmental benefits could be realised through the monitoring of NO_x and NH_3 over the vehicle lifetime (see Annex 6, Table 55). The reduction of NO_x emissions for cars/vans until 2050 is expected to result in a health and environmental benefit of €33.5 billion, while for lorries/buses it is expected to result in a benefit of €89.6 billion. Also the emission reductions for NH_3 in PO3 result in additional health and environmental benefits beyond PO2, more so for lorries/buses than for cars/vans. These benefits are expected to amount up to €1.5 billion for cars/vans (€60-€50 million more than in PO2a and PO2b) and up to €0.9 billion for lorries/buses.

Table 8 – Monetised health and environmental benefits for PO3a compared to the baseline, Source: SIBYL/COPERT 2021

	Monetised health and environmental benefits until 2050 (billion €)					
	NO_x	$PM_{exhaust}$	$PM_{non-exhaust}$	NH_3	NMHC	N_2O+CH_4
Cars and vans	33.45	0.37	9.90	1.51	0.67	9.77
Lorries and buses	89.63	6.22	0.00	0.91	0.10	36.63

6.3.3.2 Employment and skills

In PO3, a low positive impact is expected on employment by vehicle manufacturers. The introduction of CEM in addition to stricter emission limits, will require some additional workforce for the manufacturing and R&D for new components in the vehicles' emission control systems and new specialised IT jobs on data communication. The CEM functionality could simplify and modernise the existing on-board diagnostics.

PO3 is expected to result in a direct positive impact on employment, exceeding the impacts of PO2a, in the supply segment of the industry. CEM would require the most intensive R&D and innovation activity among all options to develop and implement the necessary technologies (e.g. on-board sensors and intelligent vehicle communication protocols). This would apply for cars/vans as well as lorries/buses, since sensors are designed for application in all vehicles, light and heavy-duty ones. In addition, almost half of the suppliers stressed in the targeted consultation that the requirements in PO3 could create new business opportunities and quality jobs in the field of sensor technology.

A large share of **industry, Member States and civil society stakeholders** indicated that a higher-level education and new skills will be required for the majority of the personnel in the entire automotive supply chain to successfully apply the measures in PO3a. Compared to the baseline and the previous policy options, a significant up- and re-skilling of the workforce in the automotive supply chain is expected due to the introduction of CEM.

While the **automotive industry** is already expanding relevant expertise by investing in module integration, software development and semiconductor design[187], CEM is expected to further encourage demand for connected vehicles with advanced electronic information and communication. Therefore, the industry will need re- and up-skilling in order to bridge the existing knowledge gap between the automotive and ICT sector and contribute to the digital transformation. This will be a key enabler for reaching the Green Deal objectives.

Some re- and up-skilling regarding sensor operation and verification may be required for type-approval authorities. In PO3, in-service conformity and market surveillance are expected to be mostly dependent on the verification of on-board monitored emissions of the vehicle model family.

The contribution of PO3a to the cumulative impact with CO_2 emission standards[32] on employment is expected to be low, since it is based on existing technologies not requiring a sector transformation. While the CO_2 emission standards for cars/vans are expected to result in the number of jobs increasing by 39 000 in 2030 and even by 588 000 in 2040, the low positive impact of PO3a could indicatively lead to an additional increase of about 9 thousand jobs in 2030 in the cars/vans segment. See detailed analysis on the cumulative impacts on employment in Annex 4 section 1.5.3.

6.3.3.3 Consumer affordability

The total regulatory costs for industry introduced by PO3 are expected to be passed on to the consumers, at least in the longer term. This is especially important for the segment of small cars/vans which is the most relevant for low-income consumers. For small petrol vehicles, PO3a is expected to lead to vehicle price increases up to 0.8% (see Annex 4, Table 25). The impact on consumer affordability will be low since small diesel vehicles, with an estimated price increase of 2.2%, are no longer the technology of choice for the small vehicle segment. This conclusion is in line with the view from a **consumer organisation** which stated that an appropriate level of ambition can make vehicles significantly cleaner while not making them disproportionately more expensive.

Private users are not considered relevant for heavy-duty vehicles. The impact on SME users of heavy-duty vehicles are discussed in section 6.3.1.4.

Looking into the cumulative impact with the newly proposed CO_2 emission standards for cars/vans[32], PO3 is estimated to decrease the net savings in total cost of ownership

[187] Roland Berger, 2020. The car will become a computer on wheels

(TCO)-first user from €600 per vehicle by €112 for cars and by €255 for vans in 2030. See detailed analysis on the cumulative impacts on consumers in Annex 4 section 1.5.2.

6.3.3.4 Consumer trust

Through continuous emission monitoring, more information regarding the emission performance of vehicles could be made available to consumers. The digital solutions offered in this policy option could positively affect the consumers' perception of the emission standards and subsequently improve consumer trust in good environmental performance of vehicles. Continuous emission monitoring is expected to help detecting non-compliance and malfunction at an early stage which should lead to vehicles emitting less pollutants over their lifetime. Consumers and the general public get higher assurance that their vehicles continues to be clean during its use. Hence, it is expected that PO3 has an additional positive impact on consumer trust compared to PO2a.

7 HOW DO THE OPTIONS COMPARE?

The options are compared against the following criteria:

- Effectiveness: the extent to which the different options would achieve the specific objectives;
- Efficiency: the extent to which the benefits can be achieved for a given level of resource/at least cost;
- Coherence of each option with other EU rules tackling air pollutants in the road transport sector;
- Proportionality: overall assessment of the effectiveness, efficiency and coherence of each of the options.

Table 9 and Table 10 summarise the assessment of each option against those criteria, differentiated between light- and heavy-duty vehicles and following the impacts assessed in chapter 6. Given that there is no weighing of the impacts, major impacts and the other impacts which have less impact on stakeholders are distinguished.

Table 9 – Comparison of the policy options for light-duty vehicles in terms of effectiveness, efficiency and coherence[1]

Policy option	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
Effectiveness				
Reduce complexity of the current Euro emission standards	++	++	++	+++
Provide up-to-date limits for all relevant air pollutants	0	++	+++	++
Improve control of real-world emissions	+	++	++	+++
Efficiency				
A. Major impacts on industry				
Regulatory costs: Equipment costs	-	--	---	--
Regulatory costs savings: Testing, witnessing, type-approval and administrative costs savings	++	++	++	+++
Competitiveness: Access to international key markets	0	+	+	++
Competitiveness: Innovation	0	0	+	++
B. Other impacts on industry				
Free movement within the single market	0	0	+	+
Affordability for SME users	0	-	--	-
C. Major impacts on citizens				
Health and environmental benefits	+	++	+++	++
Consumer affordability	0	-	--	-
D. Other impacts on citizens				
Consumer trust	+	++	++	+++
Employment and skills	0	0	+	+
Quantitative efficiency				
Net benefits	0	+	--	+
Coherence				
European Green Deal: Green and digital transformation	0	++	+++	+++
Ambient Air Quality/ National Emission reduction Commitments Directives	0	+	++	+
CO_2 emission standards	0	+	++	+
Roadworthiness	+	+	+	+++

[1] --- high negative, -- moderate negative, - low negative, 0 neutral, + low positive, ++ moderate positive, +++ high positive

Table 10 – Comparison of the policy options for heavy-duty vehicles in terms of effectiveness, efficiency and coherence[1]

Policy option	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Digital Ambition
Effectiveness				
Reduce complexity of the current Euro emission standards	++	++	++	+++
Provide up-to-date limits for all relevant air pollutants	0	++	+++	++
Improve control of real-world emissions	+	++	++	+++
Efficiency				
A. Major impacts on industry				
Regulatory costs: Equipment costs	0	-	--	-
Regulatory costs savings: Testing, witnessing, type-approval and administrative costs savings	+	+	+	++
Competitiveness: Access to international key markets	0	+	+	++
Competitiveness: Innovation	0	0	+	++
B. Other impacts on industry				
Free movement within the single market	0	0	+	+
Affordability for SME users	0	-	--	-
C. Major impacts on citizens				
Health and environmental benefits	+	+++	+++	+++
Consumer affordability	Private users not relevant for heavy-duty vehicles			
D. Other impacts on citizens				
Consumer trust	+	++	++	+++
Employment and skills	0	0	+	+
Quantitative efficiency				
Net benefits	0	+++	++	+++
Coherence				
European Green Deal: Green and digital transformation	0	++	++	+++
Ambient Air Quality/ National Emission reduction Commitments Directives	0	++	+++	++
CO_2 emission standards	0	++	+++	++
Roadworthiness Directives	+	+	+	+++

[1] --- high negative, -- moderate negative, - low negative, 0 neutral, + low positive, ++ moderate positive, +++ high positive.

7.1 Effectiveness

The policy options address to different degrees the specific objectives of the initiative, without going beyond what is necessary.

Concerning the specific objective to **reduce complexity of the current Euro emission standards**, it is effective that the proposed Euro 7 regulation combines Euro 6 emission standards for cars/vans and Euro VI emission standards for lorries/buses in one single regulation, with simplification measures such as references to relevant UNECE regulations regarding testing procedures, fuel- and technology-neutral limits and the use of a single date of Euro 7 introduction per vehicle segment applied for all cars/vans and lorries/buses respectively in all policy options. For cars/vans as well as lorries/buses, PO3a seems to be most suitable to reduce complexity, as continuous emission monitoring equipment is expected to simplify the reporting and other information provision obligations for granting of type-approval and ease the verification testing procedures.

Due to the strictest update of existing emission limits and setting of new ones, PO2b is considered for cars/vans as well as lorries/buses as most effective regarding the specific objective to **provide up-to-date limits for all relevant air pollutants.** PO1 is considered to be not more effective than the baseline as the update of obsolete limits is too limited. PO2a and PO3a are slightly less ambitious than PO2b, but go significantly beyond PO1 for all vehicles.

Regarding the specific objective to **improve control of real-world emissions**, the effect of PO1 is rather limited as the RDE testing conditions are only slightly and the durability requirements are not expanded compared to Euro 6/VI. PO2a/PO2b go further by extending the durability to the average/full lifetime of the vehicle and covering medium/high ambitious real-driving testing conditions. However, the additional use of continuous emission monitoring through on-board sensors, in addition to PO2a, leads to the highest effectiveness in PO3a for cars/vans as well as lorries/buses.

7.2 Efficiency

Major impacts on industry

Regulatory costs (covering substantive compliance costs due to equipment costs for emission control technologies and the related R&D and calibration costs including facilities and tooling costs) are assessed to be highest for PO2b, in the order of €67 billion between 2025 and 2050 for light-duty vehicles and €26 billion for heavy-duty vehicles, due to the use of more advanced equipment for emission control (brake filters for cars/vans segment instead of brake pads used in PO2a and PO3a, and advanced tailpipe emission control technology for both vehicle segments). PO1 is the least costly as only limited emission control technologies are introduced for light-duty vehicles and none for heavy-duty vehicles.

In terms of **regulatory costs savings** (covering substantive compliance costs savings during testing, witnessing of tests by type-approval authorities and type-approval fees as well as administrative costs savings for reporting and other information obligation as part of the type-approval procedures), the assessment indicates for all policy options a reduction compared to baseline in the order of €3.5 to €4.7 billion until 2050 for light-duty vehicles and €0.4 to €0.6 billion for heavy-duty vehicles. This difference is due to the limited number of heavy-duty vehicles sold each year. PO3a shows for all vehicles higher reductions than the other options, as continuous emission monitoring equipment is expected to facilitate the type-approval and testing procedures.

Especially automotive industry has raised concerns regarding too high **cumulative investments with CO_2 emission standards**. With the end-date of combustion-engine cars/vans by 2035, the cumulative annual investment of PO2a/PO2b/PO3a and CO_2 emission standards[32] over 2021-2040 for the whole automotive industry amounts to €20.2/€21.4/€20.2 billion, out of which €19 billion is due to the proposed CO_2 target and €1.2/€2.4/€1.2 billion[188] due to PO2a/PO2b/PO3a. The investment attributable to PO2a and PO3a are considered not too high, while the investment attributable to PO2b is considered with 13% high.

Despite the regulatory costs for industry and cumulative investments with CO_2 emission standards, PO2 and PO3 are expected to have some positive effect on **competitiveness**. PO3a shows for cars/vans as well as lorries/buses the highest positive impacts in terms of **access to international key markets** and **innovation**. This is due to new market opportunities stemming from the use of available sensors. The use of best available emission control technologies and sensors in PO3a supports access to international key markets, in particular United States and China. Stimulating twin innovation in zero-emission technologies by proposed CO_2 emission standards and in low emission technology by proposed Euro 7 pollutant standards, the competitive position of the EU automotive sector can be improved over the baseline.

Other impacts on industry

PO3a and PO2b are considered to have some positive impact on the **single market** for both vehicle segments. Introduction of the best available emission control technologies and continuous emission monitoring on EU level could prevent Member States from taking unilateral decisions to address excessive emissions from road transport. PO3a offers additionally the possibility of geo-fencing to support Member States and cities in their journey towards improving air quality in densely populated areas. This technology could make it possible to allow a wider range of powertrains in zero-emission zones (i.e. zero-emission enabled PHEVs).

As far as SMEs are concerned, no significant impacts are expected, except of **affordability for SME users** (e.g. transport or logistics services, vehicle rental or leasing companies, companies using vehicles). Vehicle prices are expected to increase due to additional costs for emission control systems. This effect is expected to be the most pronounced in the smaller vehicle segments with lower average prices. For small cars/vans, a low negative impact on the affordability for SME users is supposed in PO2a and PO3a where total regulatory costs could reach about 2% of the vehicle price. A medium negative impact is assumed in PO2b where the total regulatory costs could reach about 3% of the vehicle price. For small lorries, also a low negative impact is expected in PO2a and PO3a, whereas a medium negative impact is supposed in PO2b.

[188] While in the CO_2 impact assessment the investments are assessed over the period 2021-2040, Euro 7 investments only start in 2025 after its application. Nevertheless, the annual average of Euro 7 is still calculated over the period 2021-2040 to provide comparable numbers with the investments in the CO_2 impact assessment. (For more information see Annex 4: chapter 1.5.4. Cumulative impacts on industry)

Major impacts on citizens

PO2a, PO2b and PO3a offer substantial **health and environmental benefits** due to reduced emissions of harmful air pollutants (see Table 11 and Table 12). The main benefits for citizens are substantial health benefits, expected to result in a reduction of medical treatment costs, production losses due to illnesses and even deaths. Since the emission savings also reflect reduced damage costs on crop and biodiversity losses and material and building damage, i.e. environmental benefits, no policy option is expected to do significant harm to the environmental Sustainable Development Goals. **The main driver of the high positive impacts is the reduction of NO_x and $PM_{2.5}$ emissions, while the reduction potential for heavy-duty vehicles is in kilotons twice as high as for light-duty vehicles.**

Table 11 – Assessment of the environmental impacts of policy options compared to the baseline: reduction of emissions of air pollutants in 2035 for cars/vans, Data source: SIBYL/COPERT 2021

Pollutant	Latest available emissions	Baseline	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
	2018 in kt	2035 in kt, % compared to baseline				
NO_X	1 689.67	389.40	285.30 (-27%)	224.40 (-42%)	221.80 (-43%)	220.80 (-43%)
$PM_{2,5,\text{ brake emissions}}$	14.90	16.04	16.04 (-0%)	11.82 (-26%)	9.71 (-40%)	11.82 (-26%)
$PM_{2,5,\text{exhaust}}$	43.85	1.50	1.31 (-13%)	1.28 (-15%)	1.25 (-16%)	1.28 (-15%)
PN_{10} [in #]	$6.55x10^{25}$	$1.92x10^{24}$	$1.63x10^{24}$ (-15%)	$1.06x10^{24}$ (-45%)	$1.05x10^{24}$ (-45%)	$1.06x10^{24}$ (-45%)
CO	2 796.13	584.50	550.50 (-6%)	414.90 (-29%)	405.10 (-31%)	414.90 (-29%)
THC	412.22	146.10	145.50 (-0%)	113.20 (-23%)	110.50 (-24%)	111.50 (-24%)
NMHC	369.70	119.20	119.00 (-0%)	93.80 (-21%)	91.10 (-24%)	92.11 (-23%)
NH_3	38.41	23.85	18.73 (-21%)	16.15 (-32%)	16.14 (-32%)	15.90 (-33%)
CH_4	42.52	26.85	26.52 (-1%)	19.42 (-28%)	19.38 (-28%)	19.42 (-28%)
N_2O	16.34	41.26	40.69 (-1%)	28.91 (-30%)	23.81 (-42%)	28.91 (-30%)

Table 12 – Assessment of the environmental impacts of policy options compared to the baseline: reduction of emissions of air pollutants in 2035 for lorries/buses, Data source: SIBYL/COPERT 2021

Pollutant	Latest available emissions	Baseline	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
	2018 in kt	2035 in kt, % compared to baseline				
NO_X	1 689.73	705.40	605.60 (-14%)	316.10 (-55%)	314.00 (-55%)	312.60 (-56%)
$PM_{2,5}$, brake emissions	-	-	-	-	-	-
$PM_{2,5}$, exhaust	23.45	8.81	8.81 (-0%)	5.37 (-39%)	5.35 (-39%)	5.37 (-39%)
PN_{10} [#]	$3.70x10^{25}$	$7.49x10^{23}$	$7.49x10^{23}$ (-0%)	$4.06x10^{23}$ (-46%)	$4.05x10^{23}$ (-46%)	$4.06x10^{23}$ (-46%)
CO	412.92	111.50	111.50 (-0%)	97.90 (-12%)	89.08 (-20%)	97.93 (-12%)
THC	43.38	26.55	26.55 (-0%)	23.06 (-13%)	22.84 (-14%)	23.06 (-13%)
NMHC	36.71	16.66	16.66 (-0%)	12.95 (-22%)	12.77 (-23%)	12.95 (-22%)
NH_3	6.46	9.64	9.64 (-0%)	6.45 (-33%)	6.43 (-33%)	6.00 (-38%)
CH_4	6.67	9.89	9.89 (-0%)	10.10 (+2.1%)	10.07 (+1.8%)	10.10 (+2.1%)
N_2O	57.13	97.80	97.80 (-0%)	58.30 (-40%)	58.10 (-41%)	58.30 (-40%)

The impact of the new requirements on **consumer affordability** in the cars/vans segment would be limited[189]. The total regulatory costs compared to baseline are expected to be passed on to consumers, while the impact of the affordability for lorries/buses is explained under the impacts to the industry and SMEs. This leads in PO2 and PO3 in the segment of small petrol cars/vans, which is the most relevant for low-income consumers, to a 0.8-2.2% increase in petrol vehicle prices. While the highest price increase of 2.8% for diesel vehicles in PO2b is above the price increase in the previous Euro standard, the impact on consumers' affordability will be limited considering that this is no longer the technology of choice for this segment. The impact on the affordability of the second-hand consumers is expected to be even less. This conclusion is in line with the view from a **consumer organisation** which stated that an appropriate level of ambition can make vehicles significantly cleaner while not making them disproportionately more expensive.

When looking into the **cumulative consumer affordability with the proposed CO_2 emission standards for cars/vans**, the concept of total cost of ownership (TCO)-first user has to be used. Since fuel and electricity savings from the use of zero-emission vehicles are significant for consumers, the CO_2 emission standards decrease the total cost of ownership (TCO) of such vehicles. The 1.7-2.3% increase in diesel vehicle prices in PO2a, PO2b and PO3a leads for the consumer to a decrease of the TCO savings in 2030 from €600 per car/van when only the effect of a 100% CO_2 target in 2035 is taken into account to €486, €356 and €488 per car/van when additionally the effect of PO2a, PO2b and PO3a are taken into account.

[189] Private users/consumers are considered not relevant in the lorries/buses segment. The affordability for SME users of this vehicle segment are discussed above under "other impacts on industry".

Other impacts on citizens

All policy options are expected to have positive impacts on **consumer trust**, as they improve vehicles' environmental impact. The impact is expected to be most extensive for all vehicles in PO3a which enables sharing more and reliable information on emission performance of vehicles to consumers through continuous emission monitoring.

The introduction of stricter emission limits and continuous emission monitoring (PO2b, PO3a) is expected to have for cars/vans as well as lorries/buses a low positive impact on **employment and re- and up-skilling of workforces.**

Since the policy options are based in general on existing technologies not requiring a sector transformation, the contribution to the **cumulative impact on employment with the CO_2 emission standards** is not significant. While the CO_2 emission standards for cars/vans are expected to result in the number of jobs increasing by 39 000 in 2030 and even by 588 000 in 2040, the low positive impact of PO2b and PO3a could indicatively still lead to an additional increase of about 15 thousand and 9 thousand jobs in 2030 in the cars/vans segment. About half of the **vehicle manufacturers** also claimed that employment in businesses focused on traditional combustion-engines would be negatively affected. This employment effect due to the shift to electric vehicles has been taken into account in these cumulative impacts.

Quantitative efficiency

In order to assess the quantitative efficiency of policy options, total regulatory costs are compared to the monetised health and environmental benefits of a reduction of air pollution (as **net benefits i.e. the difference between the present value of the benefits and costs**)[190]. The baseline against which the policy options are assessed until 2050 considers that fleet renewal would lead to a higher share of Euro 6/VI vehicles in the vehicles mix, an end-date of combustion-engine cars/vans in 2035 and a decrease of combustion-engine lorries/buses in line with the projected HDV fleets (see 5.1).

The main benefits of the policy options are substantial health and also environmental benefits for citizens due to reduced emissions of harmful air pollutants from cars/vans as well as from lorries/buses. This health and environmental benefit can be monetised using the concept of external costs developed for the Commission's Handbook on the external costs of transport. It reflects the damage costs by air pollution to health and environment, in particular medical treatment costs, production losses due to illnesses and even deaths. In addition, the benefits reflect impact on the environment by air pollutants such as crop and biodiversity losses as well as material and building damage.

The total regulatory costs in the cars/vans as well as in the lorries/buses segment consist of 1) equipment costs for emission control technologies and the related R&D and calibration costs including facilities and tooling costs, 2) costs during implementation

[190] For methodological reasons and for clarity purposes, the focus of the efficiency assessment is on net benefits which are an indicator of the attractiveness of an option in absolute terms (thus the larger the difference between benefits and costs, the better) and do not bias the results for low-cost options, compared to the benefit-cost ratio (BCR). The BCR gets disproportionally high when costs are low which gives an unjustified advantage to low-cost options (i.e. PO1) and has the potential to mislead policy makers. Moreover, the BCR is independent form the scale of options considered, which contradicts the necessity to consider in absolute terms the regulatory costs and environmental and health benefits of reducing air pollutants. The BCR is therefore disregarded to choose one option and is included in Tables 27, 29, 59 and 60 of the Annexes 4 and 8 for completeness purposes only.

phase for testing, witnessing of tests by type-approval authorities and type-approval fees and 3) administrative costs (reporting and other information obligations as part of the type-approval procedures). In all policy options the increase in total regulatory costs is due to 1) equipment costs, reduced by 2) cost savings during the implementation phase and 3) administrative costs savings both due to simplification measures (see Annex 4, Table 15, 18, 19 and 23). Regulatory cost from 1) is considered as cost; and regulatory costs savings from 2) and 3) are considered as benefit in the efficiency assessment.

As shown in Table 13, the benefits outweigh the costs in the policy options, except in PO2b for cars/vans in which the benefits equal the costs. For the other policy options, positive results are also expected when considering the medium to high level of confidence of the benefits and cost estimations (see details on uncertainty of the cost-benefit analysis in Annex 4, section 1.3.2.1).

For cars/vans, PO2a and PO3a are estimated to lead to sufficient net benefits among the analysed options with an average of about €25 billion and a range from €22-€28 billion. However, for PO2b, based on more advanced emission control technologies such as brake filters instead of brake pads leading to higher costs, the low net benefits are with the range of €0.87-€1.81 billion considered not sufficient.

For lorries/buses, PO2a and PO3a offer very high net benefits with an average of about €117 billion and a range from €99-€134 billion, while PO2b shows lower relative benefits. **The difference in net benefits compared to cars/vans can be explained by the higher emission reduction potential for HDV.**

For all vehicles, PO1 offers only low net benefits, compared to other options. Although PO1 is estimated to lead to significantly lower regulatory costs due to minimal change to the emission limits and testing requirements and cost savings by simplification measures, the health and environmental benefits in terms of emission reductions are however lower than for all other policy options.

To further analyse PO2a and PO3a having about the same average net benefit as well as different net benefits in the cars/vans and lorries/buses segment, qualitative elements of the effectiveness, efficiency and coherence analysis will be taken into account in the proportionality analysis (see 7.4).

Table 13 – Assessment of quantitative efficiency of policy options for light- and heavy-duty vehicles compared to baseline*, 2025-2050, Introduction of Euro 7 in 2025, Data source: SIBYL/COPERT 2021

Policy option	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
Cars and vans				
Health and environmental benefits, 2025 NPV in billion €	22.37±3.29	54.82±8.22	65.18±9.77	55.75±8.35
Regulatory costs savings, 2025 NPV in billion €	3.50±0.35	3.45±0.35	3.45±0.35	4.67±0.47
Regulatory costs, 2025 NPV in billion €	8.54±1.41	33.73±5.52	67.30±10.58	35.48±5.71
Net benefits, 2025 NPV in billion €	**17.33±2.23**	**24.55±3.05**	**1.34±0.47**	**24.94±3.11**
Lorries and buses				
Health and environmental benefits, 2025 NPV in billion €	21.14±3.17	132.54±19.88	134.01±20.10	133.58±20.02
Regulatory costs savings, 2025 NPV in billion €	0.38±0.04	0.38±0.04	0.38±0.04	0.58±0.06
Regulatory costs, 2025 NPV in billion €	0.65±0.13	16.82±2.92	26.03±4.30	17.53±3.05
Net benefits, 2025 NPV in billion €	**20.86±3.08**	**116.10±17.00**	**108.36±15.84**	**116.64±17.03**

** The baseline considers an end-date of combustion-engine cars/vans in 2035, see section 5.1.*

Alternative set of assumptions on emission limits and durability

In the stakeholder consultations, automotive industry and civil society representatives raised concerns, often having diverging opinions, regarding the level of emission limits, length of durability requirements and the technological potential for reducing emissions over the lifetime of the vehicles. In addition to the different emission limits and durability assumed in the examined policy options an alternative set of assumptions was assessed to address remaining uncertainty around the medium green ambition on emission limits and durability in PO2a. It allows in particular to test the sensitivity of the environmental gains to the choice of the emissions limits, and the respective costs and benefits of increasing the durability of the measures.

The assessment has been carried out, based on two scenarios for each type of vehicle: one scenario assumes slightly higher (i.e. less ambitious) emission limits when compared to the medium ambition emission limits in PO2a (see Table 56 in Annex 8). Another scenario assumes increased durability by extending the durability from the average to the full lifetime of light- and heavy-duty vehicles. The alternative assumption on emission limits leads to lower emission savings when compared with PO2a, but it still results in the same regulatory costs (see Table 59 in Annex 8). The alternative assumption on durability results in slightly higher health and environmental benefits, while also increasing hardware costs lead to slightly higher regulatory costs (see Table 60 in Annex 8). In conclusion, the net benefits of the alternative set of assumptions are, in case of durability requirements, the same or, in case of emission limits, just slightly worse than PO2a, while remaining overall largely positive. **This conclusion is valid for light- and heavy-duty vehicles.**

Since the emission limits and durability assumptions are the same in PO2a and PO3a, for light-and heavy-duty vehicles, the conclusions drawn are also valid for PO3a.

7.3 Coherence

As aimed high in the **European Green Deal**, all sectors should undergo a **green and digital transformation**, including the road transport, to reach zero-pollution ambition for a toxic-free environment.

Transport should become drastically less polluting, especially in cities and Euro 7 is considered as a vital part of the transition towards zero-emission vehicles on EU roads. PO2b is considered for light-duty vehicles most effective towards zero-emission cars/vans on EU road due to the use of best available emission control technology, closely followed by PO3a using existing emission control and sensor technology. For heavy-duty vehicles, PO3a is considered most effective towards zero-emission lorries/buses on EU road. This difference between the vehicle segments is due to the fact that effective brake filters that have a high benefit can be considered in PO2b for the moment only for cars/vans (no brake emission data available for HDV). This may change in the future, once the brake filters are a more mature technology, and they may also be applied for heavy-duty applications. Moreover, NO_x emissions are already at such a very low average emission level in PO2a that further amelioration due to stricter emission levels or continuous emission monitoring have also a very low effect on emissions. Synergies should be looked for between the twin green and digital transformation, as encouraged by the European Green Deal and the New Industrial Strategy. Indeed, digital ambition by introducing continuous emission monitoring and vehicle connectivity in PO3a can ensure the reduction of emission over vehicles' lifetimes.

That way, the new Euro 7 standards can be considered as key element to deliver on a zero-pollution ambition as set out by the Communication on the European Green Deal and to contribute to the objectives of the EU's clean air policy, including the planned **revision of the Ambient Air Quality Directives (AAQD)[191] and the existing National Emission reduction Commitments Directive (NECD)[192]**. The commitment in the European Green Deal to "revise air quality standards to align them more closely with the World Health Organization recommendations" supports a high degree of ambition in source legislation such as Euro 7. By ensuring a reduction of all relevant air pollutant emissions from road transport consistent with AAQD/NECD air pollutant coverage and targets, the Euro 7 standards notably support Member States in meeting their commitments under the NECD. This is made in a similar way as the CO_2 emission standards support Member States in meeting their CO_2 targets under the Effort Sharing Regulation[193]. PO2b with the highest emission reductions, in particular for lorries/buses, offers the highest level of coherence with air quality policies, closely followed by PO2a and PO3a. The cumulative impact with the planned revision of the AAQD in 2022 cannot be calculated in this impact assessment but is estimated limited.

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[191] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12677-Air-quality-revision-of-EU-rules_en

[192] NECD is not planned for a revision in the short term.

[193] Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013

Whereas the **CO_2 emission standards** promote zero-emission technologies, such as electric vehicles, the new Euro 7 standards address the emission of harmful air pollutants from combustion engines, brakes and, in the future, tyres with the aim to protect human health and the environment. Therefore the Euro 7 general objectives remain valid insofar as the important share of ICE vehicles will continue to emit exhaust pollutants, and all vehicles will contribute to non-exhaust emissions irrespectively of the engine. Despite proposed end-date of 2035 for new combustion-engine cars/vans, the number of vehicles placed on the market with combustion engines (including hybrids) remain important, in particular for lorries/buses. Both CO_2 emission and Euro pollutant standards are considered as complementary to reach the climate and zero-pollution ambition of the European Green Deal and contribute to the shift to sustainable mobility. All policy options are in principle coherent with this approach, but PO1 to a rather limited extent, given the lower expected pollutant emission reductions.

The **cumulative investment challenge for the automotive sector to reach the climate and zero-pollution ambition** was already recognised in the European Green Deal, which stated that "Delivering additional reductions in emissions is a challenge. It will require massive public investment and increased efforts to direct private capital towards climate and environmental action, while avoiding lock-in into unsustainable practices. […] This upfront investment is also an opportunity to put Europe firmly on a new path of sustainable and inclusive growth. The European Green Deal will accelerate and underpin the transition needed in all sectors." Clear regulatory signals to the automotive sector are considered crucial for delivering climate and zero-pollution investment decisions. As shown in section 7.1, the cumulative investment attributable to PO2a and PO3a are considered not too high, while the investment attributable to PO2b is considered high. As the regulatory costs are expected to be passed on to consumers, the assessment of the cumulative consumer affordability comes to the same result.

The **Roadworthiness Directives** aim at detecting over-polluting light- and heavy-duty vehicles due to potential technical defects by means of periodic testing and inspections and roadside inspections. All policy options contain elements to support this objective, with PO3a introducing effective continuous emission monitoring mechanisms and contributing the most. Significant further cost savings are expected for PO3a in the cars/vans as well as lorries/buses segments due to such more effective continuous emission monitoring mechanisms. Such mechanisms could gradually become a primary tool in the Roadworthiness Directives, modernise the current inspection procedures and lead to lower administrative costs. While this cumulative impact could not be quantified yet in this impact assessment, it shall be part of the upcoming revision of the Roadworthiness Directives.

7.4 Proportionality

PO1: Low Green Ambition

The results from the previous sections illustrate that while PO1 is the least costly for industry, both for cars/vans and lorries/buses, it is simultaneously the least effective in achieving the objectives. PO1 is only expected to achieve significant success towards the first specific objective of reducing complexity of the current Euro emission standards. In particular, the simplification measures introduced in PO1 and continued throughout the other options lead to moderately positive regulatory cost savings for industry (covering costs for testing, witnessing of tests by type-approval authorities and type-approval fees as well as administrative costs for reporting and other information obligations as part of the type-approval procedures). Since PO1 is considered to be not more effective than the baseline in updating obsolete emission limits and only slightly more effective in improving control of real-world emissions, PO1 would only lead to minimal health and environmental benefits for citizens.

The low net benefits in PO1, especially for lorries/buses, point towards an overall low efficiency compared to other options. This indicates that this option is significantly less worthwhile as a whole than the other options.

In addition, the policy option does not improve coherence with the green and digital ambition of the European Green Deal or with other main EU rules tackling air pollutants in the road transport sector (air quality legislation and CO_2 emission standards). Still, some improvements on the coherence with Roadworthiness Directives are expected in PO1.

Considering the above, the low intensity and ambition level of PO1 are not found to match the identified problems and objectives for cars/vans and even less so for lorries/buses, for which the share of new zero- and low-emission vehicles in the fleet is projected to increase at a slower pace. Therefore, PO1 is considered a rather disproportionate policy option.

PO2a: Medium Green Ambition

Where PO1 scores poorly on effectiveness, efficiency and coherence, PO2a scores significantly better on all aspects. In PO2a the higher pressure on regulatory costs for industry is expected to have a moderately negative impact for cars/vans and low negative impact for lorries/buses. Subsequently, a low negative impact on consumer affordability is expected for cars/vans and on affordability for SME users for lorries/buses. Nevertheless, PO2a is more effective in achieving the defined objectives. Since it includes the same simplification measures as PO1, it is equally successful towards the specific objective of reducing complexity. Next to that, PO2a goes significantly beyond PO1 when it comes to the second specific objective of providing up-to-date limits for all relevant air pollutants with only PO2b being more effective. Also for the third specific objective, PO2a goes further than PO1 by extending the durability to the average lifetime of the vehicle and covering medium ambitious real-driving testing conditions. That way, PO2a would lead to the same regulatory cost savings for industry as PO1, while adding medium positive health and environmental benefits for citizens in case of cars/vans and even high positive health and environmental benefits in case of lorries/buses. In addition, PO2a would enable a low positive impact on competitiveness by maintaining for industry access to international key markets.

In contrast to PO1, PO2a is estimated to lead for cars/vans to sufficient net benefits and for lorries/buses to very high net benefits. This difference can be explained by the higher margin for emission reductions possible in HDV. Hence, PO2a is considered an efficient policy option. The assessment of an alternative set of medium-ambitious durability requirements has shown no important change in efficiency for PO2a, while the alternative set of medium-ambitious emission limits has illustrated slightly lower efficiency (see 7.2).

In addition, PO2a improves coherence with other EU policies to a certain extent. It improves coherence with the green ambition of the European Green Deal, the air quality policies, and the CO_2 emission standards, especially for lorries/buses, as it contributes complementary to reach the green and climate ambition of the European Green Deal and the shift to sustainable mobility. The cumulative impacts with CO_2 emission standards on industry and citizens in terms of investments needs and consumer affordability are expected not too high. PO2a also improves coherence with Roadworthiness Directives to the same extent as in PO1.

Considering the above, the medium intensity and ambition level of PO2a are found to match the identified problems and objectives for cars/vans and even more so lorries/buses, for which there is a higher margin for emission reductions. Hence, PO2a is considered a proportionate option, especially in comparison to PO1.

PO2b: High Green Ambition

While PO2b is similarly effective in achieving the objectives as PO2a, it does so at significantly higher cost leading to a higher negative impact for industry compared to PO2a, especially for cars/vans. Subsequently, a medium negative impact on consumer affordability is expected for cars/vans and on affordability for SME users for lorries/buses. Still, PO2b is considered for the cars/vans as well as the lorries/buses segments as most effective regarding the second specific objective of providing up-to-date limits for all relevant air pollutants. While achieving the same regulatory cost savings for industry as PO1 and PO2a due to same simplification measures, PO2b does achieve a higher health and environmental benefits for citizens than both for cars/vans due to the reduction of harmful particles emission from brakes. For lorries/buses, however, these benefits are of the same magnitude as in PO2a. For all vehicles, PO2b would enable a low positive impact on competitiveness by maintaining for industry access to international key markets such as PO2a.

In contrast to PO2a, for PO2b cars/vans the regulatory costs are estimated in the same range as its benefits due to the still high costs for brake filters. For this reason, this policy option is measured to lack efficiency as illustrated by the insufficient net benefits in Table 13. For lorries/buses, the observation is different with PO2b still achieving high net benefits which are however estimated at a lower level than in PO2a and PO3a.

Still, PO2b is expected to be overall the most successful is improving coherence with the green ambition of the European Green Deal, the air quality policies and the CO_2 emission standards, especially for lorries/buses, as it has the highest ambition towards sustainable mobility. However, the cumulative impacts with CO_2 emission standards on industry and citizens in terms of investments needs and consumer affordability are expected high. PO2b also improves coherence with Roadworthiness Directives to the same extent as in PO1 and PO2a.

The high intensity and ambition level of PO2b are still found to match the identified problems and objectives for lorries/buses (at lower extent than PO2a and PO3a), but this cannot be said about PO2b for cars/vans. PO2b for cars/vans is considered disproportionate due to the not sufficient net benefits. PO2b for lorries/buses is considered less proportionate than PO2a and PO3a due to the lower net benefits and some negative impact on affordability for SME users.

PO3a: PO2a and Medium Digital Ambition

While PO3a is as effective as PO2a when it comes to the second specific objective of providing up-to-date limits for all relevant air pollutants, PO3a is found to be the most effective for achieving the other specific objectives. PO3a is most suitable to reduce complexity through continuous emission monitoring. In particular, continuous emission monitoring equipment is expected to simplify the reporting and other information provision obligations for granting of type-approval and ease the verification testing procedures. Subsequently, PO3a achieves the highest cost savings during the implementation phase and administrative costs not only for lorries/buses, but also for cars/vans. In addition, PO3a is also expected to achieve simplifications in the implementation of interlinked Roadworthiness Directive (see below). Also when it comes the third specific objective, PO3a is found to be the most effective to improve control of real-world emissions for all vehicles, even in view of the end-date of 2035 for combustion-engine cars/vans.

At an only slightly higher regulatory cost for industry than in PO2a through increased equipment costs for all vehicles following the introduction of continuous emission monitoring, PO3a is set out to achieve slightly higher health and environmental benefits for citizens. In PO3a, high emitting vehicles are expected to be fixed earlier, while tampering of vehicles should be avoided. Moreover, the additional regulatory costs are for a large part outweighed by the additional regulatory cost savings expected in PO3a over PO1, PO2a and PO2b during the implementation phase and administrative costs. While PO3a leads to similar low negative impacts on affordability for consumers and SMEs as PO2a, it is set out to outweigh the other options when it comes to positive effects on competitiveness by improving for industry access to international key markets and innovation. In particular, the development of sensors and digital communication systems creates market opportunities, some of them beyond the automotive supply-chain. The use of best available sensors supports access to international key markets, in particular to United States and China where similar developments are taking place.

While PO3a surpasses PO2a when it comes to effectiveness, for efficiency the options achieve similar results. When focussing solely on the quantifiable costs and benefits, PO3a scores sufficiently for cars/vans as it achieves net benefits that are equal to those estimated in PO2a. Also for lorries/buses, PO3a is found to be clearly efficient with high net benefits in the ranges of PO2a. Still, PO3a is likely to have additional qualitative benefits for all vehicles exceeding those in PO2a: a more positive impact on competitiveness (see above) and additionally on free movement within the single market, consumer trust and employment/skills (see Table 9 for light-duty vehicles / Table 10 for heavy-duty vehicles).

Overall, PO3a is found to be most coherent with other EU policies. When it comes to coherence with the air quality policies, PO3a is expected to achieve similar results as PO2a. In the context of geo-fencing, new business models using the information collected in PO3a can be developed to support the concept of Smart Cities in the EU and therefore benefit further air quality. PO3a allows for improvements over PO2a in the coherence with the green and digital ambitions of the European Green Deal through the introduction of continuous emission monitoring which contributes to the digital transformation.

When it comes to coherence with the CO_2 emission standards, PO3a is expected to achieve similar results as PO2a, while the relevant cumulative impacts with CO_2 emission standards on industry and citizens are expected not too high.

In addition, continuous emission monitoring in PO3a would allow for an ambitious revision of the Roadworthiness Directives in which a modernisation of inspection procedures to control emissions from vehicles periodically can be put forward. Although out of the scope of this impact assessment, this modernisation in inspections will likely lead to additional cost savings for the competent authorities by reducing the time needed to perform inspections. Such indirect positive impacts will likely also be felt by vehicle owners.

Considering the above, the medium intensity and ambition level of PO3a, adding digital to the green ambition compared to PO2a, are found to match in the best manner the identified problems and objectives for cars/vans and even more so lorries/buses, for which there is a higher margin for emission reductions. Hence, PO3a is clearly found to be a proportionate option.

In summary, PO1 is considered a rather disproportionate policy option, for light- and heavy-duty vehicles. PO2a and PO3a are both considered as proportionate, for light- and heavy-duty vehicles. The additional effectiveness, efficiency and coherence of PO3a over PO2a, for light- and heavy-duty vehicles, is mainly due to its positive impact on competitiveness through the introduction of continuous emission monitoring and its additional coherence with the green and digital ambitions of the European Green Deal and the Roadworthiness Directives. This makes PO3a the most proportionate policy option. PO2b, on the other hand, is considered disproportionate for light-duty vehicles due to the not efficient net benefits and less proportionate than PO2a and PO3a for heavy-duty vehicles due to the lower net benefits and some negative impact on affordability for SME users.

8 PREFERRED OPTION

The overall proportionality assessment of the effectiveness, efficiency and coherence of each of the options has demonstrated in section 7.4 that the policy options can be narrowed down to preferred **medium-ambitious PO3a, for light- and heavy-duty vehicles**. PO3a comprises simplification measures, medium ambitious pollutant emission limits, real-driving testing conditions and durability provisions and introduction of continuous emission monitoring with available sensors for all vehicles. **All arguments below are equally valid for light- and heavy-duty vehicles.**

In addition, the assessment of an alternative set of medium-ambitious durability requirements in Annex 8 (summarized in section 7.2) has shown no important change in efficiency compared with PO3a, while the alternative set of medium-ambitious pollutant emission limits has illustrated slightly lower efficiency.

Although PO3a and PO2a have about the same average net benefit as well as different net benefits for cars/vans and lorries/buses (about €25 billion in PO3a and PO2a for cars/vans, about €117 billion in PO3a and PO2a for lorries/buses), there are further qualitative benefits of PO3a in terms of effectiveness, efficiency and coherence leading to the overall conclusion that PO3a is most proportionate for both vehicle segments. Moreover, there is a clear need to act in both vehicle segments to improve our health and well-being.

PO3a is most **effective** in achieving all defined objectives, for light- and heavy-duty vehicles. It provides up-to-date limits for all relevant air pollutants and is most suitable to reduce complexity of the current Euro 6/VI emission standards and to improve comprehensively control of real-world emissions by introducing continuous emission monitoring and extending the durability requirements to the average lifetime of the vehicle.

PO3a is **cost-efficient** by reaching, as PO2a, highest health and environmental benefits for citizens at lowest total regulatory costs for industry and would lead to less than 1% vehicle price increase for small petrol cars/vans. Despite the proposed end-date of 2035 for combustion-engine cars/vans, PO3a is estimated to lead for cars/vans to sufficient net benefits in average of €25 billion and for lorries/buses to very high net benefits in average of €117 billion (see quantitative efficiency assessment in Table 13). This difference between light- and heavy-duty vehicles can be explained by the higher margin for emission reductions possible for lorries/buses.

Nevertheless, also acting for cars/vans is essential for achieving the green ambition of the European Green Deal, Zero Pollution Action Plan and new EU Urban Mobility Framework to make transport drastically less polluting, especially in cities. These net benefits cannot be ignored or assessed less relevant, since the PO3a technologies are available for the cars/vans segment and the necessary investments of €300 per car/van can be recouped until 2035. In addition, sensors for vehicles are designed for application in all vehicles. With great numbers of combustion cars/vans still being brought on the market until 2035, introducing PO3a for all vehicles will allow for economies scale from which the heavy-duty segment will still be able to profit, even after 2035.

PO3a is likely to have additional qualitative efficiency benefits for all vehicles exceeding those in PO2a: some positive impacts on competitiveness by improving for industry access to international key markets and innovation, on the single market by possibly preventing Member States from taking unilateral decisions to address excessive emissions from road transport, on consumer trust by providing reliable information on emission performance of vehicles and on employment and re- and up-skilling of workforces.

PO3a is found to be to be most **coherent** with other EU policies. It is coherent with the air quality legislation and CO_2 emission standards. PO3a ensures a cost-efficient reduction of all relevant air pollutant emissions from light- and heavy-duty vehicles, supporting Member States in meeting their emission reduction commitments under the National Emission reduction Commitments Directive and contributing complementary to reach the GHG reduction objectives of the EU. The cumulative impacts with CO_2 emission standards on industry and citizens in terms of investments needs and consumer affordability are expected not too high.

In addition, PO3a ensures highest coherence with the European Green Deal and the current and planned revision of the Roadworthiness Directives. It adds digital ambition to PO2a through introducing continuous emission monitoring in line with the twin green and digital transformation aimed at by the European Green Deal. While having the same net benefits, PO3a goes significantly beyond PO2a by adding the advantages of continuous emission monitoring. These advantages are valid for light- and heavy-duty vehicles:

- PO3a is expected to achieve the highest administrative, testing and type-approval cost savings, as continuous emission monitoring equipment is expected to facilitate the granting of type-approval and the verification testing procedures, which almost balance the additional equipment costs. These cost savings are higher for light- than for heavy-duty vehicles.

- PO3a would offer the possibility of geo-fencing which would support Member States and cities improving air quality in densely populated areas. This technology puts a plug-in hybrid electric vehicle automatically into zero-emission mode when entering zero-emission zones, such as cities. This would allow for the development of new business models using the emission information collected to support the concept of Smart Cities in the EU.

- Continuous emission monitoring introduced by PO3a would also be beneficial as monitoring indicator for a mid-term evaluation under the European Green Deal.

The air pollution modelling tools used in this impact assessment could move from limited test data to real world data.

- PO3a is expected to introduce effective continuous emission monitoring which is likely to become a primary testing method for checking the environmental compliance of vehicles. As such, it would help modernising inspection procedures to periodically control the actual emission performance of vehicles under the Roadworthiness Directives, which would allow to fix high emitting vehicles earlier and avoid tampering of vehicles. This is expected to lead to significant cost savings and health and environmental benefits that were not taken into consideration in this impact assessment. If option PO3a were not to be retained, the possibilities for the revision of the Roadworthiness Directives will be significantly limited.

From the stakeholder consultations, there is a pressure from environmental and consumer organisations and some Member States to set more ambitious requirements as in PO3a and PO2b to support further improvement in air quality and thus contribute to protecting public health and the environment. However, automotive industry has raised strong concerns in the stakeholder consultations regarding the technological potential for reducing emissions as proposed in PO2b. In particular, the question if the NO_x emission limits for cars could be reduced to a value lower than 30 mg/km and if high ambitious real-driving testing boundaries ("free driving") should be introduced led to high stakeholder interest in Euro 7. Manufacturers' concerns have been taken into account in the design of the policy options by differentiation of emission limits, real-driving testing boundaries and durability requirements and extensively discussed in AGVES meetings. In fact the proportionality assessment agrees with some of the concerns, such as the marginal gains of going to values lower than 30 mg/km for NO_x proposed in PO3a and that boundaries of testing need to be reasonable leading to PO2b being disproportionate for cars/vans.

During the consultation activities, stakeholders from Member States, component suppliers, civil society and citizens expressed their support for including the completely new continuous emission monitoring, as considered in PO3a, as an important action to measure real world emissions and to guarantee transparency and protection from tampering. Concern of making pollutant data from vehicles available was not raised by consumer organisations or citizens in the stakeholder consultations. These findings illustrate that new continuous emission monitoring is generally found to be socially acceptable. However, vehicle manufacturers were more reluctant on the matter, primarily indicating the need for independent technology and equipment for continuous emission monitoring to prevent high costs and risk for their international competitiveness. Still, the results of the cost analysis in section 6.3.1 illustrate that the cost for available sensor technology is counterbalanced by higher costs savings due to the expected simplified type-approval.

The main consumer organisation and some automotive manufacturer and Member States estimated in the targeted stakeholder consultation that even though more stringent pollutant limits will have an impact on the vehicle price, it will also make battery electric vehicles even more competitive. This potential accelerated shift to electric vehicles by medium-ambitious Euro 7 has been taken into account in the modelling of the CO_2 impact assessment for cars and vans[32] by common econometric modelling of the projected vehicle fleet (see Figure 7) and looking into the net benefits for high CO_2 target level taking into account other policies including stricter PO3a pollutant limits (see Annex 4, Figure 14 and 15).

Automotive industry also raised concerns regarding competitiveness in view of the investments that need be focussed on the climate ambition of the European Green Deal, in particular in view of the proposed end-date for combustion-engine cars and vans. The investment challenge for the automotive sector to reach the climate and zero-pollution ambition was already recognised in the European Green Deal. The impact assessment shows that the investment attributable to PO3a is not high. With the end-date of combustion-engine cars/vans by 2035, the cumulative annual investment of PO3a and CO_2 emission standards amounts to €20.2 billion, out of which €19 billion is due to the proposed CO_2 target and €1.2 billion due to PO3a. Furthermore, the analysis of the cumulative CO_2 and PO3a investments also shows that there are benefits for the competitiveness of the automotive industry for zero- and low-emission technologies which will both be more and more demanded on the global market.

In conclusion, the preferred option for Euro 7 is medium-ambitious PO3a, for light- and heavy-duty vehicles.

9 How will actual impacts be monitored and evaluated?

The Euro 6/VI evaluation identified as lesson learnt the lack of monitoring indicators in the Euro 6/VI emission standards[83]. Arrangements should be made to monitor and evaluate the effectiveness of Euro 7 emission standards against operational objectives and to establish causality between the observed outcomes and the legislation. For this purpose, a number of monitoring indicators are proposed for the review of Euro 7 emission standards planned with the mid-term evaluation of the 'fit-for-55' initiatives.

Table 14 – Operational objectives and respective monitoring indicators for the preferred policy option 3a

Operational objectives	Monitoring indicators
Simplify the Euro emission standards	• Number of emission type-approvals under Euro 7 per vehicle type • Costs during implementation phase and administrative costs per emission type approval
Provide appropriate air pollutant limits for road transport	• Proof of improved control of emissions under all conditions of use for all regulated pollutants • Enforcement costs, including costs for infringements and penalties in case of non-compliance and monitoring costs
Enhance emission control over the vehicles' lifetime	• Evolution of emissions over the lifetime of vehicles as evidenced by appropriate testing campaigns and continuous emission monitoring

The review of Euro 7 emission standards will also evaluate a set of more general indicators from other EU air pollutant policies for road transport:

- Annual pollutant concentration levels in Europe's urban areas and annual share of road transport to the pollutant emissions as reported by the Member States to the EEA under the National Emission reduction Commitments Directive (NECD)[28] and included in the annual report on air quality in Europe[1].
- Annual number of registered vehicles and share of powertrain technologies on EU roads as reported by the Member States to the European Alternative Fuels Observatory.[108]
- Annual development of impacts of air pollution on health (i.e. premature deaths related to exposure of certain pollutants) as included in the annual report on air quality in Europe.

- Annual share of road transport to the pollutant emissions of certain pollutants as reported by the Member States to the EEA under the NECD.
- Annual number of notifications received from Member States for barriers of internal EU trade of cars, vans, lorries/buses caused by technical prescriptions imposed by national, regional or local authorities (i.e. bans of any kind) under the notification procedure of Directive 2015/1535[194].

[194] Directive (EU) 2015/1535 laying down a procedure for the provision of information in the field of technical regulations and of rules on Information Society services; see also 2015/1535 notification procedure

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PART 2/3

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

(ANNEX 1-4)

Accompanying the document

PROPOSAL FOR A REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on type-approval of motor vehicles and of engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009

{COM(2022) 586 final} - {SEC(2022) 397 final} - {SWD(2022) 358 final} - {SWD(2022) 360 final}

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Contents

Annex 1: Procedural information

1. Lead DG, Decide Planning/CWP references

This initiative is led by Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW).

The European Green Deal[1] announces a proposal by 2021 for more stringent air pollutant emissions standards for combustion-engine vehicles (Euro 7).

The Agenda Planning Reference is PLAN/2020/6308 for the development of Euro 7 emission standards for cars, vans, lorries and buses which is part of the Commission's 2020/2021 Work Programme.

2. Organisation and timing

The evaluation of Euro 6/VI emission standards and impact assessment for more stringent air pollutant emissions standards for combustion-engine vehicles (Euro 7) were conducted in a back-to-back approach to meet the roadmap set by the European Green Deal. That way, the findings of the evaluation which are included in Annex 5 are used to inform further reflection on whether Euro 6/VI emission standards continue to provide high level environmental protection in the EU and to ensure the proper function of the internal market for motor vehicles.

DG GROW established on 10 February 2020 and chaired the Inter-Service Steering Group for the development of Euro 7 emission standards for cars, vans, lorries and buses. The following Directorates-General (DG) participated: Secretary-General, DG Climate Action, DG Environment, DG Joint Research Centre, DG Justice and Consumers, DG Mobility and Transport, DG Research and Innovation and DG Communications Networks, Content and Technology. The following meetings took place:

1) 4 March 2020 – on the combined evaluation roadmap/inception impact assessment, consultation strategy and public consultation
2) 10 July 2020 – on the Advisory Group on Vehicle Emission Standards (AGVES) meeting of the 9 July, the first results from the Euro 6/VI evaluation and stakeholder feedback to the inception impact assessment and targeted consultation of the evaluation
3) 11 September 2020 – on the AGVES meeting of the 10 September, coherence to air quality and Euro 7 in a global picture
4) 17 December 2020 – on the AGVES meeting of the 26/27 November, stakeholder feedback to the public consultation and targeted consultation on the impact assessment, on the final results from the Euro 6/VI evaluation and the inter-service collaboration on the impact assessment
5) 7 April 2021 –on the first chapters 1-4 of the impact assessment staff working document and the first results on the emission limits from the studies
6) 3 June 2021 – on the full impact assessment staff working document
7) 18 November 2021 – on the revised impact assessment staff working document following RSB opinion

[1] COM(2019) 640 final, The European Green Deal

3. CONSULTATION OF THE RSB

First submission

The Regulatory Scrutiny Board (RSB) of the European Commission assessed a draft version of the present Impact Assessment on 7 July 2021 and issued its negative opinion on 9 July 2021.

The Board's main findings were the following and these were addressed in the revised impact assessment report as indicated below.

Main RSB findings	**Revision of the Impact Assessment Report**
(1) The report does not present a convincing case on the reasons for revising the Regulation at this point of time. It lacks clarity on the implications of related initiatives such as the CO_2 emission standards for new cars and vans proposal or the horizontal Ambient Air Quality Directives.	The impact assessment has been fully revised following the adoption of "fit-for-55 package" and hence the end-date of combustion-engine cars/vans by 2035 under the CO_2 emission standards for new cars and vans proposal was introduced in the modelling. The reasoning for the Euro 7 initiative, as announced in the European Green Deal, and the link to the Ambient Air Quality Directives has been clarified in chapters 1, 2, 5, 7 and 8.
(2) The performance of the option packages depends significantly on the final political choices on the proposal for CO_2 emission standards. The report does not deal adequately with this critical uncertainty	The implication of the end-date of combustion-engine cars/vans by 2035 has led to a revised baseline in chapter 5, a revised assessment in chapters 6 and 7 and discarded high ambitious policy option 3b on future sensor technology in section 5.3.
(3) The report does not present a clear comparison of option packages in terms of effectiveness, efficiency and coherence. The proportionality assessment of the preferred option(s) is not sufficiently balanced and informed by the most important costs and benefits. It does not sufficiently differentiate between light and heavy duty vehicles.	Chapter 7 has been fully revised to present a clear comparison of policy options in terms of effectiveness, efficiency and coherence and overall proportionality assessment, differentiated between light- and heavy-duty vehicles. For methodological reasons and for clarity purposes, the focus of the efficiency is on net benefits (i.e. present value of the benefits minus present value of the costs) which do not bias the results for low-cost options, in contrast to the benefit-cost ratio. New chapter 8 on preferred options has been elaborated, narrowing down the options for light- and heavy-duty vehicles based on the proportionality assessment in chapter 7 and informed by the most

	important costs and benefits.
(4) The report does not provide sufficient information on the robustness of the modelling work and the credibility of the quantitative estimates. It does not address the cumulative impacts from regulating road transport emissions on consumers, industry, competitiveness and employment. Differences in stakeholders' views have not been reflected sufficiently in the analysis.	The uncertainty and validation of the cost and benefits have been further elaborated in Annex 4, new section 1.3.2.1, discussed in chapter 6 and considered in the conclusions in chapters 7 and 8, to underpin the robustness of the modelling work and credibility of the quantitative estimates. Cumulative impacts from regulating CO_2 and pollutant emissions from road transport on consumers, competitiveness and employment have been assessed in chapter 6 and Annex 4, new section 1.5, and considered in chapters 7 and 8. Differences in stakeholders' views have been further reflected in chapters 6, 7 and 8.

The Board also mentioned the following improvements needed, which were addressed in the revised impact assessment report as indicated below.

RSB opinion: "what to improve"	Revision of the Impact Assessment Report
(1) The report should better explain the evolution of the problem of air pollutants related to road transport and the need for further action on reducing them. It should clarify upfront how a possible earlier end-date for introducing new combustion engine cars in the EU market would affect the magnitude of the problem and how big the problem of unaccounted real driving emissions is.	The magnitude and evolution of the problem of air pollutants related to air pollutants has been clarified in chapter 2. In particular, Figure 2 has been replaced to clarify upfront how an end-date of combustion engine cars and vans by 2035 affect the problem and how big the problem of unaccounted real driving emission is.
(2) For some emissions, the report should present the reduction efforts in their broader policy context. For example, the report should describe how this initiative interacts with the planned revision of Ambient Air Quality Directives. It should explain why industry specific action is necessary ahead of this horizontal revision and how it will ensure coherence and overall cost-efficient emission reduction.	The interaction with the planned revision of Ambient Air Quality Directives has been elaborated in chapters 1, 2, 5, 7 and 8, including an explanation how Euro 7 standards will contribute coherently and cost-efficiently to the horizontal revision, notably by supporting Member States in meeting their air quality commitments and ensuring a consistent coverage of all relevant air pollutants.

(3) The design of options packages should facilitate an understanding of the differences between certain types of actions. The actions on comprehensive real driving testing and extended durability are either both absent or both present in all options. The presentation of options should better distinguish between the effects of these measures.	The design of policy options has been revised in chapter 5 and subsequently in the analysis and conclusions, including a differentiation of real driving testing boundaries and durability and their effects in all options. Cost and benefit of each action included in the policy options are presented in Annex 3, if possible.
(4) The report should narrow the range of the preferred options, given the significant performance differences between the option packages, as well as between light and heavy duty vehicles. It should present clearly the trade-offs between the policy packages. In view of the low benefit-cost ratio of some option packages and the uncertainty as regards the robustness of the related estimates, the report should better justify the proportionality of the policy option packages.	Chapter 8 on preferred options has been elaborated, narrowing down the options to one preferred option 3a for light- and heavy-duty vehicles based on the comparison of the options in chapter 7, informed by the most important costs and benefits and presenting the main trade-offs that are left to policy-makers to decide. The proportionality of the preferred option for light-duty vehicles has been elaborated in chapter 7.4 in view of the low net benefits.
(5) The report should explain to what extent the analysis and the conclusions reached in the support studies are uncontested and verified. It should explain the buy-in of stakeholders to the conclusions, especially in relation to the technological potential for reducing emissions, the potential accelerated shift to electric vehicles and the impacts on competitiveness, where industry stakeholders seem to have different views. In case of remaining uncertainty, the report should complement the analysis by providing ranges of expected costs and benefits for the car and van option packages, based on alternative sets of assumptions on costs and benefits.	The uncertainty and validation of the cost and benefits have been further elaborated in Annex 4, new section 1.3.2.1. The medium to high level of confidence of the cost and benefit estimates verified by stakeholders and experts is considered sufficiently robust to present in chapter 6 average values for the cost and benefit elements. Nevertheless, the cost-benefit analysis in chapter 7 is complemented by providing ranges of expected costs and benefits to make political choices of the policy options for light- and heavy-duty vehicles. The buy-in of stakeholders to the conclusions is discussed in chapter 8, especially in relation to the technological potential for reducing emissions, the potential accelerated shift to electric vehicles and the impacts on competitiveness. In addition, an alternative set of assumptions on emission limits and durability to address remaining uncertainty in relation to technological potential for reducing emissions is

	assessed in Annex 8 and considered in chapters 7 and 8.
(6) The report should better discuss the cumulative impacts on consumers, employment and industry competitiveness. For example, when discussing affordability it should acknowledge that consumers will face not only the pass-on of additional regulatory costs from Euro7 but also from the new CO2 emission standards.	Cumulative impacts from regulating CO_2 and pollutant emissions from road transport on consumers, employment and competitiveness have been assessed in chapter 6 and Annex 4, section 1.5 and considered in chapter 7. For example, Annex 4, section 1.5.2 discusses the cumulative consumer affordability from Euro 7 and the new CO_2 emission standards for cars/vans.

Resubmission

The Regulatory Scrutiny Board (RSB) of the European Commission assessed the revised Impact Assessment and issued a positive opinion with reservations on 26 January 2022.

The Board's main findings were the following and these were addressed in the final impact assessment report as indicated below.

Main RSB findings	Revision of the Impact Assessment Report
(1) The report does not sufficiently reflect the significant differences in the scale of the problems, and corresponding need to act, between the cars/vans and lorries/buses segments.	The different contribution of light-duty compared to heavy-duty vehicles to the problem and need to act is better reflected in chapter 2. A box was added to highlight the differences between the two segments.
(2) The rationale behind the revised policy packages is not fully clear.	The rationale behind the revised policy packages is better explained in chapter 5.
(3) The report does not make a convincing case for the preferred option. The proportionality analysis does not bring out clearly enough the significant performance differences in terms of net benefits and benefit-to-cost ratios between the preferred options for cars/vans and lorries/buses respectively. The evidence presented on effectiveness, efficiency and coherence is not compelling enough to narrow the preferred options to one for both segments.	The reasoning for the preferred option 3a for light- and heavy-duty vehicles has been strengthened in chapter 8, including the underlying effectiveness, efficiency, coherence and proportionality analysis and evidence in chapter 7.

The Board also mentioned the following improvements needed, which were addressed in the final impact assessment report as indicated below.

RSB opinion: "what to improve"	Revision of the Impact Assessment

	Report
(1) The report should better reflect the significant differences in the scale and evolution of the problems between the cars/vans and lorries/buses segments in the analysis throughout the report. It should better justify the need to act as regards both segments in view of the planned phasing out of cars/vans with an internal combustion engine by 2035 and the limited time remaining to recoup the necessary investments. It should nuance the need to be the 'emission standard setter' and technological leader for a type of vehicle that will disappear from the market relatively soon.	The differences between light- and heavy-duty vehicles have been better reflected in the problem definition and throughout the report (chapters 2, 6, 7, 8). The report clarifies that the largest share of the costs for light- and heavy-duty vehicles occur in the first ten years after 2025 and only a small share of the costs remain after 2035, mainly resulting from the requirements regarding brake emissions for all cars/vans, including zero-emission vehicles. The need to be the emission standards setter and technological leader in the future was nuanced.
(2) While the report presents a revised and simplified set of policy packages, it should clarify whether these are the packages considered most relevant by stakeholders and whether other, possibly better performing, combinations of measures have been assessed. This should include, for example, an explanation why it has not considered continuous emission monitoring as part of the low ambition option package, to avoid rendering it a weaker option by design.	The rationale behind the revised policy packages is better explained in chapter 5, in particular why option 1 does not include new digital ambition and why the options presented are the best performing combination of measures while the actions have been differentiated in all options.
(3) The impact and proportionality analyses should bring out more clearly the significant performance differences between the preferred options for cars/vans and lorries/buses in terms of effectiveness and efficiency. Given that both – the net benefits and the benefit-cost ratios – are to a large extent higher for the lorries/buses segment, the report should argue more convincingly why equally ambitious action is justified as regards cars and vans. This assessment should take into account that the low green ambition option offers net benefits that clearly outperform the high green ambition options (2b) and comes relatively close to those available under the medium green ambition option (2a) while offering by far the best benefit-cost ratio among the considered cars/vans options. The narrowing of preferred options should	The effectiveness, efficiency, coherence and proportionality analyses have been strengthened in chapter 7 acknowledging the higher net benefit of heavy-duty vehicles, while underlining that also the lower net benefit of light-duty vehicles would make transport drastically less polluting, especially in cities. Chapter 7 discusses better why for methodological reasons and for clarity purposes, the focus of the efficiency is on net benefits (i.e. present value of the benefits minus present value of the costs) which do not bias the results for low-cost options, in contrast to the benefit-cost ratio. The reasoning for the preferred option 3a for light- and heavy-duty vehicles has been strengthened in chapter 8, including

take into account all available evidence presented in the report, including, to the extent possible, the acceptance of the stakeholders and the potential concerns of social acceptability of continuous emissions monitoring as the report states.	the acceptance of stakeholders (industry, NGOs, citizens).
(4) The report (still) needs to be clearer on how big the problem of unaccounted real driving emissions is. It should assess the robustness of the evidence that 20% of current real-driving testing may exceed significantly the current emission limits. The results of the preliminary analysis done for the revision of the EU air quality legislation should be better presented, including in a more accessible manner.	Evidence on the 20% unaccounted real driving emissions and results of the preliminary analysis done for the revision of the EU air quality legislation have been added in chapter 2.

4. EVIDENCE, SOURCES, QUALITY AND EXTERNAL EXPERTISE

In autumn 2018, preparatory work of the Euro 7 initiative started with the first stakeholder conference organised in October. During this conference, an Advisory Group on Vehicle Emission Standards (AGVES) was set up by joining all relevant expert groups working on emission legislation (see Annex 2 for more details on AGVES). The broad evidence and sources provided and discussed in this expert group are available in the public AGVES CIRCABC[2].

In further preparation of the initiative and to collect convincing and robust scientific evidence, a first post-Euro 6/VI study (Part A) was launched with the tasks to review, compare and draw lessons from legislation in other part of the world, evaluate the effectiveness of current EU emission tests and develop and assess new emission tests for regulated and non-regulated pollutants[3]. As a follow-up for this first study, a second commissioned study, post-Euro 6/VI Study Part B, covered a thorough review of the cost-effectiveness of measures that were introduced by the first study in addition to a feasibility assessment of new pollutant emission limits for all vehicles and an analysis of the simplification potential of vehicle emission standards. This study also supported the evaluation of the Euro 6/VI framework, while providing the evidence necessary for this impact assessment.[4] Both studies were carried out by the CLOVE consortium which

[2] AGVES CIRCABC, This group has been established to facilitate the exchange of information between the members of the Advisory Group on Vehicle Emission Standards (AGVES).

[3] CLOVE, 2022. Study on post-Euro 6/VI emission standards in Europe – Combined report: PART A including PART B Techno-economic feasibility of new pollutant emission limits for motor vehicles. The findings from the study were presented and discussed continuously in the AGVES meeting.

[4] CLOVE, 2022. Study on post-Euro 6/VI emission standards in Europe – PART B Potentials for simplification of vehicle emission standards; CLOVE, 2022. Study on post-Euro 6/VI emission standards in Europe – PART B: Retrospective assessment of Euro 6/VI vehicle emission standards; CLOVE, 2022. Study on post-Euro 6/VI emission standards in Europe - PART B: Assessment and comparison of post-Euro 6/VI impact assessment options. The findings from the studies were presented and discussed continuously in each AGVES meeting.

included key experts in Europe from the Laboratory of Applied Thermodynamics of the Aristotle University of Thessaloniki (LAT) (GR), Ricardo (UK), EMISIA (GR), TNO (NL), TU Graz (AT), FEV (DE) and VTT (FI). Both studies were underpinned by analysis and tests performed by the Joint Research Centre of the Commission, in its facilities located in Ispra Italy. Further elements were considered taking advantage of work performed in the context of UN GRPE[5] (Working Party on Pollution and Energy) for the harmonisation of emission type approval regulations. Such elements included battery durability and brake emissions.

Since the post-Euro 6/VI Study Part B supported both the evaluation and the impact assessment, it also helped collecting evidence and data through different channels, including both targeted stakeholder consultations on the evaluation and impact assessment (see Annex 2). When it comes to estimating the costs for both the impact assessment and the evaluation, the contractors had some difficulties due to limited provision of cost data by stakeholders during the targeted consultations. To prevent implications on the robustness of the findings, the methodology was changed to consider additional data from various databases, including EEA NECD database[6], Euro 6/VI vehicle sales data from IHS Markit[7], OECD statistics[8], the Handbook on external costs and emission factors of Road Transport[9], structural business statistics from Eurostat[10], data requests to type-approval authorities and CLOVE expertise. The subsequent estimates have later been validated by key stakeholders to ensure robust results.[11]

[5] https://unece.org/transportvehicle-regulations/working-party-pollution-and-energy-introduction
[6] EEA, 2021. National Emission reduction Commitments Directive (NECD) emissions data viewer 1990-2018
[7] IHS Market, 2021. Provision of data on vehicle sales in the EU-28 for Evaluation of Euro 6/VI vehicle emission standards
[8] OECD, 2020. Statistics on Patents –Technology Development Environment
[9] European Commission, 2019. Handbook on the external costs of transport
[10] Eurostat, 2020. Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]; Eurostat, 2020. Passenger cars, by age [road_eqs_carage]; Eurostat, 2020. Passenger cars, by type of motor energy [ROAD_EQS_CARPDA]
[11] For more information see CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 4.2. Study limitations.

Annex 2: Stakeholder consultation

1. Introduction and overview consultation activities

This synopsis report summarises all the consultation activities for the preparation of the proposal for the development of Euro 7 emission standards for cars, vans, lorries and buses. The consultation process for this development was more extensive than what is usually reserved for similar regulations and went into details of the testing regime, boundary conditions and technologies required to achieve the emission limits.

The initiative was discussed for the first time with stakeholders during a stakeholder conference in October 2018[12]. Subsequently, the Advisory Group on Vehicle Emission Standards (AGVES) was set up by merging relevant expert groups from industry, civil society and Member States, with ten meetings and one ad-hoc workshop on simplification from July 2019 to April 2021. The result of these extensive consultation activities were used for the preparation of the Euro 6/VI evaluation and Euro 7 impact assessment.

The Inception Impact Assessment (IIA) was launched on the "Have your say" page of the Europa website on 27 March to 3 June 2020. The 18-week Public Consultation (PC) on the proposal followed on 6 July 2020 and was open for contributions until 9 November 2020. In addition, two 14-week targeted consultations (TC) – one for the Evaluation of Euro 6/VI (4 March to 8 June 2020) and one for the Impact Assessment of Euro 7 (3 August to 9 November 2020) – were performed by the CLOVE consortium focussing more on the detailed and technical aspects of to the initiative. Due to the effects of COVID-19 and containment measures, the public and targeted stakeholder consultations were extended by 6 weeks.

The stakeholder consultation was intended to collect evidence and views from a broad range of stakeholders and citizens with an interest in vehicle emissions. The aim was assessing the five evaluation criteria of the Euro 6/VI[13] (see Annex 5) as well as potential impacts of the reviewed framework. Since this Impact Assessment took a back-to-back approach, both questions on the implementation of the current Euro 6/VI emission standards and potential policy options regarding the Euro 7 initiative were considered for the different consultation activities. For this purpose, the views of each stakeholder group were considered important (see 2.1).

The main communication channel was the "Have your say" portal for the PC and the public AGVES CIRCABC and extensive bilateral communication with stakeholders for the TC. Awareness of the PC was also raised on Commission websites, platforms such as EIONET, social networks and newsletters. The link to the PC was also shared with appropriate representatives from Member State authorities, who were encouraged to reach out to national stakeholders, as well as with the European Economic and Social Committee and the European Parliament. In addition, the stakeholders participating in

[12] Preparing automotive emission standards for the future | Internal Market, Industry, Entrepreneurship and SMEs (europa.eu)

[13] Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and its implementing Regulation (EU) 2017/1151; Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and its implementing Regulation (EU) No 582/2011

the AGVES meetings were especially encouraged to contribute.

2. RESULTS OF THE CONSULTATION

2.1. Description of the respondents

Table 1 provides an overview of the number of stakeholders that participated in each consultation activity described above. The PC also includes the feedback received on the IIA. Stakeholders are divided in three large groups, namely Member States and national authorities (hereafter referred to as "Member States"), automotive industry and civil society. The group, civil society, is a combination of separated groups from the consultation strategy: consumer organisations, environmental NGOs and other stakeholders. Since contributions from these separate groups were limited in certain activities, the aggregate was considered for the analysis. In case of striking differences, the categories are discussed in parallel. Citizens participated only in the consultation activities open to the public.

Each stakeholder group has a different level of interest and is either directly or indirectly affected by the current and future vehicle emissions standards. In the TC, a number of interviews with stakeholders were also conducted by the CLOVE consortium, further elaborating on the responses to the questionnaire. Comments received during these interviews were integrated in the analysis.

Table 1 – Participation rates per stakeholder group, category and activity

Stakeholder group	Category	Consultation activity			
		Public consultation	Targeted consultation evaluation	Targeted consultation impact assessment	Expert groups of the Commission
1.Member States and National Authorities	National, regional and local authorities	20	9	7	3
	Type-approval authorities	1	5	2	—
	Technical services	1	7	7	—
2.Automotive Industry	Vehicle manufacturers	20	14	16	4
	Component suppliers	46	12	17	6
	Associations/Other industry stakeholders	54*	17	12	9
3.Civil Society	Consumer organisations	7	2	2	2
	Environmental NGOs	12	3	2	2
	Other stakeholders	8	4	2	—
4.Citizens[14]	—	64	—	—	—
Total	—	233	73	67	24

* including 30 contributions from fuel and energy industry

2.2. Analysis of responses

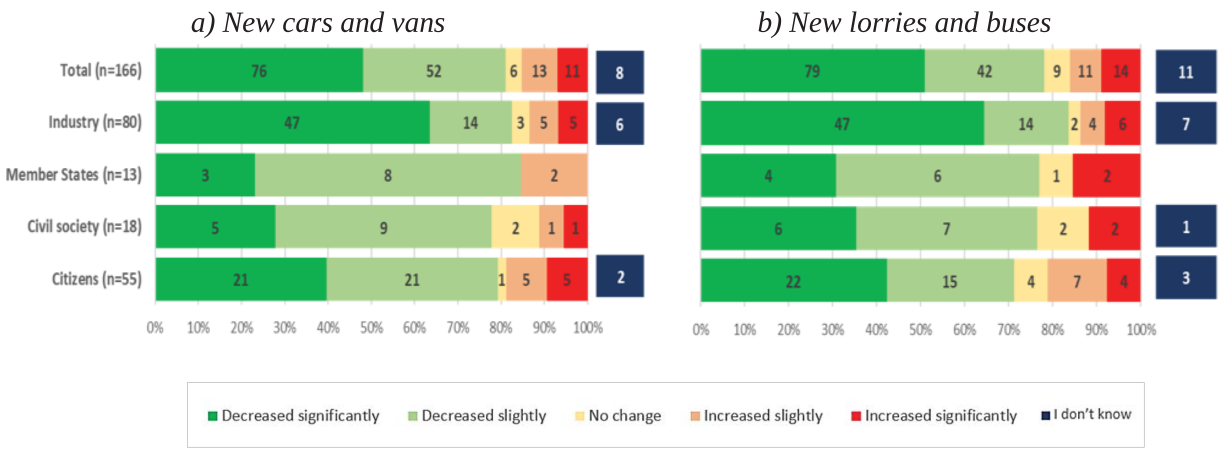
2.2.1. Evaluation Euro 6/VI emission standards

As presented in Figure 1, in the PC stakeholders from all groups believe that over the last

[14] The lower response rate is not necessarily a problem, since the interest of the general public is represented by both the respondents from civil society and from Member States and national authorities.

10 years, air pollution from new vehicles has reduced suggesting a positive perception of Euro 6/VI's effectiveness.

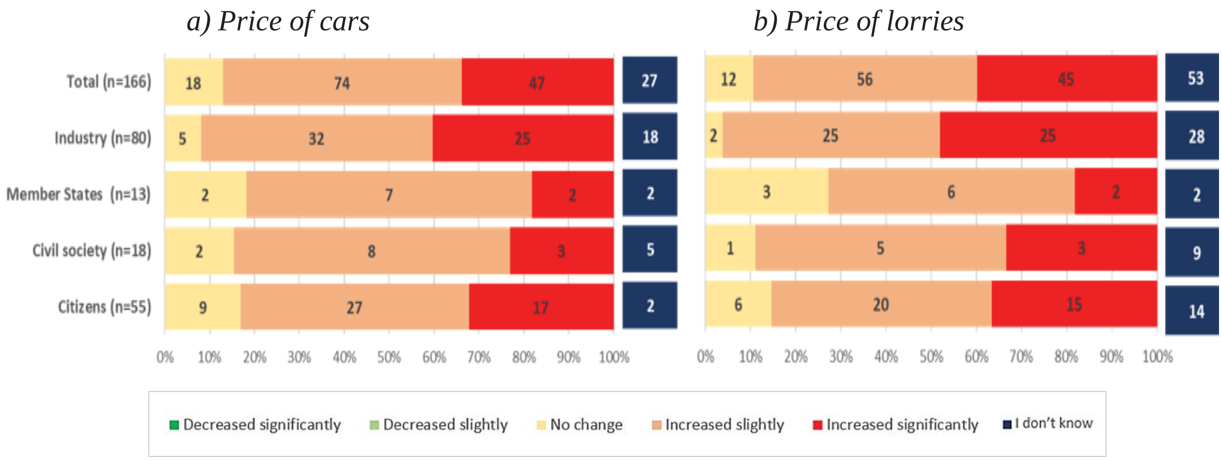
Figure 1 – PC Q3: Over the past 10 years, based on your experience what has happened to air pollution originating from:



The responses from all groups participating in the TC suggest that the Euro 6/VI has made vehicles on EU roads cleaner with the majority of automotive industry considering Euro 6/VI as the most important factor. In TC and PC, two suppliers and an environmental NGO also indicated that there is room for improvement to meet the targets of the European Green Deal. While the responses from all stakeholder groups to TC suggest that the introduction of RDE testing reduced the gap between type-approval and real-world emissions, in PC the majority of industry and citizens indicated that RDE testing truly ensures that cars and vans are compliant with the pollutant limits in all driving conditions. In addition, responses from all groups to PC, excluding industry, suggest that the current shortcomings in the existing on-road tests at least contribute somewhat to increasing emissions. In different activities, automotive industry stressed that the actual impact of the latest standards is not yet fully known and that air quality modelling is important to determine what measures will lead to improved air quality.

While in TC the regulatory costs associated with the standards were reported to have increased significantly with Euro 6/VI by the groups (civil society to a lesser extent), the majority of automotive industry and Member States indicated that compared to the benefits for their organisation the costs were not high. Additionally, the responses from all stakeholder groups suggest that the costs compared to the benefits for society are low. Next to that, Figure 2 illustrates that the vast majority of all groups in PC were of the view that Euro 6/VI has increased vehicle prices. Further, the majority of stakeholders from all groups in TC and PC indicated that instead of achieving simplification, Euro 6/VI has resulted in further complexities in nearly all aspects (e.g. tests, differences in limits, reporting requirements). Lastly, a key consumer organisation in TC indicated that the last Euro 6d step including the introduction of RDE testing had positive effects on consumer trust damaged by Dieselgate.

Figure 2 – PC Q3.1: In your view, what effect did the Euro 6/VI standards have on the price of the following vehicles?[15]



The responses from automotive industry, Member States and civil society to TC highlight that there are ongoing air pollution and health issues associated with road transport and that there is still need for action. In addition, key environmental NGOs stressed that there is no safe level of air pollution. When asked to evaluate policy measures based on their success in limiting vehicle emissions in the PC, the majority of all groups indicated that strict regulations are the most successful. Still, the majority of civil society and Member States indicated that the current emission limits are not strict enough, while the majority of all groups believes that Euro 6/VI does not cover all relevant pollutants. In addition, the results of PC suggest that the majority from all groups apart from industry believes that vehicles do not comply with emission limits in all driving conditions and over their entire lifetime. The responses to TC suggest that, despite the emergence of electric vehicles, the cleaning of the ICE remains relevant for all groups.

The responses from all groups to TC suggest that overall manufacturers are provided with a coherent legal framework. However, a large share from industry indicated that there are important internal inconsistencies in relation to the emission limits, requirements and testing procedures, especially for cars/vans. Additionally, a significant part of the respondents from industry and the Member States reported incoherence of Euro 6/VI emission standards with Ambient Air Quality directive[16] and the CO_2 emissions[17]. A majority of respondents from Member States and civil society indicated incoherencies with the Roadworthiness Directives[18].

The results of TC and PC illustrate that the majority of from all groups believe that there is significant added value in regulating vehicle emissions at EU level compared to what could have been achieved at national or international level. Still, industry believes that lower costs could be achieved when emissions were regulated at international level.

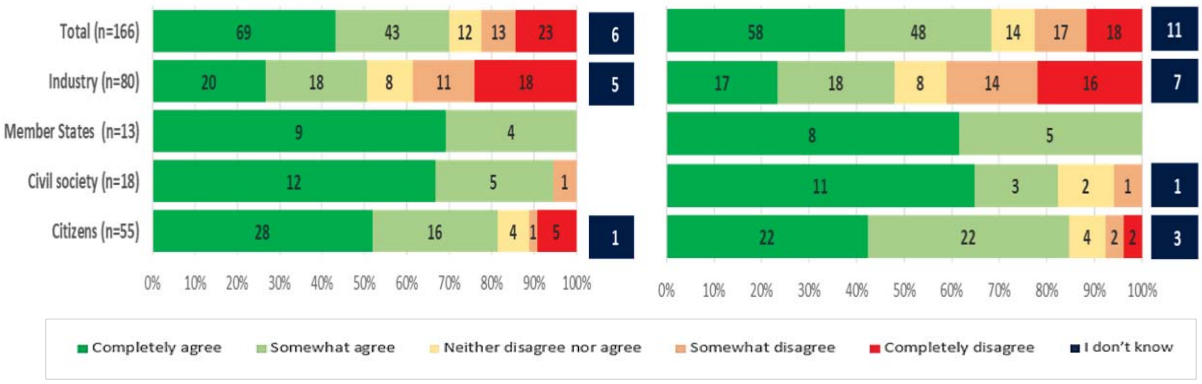
[15] Similar results were found for the price of vans and buses.
[16] Directive 2008/50/EC on ambient air quality and cleaner air for Europe
[17] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011; Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles
[18] Directive 2014/45/EU on periodic roadworthiness tests for motor vehicles and their trailers; Directive 2014/47/EU on the technical roadside inspection of the roadworthiness of commercial vehicles circulating in the Union

2.2.2. Baseline

The results from PC emphasise that the majority of Member States, civil society and citizens consider new Euro standards to be appropriate to further reduce vehicle emission. For automotive industry 29 respondents disagree for cars/vans, while 30 disagree for lorries/buses (Figure 3).

Figure 3 – PC Q5: To what extent do you agree with the following statements? New Euro standards would be appropriate to further reduce air pollutant emissions from:

a) Cars and vans *b) Lorries and buses*

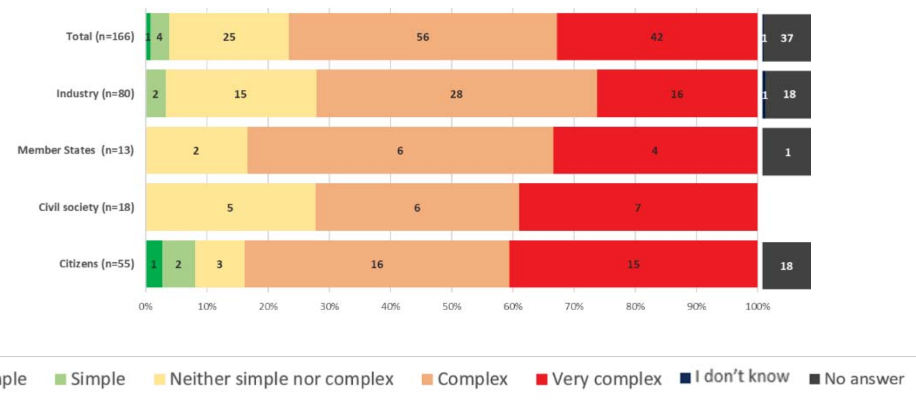


Also in other activities, industry stressed that preserving the Euro 6/VI is a realistic and balanced option. They claim that without action industry is given better stability, while further improvements in air quality would be realised through the renewal of the fleet and through focussing on CO_2 measures. Several stakeholders from civil society and industry indicated in PC that a new Euro emission standard is needed.

2.2.3. Simplification measures

The results from PC showed that the majority from all groups consider Euro 6/VI to be complex (Figure 4). While a large share of industry stakeholders reported inconsistencies for Euro 6/VI in TC, the responses from civil society and Member States suggest that the legislation for lorries/buses is considered less complex. The responses to PC from all groups show that complexities lead to significant compliance costs and administrative burden. Additionally, all groups apart from industry believe that complexity hampers environmental protection, while civil society adds that it leads to misinterpretations.

Figure 4 – PC Q8: Please indicate if you consider the Euro 6/VI simple or complex.



Single legislative tool

The responses to PC suggest that the majority from all groups, especially industry, does not support introducing a single Euro emission standard for cars, vans, lorries and buses due to lack of understanding what this would imply. Industry indicated that the two standards should remain distinct to allow for proper differentiation and international harmonisation. Still, Member States express support to merge the basic acts for Euro 6/VI with almost identical legal structure (715/2007 and 595/2008). Support from all groups is given towards eliminating the currently overlapping area between the two regulations.

Streamlined testing and uniform limits

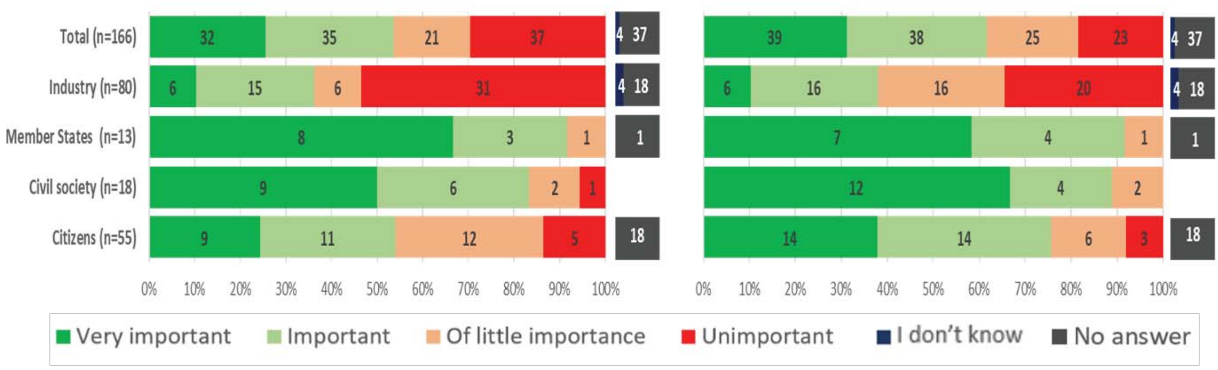
The results of PC demonstrate that a large majority across all groups considers the introduction of technology-neutral limits and testing to be important to reduce complexity. Member States, civil society and citizens also support the introduction of common application dates for new vehicle types and new vehicles, automotive industry does not consider this to be feasible. Automotive industry showed great support for the removal of obsolete tests in all consultation activities. Member States were rather divided on the matter. In TC, industry was sceptical regarding the replacement of all laboratory-based tests by extended on-road testing, which was generally supported by the other groups. In PC the vast majority of Member States, civil society and citizens believe that shortcoming in the existing on-road tests contribute to an increase in emissions. Stakeholders from all groups already mentioned in their feedback to IIA that RDE and PEMS need to be improved to cover all or more conditions of use. Additionally, Member States and civil society (and industry to a lesser extent), consider it important to extend the operation conditions (e.g. trip duration) and environmental conditions (e.g. temperatures). Through AGVES, industry indicated that such extensions should take into account the statistical relevance of these conditions.

2.2.4. Stricter air pollutant limits for new vehicles

Figure 5 shows that apart from industry, the majority of all groups in PC show support for the development of stricter limits for regulated pollutants and new limits for non-regulated pollutants.

Figure 5 – PC Q13: Indicate to what extent the following actions are important to improve the effects of emission limits.

a) Developing stricter limits for regulated pollutants *b) Setting new limits/testing procedures for non-regulated pollutants*



Stricter limits for regulated pollutants

The responses to PC indicate that the vast majority from Member States, civil society and citizens believe that the current emission control technology leave room for additional reductions. Through AGVES and IIA, three environmental NGOs, one main supplier and a respondent from the fuel- and energy industry expressed that technologies to further reduce the emissions are mature and either already or close to be commercially available. Other industry stakeholders mentioned in the different activities that reviewing the limits should start with a careful assessment of the real benefits for air quality. The result from the public consultation shows that most stakeholders from civil society and Member States consider the current limits for NO_x and PM/PN to be insufficiently strict.

New limits for non-regulated pollutants

The large majority of stakeholder from Member States, civil society and citizens in PC indicated that there are emerging unregulated air pollutants. In both PC and TC, several stakeholders (mostly industry), declared that such pollutants should only be regulated if they can be reliably measured and if regulating them would have real benefits for air quality. When looking into which pollutants should be added, both consultation activities suggest high support from Member States and civil society in reducing the size of PN emissions to also cover ultra-fine particles. High support was also given towards the inclusion of non-exhaust emissions (i.e. brake and tyre emissions). The majority of respondents from Member States, civil society and citizens mentioned the increasing importance of these emission sources following the rising popularity of larger and fast-accelerating vehicles (e.g. SUVs, battery electric vehicles). Also, introducing an NH_3 limit for cars and vans receives significant support from Member States and civil society. Including limits for NO_2, N_2O and CH_4 (for cars and vans) is also supported by these groups, but to a lesser extent. In TC, however, the majority of industry and Member States indicated that separate NO_2 limits are not necessary, as long as NO_x emissions remain low in real-world conditions.

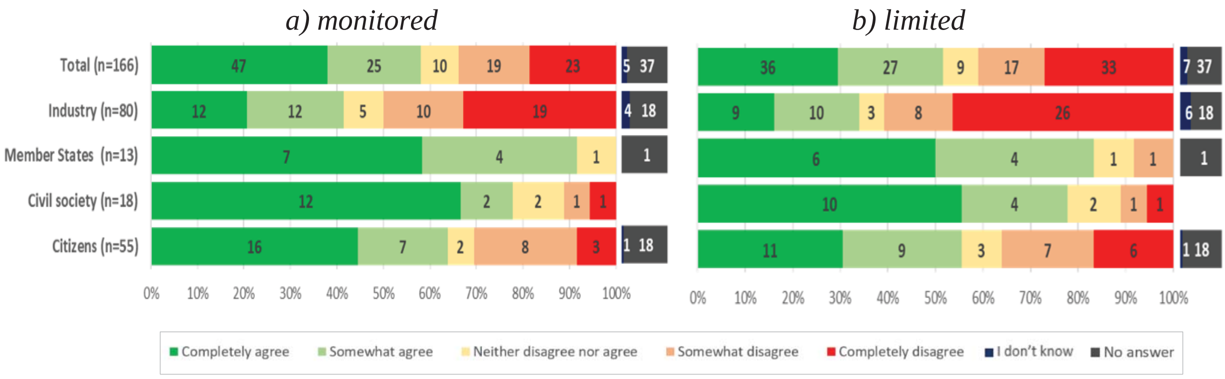
Through their feedback to IIA, several industry stakeholders underlined that legislative changes should be preceded by a careful cost-benefit analysis, which considers the current economic situation, and incentives for the introduction of more advanced technology by early adopters are important.

Real-world emissions and durability

Figure 6 illustrates that in PC the majority of all groups, excluding automotive industry, believe that in Euro 6/VI real-world emissions are not adequately monitored or limited over the entire lifetime of vehicles. Tampering, vehicle ageing, inadequate technical inspections and the cost of maintenance were indicated as potential causes. In all activities all groups have shown support for the development of clear requirements for the protection against tampering.

Through feedback to IIA, a number of stakeholders from industry, Member States and environmental NGOs indicated that emission performance should remain consistent over the real lifetime of vehicles and that durability requirements need to be extended to ensure this. In TC, the majority from Member States, civil society and industry (to a lesser extent) identified the importance of limiting emissions over the average age of vehicles until the end-of-life. In the AGVES meetings, stakeholders from civil society have stressed on several occasions that while on average cars in the EU are 10.8 years, cars stay on the road much longer in Eastern and Southern Europe, often in excess of 15 years. Most manufacturers stressed in this consultation that the emissions of older vehicles are generally dependent on maintenance which is outside their responsibility.

Figure 6 – PC Q14: To what extent do you agree with the following statements? Real-world emissions are not adequately *[insert a/b]* over the entire lifetime of a vehicle in Euro 6/VI.



2.2.5. Continuous emission monitoring

While only few manufacturers expressed support, the results of PC show that the majority of the other stakeholder groups support the implementation of continuous emission monitoring (CEM) of emissions as an action to measure real-world emissions. In TC, a large majority from automotive industry and all respondents of Member States and civil society indicated a combination of methods, such as new on-board monitoring (OBM) and existing on-board diagnostics (OBD), may be required to ensure lifetime compliance. The large majority of manufacturers, however, indicated that they do not know whether such a combination of methods would be required. In addition, most manufacturers added that OBM can only be used for a limited number of pollutants in the near future. Regarding how OBM should be used, the majority of respondents from industry, Member States and civil society in TC somewhat agreed that the relevant values should be read-out during technical inspections. On the other hand, two suppliers and one Member State consider "over the air transfers" to be more effective. In their feedback to IIA, two industry respondents indicated that that CEM in combination with stricter limits could be overly burdensome for European manufacturers.

In PC, geo-fencing was only considered to be an important action for improving the effect of emission limits by a majority of respondents from the Member States and citizens. The responses to TC suggest that civil society thinks that a vehicle should be operated in zero-emission mode in more polluted areas. The responses from automotive industry to this consultation, on the other hand, suggest that they think it would be difficult to precisely monitor and enforce geo-fencing.

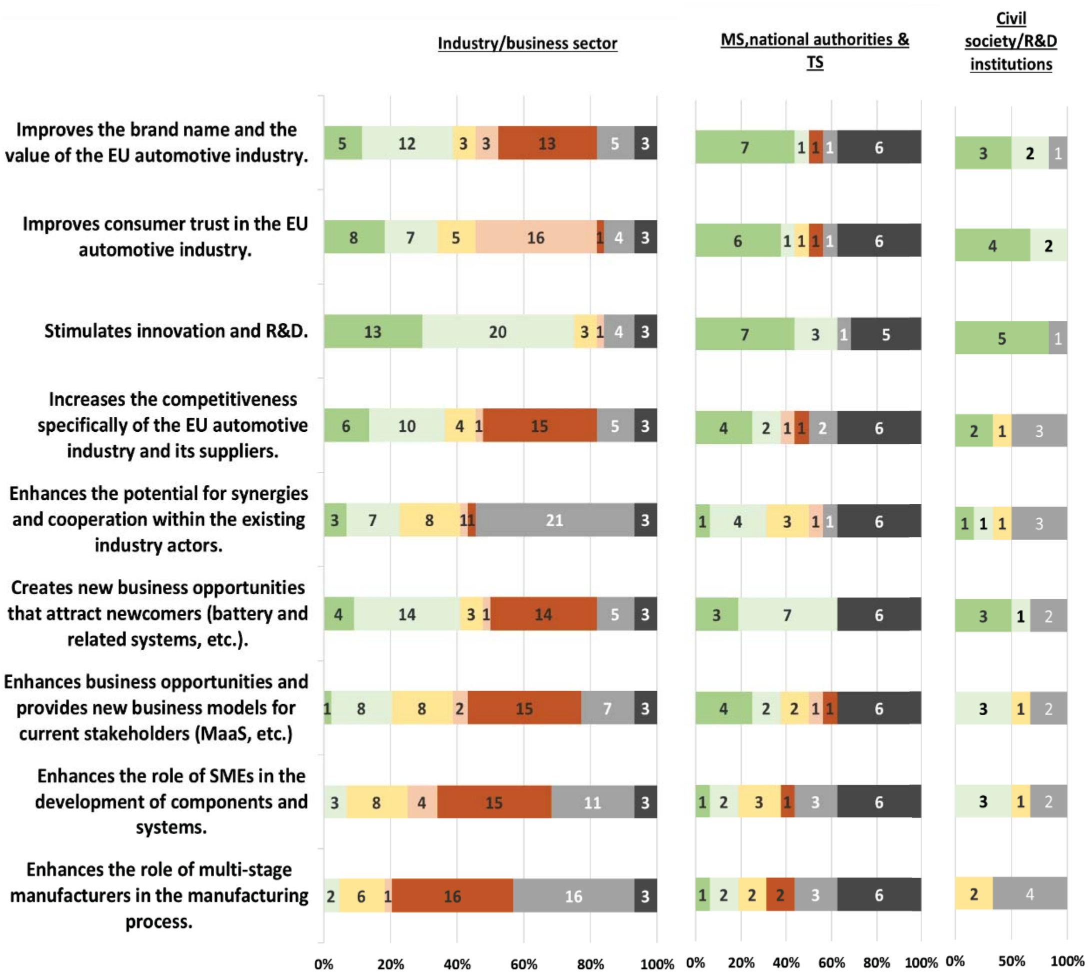
2.2.6. Impacts of a stricter emission standard

Through TC, views on the possible impacts of new emission standards on industry competitiveness were collected. The results in Figure 7 show that while Member States and civil society generally expect a positive relationship between stricter standards and competitiveness, differing views were found amongst industry stakeholders with suppliers anticipating positive impacts and manufacturers anticipating negative impacts.

Almost half of the suppliers stressed that new limits will create new business opportunities and quality jobs. A large share of industry, Member States and civil society stakeholders indicated that a higher-level education and new skills will be required for the majority of the personnel. The majority of vehicle manufacturers, however, expressed concern that stringent emission limits and testing over all driving conditions may accelerate the shift to electric vehicles or even take the ICE off the market. About half of industry claimed that employment in businesses focused on traditional ICE and/or exhaust after treatment parts would be negatively affected.

Input from TC on consumer affordability indicated that the majority from industry consider stringent emission limits to increase the price of vehicles and to reduce demand and fleet turn-over. In PC, the majority from Member States and civil society disagreed that the Euro standards are too costly and make cars unduly expensive. In, TC a consumer organisation stated that the previous Euro standards illustrate that an appropriate level of ambition can make vehicles significantly cleaner while not making them disproportionately more expensive.

Figure 7 – TC Q14: Please indicate to what extent you agree or disagree with the following statement(s) relating to how stricter post-Euro 6/VI standards may affect the relevant EU industry[19]



[19] Supporting Euro 7 impact assessment study, Annex II: Input from targeted stakeholder consultation (10.6 Other impacts of new vehicle emission standards)

2.3. Use of Consultation Results

The replies to the three questionnaires as well as information and data through all consultation activities were taken into consideration for the evaluation of the Euro 6/VI and for the preparation of the Euro 7 impact assessment. The collected stakeholder evidence made it possible to supplement, cross-check and confirm the evidence already gathered through other research (see Annex 4) in this staff working document and the supporting studies[20,21,22,23,24].

Depending on the nature of the specific questions, the responses were analysed in the Euro 6/VI evaluation and Euro 7 impact assessment quantitatively or qualitatively for each stakeholder group. For this purpose, the closed questions (Yes/No and Likert-scale questions) in PC[25] and TC[26] were analysed using visual aids, such as bar charts, while the responses to the open questions and other feedback were examined by labelling and organising common elements in the responses over the different stakeholder groups. If no clear position was expressed within the same group, the groups were further disaggregated based on the sub-groups to identify common views. In the case of the Member State and civil society stakeholder groups, the views were generally found to be consistent. The further disaggregation was especially relevant in the case of automotive industry, where vehicle manufacturers and component suppliers often had differing views. In addition to this, the individual manufacturers and suppliers coordinated their responses to the different consultation activities through the main manufacturers and suppliers associations (ACEA and CLEPA).

The feedback from all stakeholder groups has been taken into account for evaluating Euro 6/VI. Feedback and differences in stakeholders' views were carefully analysed and taken into account if credible. Stakeholder views from industry and Member States have been particularly useful for identifying the standards' effectiveness, efficiency and coherence. For evaluating relevance and EU-added value, views from all stakeholder groups have been taken into account. All feedback and concerns were taken into account in the Euro 7 impact assessment. In particular, the views from industry and Member States were helpful to analyse the problem of complexity and in that way develop option 1 and information provided by industry on the hardware costs for emission control technologies were assessed in option 2 and 3. Feedback and concerns raised by the Member States, industry, civil society and citizens have been taken into account in the design and assessment of the options, particularly with regard to the technological potential for reducing emissions by emission limits, durability, testing conditions and CEM, the potential accelerated shift to electric vehicles and the impacts on competitiveness, where industry stakeholders seem to have different views.

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[20] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[21] CLOVE, 2022. Technical studies for the development of Euro 7: Simplification. ISBN 978-92-76-56405-8.

[22] CLOVE, 2022. Technical studies for the development of Euro 7: Durability of light-duty vehicle emissions. ISBN 978-92-76-56405-8.

[23] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3.

[24] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7

[25] European Commission, 2020. Presentation AGVES Meeting 26 November 2002: Post-Euro 6/VI public stakeholders consultation (Question 5)

[26] See footnote 20 and 21

The widely supported view against the introduction of a single Euro emission standard for cars/vans and lorries/buses was not entirely considered, since the objectives of proper differentiation as well as international harmonisation stated by industry should be achievable also with the basic acts (715/2007 and 595/2008) merged while the specific implementing regulations are kept separate. This was confirmed with the stakeholders in the follow-up interviews linked to the targeted consultation on the impact assessment and in the AGVES meeting of 16 November 2020.

Annex 3: Who is affected and how?

1. Practical implications of the initiative

The Euro 7 emission standards will apply to vehicle and component manufacturers active in the automotive supply chain and national authorities responsible for type-approval of vehicles in the Member States. They will need to comply with the requirements of the Euro 7 emission standards summarised in Table 2.

Table 2 - Summary of Euro 7 requirements

What	By whom	By when
Option 1		
Adapt vehicle production to technology-neutral limits for certain regulated pollutants.	Manufacturers, including component suppliers.	2025
Apply or witnessing simplified and revised testing procedures for emission testing of cars, vans, lorries and buses.	Manufacturers, including component suppliers. National authorities responsible for type-approval.	2025
Granting Euro 7 emission type-approvals	National authorities responsible for type-approval.	2025
Checking compliance during market surveillance	National authorities responsible for market surveillance	2025
Option 2		
Adapt vehicle production to medium/high ambitious emission limits, testing procedures and durability.	Manufacturers, including component suppliers	2025
Apply or witnessing simplified and revised testing procedures for emission testing of cars and vans, and lorries and buses.	National authorities responsible for type-approval. Manufacturers, including component suppliers.	2025
Granting Euro 7 emission type-approvals	National authorities responsible for type-approval.	2025
Checking compliance during market surveillance	National authorities responsible for market surveillance	2025
Option 3		
Adapt vehicle production to medium ambitious emission limits, testing procedures and durability.	Manufacturers, including component suppliers	2025
Adapt vehicle production to continuous emission monitoring (CEM).	Manufacturers, including component suppliers.	2025
Shift part of the emission testing to controlling emissions through CEM functions.	National authorities responsible for type-approval.	2025
Granting Euro 7 emission type-approvals	National authorities responsible for type-approval.	2025
Checking compliance during market surveillance	National authorities responsible for market surveillance	2025

2. Summary of costs and benefits

2.1 Euro 6/VI evaluation

Table 3 - Overview of costs and benefits following the introduction of the Euro 6/VI emission standards[27]

I. Overview of costs – benefits identified in the evaluation for EU-28				
Type of costs and benefits[28]	**Stakeholder group**			**Overview of costs and benefits identified in the evaluation[29]**
	Manufacturers and suppliers	**Administrations**	**Citizens and consumers**	
Direct costs (regulatory costs)				
1) Equipment costs Compared to the estimates of the former Euro 6/VI Impact Assessments: €213 per diesel LDV[30] €2 539-€4 009 per HDV	X			• **Hardware costs** Cost of €228-€465 per petrol LDV and €751-€1703 per diesel LDV (moving from Euro 5 to Euro 6d) Cost of €1 798-€4 200 per HDV Total cost up until 2020: €17.2–€43.2 billion for Euro 6 €4.1-€9.5 billion for Euro VI High level of confidence that costs are within the above intervals. Costs per vehicle are expected to decline gradually following a learning effect. • **R&D, calibration, facilities, tooling costs** €36-€108 per petrol LDV and €43-€156 per diesel LDV €1 900-€3 800 per HDV Total cost up until 2020: €3.1-€10.7 billion for Euro 6 €5.35-€10.7 billion for Euro VI Also for suppliers in the form of costs for the development of new equipment, but partly covered by hardware costs for manufacturers. Moderate level of confidence due to limited data points and variation between manufacturers (wide range intended to capture this).
2) Costs during implementation phase	X	X		• **Testing and witnessing costs for manufacturers and suppliers** Cost of €150-€302 thousand per model family for LDV (moving from Euro 5 to Euro 6 d) Cost of €95.7-€232 thousand per engine family for HDV Total cost up until 2020: €401-€921 million for Euro 6 €52.5-€128.8 million for Euro VI

[27] All estimates for the cost and benefits are based on the Supporting evaluation study (CLOVE, 2022), which are featured in Annex 5: Evaluation Euro 6/VI emission standards
[28] Detailed explanations of the cost typology for manufacturers and supplier can be found in Table 39 in Annex 5: Evaluation Euro 6/VI emission standards
[29] More detailed cost estimates for the regulatory costs for manufacturers can be found in Table 40 in Annex 5: Evaluation Euro 6/VI emission standards
[30] In the Euro 6 Impact Assessment, no estimates were made for petrol cars and vans. It only focused on the cost of the key technology expected to be needed to comply with the limits (SCR or LNT) and did hence not cover other aspects such as the costs of sensors and other supporting hardware. In addition, only the initial stages of Euro 6 (prior to changes in the testing requirements, including RDE testing).

				Medium level of confidence as a result of the limited data provided and the different way that manufacturers go about type-approval (grouping of model/engine families) (broad range reflects this uncertainty). • **Witnessing costs for type-approval authorities** Euro 6 resulted in a medium increase in costs mainly from training and more demanding testing and witnessing requirements. Expected to be largely covered by manufacturers. • **Type-approval fees for manufacturers** Total cost up until 2020: €6-€10 million for Euro 6 The overall fee per type-approval remained small (€0-€1 500). Increase in total costs for cars and vans realized through an increase in the number of emission type-approvals. Medium to high level of confidence based on data on fees charged by 6 authorities and confirmed by manufacturers.
3) Administrative costs	X			Cost of €16-€52 thousand per LDV type approval (moving from Euro 5 to Euro 6d) Cost of €17.5-€27.5 thousand per HDV type approval Total cost up until 2020: €247-€794 million for Euro 6 €26-€41 million for Euro VI Medium level of confidence (see explanation witnessing costs)
Total regulatory costs 1)+2)+3)	X	X		• **Total costs for manufacturers and suppliers** Based on the sector market structure, all regulatory costs to industry are expected to be passed down to consumers. Total cost up until 2020: €21.1-€55.6 billion for Euro 6 €9.5-€20.4 billion € for Euro VI • **Total costs for type-approval authorities** Total cost associated with the implementation process (see above). Expected to be largely covered by manufacturers in the form of witnessing costs for type-approval.
Indirect costs (prices)				
			X	• **Costs for users of vehicles (both citizens and businesses users)** Regulatory costs to industry are expected to be passed down to consumers in the form of higher vehicle prices. Cost increase per vehicle in comparison to average vehicle prices: Increase of 2.7-4.3% for diesel LDV and 0.6-1.2% for petrol LDV (Euro 6d) Increase of 4.2-5.0% for lorries and 2.1-3.0% for buses
Direct benefits (environmental and health benefits)				
Compared to the estimates of the former Euro 6/VI impact assessment up until 2020: Euro 6: 24% savings of NOx resulting in 60-90% increase in health benefits. Euro VI: 37% savings of NOx and 22% of PM			X	High impact through reductions of emissions from a number of regulated pollutants up to 2020 and even higher level of reduction expected in the future. Emission savings up until 2020: NOx savings: 21.8% for Euro 6 and 35.7% for Euro VI Exhaust PM10 savings: 28% for Euro 6 and 13.5% for Euro VI THC savings: 20.5% for Euro 6 and 14% for Euro VI NMHC savings: 11.9% for Euro 6 Total monetised benefits up until 2020: For NOx: €28.5 billion for Euro 6 and €65.1 billion for Euro VI For PM: €2 billion for Euro 6 and €1.4 billion for Euro VI

				High confidence since calculations are based on best available information on emission savings, including generally accepted emission factors and factors to monetise external costs (handbook of external costs of transport).

2.2 Euro 7 impact assessment

Table 4 – Overview of direct and indirect benefits in the policy options (2025-2050)

I.A Overview of Benefits (total for all provisions for light- and heavy-duty vehicles) – Option 1		
Description	***Amount***	***Comments***
Direct benefits		
Regulatory costs savings: Testing, witnessing, type-approval and administrative costs savings	€3.88 billion	• Main recipients of the benefit: Automotive industry and eventually citizens through reduced vehicle prices
Health and environmental benefits	€43.50 billion	• Main recipient of the benefit: citizens
Indirect benefits		
Consumer trust	Low benefit	• Main recipient of the benefit: citizens

I.B Overview of Benefits (total for all provisions for light- and heavy-duty vehicles) – Option 2a		
Description	***Amount***	***Comments***
Direct benefits		
Regulatory costs savings: Testing, witnessing, type-approval and administrative costs savings	€3.83 billion	• Main recipients of the benefit: Automotive industry and eventually citizens through reduced vehicle prices
Health and environmental benefits	€187.36 billion	• Main recipient of the benefit: citizens
Indirect benefits		
Competitiveness: Access to international key markets	Low benefit	• Main recipient: automotive industry
Consumer trust	Moderate benefit	• Main recipient: citizens

I.C Overview of Benefits (total for all provisions for light- and heavy-duty vehicles) – Option 2b		
Description	***Amount***	***Comments***
Direct benefits		
Regulatory costs savings: Testing, witnessing, type-approval and administrative costs savings	€3.83 billion	• Main recipients of the benefit: Automotive industry and eventually citizens through reduced vehicle prices
Health and environmental benefits	€199.18 billion	• Main recipient of the benefit: citizens
Indirect benefits		
Competitiveness: Access to international key markets	Moderate benefit	• Main recipient: automotive industry

Competitiveness: Innovation	Low benefit	• Main recipient: automotive industry
Free movement within the single market	Low benefit	• Main recipient: automotive industry
Consumer trust	Moderate benefit	• Main recipient: citizens
Employment and skills	Low benefit	• Main recipient: citizens

I.D Overview of Benefits (total for all provisions for light- and heavy-duty vehicles) – Option 3a		
Description	***Amount***	***Comments***
Direct benefits		
Regulatory costs savings: Testing, witnessing, type-approval and administrative costs savings	€5.25 billion	• Main recipients of the benefit: Automotive industry and eventually citizens through reduced vehicle prices
Health and environmental benefits	€189.33 billion	• Main recipient of the benefit: citizens
Indirect benefits		
Competitiveness: Access to international key markets	Moderate benefit	• Main recipient: automotive industry
Competitiveness: Innovation	Moderate benefit	• Main recipient: automotive industry
Free movement within the single market	Low benefit	• Main recipient: automotive industry
Consumer trust	High benefit	• Main recipient: citizens
Employment and skills	Low benefit	• Main recipient: citizens

Table 5 – Overview of direct and indirect costs in the policy options

II.A Overview of costs for light- and heavy-duty vehicles – Option 1							
Billion €		**Citizens/Consumers**		**Manufacturers**		**Administrations**	
		One-off	**Recurrent (annual)**	**One-off**	**Recurrent (annual)**	**One-off**	**Recurrent (annual)**
Simplification measures (cost savings see above)	Direct costs (regulatory costs)	0.00	0.00	0.00	-0.15	0.00	0.00
	Indirect costs (prices)	0.00	-0.15	0.00	0.00	0.00	0.00
Technology-neutral limits and low ambition real-driving testing[1]	Direct costs (regulatory costs)	0.00	0.00	3.19	0.23	0.00	0.00
	Indirect costs (prices)	0.00	0.35	0.00	0.00	0.00	0.00

[1] It is not possible to detangle costs for low ambition (technology-neutral Euro 6/VI) limits and boundaries, as it is one low-ambition emission control system.

II.B Overview of costs for light- and heavy-duty vehicles – Option 2 (including a and b)							
Billion €		Citizens/Consumers		Manufacturers		Administrations	
		One-off	Recurrent (annual)	One-off	Recurrent (annual)	One-off	Recurrent (annual)
Simplification measures (cost savings see Table 4)	Direct costs (regulatory costs)	0.00	0.00	0.00	-0.15	0.00	0.00
	Indirect costs (prices)	0.00	-0.15	0.00	0.00	0.00	0.00
Medium ambition emission limits, real driving testing boundaries and durability (2a)[2]	Direct costs (regulatory costs)	0.00	0.00	16.30	1.32	0.00	0.00
	Indirect costs (prices)	0.00	1.94	0.00	0.00	0.00	0.00
High ambition emission limits, real driving testing boundaries and durability (2b)[2]	Direct costs (regulatory costs)	0.00	0.00	16.30	2.96	0.00	0.00
	Indirect costs (prices)	0.00	3.59	0.00	0.00	0.00	0.00

[2] It is not possible to detangle costs for medium ambition limits, boundaries and durability, as it is one medium-ambition emission control system. The same applies to the high-ambition emission control system.

II.C Overview of costs for light- and heavy-duty vehicles – Option 3a							
Billion €		Citizens/Consumers		Manufacturers		Administrations	
		One-off	Recurrent (annual)	One-off	Recurrent (annual)	One-off	Recurrent (annual)
Simplification measures (cost savings see Table 4)	Direct costs (regulatory costs)	0.00	0.00	0.00	-0.20	0.00	0.00
	Indirect costs (prices)	0.00	-0.20	0.00	0.00	0.00	0.00
Medium ambition emission limits, real driving testing boundaries and durability (2a)[3]	Direct costs (regulatory costs)	0.00	0.00	16.30	1.32	0.00	0.00
	Indirect costs (prices)	0.00	1.94	0.00	0.00	0.00	0.00
Continuous emission monitoring	Direct costs (regulatory costs)	0.00	0.00	1.25	0.05	0.00	0.00
	Indirect costs (prices)	0.00	0.09	0.00	0.00	0.00	0.00

[3] It is not possible to detangle costs for medium ambition limits, boundaries and durability, as it is one medium-ambition emission control system.

Annex 4: Analytical methods and results

1. Description and results of methods and modelling tools

Since the evaluation and impact assessment are carried out in parallel through a "back-to-back" approach, the methods and modelling have been harmonised to ensure continuity and consistency. In both cases, models have been important for calculating and visualizing the future vehicle fleet and the related emission inventories. Cost models have been applied to calculate all the relevant costs and benefits to support the assessment of the impacts in Chapter 6 and 7 of the impact assessment.

COPERT is an internationally recognized and widely used tool for calculating greenhouse gas and air pollutant emission inventories for road transport based on real-world emissions coordinated by European Environment Agency (EEA) and by the JRC[31][32]. The COPERT methodology is part of the EMEP/EEA air pollutant emission inventory guidebook for the calculation of air pollutant emissions[33] and **is used by the large majority of European countries for reporting official emissions data**. The tool uses vehicle population, mileage, speed and other data (e.g. ambient temperature) to calculate emissions and energy consumption in a specific country or region. In particular, COPERT develops reliable and widely recognised emission factors that indicate the level of pollutant emissions released by a polluting activity

SIBYL was used to project the vehicle fleet. **SIBYL is a specialised tool for projecting the impact of detailed vehicle technology on future fleets, energy, emissions and costs designed to support policy making**. It has the ability to project emissions based on fleet dynamics, expected market trends and forecasted fleet growth scenario up to 2050. Based on these features and by utilising proper emission (see COPERT above*)* and consumption factors, SIBYL is able to project emission and energy evolutions from road vehicles. SIBYL is also the core calculation module of the JRC DIONE[34] model. The latter has a successful record of use in the Commission's transport, energy and climate impact assessments, including the CO_2 standards for light- and heavy-duty vehicles[35].

In addition and in order to maintain compatibility with other Commission policies and modelling, the SIBYL baseline was calibrated to the EU reference scenario from the PRIMES 2020 model[36], the main model used in the Commission's energy and climate policy assessments, and more specifically the 2030 climate target plan following the

[31] COPERT: The industry standard emissions calculator
[32] EEA, 2016. Copert 4
[33] EEA, 2019. EMEP/EEA air pollutant emission inventory guidebook
[34] JRC, 2017. Light Duty Vehicle CO2 emission reduction cost curves and cost assessment – the DIONE Model and JRC, 2018. Heavy duty vehicle CO2 emission reduction cost curves and cost assessment – enhancement of the DIONE model
[35] Regulation (EU) 2019/631 CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, Regulation (EU) 2019/1242 CO_2 emission performance standards for new heavy-duty vehicles
[36] E3 Modelling, 2020. The core PRIMES model

announcement of the Fit-for-55 Commission proposal[37].

In combination with the COPERT, the SIBYL[38] vehicle stock, activity and emission projection tool was used to estimate emission reductions until 2050 and compare them with the baseline, i.e. the "no policy change" scenario (see chapter 5.1). The SIBYL and COPERT model were updated with the data collected, latest emission factors that represent the quantity of a pollutant released to the atmosphere through a polluting activity and literature reviews in the supporting Euro 7 impact assessment study[39] and synchronised with the PRIMES 2020 vehicle stock and vehicle activity used for the revision of the CO_2 emission performance standards for new passenger cars and for new light commercial vehicles[40].

There is a close interaction between the models in the assessment. As shown in Figure 8, the output from SIBYL serves as input for both COPERT and the cost models. That way, the total emissions and associated technology costs can be calculated to support the analysis of the effectiveness and efficiency of the Euro 6/VI emission standards and the assessment of the impacts for a Euro 7 initiative.

In the context of the Euro 6/VI evaluation and Euro 7 impact assessment, the modelling tools and methods cover:

- The **broad vehicle categories**, including: cars, vans, lorries and buses and for each category a number of different segments. No distinction is made for small volume manufacturers.[41]
- A **broad range of fuel and powertrain vehicle technologies**, including: petrol, diesel, hybrids, LPG/CNG (bi-fuel), plug-in hybrids (PHEV), battery electric, fuel cell electric vehicle (hydrogen) and flexi-fuel (bioethanol).
- **Geography**: While the backward-looking evaluation of Euro 6/VI considers the dataset for the EU-27 countries and the United Kingdom, for the forward-looking impact assessment of the Euro 7 initiative the EU-27 data file was used for emission modelling. Hence, the geography of both assessments is limited to the EU market.[42]
- **Time horizon**:
    - evaluation of Euro VI: 2013-2050, Euro 6: 2014-2050

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[37] COM(2020) 562 final, Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people

[38] SIBYL: Ready to go vehicle fleet, activity, emissions and energy consumption projections for the EU 28 member states

[39] CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7.

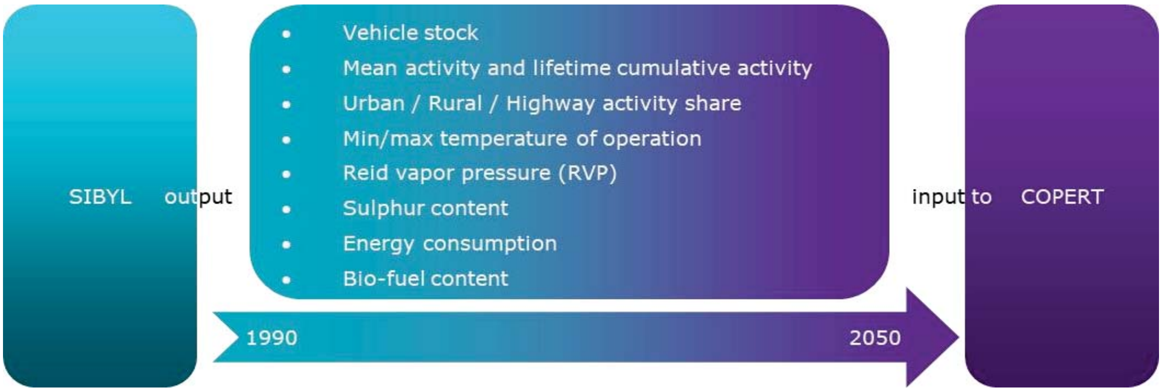
[40] SWD(2021) 613 final, Commission Staff Working Document, Impact Assessment, Accompanying the document Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition

[41] The contribution of small volume manufacturers (i.e. those with less than 10 000 vehicles produced worldwide annually) to the overall emissions from road transport is minimal since they only comprise less than 0.4 percent of total vehicle registrations in Europe each year. Moreover such vehicles travel far less km (around 3 700 km/year) (ESCA, 2021) than the average cars in Europe. The combined effect on emissions is therefore much less than 0.4% and can be considered as negligible. Any special provisions for such manufacturers will thus have negligible effect in the impacts of Euro 7 and are therefore not addressed in this impact assessment.

[42] Since the Euro standards are only applicable to vehicles sold in the EU and not to vehicles produced in the EU for other markets, exports are not considered in the cost-benefit analysis. Still, the indirect impact of Euro 7 policy options on competitiveness of EU manufacturers is assessed (see Annex 4 section 1.4.1).

- impact assessment Euro 7: 2025-2050

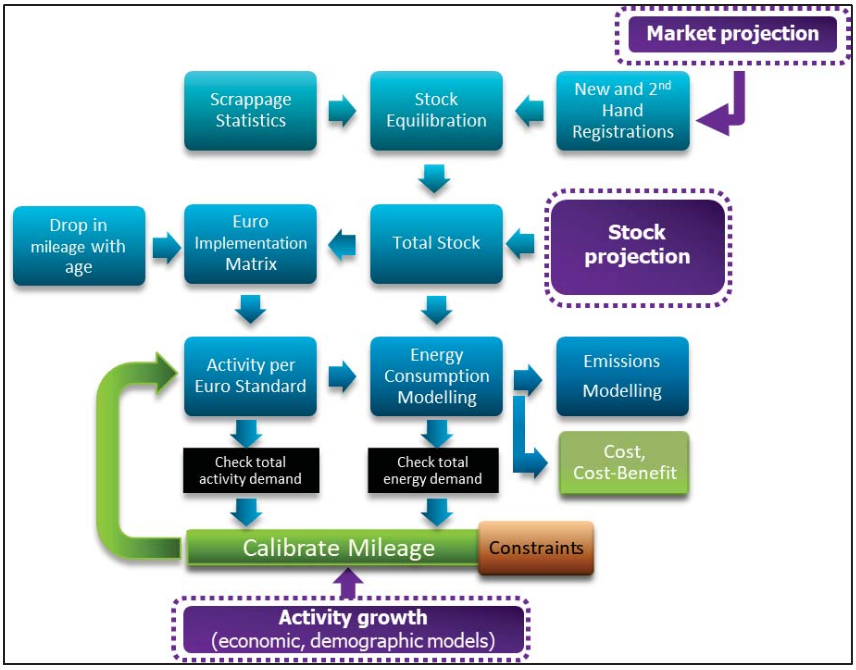
Figure 8 – Interlinkage between SIBYL and COPERT[43]



1.1. Fleet modelling with SIBYL

The process towards fleet modelling with SIBYL is illustrated in Figure 9. As a first step, the vehicle stock is balanced with the statistical data by taking into account the new registered vehicles (including used vehicles) and scrappage[44] statistics. Afterwards, the vehicles are classified in the various Euro emission standards on the basis of a "technology matrix" that connects the technology of new registrations with the year they entered into the fleet by taking into account the introduction date of each Euro standard. The annual mileage is then calibrated to ensure that the energy demand is consistent with the statistical energy consumption. **For the projected years, the stock and mileage are then calibrated in line with the activity growth described in the EU reference scenario from the PRIMES 2020 model.**

Figure 9 – Process for developing the SIBYL baseline[45]



[43] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.1 Introduction of COPERT/SIBYL tools

[44] Scrappage is the act of offering people money if they get rid of an old vehicle and buy a new one.

[45] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.2 Fleet modelling

The reliability, quality, completeness and consistency of the SIBYL tool and data are ensured by the high expertise of the developers in combination with an extensive level of reviewing and cross-checking. Next to that, the **SIBYL fleet data** takes into account a) the Euro 6/VI emission standards, b) the impact of COVID-19 on road transport activity[46] and c) the impact of the new 55% (cars) and 50% (vans) CO_2 targets by 2030 and 100% CO_2 targets for cars and vans by 2035[47] and the projected fit-for-55 HDV fleet evolution to contribute to the 55% net greenhouse gas emission reduction by 2030 and the 2050 climate neutrality objective[48]. Lastly, it has been harmonised with **official statistics from several official EU sources** (e.g., Eurostat, European Alternative Fuels Observatory). Table 6 gives an overview of these official sources and the main information provided, while also showing other sources used for the SIBYL fleet data. In the context of the work on the Euro 6/VI evaluation and the Euro 7 impact assessment, an effort was done to gather additional data directly from the Member States and research institutes. Bilateral consultations took place which were targeted at acquiring data on new vehicle registrations. These consultations led to the update of the datasets for a group of 10 Member States. While not covering all Member States, this group is found to have a rate of renewal of passenger cars which is close to the EU average.[49] Next to that, other relevant datasets on new registration[50] were used for cross-checking.

Table 6 – Overview data sources for the SIBYL fleet modelling, based on CLOVE, 2022[51]

Source	Main information provided
Official EU sources	
Eurostat[52]	Stock and new registrations per fuel and engine capacity / GVW
EC Statistical Pocketbook[53] (EU Transport in figures)	Stock and new registrations
CO_2 monitoring database[54]	New registrations per fuel and segment (PCs and LCVs)

[46] Road transport activity is the volume-km driven by vehicles on EU roads and is projected by the estimated evolution of vehicle sales.
[47] A linear interpolation was used for the year 2030 for both the activity and shares of vehicles between the two existing scenarios in the CO_2 Impact Assessment (TL_Med and TL_High), while the TL_High scenario was used for the year 2035. This approach is the estimated representation of the impact of the Commission proposal for CO_2 targets for cars/vans.
[48] For heavy–duty vehicles, the activity and fleet shares of vehicles are based on the SWD(2020) 176 final, Impact Assessment on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people (part 1) and SWD(2020) 176 final (part 2), supplemented for buses by CLOVE, 2022.
[49] See footnote 45
[50] See footnote 129
[51] See footnote 45
[52] Eurostat, 2021. New registrations of passenger cars by type of motor energy and engine size
[53] Publications Office of the EU,2019."EU transport in figures"
[54] EEA, 2020."Monitoring of CO2 emissions from passenger cars – Regulation (EU) 2019/631",2020

EAFO[55] (European Alternative Fuels Observatory)	Stock and new registrations of alternative fuels (LPG, NG, electric, H_2)
Other sources	
ACEA[56]	Stock per fuel, new registrations per fuel and per segment / GVW
ACEM[57]	Stock, new registrations per fuel and engine capacity (L-vehicles)
NGVA Europe[58] (Natural Gas Vehicle Association) / NGV Global[59] (Natural Gas Vehicle Knowledge Base)	Stock of natural gas vehicles
UNFCCC[60]	Fuel sold, based on Eurostat and disaggregated per vehicle category
Others: literature, studies, reports, national statistics web sites	Various information (level of detail is country-dependent)

SIBYL reflects the real situation to the extent possible and contains highly accurate emissions figures. The dataset of the SIBYL model covers the horizon from 1990 until 2050 and includes all Member States of the EU individually, as well as neighbouring and candidate countries. Hence, a complete and consistent transport dataset has been created and harmonised with official national statistics.

However, some issues have been identified with these data sources. None of these sources provided all the necessary data at the required level of detail and some gaps or incomplete time series (missing countries/years) were discovered. In addition, the collected information was sometimes found to be inconsistent with different sources presenting different values or vehicle classifications. In order to overcome such issues, a processing methodology has been developed to combine the primary information from various sources in order to produce total numbers for the vehicle fleet (for each vehicle category/fuel/segment). The different steps for ensuring that the outcome of the processing methodology is a complete and consistent dataset is explained in Box 1.

It is important that the SIBYL fleet data takes into account the age distribution of the fleet. To ensure better modelling of the fleet structure, technologies and the specific Euro standards per country, the average age of the vehicle category considered in the model must be consistent with statistical data. Therefore, the methodological steps summarized in Box 2 have been followed. The outcome of this phase is then an age distributions per fuel and segment for each vehicle category so that the checking rules in Box 1 are satisfied for all age bins[61]. Once the age distributions have been finalised, vehicles have been allocated to the different Euro emission standards based on the previously described technology matrices.

The consistency of the SIBYL fleet data with the national inventory submissions of fuel

[55] EAFO,2017.”The transition to a Zero Emission Vehicles fleet for cars in the EU by 2050”,2017
[56] ACEA, 2020. Consolidated registrations by country
[57] acem, 2021.
[58] NGVA Europe, 2021.
[59] NGV Global, 2021.
[60] UNFCC,2020, “National Inventory Submissions 2020”
[61] There are 30 age bins in the dataset: from age 0 (new registrations) to age 29. All stock vehicles are allocated to these bins, so that the sum of vehicles in all age bins equals to the total number of vehicles.

consumption data was checked for the different vehicle categories through the UNFCCC[62]. Subsequently, micro-adjustments have been made in the mileage of the vehicles in order to match the calculated fuel consumption with the statistical one.

Box 1 – Data processing methodology for SIBYL fleet data[63]

- Comparison of the source – one data source is selected as the main source (based on data quantity and quality).
- Gap-filling based on other sources taking into account possible inconsistencies. For example, in case of significant differences between two sources, the relative trend is considered instead of the absolute value.
- If gaps remain, these are filled in based on: 1) Interpolation, 2) Relative trend or data from another country (e.g. percentages for split/disaggregation), 3) Estimates and expert judgement calculations.
- As a last step, some checks are performed based on the following questions (i.e. checking rules):
    - Do all fuels add up to the total?
    - Do all segments of a fuel add up to this specific fuel?
    - Are there no negative values?
    - Do all percentages add up to 100%?

Box 2 – Methodological steps for determining the fleet's age distribution[64]

- An estimate was made for the age distribution in 1990 based on the new registrations of this year and expert judgement.
- The age distribution for the following years have been derived using lifetime functions, which model the ages at which vehicles are deregistered from the fleet.
- Then, modifications were made in the age distribution, by internal "transferring" of vehicles among age groups to ensure coherence with the statistical average age data (from the different sources in Table 6).
- This results in an age distribution for the total stock which has been used as a guide to produce age distributions per fuel and segment, taking into account the characteristics of individual vehicle subcategories. For example:
    - Many LPG vehicles are conversions from petrol vehicles, not actual sales.
    - The age distribution for electric vehicles is expected to be completely different compared to conventional vehicles, as the former only entered the fleet recently.
    - Differentiations in the age distribution for petrol and diesel vehicles which has been driven by past sales patterns. That way, the petrol fleet is currently older than the diesel fleet.

1.2. Emissions modelling with COPERT

1.2.1. Emission factors

To calculate the environmental benefits in both the Euro 6/VI evaluation and Euro 7 impact assessment, the total annual emissions have to be analysed. The general scheme for calculating the emissions of a pollutant for a specific vehicle category and year is presented in the equation below.

Equation 1[65]

$$E_{p,j,x} = N_{j,x} \times M_{j,x} \times EF_{p,j,x}$$

[62] See footnote 60
[63] See footnote 45
[64] See footnote 45
[65] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.4.1 Emissions modelling: overall methodological approach

Where

- E = total annual emissions
- N = number of vehicles in operation
- M = annual mileage per vehicle
- EF = estimated emission factor in g/km
- p = air pollutant or greenhouse gas
- j = vehicle category
- x = year of calculation

While the first two elements of the calculation (i.e. N and M) are a direct output from the SIBYL fleet modelling discussed in the previous chapter, the sources for finding the emission factors ($EF_{p,j,x}$) differs for the Euro standard vehicle technologies. The evaluation, which considers the different steps of Euro 6 and Euro VI, could mostly rely on the COPERT model for determining the emission factors. However, for the latest steps in Euro 6 – Euro 6d-temp and Euro 6d – other sources were consulted.[66] Also for the policy options in the impact assessment, different emission factor sources had to be considered in the supporting impact assessment study[67] to take into account future technologies and assess their environmental impact which were included in the last version of the COPERT model v5.4. The first update includes the revision of emission factors for Euro 5 vehicles in order to be in line with the latest information on defeat devices. This revision is expected to influence the current emissions benefits of Euro 6 over Euro 5 and was performed after screening with the Handbook Emission Factors for Road Transport (HBEFA 4.1)[68]. This handbook was originally developed on behalf of the Environmental Protection Agencies of Germany, Switzerland and Austria. Over the years, further countries as well as the JRC are supporting the HBEFA. The handbook provides emission factors for all current vehicle categories for a wide variety of traffic situations, while covering all regulated and the most important non-regulated pollutants.[69]

Moreover, the emission factors for all Euro 5 - V and Euro 6 a/b/c - VI A/B/C technologies were re-calculated in order to take into account the effect of driving conditions outside the current RDE boundaries, including the effect of cold-start, the operation under hot conditions, the degradation of emission control systems due to high mileage or age, as well as the impact of tampering and malfunctions not detected by OBD.

For cars and vans using the latest technology (Euro 6d-temp and Euro 6d), an emission performance analysis has been conducted. In order to assess the emission levels of these vehicles and to support the update of the existing databases for emission factors, emission data from more than 500 tests from a pool of 45 vehicles were collected and analysed. Data sources from nine partners have been consulted, including CLOVE, JRC, H2020 projects and stakeholders. That way, these detailed data could be used over the other models (COPERT, HBEFA and VERSIT[70]) to achieve a higher accuracy for the

[66] CLOVE, 2022. Euro 6/VI Evaluation Study. Annexes 1:6 ISBN 978-92-76-56522-2, Chapter 9.3 Annex 3: Euro 6/VI SIBYL/COPERT model data
[67] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.4.2 Emission Factors (EFs) calculation/modelling
[68] Handbook emission factors for road transport (HBEFA), 2020.
[69] See footnote 68
[70] TNO, 2007. VERSIT+ state-of-the art road traffic emission model.

emission factors. For lorries and buses, input on the emission factors of Euro VI D/E vehicles was derived from HBEFA, while experimental data provided by CLOVE were used for calculating emission factors under test conditions not covered by HBEFA (e.g. in terms of trip characteristics or composition).[71]

When it came to emission factors for future technologies following future possible legislation, the current models fell somewhat short. Therefore, scenarios were created for the policy options, resulting in corresponding estimated emission factors.

In general, emission factors of the various pollutants for each vehicle category depend on many parameters, including driving patterns, environmental conditions, road gradient and the level of maintenance of the vehicle (e.g. cold versus hot temperatures, evaporation, degradation, tampering, malfunction etc.). To control for this, components or emission processes related to such parameters and their individual effects on vehicle emissions are considered separately to estimate the impact of the different policy options. That way, only relevant parts of the emission factor will be affected when a new policy action is introduced in the simulations. For example, if new requirements on On-Board Diagnostics (OBD) were to be introduced, only the component on malfunctions will be affected and not the base emission factor.

This is summarized in the following equation, which represents the general scheme for calculating emissions factors.

Equation 2[72]

$$EF = [(w_1\, EF_{hotRDE} + w_2\, EF_{hotNonRDE}) \times DF(M) + w_1\, EF_{coldRDE} + w_2\, EF_{coldNonRDE}] \times (1 - Tamp.share) + (w_1\, EF_{hotRDE} + w_2\, EF_{hotNonRDE}) \times (Tamp.share) \times (Tamp.rate)$$

Where:

- w1: fraction of mileage to RDE conditions
- w2: fraction of mileage to non RDE conditions (w2 = 1 - w1)
- hotRDE: hot mean emission level over RDE driving
- hotNonRDE: hot mean emission level outside of RDE (incl. AES)
- coldRDE: cold mean emission level over RDE driving
- coldNonRDE: cold mean emission level over RDE driving
- DF(M): deterioration factor of emission at mean fleet mileage (M)
- Tamp.share : % of tampered vehicles
- Tamp.rate: tampering emission rate (tampered/ok)

The above equation decomposes the final emission factor into the various components that are meaningful for the purpose of the impact assessment on the different policy options. Every term in Equation 2 is calculated in a separate modeling activity based on the available data (more information on these separate modeling activities can be found in the supporting impact assessment study Annex 1)[73].

The emission factors for each pollutant considered in the Euro 6/VI evaluation are presented in Table 7.

[71] See footnote 65; and CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.
[72] See footnote 65
[73] See footnote 65

Table 7 – Emission factors for the different pollutants used in the evaluation baseline and under the different steps of Euro 6/VI[74] (*Average ± standard deviation, mg/km)*

	Diesel cars and vans				Petrol cars and vans			
	Euro 5	Euro 6 a-c	Euro 6d-temp	Euro 6d	Euro 5	Euro 6 a-c	Euro 6d-Temp	Euro 6d
NO_x	1 204.37 ± 88.78	656.65 ± 95.40	148.14 ± 14.10	127.57 ± 2.35	58.11 ± 1.34	43.11 ± 1.41	22.92 ± 1.55	20.66 ± 0.20
PM_{total}	26.98 ± 2.30	23.34 ± 2.46	23.00 ± 2.20	21.50 ± 0.68	21.38 ± 2.09	20.37 ± 2.15	19.34 ± 2.21	18.84 ± 0.03
$PM_{exhaust}$	4.88 ± 0.00	1.17 ± 0.10	0.45 ± 0.00	0.43 ± 0.01	2.37 ± 0.02	1.40 ± 0.06	0.34 ± 0.00	0.32 ± 0.01
CO	82.03 ± 5.22	74.75 ± 15.76	77.31 ± 13.47	61.15 ± 4.84	2 949.56 ± 204.73	1. 55.45 ± 79.61	582.26 ± 59.93	513.24 ± 15.85
THC	20.70 ± 0.00	19.21 ± 4.16	20.18 ± 3.71	16.20 ± 1.86	1 714.87 ± 2.897.72	1 667.61 ± 2.956.09	781.70 ± 1.440.61	96.11 ± 4.24
NMHC	2.61 ± 0.00	2.37 ± 0.42	2.47 ± 0.37	2.06 ± 0.18	1 694.22 ± 2 897.11	1 648.51 ± 2 956.23	777.30 ± 1 440.45	91.23 ± 3.92
	Lorries and buses							
	Euro V				Euro VI			
NO_x	9 090.69 ± 170.38				2 014.95 ± 407.06			
PM_{total}	124.28 ± 1.97				92.63 ± 11.48			
$PM_{exhaust}$	65.47 ± 1.10				33.78 ± 9.34			
CO	2 761.01 ± 45.71				224.00 ± 129.11			
THC	61.18 ± 0.97				32.39 ± 7.54			
NMHC	60.06 ± 0.95				31.75 ± 7.41			
NH_3	12.49 ± 0.24				22.35 ± 1.18			
CH_4	1.13 ± 0.02				0.63 ± 0.14			

Table 8 presents the four sets of emission factors which are used in the impact assessment baseline to calculate the emission savings. This set of conservative emission factors reflects the limitation of available measurement data and a worsening of today's measured emission levels in the future[75]:

- Current data mostly contains results from vehicles of the higher segments that often contain expensive emission control systems. It has been shown that vehicles at lower segments are generally not equipped with such sophisticated systems thus exhibiting higher emissions over certain operation conditions.

- Current data is still limited and shows a significant range[76]. Maximum values should be taken into account by manufacturers to demonstrate compliance with emission limits.

- The trade-offs between CO_2 and air pollutants (primarily NO_x) could potentially push vehicle manufacturers to relax NO_x control to benefit CO_2 to reach the new and more

[74] See footnote 190
[75] Supporting Euro 7 impact assessment study, chapter 4.1 Baseline development without introduction of a new emission standard
[76] For example, the 33 RDE compliant tests of Euro 6d diesel cars by JRC, TNO and GreenNCAP comprise 26 diesel cars without diesel particulate filter (DPF) regeneration with in average 33 mg NOx/km (7-116 mg NOx/km) and 7 diesel cars with DPF regeneration with in average 58 mg NOx/km (18-136 mg NOx/km).

ambitious CO_2 emission standards. This is a behaviour observed in the past with each new emission standard. Example is the recent increase in PN emissions from port-fuel injection gasoline vehicles with the introduction of Euro 6 PN limit which did not apply for these vehicles in order to better control other regulated emissions.

- As manufacturers gain experience in calibration and optimisation of the emission control system while also improvements in the measuring techniques are made, this can enable a decrease in the margin of safety over the limit value.

All these factors may contribute to higher real-world emission levels and an increase in the real-world average emission levels of new registrations with time. Since such a trend is not uncommon and has been observed in the past, this approach of conservative Euro 6/VI emission factors was taken.[77]

Table 8 – Average emission factors (EF) for the different pollutants under the impact assessment baseline[78]

A) Cars and vans – Euro 6d (-temp) (in mg/km or #/km for PN_{10})

	NO_x	CO	PM	PN_{10}	THC	CH_4	NH_3	N_2O
Hot EFs for RDE driving								
Petrol	10.2	186.6	0.160	7.6E+11	5.1	2.4	11.3	0.3
Diesel	33.1	31.6	0.150	3.3E+10	12.8	11.5	0.3	12.4
CNG	10.2	186.6	0.080	3.5E+11	37.7	20.8	11.3	0.3
Hot EFs for outside RDE driving								
Petrol	22.1	1202.6	0.450	1.1E+12	5.1	2.4	11.3	0.3
Diesel	190.9	43.4	0.375	1.4E+11	12.8	11.5	0.3	12.4
CNG	22.1	1202.6	0.225	7.0E+11	37.7	20.8	11.3	0.3
Excess Cold EFs for RDE driving								
Petrol	5.0	75.0	0.090	2.8E+11	17.1	1.2	1.2	0.5
Diesel	12.5	17.2	0.120	1.3E+10	0.6	0.1	0.0	0.6
CNG	5.0	75.0	0.045	2.0E+11	17.5	9.3	1.2	0.5
Excess Cold EFs for outside RDE driving								
Petrol	21.2	250.8	0.170	5.9E+11	17.1	1.2	1.2	0.5
Diesel	54.4	19.5	0.310	9.6E+09	0.6	0.1	0.0	0.6
CNG	21.2	250.8	0.085	1.9E+11	17.5	9.3	1.2	0.5

[77] For example, the first set of emission factors for Euro 6a/b vehicles developed by the ERMES group was based on vehicles of higher segments and was actually lower than subsequent revisions which also used data from lower segments. See also Keller, M. 2013. HBEFA Status Report ERMES Meeting Sept. 2013.
[78] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.4 Emissions modelling

B) Lorries and buses – Euro VI D/E (in g/kWh or #/kWh for PN)

EF	HDV type	Driving mode	NO_x	PM	PN	THC	NH_3	N_2O	CH_4	CO
Hot RDE	Long haul lorries	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
		Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
		Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
	Rigid lorries	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
		Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
		Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
	Urban buses	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
		Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
		Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
Hot outside RDE	Long haul lorries	-	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.00144	0.216
	Rigid lorries	-	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.00144	0.216
	Urban buses	-	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.00144	0.216
Excess Cold start	Long haul lorries	-	12	0.1	6.00E+11	0.25	0.012	5.25	0.013	1.85
	Rigid lorries	-	6.36	0.027	3.18E+11	0.1326	0.006	2.78	0.007	0.980
	Urban buses	-	8.73	0.036	4.36E+11	0.1818	0.009	3.82	0.009	1.34

C) Brake emissions (in mg/km)

Vehicle category	$PM_{2,5}$ from brakes	PM_{10} from brakes
Cars	4.37	11
Vans	7.71	19.4
Lorries	11.3 - 11.8	28.5 - 29.5
Buses	11.1 - 19.7	27.9 - 49.6

The emission factors for the different policy options are presented in Table 9. It is important to note that the emission levels in PO2a/PO3a and PO2b are extremely low and only differ with regard to the excess cold emission factors, while the hot emission factors are assumed to be the same leading to overall small emission levels in PO2a/PO3a and PO2b.

Table 9 -Average emission factors for the different pollutants in the policy options[79]

A) Cars and vans (in mg/km or #/km for PN_{10})

Policy option (PO)	Fuel	NO_x	CO	PM	PN_{10}	THC	CH_4	NH_3	N_2O
	Hot EFs for RDE driving								
PO1	Petrol	10.2	186.6	0.160	7.6E+11	5.1	2.4	11.3	0.3
	Diesel	33.1	31.6	0.150	3.3E+10	12.8	11.5	0.3	12.4
	CNG	10.2	186.6	0.080	3.5E+11	37.7	20.8	11.3	0.3
PO2a. PO3a	Petrol	1.6	33.9	0.151	9.6E+09	0.3	2.4	5.3	0.3
	Diesel	3.0	31.6	0.135	1.1E+10	6.5	5.2	0.3	12.4
	CNG	1.6	33.9	0.076	3.8E+10	0.3	20.8	5.3	0.3
PO2b	Petrol	1.6	33.9	0.151	9.6E+09	0.3	2.4	5.3	0.3
	Diesel	3.0	31.6	0.135	1.1E+10	6.5	5.2	0.3	6.6
	CNG	1.6	33.9	0.076	3.8E+10	0.3	20.8	5.3	0.3
	Hot EFs for outside RDE driving								
PO1	Petrol	22.1	1.203	0.450	1.1E+12	5.1	2.4	11.3	0.3
	Diesel	100.5	43.4	0.375	1.4E+11	12.8	11.5	0.3	12.4
	CNG	22.1	1203	0.225	7.0E+11	37.7	20.8	11.3	0.3
PO2a. PO3a	Petrol	4.2	114.9	0.435	3.4E+10	0.8	2.4	5.6	0.3
	Diesel	10.0	43.4	0.314	6.3E+10	6.5	5.2	0.3	12.4
	CNG	4.2	114.9	0.217	1.4E+11	0.8	20.8	5.6	0.3
PO2b	Petrol	4.2	114.9	0.435	3.3E+10	0.8	2.4	5.6	0.3
	Diesel	10.0	43.4	0.314	6.3E+10	6.5	5.2	0.3	6.6
	CNG	4.2	114.9	0.217	1.3E+11	0.8	20.8	5.6	0.3

[79] See footnote 78

PO	Fuel	NO_x	CO	PM	PN_{10}	THC	CH_4	NH_3	N_2O
	Excess Cold EFs for RDE driving								
PO1	Petrol	5.0	75.0	0.090	2.8E+11	17.1	1.2	1.2	0.5
	Diesel	12.5	17.2	0.120	1.3E+10	0.6	0.1	0.0	0.6
	CNG	5.0	75.0	0.045	2.0E+11	17.5	9.3	1.2	0.5
PO2a. PO3a	Petrol	4.5	73.3	0.089	3.7E+10	10.1	1.2	0.6	0.5
	Diesel	3.0	17.2	0.115	4.5E+09	0.2	0.1	0.0	0.6
	CNG	4.5	73.3	0.044	1.5E+11	10.1	9.3	0.6	0.5
PO2b	Petrol	3.3	59.0	0.089	3.7E+10	6.8	1.2	0.6	0.5
	Diesel	2.4	17.2	0.115	4.5E+09	0.2	0.1	0.0	0.4
	CNG	3.3	59.0	0.044	1.5E+11	6.8	9.3	0.6	0.5
	Excess Cold EFs for outside RDE driving								
PO1	Petrol	21.2	250.8	0.170	5.9E+11	17.1	1.2	1.2	0.5
	Diesel	35.1	19.5	0.310	9.6E+09	0.6	0.1	0.0	0.6
	CNG	21.2	250.8	0.085	1.9E+11	17.5	9.3	1.2	0.5
PO2a. PO3a	Petrol	21.2	105.1	0.170	6.3E+10	17.1	1.2	0.6	0.5
	Diesel	12.9	19.5	0.306	4.4E+09	0.6	0.1	0.0	0.6
	CNG	21.2	105.1	0.085	1.9E+11	17.5	9.3	0.6	0.5
PO2b	Petrol	21.2	90.8	0.170	5.8E+10	17.1	1.2	0.6	0.5
	Diesel	10.2	19.5	0.306	4.4E+09	0.6	0.1	0.0	0.4
	CNG	21.2	90.8	0.085	1.9E+11	17.5	9.3	0.6	0.5

B) Lorries and buses (in g/kWh or #/kWh for PN)

PO	Driving mode	NO_x	PM	PN	THC	NH_3	N_2O	CH_4	CO
	Hot EFs for RDE driving								
PO1	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
	Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
	Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
PO2a. PO3a	Urban hot	0.009	0.0028	2.88E+10	0.0019	0.005	0.082	0.00038	0.018
	Rural	0.007	0.0013	1.32E+10	0.0010	0.004	0.056	0.00016	0.010
	Motorway	0.005	0.0012	1.30E+10	0.0009	0.004	0.045	0.00015	0.008
PO2b	Urban hot	0.009	0.0028	2.88E+10	0.0026	0.005	0.082	0.00038	0.018
	Rural	0.007	0.0013	1.32E+10	0.0014	0.004	0.056	0.00016	0.010
	Motorway	0.005	0.0012	1.30E+10	0.0013	0.004	0.045	0.00015	0.008
	Hot EFs for outside RDE driving								
PO1		8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.0014	0.216
PO2a. PO3a		0.178	0.0035	3.63E+10	0.0046	0.005	0.018	0.0010	0.068
PO2b		0.124	0.0035	3.63E+10	0.0058	0.005	0.018	0.0009	0.060

PO	HDV	NO_x	PM	PN	THC	NH_3	N_2O	CH_4	CO
	Excess Cold EFs for inside and outside RDE driving								
PO1	Long haul lorries	12	0.050	6.00E+11	0.250	0.012	5.25	0.013	1.85
	Rigid lorries	6.36	0.0265	3.18E+11	0.1326	0.006	2.784	0.0066	0.980
	Urban buses	8.73	0.0364	4.36E+11	0.1818	0.009	3.818	0.0091	1.344
PO2a. PO3a	Long haul lorries	2.38	0.002	2.40E+10	1.182	0	0.693	0.330	25.23
	Rigid lorries	1.26	0.0011	1.27E+10	0.6266	0	0.368	0.175	13.38
	Urban buses	1.73	0.0015	1.75E+10	0.8593	0.0	0.504	0.240	18.35
PO2b	Long haul lorries	0.853	0.002	2.40E+10	0.615	0	0.693	0.285	12.53
	Rigid lorries	0.452	0.0011	1.27E+10	0.3260	0	0.368	0.151	6.64
	Urban buses	0.620	0.0015	1.75E+10	0.4471	0.0	0.504	0.208	9.11

C) **Brake emissions (in mg/km)**

PO	Vehicle category	$PM_{2,5}$ from brakes	PM_{10} from brakes
PO1	Cars	4.37	11
	Vans	7.71	19.4
	Lorries	11.3 - 11.8	28.5 - 29.5
	Buses	11.1 - 19.7	27.9 - 49.6
PO2a, PO3a	Cars	2.8	7.0
	Vans	4.9	12.3
	Lorries	11.3 - 11.8	28.5 - 29.5
	Buses	11.1 - 19.7	27.9 - 49.6
PO2b	Cars	2.0	5.0
	Vans	3.5	8.8
	Lorries	11.3 - 11.8	28.5 - 29.5
	Buses	11.1 - 19.7	27.9 - 49.6

1.2.2. Damage costs

Based on the emissions factors, the environmental benefits in the form of emissions savings can be calculated as an accumulated difference over the baseline over time. Since emission savings are a form of prevented pollution which could have negative effects on human health and environment, these savings create a benefit when expressed in monetised terms. This monetised health and environmental benefit (in €) has been calculated by multiplying the emission savings with the external damage costs per tonne of pollutant for each examined pollutant based on the handbook on the external costs of transport[80] (hereafter "the Handbook"). While the Handbook includes 2016 values, the Euro 6/VI evaluation and Euro 7 impact assessment are based on 2020 values by taking into account the annual inflation in the Member States.[81] The final damage costs were calculated as the weighted average of the Member States' damage costs over the activity of each Member State. Box 3 summarises the four types of impacts caused by road transport emissions resulting in damage costs according to Annex C.2 of the Handbook[82].

Box 3 – Impacts by air pollutants from road transport emissions based on the handbook

[80] European Commission, 2019. Handbook on the external costs of transport
[81] Eurostat, 2021. HICP – monthly data
[82] See footnote 80

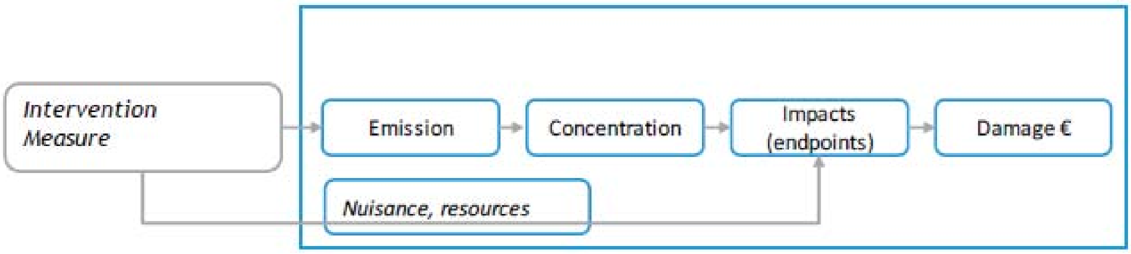
on the external costs of transport (2019)[83][84]

- **Health effects:** The inhalation of air pollutants - such as particles and NO_x - leads to a higher risk of respiratory diseases (e.g. bronchitis, asthma, lung cancer) and cardiovascular diseases. These negative health effects lead to medical treatment costs, production loss at work (due to illness) and even to death.
- **Crop losses:** As a secondary air pollutant, primarily caused by the emissions of NOx and VOC, ozone together with other acidic air pollutants (e.g. NOx) can damage the agricultural crops. Therefore, higher concentrations of these pollutants can result in a lower crop yield.
- **Material and building damage:** Emissions of air pollutants can damage buildings and other materials through two different mechanisms: a) Pollution of building surfaces through particles and dust; b) Damage of building facades and materials due to corrosion processes caused by acidic substances (e.g. NOx).
- **Biodiversity loss:** Air pollution can lead to damage of ecosystems. The acidification of soil, precipitation and water and the eutrophication of ecosystems are of most concern in this context. Such damages at ecosystems can lead to a decrease in biodiversity (fauna, flora).

The steps for the calculation of the damage costs are illustrated in Figure 10. This diagram shows how transport emissions[85] are released in the atmosphere of other regions increasing these respective concentrations. Subsequently, this leads to changes in 'endpoints' relevant to human welfare. These changes can be monetarily valued by quantifying the amount of damage caused at the endpoints.

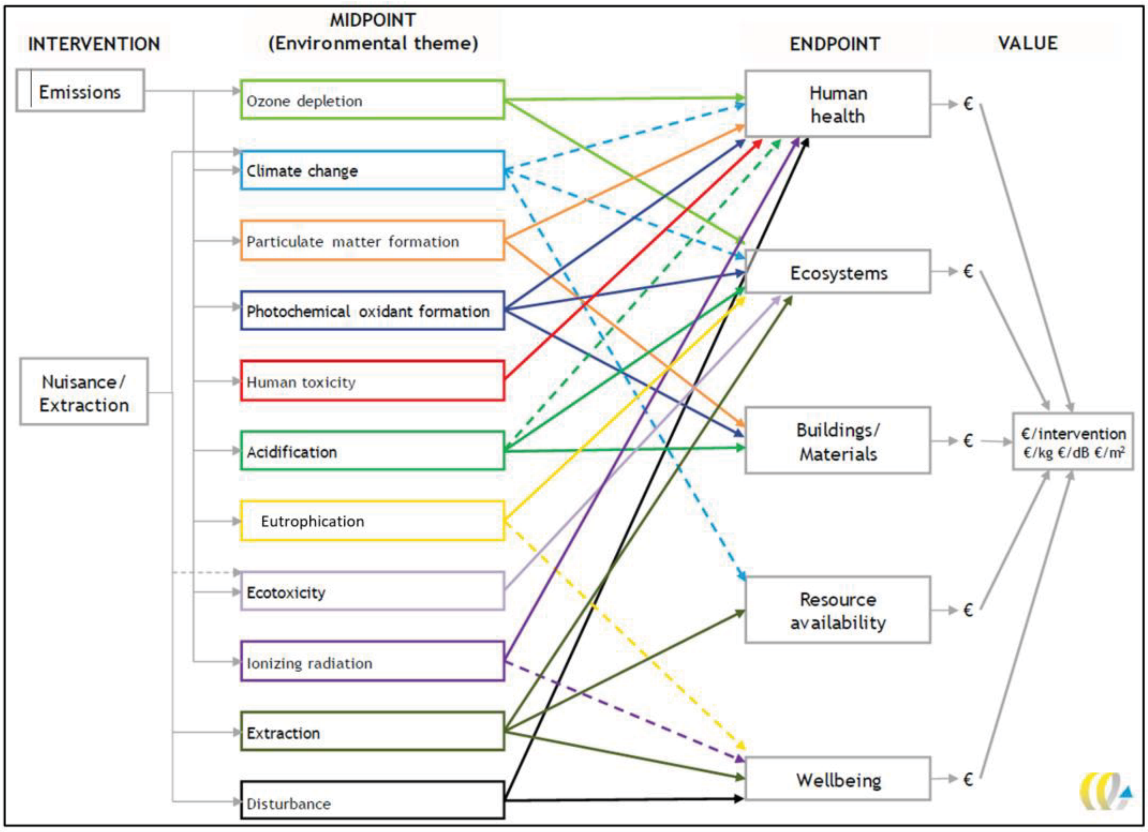
While Box 3 illustrated that vehicle emissions result in damage to a variety of endpoints through different interactions or midpoints, Figure 11 reflects the relationship between intervention, midpoints, endpoints and values as reported in the Environmental Prices Handbook[86]. An intervention would have an effect on certain environmental themes – midpoints – which would have an impact on the third level of the scheme: the endpoint representing the broader topics discussed in Box 3. The impact of the intervention at the endpoints is then represented by the impacts at each endpoint, calculated as damage costs.

Figure 10 – Calculation of damage costs[87]



[83] See footnote 80
[84] Since damage costs of N2O and CH_4 as air pollutant are not available, damage costs of N2O and CH4 are monetised as greenhouse gases. The Handbook monetises climate change costs from road transport as the costs associated with all of the effects of global warming, such as sea level rise, biodiversity loss, water management issues, more and more frequent weather extremes and crop failures.
[85] In this diagram, emissions refer to air pollutants, and not to emissions to soils or water occurred by tyre wear. As it is not yet feasible to develop limits or tests for tyre emissions, it is suggested to include a review clause in Euro 7.
[86] S. de Bruyn, M. Bijleveld, L. et al., 2018. Environmental Prices Handbook: EU-28 version (CE Delft)
[87] See footnote 80

Figure 11 - Relationships between interventions, midpoints, endpoints and valuation of environmental policies[88]



In order to estimate the damage costs per vehicle-kilometre (vkm) activity for different vehicle categories, the Handbook uses the emission data from the COPERT model. Costs are calculated to monetise the health and environmental impacts while taking into account concentration-response functions, population size and structure, population density, the relationship factors between damage and emissions for various emission scenarios and the most recent valuation of human health. Table 10 gives an overview of the damage costs for the pollutants that were considered in the monetisation scheme based on the respective area where the vehicle activity took place. The Handbook, however, does not cover the contribution of harmful NMHC (i.e. NMVOC) emissions to the formation of secondary organic aerosols.[89] Hence, information on the damage costs related to this phenomenon have been collected from other sources.[90][91] In addition, the damage costs are classified based on the area where a vehicle activity is considered to take place. In the calculation for the cost-benefit analysis, the activity was obtained from COPERT.

[88] See footnote 86

[89] While the damage costs for CH_4 and N_2O are considered through their global warming potential later in the text, CO and THC are not taken into account as no damage costs information is available in the Handbook for these pollutants.

[90] Such as: Lu Q., Zhao Y., Robinson A.L., 2018. "Comprehensive organic emission profiles for gasoline, diesel, and gas-turbine engines including intermediate and semi-volatile organic compound emissions"; and He Y., et al., 2020. "Secondary organic aerosol formation from evaporated biofuels: comparison to gasoline and correction for vapor wall losses".

[91] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.4.5 Emission benefits

Table 10 - Damage costs for air pollutants for transport[92]

Pollutant	NO_x		NH_3	NMHC			$PM_{2.5}$ (both exhaust and non-exhaust)		
Area	City	Rural	All areas	Metro-politan*	City	Rural**	Metro-politan*	City	Rural**
Damage cost [€/kg]	24.5	14.5	19.5	3.41	2.06	1.78	401	132	76

* Only for cities/agglomeration with > 0.5 million inhabitants ** Outside cities

In order to perform the Cost-Benefit Analysis (see Chapter 1.3.), the described benefits were transformed into monetary values. The respective calculation takes into account the weighted averages of the activity shares of the different vehicle categories, weighted over the activity (in km/year) of the different categories and taking into account fleet composition data, in order to split the emissions based on the vehicle activity in urban, rural and highway traffic conditions, as included in COPERT. As an example, the equation for calculating the monetary benefits for NO_x is presented below. Similar equations were established for calculating monetary benefits from NH_3, NMHC and $PM_{2,5}$ are included in the supporting impact assessment study.[93] The total monetised benefit are then calculated as the sum of all the pollutant-specific monetised benefits.

In line with the WHO approach on health impacts from pollution[94] and the Handbook on the external costs of transport, the benefits of reducing emissions are independent of the absolute emission levels. This means that health benefits of decreasing NO_x emission by 1 ton is the same regardless of whether the concentration of the pollutant is low or high. The exposure of citizens to these concentrations, however, is of great importance. Therefore, Table 10 separates damage costs in metropolitan areas, urban areas and rural areas transport. Hence, emission reductions in a metropolitan area this will lead to larger health benefits than if this is decreased by the same amount in a rural area. This follows from the fact that more people will be affected in the dense metropolitan environment compared to the sparsely populated rural environment.

Equation 3[95]

$$NO_x[€] = NO_x[t] * \left(NO_{x,\ city}[€/t] * share_{urban}[\%] + NO_{x,\ rural} * [€/t]\left(share_{rural}[\%] + share_{highway}[\%]\right)\right)$$

Where:

- $NO_x[€]$ indicates the resulting monetized benefits
- $NO_x[t]$ indicates the emission saving calculated from COPERT
- $NO_{x,\ city}[€/t]$ indicate the damage/avoidance costs presented in Table 10
- $share_{urban/rural/highway}$ expressed in [%] indicate the respective vehicle activity obtained from the COPERT

[92] See footnote 68
[93] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.4.6 Calculation of monetised benefits
[94] WHO, 2013. Health risks of air pollution in Europe – HRAPIE project
[95] See footnote 93

1.2.3. Environmental impacts

1.2.3.1. Environmental impacts in policy option 1

The environmental impacts in terms of air pollutant emission reductions from road transport are the emission savings that would be achieved over the savings expected in the baseline with merely Euro 6/VI vehicle fleet renewal in combination with the impact of the new CO_2 standards.

As shown in Table 11, the overall emission savings that can be expected in policy option 1 are rather limited. Reason for this being that next to the introduction of low ambition extended real-driving conditions covering conditions outside the current RDE or PEMS boundaries and improved OBD to enable more effective ISC and MaS over the lifetime of vehicles, the emission limits are not really reduced, but only made technology-neutral.

For cars and vans, NO_x emissions are expected to further decrease compared to the baseline by 13% in 2030 to 55% in 2050. This decrease follows from the introduction of extended real-driving testing covering conditions outside the current RDE boundaries and a technology-neutral NO_x emission limit of 60 mg/km for cars, which replaces the current diverging NO_x limits in the Euro 6 standard of 60 mg/km for petrol cars and 80 mg/km for diesel cars.

Some savings can be expected for particles, NH_3 and CO emissions from cars and vans compared to the baseline. $PM_{2,5,exhaust}$ emissions are expected to decrease by 4% in 2030 to 29% in 2050, due to the increased use of improved particle filters and shift to electric vehicles, whereas $PM_{2,5,total}$ is not expected to decrease as option 1 does not include limits for unregulated brake and tyre emissions. PN emissions are expected to decrease by 5% in 2030 to 30% in 2050 due to the extension of the threshold for particle numbers from 23 nm to 10 nm. NH_3 emissions from cars and vans are expected to decrease by 7% in 2030 to 47% in 2050 due to the technology-neutral use of a NH_3 limit for all vehicle categories. CO emissions from cars and vans are expected to decrease to a lesser extent. These emissions are expected to decrease by 3% in 2030 and by 12% in 2050 following the introduction of a technology-neutral CO limit for cars and vans. It seems that to optimise performance and to protect emission control components against high exhaust temperatures, engines may be shifted to rich fuel operation when outside of the current RDE conditions. Such fuel-rich conditions are known to produce high CO emissions in the engine.[96]

For lorries and buses, NO_x emission savings are the only emission savings expected in policy option 1. No new emission limits are considered for these vehicles, as the Euro VI limits are already technology-neutral. The decreases in NO_x emissions, 7% in 2030 to 19% in 2050, derive from enhanced real-driving testing covering conditions outside the current PEMS boundaries and assumed increased frequency of ISC and MaS testing.[97]

[96] Supporting Euro 7 impact assessment study, chapter 5.1.1. Environmental impacts
[97] See footnote 96

Table 11 – Emission savings for regulated pollutants from road transport in policy option 1 compared to the baseline[98]

Pollutant		2025	2030	2035	2040	2045	2050
Cars and vans							
NO_x	in kt	17.79	87.9	104.10	80.60	44.56	15.80
	in %	1.72	13.40	26.73	39.04	49.11	55.17
$PM_{2.5}$, total	in kt	0.04	0.17	0.19	0.14	0.07	0.02
	in %	0.08	0.51	0.80	0.99	1.14	1.20
$PM_{2.5}$, exhaust	in kt	0.04	0.17	0.19	0.14	0.07	0.02
	in %	0.29	4.31	12.80	20.54	25.72	28.78
PN_{10}	in #	5.77E+22	2.69E+23	2.92E+23	2.04E+23	9.95E+22	3.22E+22
	in %	0.32	5.06	15.18	22.54	26.97	30.33
CO	in kt	5.64	28.30	34.06	26.36	13.86	4.72
	in %	0.37	2.94	5.83	8.49	10.79	12.35
THC	in kt	0.09	0.45	0.54	0.43	0.24	0.08
	in %	0.03	0.21	0.37	0.49	0.50	0.42
NMHC	in kt	0.04	0.19	0.22	0.16	0.08	0.03
	in %	0.02	0.11	0.18	0.22	0.20	0.15
NH_3	in kt	0.03	1.92	5.13	5.34	2.93	0.98
	in %	0.12	7.32	21.49	33.36	41.22	46.61
CH_4	in kt	0.05	0.25	0.33	0.27	0.16	0.06
	in %	0.13	0.74	1.21	1.58	1.87	2.07
N_2O	in kt	0.05	0.34	0.57	0.55	0.34	0.12
	in %	0.22	0.99	1.38	1.65	1.88	2.07
Lorries and buses							
NO_x	in kt	9.43	57.81	99.86	112.89	98.15	84.96
	in %	0.89	7.14	14.16	18.20	19.27	19.30
$PM_{2.5}$, total	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0
$PM_{2.5}$, exhaust	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0
PN	in #	0	0	0	0	0	0
	in %	0	0	0	0	0	0
CO	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0
THC	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0
NMHC	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0
NH_3	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0
CH_4	in kt	0	0	0	0	0	0
	in %	0	0	0	0	0	0

1.2.3.2. Environmental impacts in policy option 2

The environmental impacts in terms of air pollutant emission reductions from road transport are the emission savings that would be achieved over the savings expected in the baseline with merely Euro 6/VI vehicle fleet renewal in combination with the impact

[98] See footnote 38

of the new CO_2 standards.

In policy option 2, stricter emission limits in medium and high ambition are considered for all vehicle categories and pollutants regulated under Euro 6/VI (NO_x, PM, PN, CO, THC, NMHC, NH_3, CH_4), new emission limits for the unregulated pollutants N_2O, HCHO and brake emissions[99] and extended real-driving testing. Sub-option 2a considers a Medium Green Ambition with medium ambition limits and real-driving testing boundaries (see Table 50); sub-option 2b considers a High Green Ambition with high ambition limits and real-driving testing boundaries (see Table 51).

Medium Green Ambition (option 2a)

As shown in Table 12, the emission savings that can be expected in sub-option 2a compared to the baseline are significant, in particular for lorries and buses. However, also the decrease of emissions for cars and vans is relevant, as those vehicles are predominantly used in densely populated urban areas where more citizens are exposed to respiratory health risk.

For cars and vans, NO_x emissions are expected to decrease significantly and rapidly compared to the baseline by 21% in 2030, 42% in 2035, 62% in 2040 to 88% in 2050. This significant decrease follows from the introduction of medium ambition extended real-driving testing covering more conditions outside the current RDE boundaries and a technology-neutral NO_x emission limit of 30 mg/km for cars, which replaces the current diverging NO_x limits in the Euro 6 standard of 60 mg/km for petrol cars and 80 mg/km for diesel cars. The decrease illustrates that cars and vans go more rapidly toward zero-pollution levels (about 80 kt NO_x/a) in 2040, compared to similar levels reached in 2050 in the baseline.

Significant savings can be expected also due to the more stringent air pollutant emission limits and increased durability requirements for particles, hydrocarbons, NH_3 and N_2O emissions from cars and vans. Regarding particles, $PM_{2,5}$ exhaust emissions are expected to decrease by 5% in 2030 to 22% in 2050 and PN emissions by 15% in 2030 to 88% in 2050 (PM exhaust and PN emissions also thorough inclusion of DPF regeneration control[100]). Brake emissions, which have become increasingly relevant sources of non-exhaust particles, are assumed to go down by 16% in 2030 to 36% in 2050 through the use of brake pads. CO emissions are expected to decrease by 14% in 2030 to 47% in 2050, NMHC by 13% in 2030 to 26% in 2050 and CH_4 emissions by 15% in 2030 to 32% in 2050. NH_3 emissions from cars and vans are presumed to drop by 11% in 2030 to 74% in 2050, and N_2O emissions by 7% in 2030 to 55% in 2050.

For lorries and buses, the highest emission savings can be expected under sub-option 2a due to the more stringent air pollutant emission limits for NO_x, particles, hydrocarbons, NH_3 and N_2O emissions. NO_x emissions are assumed to decrease by 209 kt in 2030 to 411 kt in 2050. This high reduction comes from the fact that in the EU fleet a significant number of heavy-duty vehicles, in particular diesel lorries, is still expected to be equipped with a combustion engine vehicle until 2050.

[99] As there are no testing methods for brake emissions from lorries and buses and for tyre emissions from all vehicle categories developed so far, the environmental impact of those non-exhaust particles cannot be determined and subsequently assessed.

[100] Supporting Euro 7 impact assessment study, chapter 5.2.1. Environmental impacts

$PM_{2,5}$ emissions are expected to decrease by 2.1 kt in 2030 to 3.1 kt in 2050, with a larger relative impact on PN emissions decrease due to the required particle filter for PI vehicles[101]. CO emissions are expected to fall by 6.4 kt in 2030 to 16 kt in 2050, also by control of emissions under the complete engine operation map, as CO emissions could increase somewhat for the vehicle to meet the required NO_x reductions at cold-start[102]. Moreover, THC emissions are presumed to drop by 2 kt in 2030 to 3.3 kt in 2050, NH_3 emissions by 2.0 kt in 2030 to 2.6 kt in 2050, and N_2O emissions by 25 kt in 2030 to 32 kt in 2050.

Table 12 – Emission savings for pollutants from road transport in policy option 2a compared to the baseline[103]

Pollutant		2025	2030	2035	2040	2045	2050
Cars and vans							
NO_x	in kt	27.97	138.31	165.00	128.60	71.33	25.31
	in %	2.71	21.07	42.37	62.28	78.61	88.37
$PM_{2.5,brake\ emissions}$	in kt	0.44	2.55	4.22	5.41	6.01	6.16
	in %	2.96	16.34	26.32	32.63	35.52	36.28
$PM_{2.5,exhaust}$	in kt	0.04	0.20	0.23	0.15	0.06	0.02
	in %	0.35	5.06	14.99	21.61	22.39	21.97
PN_{10}	in #	1.73E+23	8.00E+23	8.67E+23	6.03E+23	2.90E+23	9.29E+22
	in %	0.97	15.09	45.09	66.50	78.53	87.55
CO	in kt	28.20	137.96	169.67	124.68	58.28	18.09
	in %	1.86	14.31	29.03	40.16	45.36	47.36
THC	in kt	5.99	28.87	32.89	24.34	13.29	5.31
	in %	2.15	13.62	22.51	27.38	27.82	26.95
NMHC	in kt	5.16	23.75	25.46	18.71	10.54	4.45
	in %	2.13	13.34	21.36	26.13	26.83	26.16
NH_3	in kt	0.41	2.83	7.70	8.38	4.68	1.56
	in %	1.58	10.75	32.30	52.30	65.87	74.27
CH_4	in kt	0.82	5.12	7.43	5.64	2.74	0.87
	in %	2.23	15.09	27.66	32.57	32.42	31.86
N_2O	in kt	-0.42	2.39	12.35	15.20	9.15	3.31
	in %	-1.85	6.88	29.93	45.18	51.08	54.80
HCHO	in kt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	in %	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lorries and buses							
NO_x	in kt	32.44	209.13	389.30	480.90	455.90	410.60
	in %	3.06	25.83	55.19	77.55	89.48	93.30
$PM_{2.5,\ total}$	in kt	0.37	2.08	3.44	3.88	3.50	3.08
	in %	1.46	9.50	17.71	23.88	27.59	29.02
$PM_{2.5,exhaust}$	in kt	0.37	2.08	3.44	3.88	3.50	3.08
	in %	2.61	19.40	39.08	54.35	62.74	65.37
PN_{10}	in #	2.93E+22	1.94E+23	3.44E+23	4.30E+23	4.11E+23	3.70E+23
	in %	0.37	10.08	45.88	71.66	78.38	79.95
CO	in kt	0.69	6.42	13.58	18.42	17.66	15.95
	in %	0.32	4.70	12.18	17.42	18.97	19.17
THC	in kt	0.33	2.00	3.49	4.06	3.69	3.27
	in %	1.35	8.08	13.15	15.06	15.44	14.90
NMHC	in kt	0.36	2.13	3.70	4.30	3.92	3.47

[101] See footnote 100
[102] See footnote 100
[103] See footnote 38

	in %	1.70	11.73	22.24	29.04	31.65	30.09
NH_3	in kt	0.37	2.04	3.19	3.41	2.98	2.58
	in %	4.80	22.52	33.14	37.24	38.79	38.99
CH_4	in kt	-0.02	-0.13	-0.21	-0.25	-0.23	-0.21
	in %	-0.63	-2.03	-2.14	-2.02	-2.01	-2.00
N_2O	in kt	4.61	25.13	39.45	42.28	37.08	32.17
	in %	4.68	23.97	40.35	51.72	58.16	60.06
HCHO	in kt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	in %	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

High Green Ambition (option 2b)

As shown in Table 13, the emission savings that can be expected in sub-option 2b compared to the baseline are significant, in particular for lorries and buses. In comparison to sub-option 2a, stricter emission limits are assumed for NO_x emissions from cars and vans (20 mg/km instead of 30 mg/km) and lorries and buses (100 mg/kWh instead of 150 mg/kWh), and NMHC (20 mg/km instead of 40 mg/km) and brake emissions (5 instead of 7 mg/km) from cars and vans.

It is important that sub-option 2b is expected to lead only to marginal reductions of NO_x and NHMC emission compared to sub-option 2a.

For cars and vans, the marginal NO_x effect (-21.1% in 2030 and -88.4% in 2050 in sub-option 2a and -21.4% in 2030 and -90.4% in 2050 in sub-option 2b) is explained by the fact that manufacturers consider a safety factor to comply with emission limits, which results in average emissions being lower than the emission limit. Assuming a 30 mg/km emission limit for NO_x under sub-option 2a would already lead to a very low average emission level, which is not expected to be significantly lowered with a 20 mg/km emission limit under sub-option 2b. For lorries and buses, the marginal NO_x effect (-25.8% in 2030 and -93.3% in 2050 in sub-option 2a and -26.0% in 2030 and -93.8% in 2050 in sub-option 2b) is explained by the fact that the testing conditions are already comprehensively extended in sub-option 2a leading to the major positive effect on the emission performance, whereas the reduction of the NO_x limit from 150 mg/kWh to 100 mg/kWh and the extended real-driving testing boundaries in sub-option 2b offers a low emission savings.[104]

Reductions are expected for non-exhaust $PM_{2.5}$ emissions from cars and vans, since sub-option 2b includes more stringent limits for brake emissions which require brake pads and the installation of brake dust particle filter in the vehicle. That way, brake emission savings are achieved (54% in 2050 in sub-option 2b compared to 36% in 2050 in sub-option 2a).

Table 13 – Emission savings for pollutants from road transport in policy option 2b compared to the baseline[105]

Pollutant		2025	2030	2035	2040	2045	2050
Cars and vans							
NO_x	in kt	28.45	140.6	167.60	130.90	72.80	25.88
	in %	2.76	21.42	43.04	63.43	80.27	90.35

[104] See footnote 100
[105] See footnote 38

$PM_{2.5,brake}$ emissions	in kt	0.66	3.83	6.33	8.12	9.02	9.24
	in %	4.44	24.51	39.48	48.95	53.28	54.42
$PM_{2.5}$, exhaust	in kt	0.05	0.23	0.25	0.19	0.10	0.03
	in %	0.39	5.69	16.90	27.16	34.08	38.19
PN_{10}	in #	1.74E+23	8.06E+23	8.73E+23	6.09E+23	2.94E+23	9.49E+22
	in %	0.97	15.20	45.42	67.22	79.85	89.38
CO	in kt	30.05	146.60	179.50	139.30	69.90	22.87
	in %	1.98	15.20	30.70	44.86	54.42	59.86
THC	in kt	6.50	31.29	35.61	27.67	15.79	6.51
	in %	2.33	14.76	24.38	31.13	33.06	33.00
NMHC	in kt	5.67	26.17	28.14	20.92	11.90	5.15
	in %	2.35	14.70	23.60	29.22	30.29	30.28
NH_3	in kt	0.41	2.83	7.71	8.46	4.81	1.63
	in %	1.59	10.78	32.34	52.80	67.69	77.26
CH_4	in kt	0.82	5.12	7.47	6.76	3.88	1.36
	in %	2.23	15.09	27.82	39.04	45.91	49.96
N_2O	in kt	0.49	6.81	17.46	20.50	13.12	4.92
	in %	2.16	19.59	42.31	60.93	73.28	81.48
HCHO	in kt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	in %	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lorries and buses							
NO_x	in kt	32.66	210.40	391.50	483.60	458.60	413.20
	in %	3.08	25.98	55.49	77.99	90.02	93.88
$PM_{2.5}$, total	in kt	32.66	210.40	391.50	483.60	458.60	413.20
	in %	3.08	25.98	55.49	77.99	90.02	93.88
$PM_{2.5}$, exhaust	in kt	0.37	2.09	3.46	3.93	3.57	3.17
	in %	2.61	19.44	39.31	55.14	64.16	67.17
PN_{10}	in #	2.94E+22	1.95E+23	3.44E+23	4.31E+23	4.12E+23	3.71E+23
	in %	0.37	10.08	45.91	71.76	78.54	80.15
CO	in kt	1.67	11.92	22.43	28.77	27.48	24.80
	in %	0.77	8.72	20.11	27.21	29.53	29.80
THC	in kt	0.36	2.13	3.71	4.33	3.96	3.52
	in %	1.44	8.62	13.97	16.07	16.59	16.06
NMHC	in kt	0.38	2.24	3.89	4.53	4.15	3.69
	in %	1.79	12.35	23.33	30.59	33.52	31.95
NH_3	in kt	0.37	2.04	3.21	3.49	3.11	2.72
	in %	4.80	22.52	33.31	38.12	40.41	41.12
CH_4	in kt	-0.02	-0.11	-0.18	-0.20	-0.19	-0.17
	in %	-0.53	-1.71	-1.80	-1.67	-1.63	-1.61
N_2O	in kt	4.61	25.13	39.68	43.43	38.88	34.21
	in %	4.68	23.97	40.59	53.13	60.98	63.86
HCHO	in kt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	in %	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

1.2.3.3. Environmental impacts in policy option 3

The environmental impacts in terms of air pollutant emission reductions from road transport are the emission savings that would be achieved over the savings expected in the baseline with merely Euro 6/VI vehicle fleet renewal in combination with the impact of the new CO_2 standards.

Policy option 3a considers the introduction of continuous emission monitoring (CEM), to control real-driving emissions throughout the vehicle’s lifetime in a Medium Green and

Digital Ambition. It is based on available NO_x, NH_3 and PM sensor technologies (see Table 55). Policy option 3a builds on the medium ambition stricter air pollutant emission limits, real-driving testing boundaries and durability requirements as policy option 2a (see Table 50).

As shown in Table 14, the emission savings that can be expected in PO3a compared to the baseline are significant, in particular for lorries and buses. Also for cars and vans very low NO_x emission levels are reached in 2040, compared to 2050 in the baseline.

Through the introduction of CEM for NO_x and NH_3 emissions, some savings are expected to be achieved compared to the introduction of strict emission limits (PO2a), by guaranteeing lifetime compliance with emission limits and improved protection against tampering with the NO_x emission control system. For cars and vans, NO_x emissions are expected to decrease by 141 kt in 2030, 132 kt in 2040 to 26 kt in 2050 (compared to 138 kt in 2030, 129 kt in 2040 to 25 in 2050 in policy option 2a). For lorries and buses, NO_x emissions are expected to decrease by 211 kt in 2030, 485 kt in 2040 to 415 kt in 2050 (compared to 209 kt in 2030, 481 kt in 2040 to 411 kt in 2050 in policy option 2a).

Some emission savings are also expected by the use of NH_3 sensors over the vehicle's lifetime. For cars and vans, NH_3 emissions are expected to decrease by 2.8 kt in 2030, 8.8 kt in 2040 to 1.7 kt in 2050 (compared to 2.8 kt in 2030, 8.4 kt in 2040 to 1.6 in 2050 in policy option 2a). For lorries and buses, NH_3 emissions are expected to decrease by 2.3 kt in 2030, 4.0 kt in 2040 to 3.1 kt in 2050 (compared to 2.0 kt in 2030, 3.4 kt in 2040 to 2.6 kt in 2050 in policy option 2a).

Table 14 – Emission savings for pollutants from road transport in policy option 3a compared to the baseline[106]

Pollutant		2025	2030	2035	2040	2045	2050
Cars and vans							
NO_x	in kt	28.59	141.30	168.60	131.90	73.50	26.20
	in %	2.77	21.53	43.31	63.90	81.03	91.33
$PM_{2.5,brake\ emissions}$	in kt	0.44	2.55	4.22	5.41	6.01	6.16
	in %	2.96	16.34	26.32	32.63	35.52	36.28
$PM_{2.5,exhaust}$	in kt	0.04	0.20	0.23	0.15	0.06	0.02
	in %	0.35	5.06	14.99	21.61	22.39	21.97
PN_{10}	in #	1.73E+23	8.00E+23	8.67E+23	6.03E+23	2.90E+23	9.29E+22
	in %	0.97	15.09	45.09	66.50	78.53	87.55
CO	in kt	28.20	138.00	169.70	124.70	58.30	18.10
	in %	1.86	14.31	29.03	40.16	45.36	47.36
THC	in kt	6.01	29.70	34.56	26.17	14.83	6.49
	in %	2.16	14.01	23.65	29.44	31.05	32.92
NMHC	in kt	5.19	24.58	27.13	20.53	12.09	5.62
	in %	2.15	13.80	22.75	28.68	30.75	33.09
NH_3	in kt	0.41	2.84	7.95	8.81	5.04	1.71
	in %	1.58	10.80	33.33	54.97	70.87	81.13
CH_4	in kt	0.82	5.12	7.43	5.64	2.74	0.87
	in %	2.23	15.09	27.66	32.57	32.42	31.86
N_2O	in kt	-0.42	2.39	12.35	15.20	9.15	3.31
	in %	-1.85	6.88	29.93	45.18	51.08	54.80
HCHO	in kt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[106] See footnote 38

	in %	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lorries and buses							
NO_x	in kt	32.78	211.20	392.80	485.30	460.20	414.70
	in %	3.10	26.08	55.69	78.25	90.34	94.22
$PM_{2.5,total}$	in kt	0.37	2.08	3.44	3.88	3.50	3.08
	in %	1.46	9.50	17.71	23.88	27.59	29.02
$PM_{2.5,}$ exhaust	in kt	0.37	2.08	3.44	3.88	3.50	3.08
	in %	2.61	19.40	39.08	54.35	62.74	65.37
PN_{10}	in #	2.94E+22	1.95E+23	3.44E+23	4.30E+23	4.11E+23	3.70E+23
	in %	0.37	10.08	45.88	71.66	78.38	79.95
CO	in kt	0.69	6.42	13.58	18.42	17.66	15.95
	in %	0.32	4.70	12.18	17.42	18.97	19.17
THC	in kt	0.33	2.00	3.49	4.06	3.69	3.27
	in %	1.35	8.08	13.15	15.06	15.44	14.90
NMHC	in kt	0.36	2.13	3.70	4.30	3.92	3.47
	in %	1.70	11.73	22.24	29.04	31.65	30.09
NH_3	in kt	0.42	2.31	3.64	3.96	3.52	3.08
	in %	5.44	25.50	37.72	43.17	45.76	46.56
CH_4	in kt	-0.02	-0.13	-0.21	-0.25	-0.23	-0.21
	in %	-0.63	-2.03	-2.14	-2.02	-2.01	-2.00
N_2O	in kt	4.61	25.13	39.45	42.28	37.08	32.17
	in %	4.68	23.97	40.35	51.72	58.16	60.06
HCHO	in kt	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	in %	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

1.3. Cost modelling, cost-benefit and cost-effectiveness analysis

1.3.1. Cost modelling

In order to perform the cost-benefit analysis, the total regulatory cost should be calculated next to the health and environmental benefits. In order to model these costs, the regulatory cost following the implementation of each policy option should be considered, compared to the baseline. Equation 4 shows that this cost is the difference in costs over the baseline without taxes and profit margins.

Equation 4[107]

$$\textit{Incremental Cost} = \Delta(\textit{Final Price} - \textit{Taxes} - \textit{Mark-up})$$

The total regulatory costs related to the introduction of Euro 6/VI for the evaluation and related to the introduction of Euro 7 for the impact assessment are calculated as the sum of the costs over multiple cost categories, comprising substantive compliance costs and administrative costs. Considering the costs over these different categories should enhance the accuracy of the total regulatory cost by minimising uncertainty. The considered cost categories are presented in Tavle 39 in Annex 5. In the context of the impact assessment, for each policy option one or more of these cost elements need to be assessed in order to find the total societal cost, expressed as monetised health and environmental benefits. For the evaluation of Euro 6/VI, these cost elements and the respective values are discussed in detail and per stakeholder group in the Efficiency chapter.

The cost data have been verified by stakeholders and the remaining uncertainty has been estimated for all vehicles in the cost-benefit analysis (see section 1.3.2.1).

[107] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.5 Cost modelling

Each cost element is calculated over a specific unit and then scaled up to the total. These units are summarized below:

- *Number of new vehicle registrations per vehicles category* – these are obtained through the SIBYL model
- *Number of engine/model families per vehicle category* – estimated based on data from IHS Markit Database[108]. It was assumed that the current average per year will not change significantly in the future.
- *Number of type-approvals* – based on data provided by a group of type-approval authorities, presenting around 67% of the total WVTA, and extrapolated to the total EU. On the basis of this number the total average number of TAA per year was estimated. For the evaluation, an increase in the number of type-approvals for the period 2018-2020 was observed, which was linked to the need for further type-approvals following the staged introduction of Euro 6. However, the number is expected to remain constant afterwards.
- *Number of vehicle manufacturers affected* – based on information on the number of vehicle sales per manufacturer as provided by ACEA. The cost estimates focused on the main manufacturers in the different vehicle categories that, put together, represent more than 90% of the total sales.
- *Number of calibrations* – based on data from IHS Markit Database[109] on number of engine families to develop an estimate of the number of calibrations taking place per manufacturer and per year.

In addition, the assumptions made for the cost assessment are summarized in Box 4.

Box 4 – Key assumptions for cost modelling[110]

- **Discount rate:** 4%
- **Learning effect for new hardware:** The hardware costs are expected to decrease over time as the state of the art evolves and manufacturers and suppliers become more familiar with the new technologies through a learning effect. The faster these effects play out, the lower the overall costs will be. In the analysis, it is assumed that new technology incremental costs drop to 50% within a six year time-frame after their first introduction.
- **Amortization period for R&D costs**: Since R&D costs are one-off incremental costs, the main R&D investment is practically materialised before the emission standard becomes available and is then amortized over a certain period that is assumed to be between 5-10 years[111]. In our approach we have assumed that R&D costs are linked to the first model families appearing at the year of introducing the new emission standard and are amortized over the lifetime of this first model, which is of the order of 8 years in the EU.
- **Learning effect for calibration costs**: Any additional calibration effort is consider to drop to 50% of the initial additional effort as the OEM becomes more experienced with calibrating the new technology, which is already expected with the second model series after the introduction of a new standard.
- **No learning effect for testing and witnessing costs:** Since costs are related to a procedure

[108] IHS Market, 2021. Provision of data on vehicle sales in the EU-28 for Evaluation of Euro 6/VI vehicle emission standards
[109] See footnote 108
[110] See footnote 107
[111] Rogozhin et al. 2010. Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry.

demanded by the regulation, no significant cost reduction is expected over time.

The regulatory costs resulting from the cost modelling were used as input for assessing impacts in the areas of affordability for consumers and SME users. Assuming that a pass through of the costs takes place, consumers should be affected through an increase in vehicle prices. Assessing the relative impact can be examined by comparing vehicle prices with the costs per vehicle for Euro 6/VI or the different policy options to assess what share of a vehicle price they represent. Since vehicles in small size segments may not require all technologies identified in the default packages, prices and expected costs were compared for vehicles of similar size. To be more specific, low-end cost estimates were compared against the weighted average of vehicle prices[112] in the small size segments (mini/small), moderate cost estimates against the average price of the medium size segments vehicles (lower medium/medium/off-road/multi-purpose) and the high-end cost estimates against the higher cost segments of the large size segment vehicles (upper medium/sport/luxury).

While average prices from the ICCT were weighted against sales in 2018 and used for the assessment of affordability in the evaluation (see Table 41 Annex 5), in the impact assessment three additional steps were added. First, the ICE price projections of the Bloomberg New Energy Finance (BNEF) study[113] were used. That way, 1.5% annual price increases were assumed in the large vehicle segment, 2% in the medium vehicle segment and 2.5% in the small vehicle segment. Then, these increasing vehicle prices over the assessed period were discounted using the social discount rate of 4% and expressed in 2025 values. Finally, these results were weighted against the modelled vehicle registrations for each year. The results are presented in Table 17, Table 22 and Table 25 below.

1.3.1.1. Regulatory costs in policy option 1

The simplification measures introduced in policy option 1 intend to reduce complexity, remove inconsistencies and improve efficiency in the legislation. That way, the policy option was expected to result in some cost reductions, especially for costs during implementation phase and administrative costs, largely due to the streamlining of testing procedures. Table 15 presents the regulatory costs for policy option 1 over those related to the baseline.

[112] Based on the respective shares of sales by vehicle segment and average price (including tax). Data are provided by ICCT in the EU Pocketbook (ICCT, 2019).

[113] Bloomberg New Energy Finance (BNEF), 2021. Hitting the EV Inflection Point – Electric vehicle price parity and phasing out combustion vehicle sales in Europe

Table 15 – Regulatory costs for automotive industry in policy option 1 compared to the baseline, in 2025 values[114]

	Cars and vans		Lorries and buses	
	PI	CI	PI	CI
1) Equipment costs				
• **Hardware costs (emission control technologies)**				
Cost per vehicle (€)	33.26	104.10	0.00	0.00
Total cost (billion €)	1.31	4.70	0.00	0.00
• **R&D and related calibration costs including facilities and tooling costs**				
Cost per vehicle (€)	27.55	32.17	102.86	102.86
Total cost (billion €)	1.08	1.45	0.13	0.52
2) Costs during implementation phase				
• **Testing costs (granting type-approval, verification procedures)**				
Cost per model/engine family (thousand €)	-2 345.40	-9 385.64	-7 439.25	-3 121.19
Cost per vehicle (€)	-22.31	-21.55	-70.83	-32.90
Total cost (million €)	-878.49	-972.25	-87.34	-167.34
• **Witnessing costs (by type-approval authorities)**				
Cost per model/engine family (thousand €)	-156.66	-626.90	-263.47	-110.54
Cost per vehicle (€)	-1.49	-1.44	-2.51	-1.17
Total cost (million €)	-58.68	-64.94	-3.09	-5.93
• **Type-approval fees, except witnessing costs**				
Cost per type-approval (thousand €)	-1.83	-2.37	-0.52	-0.51
Cost per vehicle (€)	-0.34	-0.33	-0.52	-0.24
Total cost (million €)	-13.32	-14.74	-0.64	-1.23
3) Administrative costs (information provision)				
Cost per type-approval (thousand €)	-97.40	-126.32	-31.08	-30.35
Cost per vehicle (€)	-18.03	-17.42	-31.12	-14.46
Total cost (million €)	-710.18	-785.98	-38.38	-73.53
Total regulatory costs				
Total regulatory cost per vehicle (€)	18.64	95.53	-2.12	54.09
Total regulatory cost until 2050 (NPV in billion € - 2025 values)	0.73	4.31	0.00	0.28

The hardware costs represent recurrent costs arising from the need to install emission control technologies on vehicles to meet the actions of policy option 1. In terms of technology, no new hardware will be required to comply with technology-neutral emission limits. Reason for this being that for petrol cars and vans no new limits are proposed, while today's Euro 6d diesel cars and vans seem to be compliant with the NO_x limit of 60 mg/km limit[115]. This reasoning also applies to the decrease of particle size threshold from 23 to 10 nm in policy option 1. New hardware is, however, required for cars and vans to ensure that emissions are also controlled in low ambition extended real-driving testing outside the current RDE boundaries. This would mean including a larger three-way catalytic converter (TWC) and an improved gasoline particulate filter (GPF) for some of the PI cars and vans, which is estimated to increase the hardware costs by €33 per vehicle. CI cars and vans will need better thermal management and larger

[114] Supporting Euro 7 impact assessment study, chapter 5.1.2. Economic impacts
[115] Derived from 45 RDE compliant tests of Euro 6d diesel cars and vans by JRC, TNO and GreenNCAP.

components of exhaust aftertreatment components, which is estimated to increase the hardware costs by €104 per vehicle. Since neither the emission limits nor the PEMS testing conditions have changed for lorries and buses in comparison to the baseline, no hardware costs are expected.

Table 16 - Assumed control technology packages for policy option 1 and the respective hardware costs per vehicle for the average vehicle compared to the baseline, 2021 values[116]

Category	Petrol	Diesel	CNG/LPG
	Cars and vans		
MHEV	• 50% Mild hybrid, base TWC, base GPF • Cost per vehicle: €0	• 50% current technology • Cost per vehicle: €0	• 100% Mild hybrid, advanced calibration, larger TWC • Cost per vehicle: €78.8
	• 50% Mild hybrid, advanced calibration, larger TWC, improved GPF • Cost per vehicle: €108.8	• 50 % Mild hybrid, advanced heating calibration, larger EATS cost per vehicle: €201.7	
PHEV	• 100% Plugin hybrid, base TWC, base GPF • Cost per vehicle: €0	• 100% Plugin hybrid, advanced heating calibration, larger EATS • Cost per vehicle: €201.7	• 100% Plugin hybrid, advanced calibration, larger TWC • Cost per vehicle: €78.8
	Lorries and buses		
-	-	• 100% current technology • Cost per vehicle: €0	• 100% current technology • Cost per vehicle: €0

Next to the hardware costs for cars and vans, automotive industry is faced with R&D and calibration costs. In comparison to the baseline, these costs amount to approximately €28-€32 per vehicle for cars and vans. Although no hardware costs is needed for lorries and buses, R&D costs are required to introduce the improved OBD functionality (see Table 47) on the vehicles and to attain the PN limits with decreased threshold of 10 nm. Due to the much smaller production volumes for lorries and buses in comparison to cars and vans, the R&D cost per vehicle is with €103 per vehicle higher, while the total cost are closer in range for the different vehicle categories.

In contrast to the equipment cost, the costs during implementation phase – including testing and witnessing costs and type-approval fees – are projected to decrease significantly with the implementation of simplification measures (see Table 47). The testing costs for PI cars and vans, for example, are estimated to decrease by €2 345 thousand per model family (€22 per vehicle), while the witnessing costs for this category are estimated to decrease by €157 thousand per model family (-€1.49 per vehicle). For CI vehicles, the savings in testing costs per model family go further with €9 386 thousand. However, due to the larger number of vehicles in the average CI model family the cost per vehicle also decreases by €22. The savings in witnessing costs per vehicle are found to be lower for CI cars and vans, than for PI cars and vans. In addition, the simplification measures would achieve significant costs savings during implementation phase for lorries and buses, especially for PI vehicles. Following the implementation of the simplification measures, the fees per type-approval are estimated to decrease to a similar extent for all vehicle categories.

[116] See footnote 107

Another set of significant cost savings is expected in administrative costs (information provision). The simplification measures related to the legislative process and the testing procedures is translated into an extensive decrease in administrative burden for all vehicle categories. The administrative costs per type-approval are estimated to decrease most for CI cars and vans. For CI cars and vans for example, a cost saving of €126 thousand per type-approval (€17 per vehicle) is expected to be realised.

Table 17 – Regulatory costs of policy option 1 compared to the baseline in comparison to average purchase prices per vehicle segment, in 2025 values

	Vehicle segment	Regulatory cost per vehicle (in €)	Average vehicle price (in €)	Share of vehicle price (in %)
Cars and vans PI	Small	18.64	17 281.92	0.11
	Medium	18.64	31 293.75	0.06
	Large	18.64	65 099.78	0.03
Cars and vans CI	Small	95.53	17 144.19	0.56
	Medium	95.53	31 044.35	0.31
	Large	95.53	64 580.95	0.15
Lorries	Small	48.00	79 389.47	0.06
	Medium	48.00	100 713.53	0.05
	Large	48.00	151 183.30	0.03
Buses	Small	-4.92	152 198.85	0.00
	Medium	-4.92	185 653.41	0.00
	Large	-4.92	217 376.97	0.00

1.3.1.2. Regulatory costs in policy option 2

Policy options 2a and 2b consider two levels of ambition (medium and high) for introducing stricter pollutant emission limits to the Euro 6/VI emission limits to provide appropriate and up-to-date limits for all relevant air pollutants (see Table 50 and Table 51). In addition, option 2 develops extended real-driving testing boundaries in two ambition levels (medium and high) to improve control of real-world emissions and builds on the same simplification measures as option 1 to reduce complexity of the Euro 6/VI emission standards. Stricter air pollutant limits for vehicles and comprehensive real-driving testing result in regulatory costs for automotive industry, while the simplification measures lead to the similar cost savings as in option 1. Table 18 presents the regulatory costs for policy option 2a over those related to the baseline, while Table 19 represents those for policy option 2b.

Table 18 - Regulatory costs for tailpipe and evaporative emissions for automotive industry in policy option 2a (medium ambition stricter emission limits and real driving testing boundaries) compared to the baseline, in 2025 values[117]

	Cars and vans		Lorries and buses	
	PI	CI	PI	CI
1) Equipment costs				
• **Hardware costs (emission control technologies)**				
Cost per vehicle (€)	81.07	328.35	1 137.71	1 481.04
Total cost (billion €)	3.19	14.82	1.40	7.53
• **R&D and related calibration costs including facilities and tooling costs**				
Cost per vehicle (€)	103.52	111.74	1 245.48	1 248.22
Total cost (billion €)	4.08	5.04	1.54	6.35
2) Costs during implementation phase				
• **Testing costs (granting type-approval, verification procedures)**				
Cost per model/engine family (thousand €)	-2 228.49	-9 385.64	-7 439.25	-3 121.19
Cost per vehicle (€)	-21.20	-21.55	-70.83	-32.90
Total cost (million €)	-834.70	-972.25	-87.34	-167.34
• **Witnessing costs (by type-approval authorities)**				
Cost per model/engine family (thousand €)	-156.66	-626.90	-263.47	-110.54
Cost per vehicle (€)	-1.49	-1.44	-2.51	-1.17
Total cost (million €)	-58.68	-64.94	-3.09	-5.93
• **Type-approval fees, except witnessing costs**				
Cost per type-approval (thousand €)	-1.83	-2.37	-0.52	-0.51
Cost per vehicle (€)	-0.34	-0.33	-0.52	-0.24
Total cost (million €)	-13.32	-14.74	-0.64	-1.23
3) Administrative costs (information provision)				
Cost per type-approval (thousand €)	-97.40	-126.32	-31.08	-30.35
Cost per vehicle (€)	-18.03	-17.42	-31.12	-14.46
Total cost (million €)	-710.18	-785.98	-38.38	-73.53
Total regulatory costs				
Total regulatory cost per vehicle (€)	143.54	399.36	2 278.22	2 680.49
Total regulatory cost until 2050 (NPV in billion € - 2025 values)	5.65	18.02	2.81	13.63

Table 19 - Regulatory costs for tailpipe and evaporative emissions for automotive industry in policy option 2b (high ambition stricter emission limits and real driving testing boundaries) compared to the baseline, in 2025 values[118]

	Cars and vans		Lorries and buses	
	PI	CI	PI	CI
1) Equipment costs				
• **Hardware costs (emission control technologies)**				
Cost per vehicle (€)	252.74	387.24	2 003.76	3 074.05

[117] Supporting Euro 7 impact assessment study, chapter 5.2.2. Economic impacts
[118] See footnote 117

Total cost (billion €)	9.95	17.47	2.47	15.64
• **R&D and related calibration costs including facilities and tooling costs**				
Cost per vehicle (€)	115.21	116.26	1 249.73	1 255.19
Total cost (billion €)	4.54	5.25	1.54	6.38
2) Costs during implementation phase				
• **Testing costs (granting type-approval. verification procedures)**				
Cost per model/engine family (thousand €)	-2 228.49	-9 385.64	-7 439.25	-3 121.19
Cost per vehicle (€)	-21.20	-21.55	-70.83	-32.90
Total cost (million €)	-834.70	-972.25	-87.34	-167.34
• **Witnessing costs (by type-approval authorities)**				
Cost per model/engine family (thousand €)	-156.66	-626.90	-263.47	-110.54
Cost per vehicle (€)	-1.49	-1.44	-2.51	-1.17
Total cost (million €)	-58.68	-64.94	-3.09	-5.93
• **Type-approval fees. except witnessing costs**				
Cost per type-approval (thousand €)	-1.83	-2.37	-0.52	-0.51
Cost per vehicle (€)	-0.34	-0.33	-0.52	-0.24
Total cost (million €)	-13.32	-14.74	-0.64	-1.23
3) Administrative costs (information provision)				
Cost per type-approval (thousand €)	-97.40	-126.32	-31.08	-30.35
Cost per vehicle (€)	-18.03	-17.42	-31.12	-14.46
Total cost (million €)	-710.18	-785.98	-38.38	-73.53
Total regulatory costs				
Total regulatory cost per vehicle (€)	326.88	462.76	3 148.51	4 280.48
Total regulatory cost until 2050 (NPV in billion € - 2025 values)	12.87	20.88	3.88	21.77

The hardware costs represent recurrent costs arising from the need to install engine and emission control technologies for tailpipe and evaporative emissions on vehicles to meet the requirements of policy option 2. The cost estimates in Table 18 and Table 19 show that for all vehicle categories the hardware costs are considerably higher in policy option 2b than in policy option 2a and 1. This demonstrates that the further decrease in emission limits and the further extension of real-driving testing boundaries in policy option 2b requires further technology at a higher cost. In Table 21, the assumed technology packages to comply with the stricter emission limits in policy option 2 for are presented, together with the hardware costs of these packages compared to the baseline, i.e. costs for Euro 6d / VI E technologies. These hardware costs show that higher effort is needed to curb pollutant emissions from diesel vehicles and from larger vehicles, compared to gasoline vehicles. Comparing the hardware costs with the other cost categories in the tables above, it is clear that the rise in hardware costs is the most extensive for all vehicle categories.

The hardware costs in Table 18 and Table 19 do not include the costs of technologies required for introducing a brake emission limit, as costs for brake pads are different between ICE/MHEV and PHEV/BEV vehicles due to the different technologies and braking patterns used for these vehicles (see Table 20).

Table 20 –Regulatory costs for brake emissions in policy option 2 compared to the baseline, in 2025 values

	Cars and vans		Lorries and buses	
	ICE/MHEV	PHEV/BEV	ICE/MHEV	PHEV/BEV

Option 2a – Medium Green Ambition				
1) Equipment costs				
• **Hardware costs (emission control technologies for brakes)**				
Cost per vehicle (€)	23.06	12.78	-	-
Total cost (billion €)	1.95	4.65	-	-
	Cars and vans		**Lorries and buses**	
	ICE/MHEV	**PHEV/BEV**	**ICE/MHEV**	**PHEV/BEV**
Option 2b – High Green Ambition				
1) Equipment costs				
• **Hardware costs (emission control technologies for brakes)**				
Cost per vehicle (€)	100.28	60.07	-	-
Total cost (billion €)	8.47	21.62	-	-

Table 21 - Assumed control technology packages for policy option 2 and the respective hardware costs per vehicle for the average vehicle compared to the baseline, 2021 values[119]

a) Exhaust emissions

Policy option	Category	Petrol	Diesel	CNG/LPG
Cars and vans				
2a	MHEV	• 100% Mild hybrid, advanced calibration, larger TWC, improved GPF • Cost per car: €88.0 • Cost per van:€78.2	• 100% Mild hybrid, advanced heating calibration, larger EATS, EHC • Cost per car: €312.2 • Cost per van: €455.6	• 100% Mild hybrid, advanced calibration, larger TWC • Cost per car: €69.7 • Cost per van: €73.2
	PHEV	• 80% Plugin hybrid, base TWC, base GPF • Cost per vehicle: €0.0 • 20% Plugin hybrid, advanced calibration, larger TWC, improved GPF • Cost per car: €88.0 • Cost per van: €78.2	• 100% Plugin hybrid, advanced heating calibration, larger EATS, EHC, turbine bypass • Cost per car: €487.2 • Cost per van: €630.6	• 100% Plugin hybrid, advanced calibration, larger TWC • Cost per car: €69.7 • Cost per van: €73.2
2b	MHEV	• 80% Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC • Cost per car: €233.8 • Cost per van: €222.8	• 20% Mild hybrid, advanced heating calibration, larger EATS, EHC • Cost per car: €326.7 • Cost per van: €473.5	• 80% Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC • Cost per car: €290.2 • Cost per van: €298.5
		• 20% Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 10s preheating, secondary air injection, NH3 catalyst • Cost per car: €334.6 • Cost per van: €320.9	• 80% Mild hybrid, advanced heating calibration, larger EATS, EHC, preheating, secondary air injection • Cost per car: €404.7 • Cost per van: €551.5	• 20% Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 10s preheating, secondary air injection, NH3 catalyst • Cost per car: €386.1 • Cost per van: €394.5
	PHEV	• 50% Plugin hybrid, advanced calibration, larger TWC,	• 100% Plugin hybrid, advanced	• 50% Plugin hybrid, advanced calibration,

[119] See footnote 107

		improved GPF • Cost per car: €108.8 • Cost per van: €97.8	heating calibration, larger EATS, EHC, turbine bypass • Cost per car: €501.7 • Cost per van: €648.5	larger TWC, improved GPF, 4kW EHC • Cost per car: €165.2 • Cost per van: €173.5
		• 30% Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC • Cost per car: €233.8 • Cost per van: €222.8		• 30% Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC • Cost per car: €290.2 • Cost per van: €298.5
		• 20% Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 60s preheating, secondary air injection, NH3 catalyst • Cost per car: €334.6 • Cost per van: €320.9		• 20% Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 60s preheating, secondary air injection, NH3 catalyst • Cost per car: €386.1 • Cost per van: €394.5
Lorries and buses				
2a		-	• 50% Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR) • Cost per vehicle: €1 863	• 50% Advanced heating calibration, close-coupled EATS, optimised particulate filter, EGR (w/ cold SCR) • Cost per vehicle: €1 863
			• 50% Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), EHC • Cost per vehicle : €2 913	• 50% λ=1, advanced heating calibration, close-coupled EATS, optimised particulate filter • Cost per vehicle: €2 112.7
2b		-	• 50% Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), burner, preheating • Cost per vehicle: €3 463	• 50% Advanced heating calibration, close-coupled EATS, optimised particulate filter, EGR (w/ cold SCR), EHC • Cost per vehicle: €2 913
			• 50% Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), EHC, preheating • Cost per vehicle: €5 263	• 50% λ=1, advanced heating calibration, close-coupled EATS, optimised particulate filter, EHC • Cost per vehicle: €3 162.7

b) Evaporative emissions

Policy option	Emission control technology	Hardware cost (€/vehicle)
Evaporative emissions from PI vehicles		
2a	ORVR canister, anti spitback/vapour seal valve, and a high flow purge valve	16
2b	Higher capacity canister and low permeability fuel tank and hoses	40

c) **Non-exhaust emissions**

Policy option	Emission control technology	Hardware cost (€/vehicle)
Brake emissions from cars and vans		
2a	NAO brake pads – ICE and MHEV	37.5
	NAO brake pads – PHEV and BEV	22.5
2b	NAO brake pads – ICE and MHEV	37.5
	NAO brake pads – PHEV and BEV	22.5
	Brake dust particulate filter	160

In contrast to the findings for the hardware costs, the R&D and related calibration costs including facilities and tooling costs are not expected to differ much between the different ambition levels. In comparison to the baseline, these costs are estimated to increase by €115 for PI and €116 for CI cars and vans in PO2a and by €104 for PI and €112 for CI cars and vans in PO2b. The R&D and related calibration costs per vehicle for lorries and buses is significantly higher and estimated at €1 245-€1 248 per vehicle in PO2a and at €1 250-€1 255 in PO2b. This is related to the lower number of produced vehicles in these segments, in comparison to cars and vans.

Since policy option 2 includes the simplification measures introduced in policy option 1, the costs savings in the testing and witnessing costs, the type-approval fees and administrative costs are for the largest share estimated at the same levels as in option 1. No costs during implementation phase compared to Euro 6/VI are assumed for both stringency levels and comprehensive real-driving testing.

On the other hand, battery durability requirements would not add any costs because the level of durability is set to the level already achieved by the average batteries of today and the costs for the verification are already included in the other tests, i.e. no new test will be required.

Overall, policy option 2a (Medium Green Ambition) and policy option 2b (High Green Ambition) are expected to result in a positive impact on European competitiveness in the automotive sector. Nevertheless, the implementation of stricter emission limits is expected to increase regulatory cost for automotive industry, to a higher extend in policy option 2b than in option 2a (see Table 18 and Table 19). Since the regulatory costs in both sub-options are significantly below the regulatory costs that came with the introduction of Euro 6/VI and the proposed CO_2 emission standards, any negative effect on competitiveness through the price is expected to be limited. This is in line with the evaluation of Euro 6/VI which illustrated that costs do not necessarily have a negative impact on the competitiveness of the EU industry.

Table 22 – Regulatory costs of policy option 2 compared to the baseline in comparison to average purchase prices per vehicle segment, in 2025 values

	Vehicle segment	Regulatory cost per vehicle (in €)	Average vehicle price (in €)	Share of vehicle price (in %)
Option 2a - medium ambition stricter emission limits and real driving testing boundaries				
Cars and vans PI	Small	144.75	17 281.92	0.84
	Medium	159.66	31 293.75	0.51

	Large	174.58	65 099.78	0.27
Cars and vans CI	Small	361.32	17 144.19	2.11
	Medium	390.16	31 044.35	1.26
	Large	428.26	64 580.95	0.66
Lorries	Small	2 481.46	79 389.47	3.13
	Medium	2 617.10	100 713.53	2.60
	Large	2 796.34	151 183.30	1.85
Buses	Small	2 328.11	152 198.85	1.53
	Medium	2 453.26	185 653.41	1.32
	Large	2 618.62	217 376.97	1.20
Option 2b - high ambition stricter emission limits and real driving testing boundaries				
Cars and vans PI	Small	383.86	17 281.92	2.22
	Medium	402.39	31 293.75	1.29
	Large	420.91	65 099.78	0.65
Cars and vans CI	Small	483.43	17 144.19	2.82
	Medium	511.78	31 044.35	1.65
	Large	550.27	64 580.95	0.85
Lorries	Small	3 855.85	79 389.47	4.86
	Medium	4 082.62	100 713.53	4.05
	Large	4 390.38	151 183.30	2.90
Buses	Small	3 621.52	152 198.85	2.38
	Medium	3 832.92	185 653.41	2.06
	Large	4 119.83	217 376.97	1.90

1.3.1.3. Regulatory costs in policy option 3

Policy option 3a considers the introduction of continuous emission monitoring, to control real-driving emissions throughout the vehicle's lifetime and in all driving conditions. It is based on available sensor technologies (see Table 55). In addition, option 3 builds on the same simplification measures as option 1 to reduce complexity of the Euro 6/VI emission standards and on more stringent air pollutant emission limits as option 2a and comprehensive real-driving conditions to provide appropriate and up-to-date limits for all relevant air pollutants.

On-board monitoring result in regulatory costs, while the simplification measures lead to the same cost savings as in option 1 and the introduction of strict emission limits based on available emission control technology lead to the same costs as in option 2a. Table 23 presents the regulatory costs for policy option 3a over those related to the baseline.

Table 23 - Regulatory costs for tailpipe and evaporative emissions for automotive industry in policy option 3a compared to the baseline, in 2025 values[120]

	Cars and vans		Lorries and buses	
	PI	CI	PI	CI
1) Equipment costs				
• **Hardware costs (emission control and sensor technologies)**				
Cost per vehicle (€)	128.94	353.93	1 160.56	1 507.41
Total cost (billion €)	5.08	15.97	1.43	7.67
• **R&D and related calibration costs including facilities and tooling costs**				
Cost per vehicle (€)	78.68	104.90	1 334.22	1 332.10
Total cost (billion €)	3.10	4.73	1.65	6.78
2) Costs during implementation phase				
• **Testing costs (granting type-approval. verification procedures)**				
Cost per model / engine family (thousand €)	-3 328.13	-11 630.89	-11 305.62	-4 775.22
Cost per vehicle (€)	-31.66	-26.70	-107.64	-50.33
Total cost (million €)	-1 246.57	-1 204.83	-132.73	-256.03
• **Witnessing costs (by type-approval authorities)**				
Cost per model / engine family (thousand €)	-230.11	-776.87	-400.41	-169.12
Cost per vehicle (€)	-2.19	-1.78	-3.81	-1.78
Total cost (million €)	-86.19	-80.48	-4.70	-9.07
• **Type-approval fees. except witnessing costs**				
Cost per type-approval (thousand €)	-3.83	-4.19	-1.12	-1.10
Cost per vehicle (€)	-0.50	-0.40	-0.79	-0.37
Total cost (million €)	-19.56	-18.26	-0.97	-1.88
3) Administrative costs (information provision)				
Cost per type-approval (thousand €)	-204.42	-223.60	-67.35	-66.30
Cost per vehicle (€)	-26.49	-21.59	-47.30	-22.12
Total cost (million €)	-1 043.14	-974.00	-58.33	-112.50
Total regulatory costs				
Total regulatory cost per vehicle (€)	146.79	408.36	2 335.25	2 764.90
Total regulatory cost until 2050 (NPV in billion € - 2025 values)	5.78	18.43	2.88	14.06

The hardware costs represent recurrent costs arising from the need to install emission control technologies to comply with strict emission limits as assumed in policy option 2a (see Table 20) and new sensor technologies for CEM, on vehicles to meet the actions of policy option 3. For policy option 3a, hardware costs for available NO_x, and NH_3 and PM sensor technologies are considered. Moreover, costs for over-the-air (OTA) data transmission is included, allowing also the possibility of geo-fencing[121]. A higher cost for OTA data transmission is assumed for lorries and buses, due to the higher complexity of the data monitoring system of a HDV over a car.

[120] Supporting Euro 7 impact assessment study, chapter 5.3.2. Economic impacts
[121] Geo-fencing puts a vehicle automatically into zero-emission mode depending on its geolocation, in particular in urban areas.

The hardware costs for every vehicle category are estimated to be lower in policy option 3a than in policy option 2b which considers the most stringent set of emission limits. In other words, the costs for available emission and sensor control technologies are lower than for best available emission control technology.

In addition, policy option 3a assumes the same hardware costs for brake emissions from cars and vans as in policy option 2a (see Table 20). That means, policy option 3a €21 per ICE/MHEV vehicle and €12 per PHEC/BEV vehicle for brake pads.

Table 24 - Assumed control technology packages for policy option 3a and the respective hardware costs per vehicle for the average vehicle compared to the baseline, 2021 values[122]

a) Exhaust emissions

Policy option	Category	Petrol	Diesel	CNG/LPG
Cars and vans				
3a	MHEV	• 100% Mild hybrid, advanced calibration, larger TWC, improved GPF • Cost per car: €88.0 • Cost per van:€78.2	• 100% Mild hybrid, advanced heating calibration, larger EATS, EHC • Cost per car: €312.2 • Cost per van: €455.6	• 100% Mild hybrid, advanced calibration, larger TWC • Cost per car: €69.7 • Cost per van: €73.2
	PHEV	• 80% Plugin hybrid, base TWC, base GPF • Cost per vehicle: €0,0 • 20% Plugin hybrid, advanced calibration, larger TWC, improved GPF • Cost per car: €88.0 • Cost per van: €78.2	• 100% Plugin hybrid, advanced heating calibration, larger EATS, EHC, turbine bypass • Cost per car: €487.2 • Cost per van: €630.6	• 100% Plugin hybrid, advanced calibration, larger TWC • Cost per car: €69.7 • Cost per van: €73.2
Lorries and buses				
3a		-	• 50% Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR) • Cost per vehicle: €1 863	• 50% Advanced heating calibration, close-coupled EATS, optimised particulate filter, EGR (w/ cold SCR) • Cost per vehicle: €1 863
			• 50% Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), EHC • Cost per vehicle : €2 913	• 50% λ=1, advanced heating calibration, close-coupled EATS, optimised particulate filter • Cost per vehicle: €2 112.7

b) Evaporative emissions

Policy option	Emission control technology	Hardware cost (€/vehicle)
Evaporative emissions from PI vehicles		

[122] See footnote 107

3a	ORVR canister, anti spitback/vapour seal valve, and a high flow purge valve, pump system for active leak detection (OBD)	41

c) Non-exhaust emissions

Policy option	Emission control technology	Hardware cost (€/vehicle)
Brake emissions from cars and vans		
3a	NAO brake pads – ICE and MHEV	37.5
	NAO brake pads – PHEV and BEV	22.5

For lorries and buses, the R&D and the related calibration costs are in general expected to be higher in policy option 3 than in the previous options. This follows from the fact that policy option 3 is the most advanced option including the previous options and hence bundling the R&D costs. For example, the R&D cost for CI lorries and buses is estimated at €1 051 per vehicle in 3a, in comparison with €992 per vehicle in policy option 2.

A different observation is made for the costs for PI cars and vans, for which the R&D and related calibration cost were estimated in policy option 2 with €80 per vehicle (due to the new emission technology introduced for PI vehicles) in comparison to €49 in policy option 3a. In case of CI cars and vans, the R&D costs and related calibration costs for policy option 3a are expected to be lower than the costs in option 2. The reason for this observation is that policy option 3 allows for some cost reductions through a decreased need for calibration following the introduction of continuous emission monitoring which makes it no longer necessary to infer emissions for the operation conditions.

In comparison to the estimates for option 2, the cost savings during implementation phase in option 3 go further for all three subcategories. This follows from the fact that the introduction of CEM facilitates the granting of type-approval and verification testing procedures (see Table 55), in addition to the simplification measures introduced in option 1 (see Table 47). The testing costs for PI cars and vans are estimated to decrease by €28 per vehicle in policy option 3a, compared to €19 per vehicle in policy option 2. Similar cost savings over policy option 2 are realised for the other vehicle and costs subcategories during implementation phase. The benefits from simplification of the type-approval procedure come from the fact that a drop of 30% in the number of necessary type-approvals is anticipated for policy option 3a. This drop is considered to reflect the fact that CEM can enable a wider family concept than the current model or engine family. By verifying a single OBM family, the type-approval authority would not need to verify all details of the emission control system but ensure that the OBM system measures and reports correctly.

The cost estimates for the administrative costs follow the same trend as the costs during implementation phase. The new CEM requirements in policy option 3 are expected to further simplify the reporting and other information provision obligations for granting type-approval and verification procedures which leads to cost savings for all vehicle categories compared to the other policy options.

Table 25 – Regulatory costs of policy option 3a compared to the baseline in comparison to average purchase prices per vehicle segment, in 2025 values

	Vehicle segment	Regulatory cost per vehicle (in €)	Average vehicle price (in €)	Share of vehicle price (in %)
Cars and vans PI	Small	139.20	17 281.92	0.81
	Medium	162.92	31 293.75	0.52
	Large	186.64	65 099.78	0.29
Cars and vans CI	Small	367.80	17 144.19	2.15
	Medium	399.06	31 044.35	1.29
	Large	440.38	64 580.95	0.68
Lorries	Small	2 560.56	79 389.47	3.23
	Medium	2 698.66	100 713.53	2.68
	Large	2 881.14	151 183.30	1.91
Buses	Small	2 380.35	152 198.85	1.56
	Medium	2 507.82	185 653.41	1.35
	Large	2 676.26	217 376.97	1.23

1.3.2. Cost-benefit analysis

For both the evaluation and the impact assessment, a cost-benefit analysis model was developed to examine the specific regulatory requirements of the current Euro 6/VI emission standards or the different policy options for a Euro 7 initiative. The aim of this analysis is to indicate whether the societal benefits achieved following the past and future initiatives at least even out the respective societal costs. Societal benefits comprise health and environmental benefits for citizens and regulatory costs savings (cost savings during implementation phase and administrative cost savings) for industry which are assumed to be passed on to citizens, whereas societal costs comprise regulatory costs (equipment costs) for industry which are also assumed to be passed on to citizens.

The introduction of new vehicle technologies following new policy requirements are modelled with SIBYL/COPERT[31,38] that calculate first the vehicle stock, activity and energy consumption. Subsequently, these new requirements should have a positive environmental and health impact through the reduction of total emission levels and regulatory cost savings through the simplification measures. On the other side, they could have a negative impact through increasing the regulatory costs. To compare the costs and benefits, the equivalent monetised health and environmental benefits are calculated by multiplying the emission savings in kg with the external marginal cost in €/kg for every investigated pollutant. The costs and benefits are then scaled up to represent the total regulatory costs and the total health and environmental benefit and total regulatory cost savings. Finally, the subtraction of the total costs from the total benefit results in the net benefit. If this number has a positive value, it means that a net benefit is achieved by the intervention, while a negative value means that a net damage is realised.

The net-present value (NPV) is derived by allocating the cost and benefit to the period of investigation based on a social discount rate. Following the recommendations from the Better Regulation Guidelines[123], a social discount rate of 4% has been applied in the analysis. To take into account the full range of the equivalent monetised benefits, a time horizon up to 2050 was considered. The considered discount rate results in any benefits reaching zero in approximately 30 years after the introduction of the new emission

[123] European Commission, 2020. Better Regulation Toolbox, Tool #61. The use of discount rates

requirements for vehicles. If a higher social discount rate and shorter simulation horizon was considered, many monetary benefits would have been neglected.

1.3.2.1. Uncertainty

Uncertainty in the cost-benefit analysis was reported for the cost modelling and was due to the limited cost data received from stakeholders during the public and target stakeholder consultations and the related follow-up on both Euro 6/VI evaluation and Euro 7 impact assessment. Due to lessons learnt from the Euro 6/VI evaluation (see Annex 5, section 4.2), the data collection, including confidential sharing of data by stakeholders, and validation by key stakeholders of regulatory costs and health and environmental benefits had a great importance in the impact assessment. The results and underlying assumptions have been cross-checked with independent experts and the concerned stakeholders.

The CLOVE consortium, in which key experts from a group of seven independent research organisations and universities join forces, carried out the studies supporting this impact assessment. While the Laboratory of Applied Thermodynamics of the Aristotle University of Thessaloniki (LAT) took the lead on the supporting impact assessment study, the work was subject to cross-checking between the different institutes. Next to that, everything has been discussed and verified by experts from the JRC in Ispra working on sustainable transport. In addition, concerned stakeholders were encouraged to verify or contest any result or assumptions in the extensive stakeholder consultation. During the ten official meetings of the Advisory Group on Vehicle Emission Standards (AGVES), stakeholders (mostly from automotive industry, Member States and NGOs) were brought up-to-date regularly on the ongoing work and were able to react on the spot, in written after a meeting or in the next meeting. Feedback received through this channel was carefully analysed by experts and taken into account if credible. For further details please see Annex 1 and 2.

All relevant stakeholder groups and JRC experts were requested to validate the CLOVE cost estimates[124]. In addition, relevant datasets from other sources were used to cross-check the estimates fleet or cost estimates, including the EEA NECD database[6], OECD statistics[125], the handbook on external costs and emission factors of Road Transport[126] and data on structural business statistics from Eurostat[127]; additional data on emission type-approvals from ten type-approval authorities[128] and on Euro 6/VI vehicle sales in the EU-28 from IHS Markit[129]. Additionally, CLOVE calculated multiple scenarios for critical assumptions, such as comparing emission limits for traditional tailpipe and evaporative emissions versus new brake emissions or normal versus conservative emission factor approach[130].

Following the validation, remaining uncertainty has been addressed and minimised by

[124] Supporting Euro 7 impact assessment study, Table 9-41: Sources and assumptions made per cost category
[125] OECD, 2020. Statistics on Patents –Technology Development Environment
[126] European Commission, 2019. Handbook on the external costs of transport
[127] Eurostat, 2020. Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]
[128] Type-approval authorities provided emission type-approval data at the request of the European Commission
[129] IHS Markit, 2021. Provision of data on vehicle sales in the EU-28 for Evaluation of Euro 6/VI vehicle emission standards
[130] Supporting Euro 7 impact assessment study, chapter 6 Comparison of Policy Options

assessing the level of confidence for each regulatory cost category and the health and environmental benefit used in the cost-benefit analysis based on the availability and quality of information, data and the shared input by stakeholders. The assumed uncertainty for a high confidence level is at 10%, for a medium-high confidence level 15% and medium confidence level 20% (see Table 26).

While the level of confidence is considered high for costs during implementation phase and administrative costs, as the costs for testing, witnessing and type-approval is well known based on granting type-approval and verification procedures by type-approval authorities, the level of confidence for equipment costs is assessed medium to high. For R&D costs the upper estimates were based on the responses provided by manufacturers to the targeted consultations, and the hardware costs for Euro 7 emission control technologies is well known by CLOVE and JRC experts. The level of confidence for health and environmental benefits is assessed medium to high, as calculations are based on best available information on emission savings, including emission factors adjusted to the policy options by CLOVE and factors to monetise external costs. The concept of emission factors and external costs was developed by a consortium led by CE Delft for the Commission's Handbook on the external costs of transport[126] and is used by EU and national air quality and climate policies for road transport.

Table 26 – Estimated uncertainty for all vehicles in the cost-benefit analysis

Cost category	Level of confidence	Estimated uncertainty[1]
Regulatory costs		
1) Equipment costs		
Hardware costs (emission control technologies)	Medium/high	15%
R&D and related calibration costs including facilities and tooling costs	Medium	20%
2) Costs during implementation phase		
Testing costs (granting type-approval, verification procedures)	High	10%
Witnessing costs (by type-approval authorities)	High	10%
Type-approval fees, except witnessing costs	High	10%
3) Administrative costs		
Administrative costs (information provision)	High	10%
Health and environmental benefits	**Medium/high**	**15%**

In conclusion, the underlying methodology for the cost-benefit analysis is very robust due to the extensive stakeholder consultation process, the long-standing reputation of the SIBYL/COPERT models used by the Commission and EEA for pollutant modelling in EU air quality policies and the medium to high level of confidence level of the quantitative cost and benefit estimates. The cost-benefit analysis in Table 27 to Table 29 is complemented by providing ranges of expected costs and benefits to make political choices based on the net benefits and benefit-cost ratios of the policy options for light- and heavy-duty vehicles.

1.3.2.2. Efficiency of policy option 1-3

In order to assess efficiency of policy options, regulatory costs are compared with the health and environmental benefit of a reduction of air pollution and regulatory cost savings by simplification measures. The health and environmental benefit can be monetised using the concept of external costs, which reflect the damage costs by air pollution to environment and health, in particular medical treatment costs, production losses due to illnesses and even deaths. Decreasing pollution leads to a decrease of damage hence to an overall benefit. The results of this assessment (as net benefits i.e. the difference between the present value of the benefits and costs and as benefit-cost ratio (BCR)) is presented for tailpipe and evaporative emissions in Table 27. For methodological reasons and for clarity purposes, **the focus of the efficiency assessment is on net benefits** which are an indicator of the attractiveness of an option in absolute terms (thus the larger the difference between benefits and costs, the better) and do not bias the results for low-cost options, compared to the BCR.

The BCR gets disproportionally high when costs are low (see PO1 in Table 27 and Table 29) which gives an unjustified advantage to low-cost options and has the potential to mislead policy makers. Moreover, the BCR is independent form the scale of options considered, which contradicts the necessity to consider in absolute terms the regulatory costs and environmental and health benefits of reducing air pollutants. The BCR is therefore disregarded to choose one option and is included in the efficiency tables of the Annexes for completeness purposes only.

Table 27 – Assessment of efficiency of policy options for tailpipe and evaporative emissions compared to baseline*, 2025-2050, Introduction of Euro 7 in 2025, Data source: SIBYL/COPERT 2021

Policy option	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
Cars and vans				
Net benefits 2025 NPV (billion €)	17.33±2.23	21.25±2.55	16.58±1.82	21.64±2.61
Net benefits 2025 NPV (€/ vehicle)	205.03±27.19	251.38±30.27	196.15±21.58	256.11±31.02
Benefit-cost-ratio**	3.0 (2.2-4.1)	1.8 (1.3-2.5)	1.4 (1.1-1.9)	1.7 (1.3-2.4)
Lorries and buses				
Net benefits 2025 NPV (billion €)	20.86±3.08	116.10±17.00	108.36±15.84	116.64±17.03
Net benefits 2025 NPV (€/vehicle)	3 301.84±487.15	18 371.33 ±2 690.29	17 145.63 ±2 506.19	18 440.82 ±2 694.87
Benefit-cost-ratio**	33.1 (23.5-47.5)	7.9 (5.7-11.0)	5.2 (3.8-7.1)	7.7 (5.5-10.7)

** The baseline considers an end-date of combustion-engine cars/vans in 2035, see chapter 5.1.*

*** The benefit-cost ratio gets disproportionally high when costs are low which gives an unjustified advantage to low-cost options (i.e. PO1) and has the potential to mislead policy makers. The benefit-cost ratio is disregarded to choose one option based on benefits and costs in absolute terms only and included in this table for completeness purposes only.*

In addition to tailpipe and evaporative emissions, policy options 2 and 3 introduce limits for brake emissions from new vehicles. Brake wear has been recognized as the leading source of non-exhaust particles which are harmful to human health and emitted by all types of vehicles. Progress has been made in developing a measurement method in the GRPE Particle Measurement Programme for cars and vans[131], while the technologies to decrease brake emissions are already in the market or close to becoming commercial. While the brake emission limit of 7 mg/km in policy option 2a and 3a can be realised using better brake pad material, the stricter limit of 5 mg/km in policy option 2b and 3b require also a brake filter for the collection of the brake wear particles produced. As shown in Table 28 the use of brake filters is not cost-efficient (negative net benefits as

[131] https://wiki.unece.org/display/trans/PMP+Workshop+on+Brake+Emissions++Regulation

costs are higher than benefits), resulting in significant decrease of the net benefits of policy option 2b and 3b for total emissions of vehicles (tailpipe, evaporative and brake emissions), as shown in Table 29. This may change in the future, once the brake filters become a more mature technology, and are also be applied for heavy-duty.

Table 28 – Assessment of efficiency of policy options for brake emissions of vehicles compared to baseline*, 2025-2050, Introduction of Euro 7 in 2025, Data source: SIBYL/COPERT 2021

Policy option	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
Brake emission limit	-	7 mg/km	5 mg/km	7 mg/km
Cars and vans				
Net benefits 2025 NPV (billion €)	-	3.30±0.50	-15.24±2.29	3.30±0.50
Net benefits 2025 NPV (€/ vehicle)	-	8.34±1.25	-38.48±5.77	8.34±1.25
Benefit-cost ratio	-	1.5 (1.1-2.0)	0.5 (0.4-0.7)	1.5 (1.1-2.0)

** The baseline considers an end-date of combustion-engine cars/vans in 2035, see chapter 5.1.*

Table 29 – Assessment of efficiency of policy options for total emissions of vehicles (tailpipe, evaporative, brake) compared to baseline*, 2025-2050, Introduction of Euro 7 in 2025, Data source: SIBYL/COPERT 2021

Policy option	1 – Low Green Ambition	2a – Medium Green Ambition	2b – High Green Ambition	3a – 2a and Medium Digital Ambition
Cars and vans				
Net benefits 2025 NPV (billion €)	17.33±2.23	24.55±3.05	1.34±0.47	24.94±3.11
Net benefits 2025 NPV (€/ vehicle)	205.03±27.19	259.72±31.52	157.67±15.81	264.45±32.27
Benefit-cost ratio**	3.0 (2.2-4.1)	1.7 (1.3-2.4)	1.0 (0.8-1.4)	1.7 (1.3-2.3)
Lorries and buses				
Net benefits 2025 NPV (billion €)	20.86±3.08	116.10±17.00	108.36±15.84	116.64±17.03
Net benefits 2025 NPV (€/vehicle)	3 301.84±487.15	18 371.33 ±2 690.29	17 145.63 ±2 506.19	18 440.82 ±2 694.87
Benefit-cost ratio**	33.1 (23.5-47.5)	7.9 (5.7-11.0)	5.2 (3.8-7.1)	7.7 (5.5-10.7)

** The baseline considers an end-date of combustion-engine cars/vans in 2035, see chapter 5.1.*
*** The benefit-cost ratio gets disproportionally high when costs are low which gives an unjustified advantage to low-cost options (i.e. PO1) and has the potential to mislead policy makers. The benefit-cost ratio is disregarded to choose one option based on benefits and costs in absolute terms only and included in this table for completeness purposes only.*

1.4. Methods for other direct and indirect economic and social impacts

Next to environmental benefits and economic costs discussed above, other direct and indirect impacts should be considered. This is especially relevant for economic and social impacts. Hence, this section focusses on the assessment of:

- General macro-economic indicators, such as creation of new jobs, skills required, research and innovation, etc.;
- Competitiveness of the EU industry and internal market cohesion;

- Qualitative impacts on SMEs and consumers (incl. consumer trust).

Key information, data and findings from the different tasks in the supporting Part A and Part B studies by CLOVE was used as the basis for the assessment of these socio-economic impacts of the Euro 6/V emission standards and the different policy options in Euro 7. Next to that, findings from relevant impact assessments or evaluations on similar topics (i.e. air quality and road transport) provided key insights and evidence on how past regulatory proposals and initiatives were projected to impact the social and economic dimensions allowing for direct comparisons and assumption in the context of Euro 6/VI and Euro 7. In parallel, an extensive literature review was conducted to find relevant scientific and consultant studies which focus on assessing the impact of new developments regarding technology, regulations, global markets, EU environmental policy, and how they affect the key elements identified above.

An important source of information for evaluating the socio-economic impacts in both the impact assessment and evaluation were the views of the different stakeholder groups collected through the extensive stakeholder consultation. While input from manufacturers and suppliers in the automotive industry were mostly crucial for assessing the impact on competitiveness, SMEs, employment and skills, the views from civil society were essential for assessing consumer trust and affordability for consumers.

In the impact assessment on Euro 7, matrices were created in order to compare quantifiable impacts on a custom scale for the different policy options and identify the most important topic areas. The scaling format in the assessment matrices includes both negative and positive values, as the nature of the impacts – being positive or negative – might be different for the different policy options and impacts. The quantifiable impacts and the scores are summarized in Table 30. All impacts are expressed on a relative scale to compare the different policy options to each other, with '+++' assumed to correspond to the maximum positive impact that any policy option can offer and "---" corresponding to the maximum negative impact.

Table 30 – Scores for economic, environmental and social impacts [132]

Impact	Score	Interpretation
High negative impact	---	High negative impact is considered when a negative impact is expected that could fundamentally change the concerned criterion.
Moderate negative impact	--	Moderate negative impact is considered when a negative effect that can clearly be felt is expected, but is not to an extent that can completely change the criterion concerned.
Low negative impact	-	Low negative impact is considered when a visible negative impact on the criterion is expected but not to an extent that would significantly change the area.
No impact	0	No impact is considered when no real differences are expected in the concerned criterion.
Low positive impact	+	Low positive impact is considered when a visible positive impact on the criterion is expected but not to an extent that would significantly change the area.
Moderate positive impacts	++	Moderate positive impact is considered when a positive effect that can clearly be felt is expected, but is not to an extent that can completely change the criterion concerned.
High positive impacts	+++	High positive impact is considered when a positive impact is expected

[132] Supporting Euro 7 impact assessment study, Annex 1: Analytical methods, 9.7 Other direct and indirect economic, environmental and social impacts

		that could fundamentally change the concerned criterion.

1.4.1. Competitiveness: Export of EU motor vehicles to key destinations

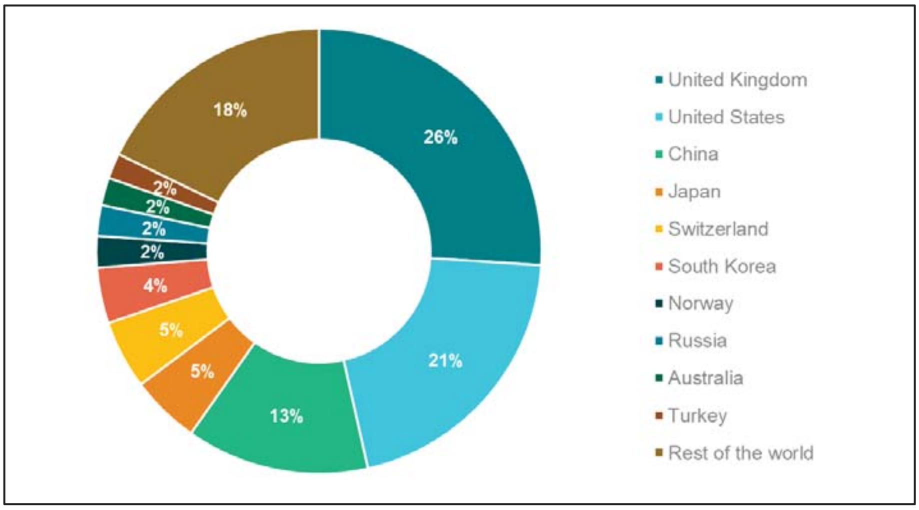
For the assessment of the impacts on competitiveness, the EU export of vehicles and the key destinations are further analysed in this section.

Table 31 illustrates how the car segment is the most crucial part of the EU-27 exports and trade surplus in the automobile trade. In 2019, €140.3 billion out of the €156.5 billion (i.e. 90%) earned by EU vehicle manufacturers in third countries was actually generated in this segment. Figure 12 illustrates that the United Kingdom, the United States and China represent the two biggest export markets for the EU automotive industry with 1.3, 0.8 and 0.4 million cars exported to the UK, the US and China respectively, resulting in exported in 2019 to the US and China respectively, resulting in €84 billion.[133] Next to China, East Asian countries Japan and South-Korea made up for a smaller 5 and 4 percent of the EU-27 export in cars in 2019. Also Norway, Switzerland and Turkey are important destinations for EU car exports.

Table 31 – EU-27 motor vehicle trade by vehicle type in 2019 (in billion €)[134]

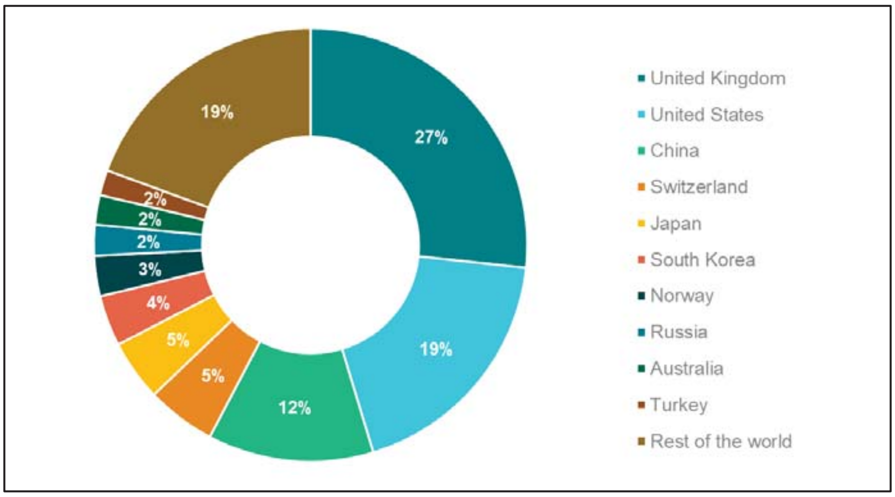
	Cars	Vans	Lorries and buses	Total
EU exports	140.3	7.6	8.6	156.5
Trade balance	71.2	2.2	5.8	85.2

Figure 12 – EU-27 passenger car exports, top 10 destinations (by value) in 2019 (total = €140.3 billion[135])



[133] ACEA, 2021. EU passenger car exports, top 10 destinations (by value)
[134] ACEA, 2020. EU motor vehicle trade, by vehicle type
[135] See footnote 133

Figure 13 – EU-27 motor vehicle (i.e. cars, vans, lorries and buses) exports, top 10 destinations (by value) in 2019 (total = €156.5 billion) [136]



Comparing the key destinations for EU cars exports to the key destinations of EU motor vehicles which also takes into account the values of the exports of vans, lorries and buses, only minimal differences are found (Figure 13). This is largely explained by the important share of cars in the trade numbers for the EU. Still, the share of exports to the US and China decreases somewhat, while exports to the UK, Norway and the rest of the world increases when looking into trade of all vehicle segments. Taking into account that the rest category also includes other EFTA countries and Eastern Europe, exports appear to be slightly more focussed on closer markets when also considering the larger vehicle segments.

Through further analysis of the 'rest of the world' category, it is found that in 2019 the EU-27 and the United Kingdom exported close to 7% of motor vehicles to the African continent.[137] However, this percentage is mainly due to the export of new EU motor vehicles to South-Africa (1.5%) and countries in North Africa, e.g. Morocco (1.1%), Egypt (0.9%), Algeria (0.7%) and Tunisia (0.4%). For the other African countries, the export of used vehicles is relatively more important. A report of the United Nations Environment Programme[138] found that in 2018 alone, the EU exported over 1 million used cars and vans to African countries, while more than 60% of vehicles added to their fleet annually is through the imports of used vehicles.[139]

In addition, several of the manufacturers of lorries and buses operating in the EU have also had a strong presence in the US market, in particular Daimler, PACCAR and Volvo.[140] However, in the Chinese and Asia Pacific markets this is less the case. These markets are dominated mainly by domestic manufacturers[141], although some EU companies such as Daimler and Volvo have joint agreements in place in these regions,

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[136] ACEA, 2021. EU motor vehicle exports, top 10 destinations (by value).
[137] Eurostat, 2021. Extra-EU trade of machinery and transport equipment (SITC 7) by partner [EXT_LT_MAINMACH]
[138] UNEP, 2020. Global Trade in Used Vehicles Report
[139] See Annex 8: Alternative set of assumptions on emission limits and durability for more details
[140] ICCT, 2015. Overview of the heavy-duty vehicle market and CO_2 emissions in the European Union
[141] Roland Berger, 2017. Truck and trailer components – Success factors for suppliers in specialized markets

which are securing them market access.[142]

Trade partners that are currently of somewhat less importance for the EU when it comes to trade of vehicles, but are expected to become more relevant in the near future include India and the ASEAN countries. The vehicle fleet in these countries has so far been relatively small in comparison to their respective populations. For example, in 2019 only 18 out of 1 000 Indians own a car, compared with nearly 500 in the European Union.[143] However, these fleets are growing rapidly, creating growth potential for European manufacturers[144].

Most of these trade partners have adopted rules of vehicle emissions that are in line with or more ambitious than the current Euro 6/VI vehicle emission standards. In addition, key markets China and the United States plan more demanding vehicle emission standards. While the China 6b emission standards for cars/vans (applicable in 2023), are already fuel-neutral and 40 to 50% more stringent than Euro 6/VI limits[145], China is progressing with an ambitious China 7 emission standards[146]. Also the US who has in place emission limits already well below the limits for almost all Euro 6 pollutants (Tier 3 Bin 30)[147] is currently working on a proposal for more stringent emission rules[148]. In August 2021, President Biden issued an Executive Order with the objective of making the US leader on clean and efficient cars and lorries by making 50% of all new passenger cars and light lorries battery electric, plug-in hybrid electric or fuel cell electric vehicles.[149] Under this Executive Order "the Administrator of the Environmental Protection Agency (EPA) shall, as appropriate and consistent with applicable law, consider beginning work on a rulemaking under the Clean Air Act […] to establish new multi-pollutant emissions standards, including for greenhouse gas emissions, for light- and medium-duty vehicles beginning with model year 2027 and extending through and including at least model year 2030." For heavy-duty vehicles, the order imposes the EPA to establish new oxides of nitrogen standards for vehicles with the same model years. Hence, global pressure to reduce transport emissions intensifies.

Japan's emission control requirements for vehicles are the strictest in Asia.[150] Other Asian trade partners have been following the Euro standards to mitigate vehicle pollutant emissions on their territory. South Korea has been following the European precedent for diesel vehicle emission standards since 2002 and the Euro 6 standard entered into force in 2020[151]. Since India is grappling with high pollution levels, it has adopted Euro 6 equivalent emission standards in 2020. In addition, ASEAN countries have adopted emission requirements based on the EU and Japanese rules. However, the specific Euro

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[142] SWD(2018) 185 final Commission Staff Working Document, Impact Assessment on setting CO_2 emission performance standards for new heavy-duty vehicles: For example, Daimler holds a 90% stake in the Japanese company Fuso, which has a 24% share of the Asia-Pacific market

[143] Automotive News Europe, 2019. Why cracking India's booming car market is not so simple

[144] Automotive News Europe, 2020. Mercedes, BMW, others fear parts-rule hit in India

[145] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[146] European Commission – JRC, 2021. Sino-EU Workshop on New Emissions Standards and Regulations for Motor Vehicles

[147] ICCT, 2019. Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union

[148] The Wall Street Journal, 2021. Biden Administration Moves to Unwind Trump Auto-Emissions Policy

[149] The White House Briefing Room, 2021. Executive Order on Strengthening American Leadership in Clean Cars and Trucks (August 05 2021)

[150] ICCT, 2021. Japan

[151] Transport Policy, 2021. South Korea: Light-duty emissions

standard differs between the different nations with ASEAN standards ranging from Euro 1/I to Euro 6/VI.[152] Singapore is the clear frontrunner, having already implemented Euro 6/VI in 2018.[153]

Norway, Switzerland, Turkey and the United Kingdom are all currently following the EU rules regarding the air pollutant emissions from vehicles. As member of the European Economic Area (EEA), Norway is obliged to implement the current and future Euro vehicle emission standards to ensure the functioning of the Single Market. Since Switzerland participates in the EU vehicle market, it has also adopted the EU legislation on vehicle emission standards. Turkey, who is a member of the EU Customs Union, but not of EEA or EFTA, is required to enforce rules on competition, product and environment that are equivalent to those in the EU in areas where it has access to the EU market. For the United Kingdom, a future mutual agreement shall have the ambition to continue the implementation of any future Euro standards in the country.[154]

1.5. Cumulative impacts on consumers, employment and industry competitiveness

1.5.1. Introduction

A Euro 7 emission standard for new vehicles would not stand alone, but would instead interact with other policies. The revised CO_2 emission standards for cars and vans[155] – presented on 14 July 2021 – are of particular relevance in this context. The proposed CO_2 emissions standards for cars and vans will accelerate the transition to zero-emission mobility by requiring average CO_2 emissions to come down by 55% for new cars and by 50% for new vans in 2030 (compared to 2021 levels) and by 100% for both categories in 2035. As a result, all new cars and vans registered as of 2035 should be zero-emission.

The CO_2 standards affect the European vehicle fleet and subsequently result in economic, environmental and social impacts. While most economic or social impacts associated with the policy options introduced in Chapter 5 are in most cases expected to be limited on their own, the cumulative impact – taking into account the effects of the CO_2 standards – could be more extensive. This section will dive into such impacts on consumers, employment and industry competitiveness.

Since the recently proposed CO_2 standards only have implications for cars and vans and a revision of the CO_2 standards for heavy-duty vehicles[156] is only planned for 2022, this assessment will focus on the cumulative impacts in the cars and vans segments. Similarly, a revision of the Ambient Air Quality Directive is only planned for 2022, hence cumulative impacts through more local actions taken at Member State level such as city bans cannot be quantified yet. Still, an ambitious Euro 7 (and CO_2 standards) will help Member States meet current and future air quality targets (especially for NO_x and $PM_{2.5}$) and will contribute to the long-term reductions of these pollutants required by NECD.

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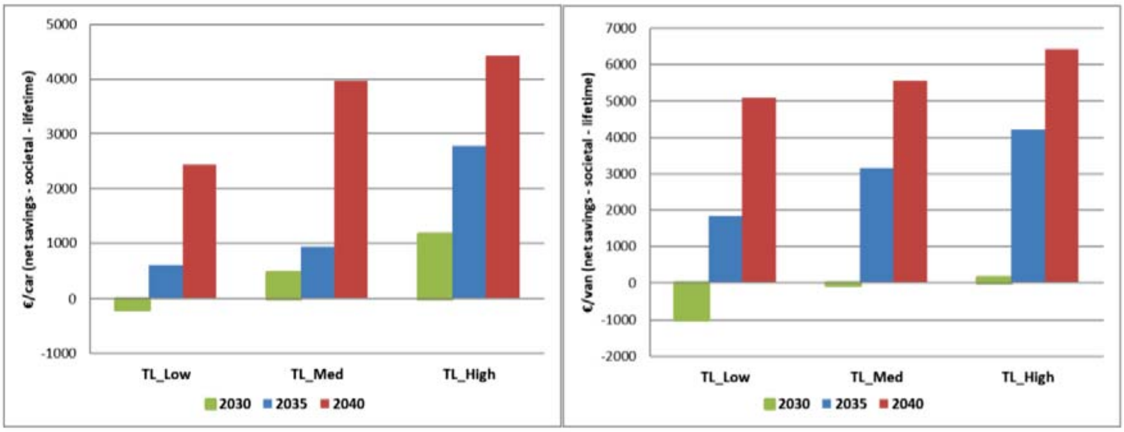
[152] Fuels and lubes Magazine, 2019. ASEAN: a roadmap to Euro VI.
[153] Dieselnet, 2021. Standards: Singapore
[154] Institut for Government, 2020. Brexit Brief. Options for the UK's future trade relationship with the EU
[155] COM(2021) 556 final. Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition
[156] Regulation (EU) 2019/1242 CO_2 emission performance standards for new heavy-duty vehicles

The CO_2 impact assessment[157] looked into the net savings (i.e. net benefits) over the vehicle lifetime from a societal perspective for different CO_2 target level (TL) scenarios taking into account other policies including strengthening of the EU ETS (the possible emissions trading for buildings and road transport), the increased use of renewable fuels in road transport required under the Renewable Energy Directive and Euro 7 based on preliminary assumptions close to the current PO2a. **Scenario TL_High**, which is the closest scenario to the final adopted CO_2 proposal, in Figure 14 presents the results of the analysis for vehicles registered in 2030, 2035 and 2040. As a point of comparison, the same scenario in Figure 15 shows the net savings resulting solely from the CO_2 emission standards.

The figures illustrate that the average net savings of the TL_High scenario decrease when considering the cumulative impacts with Euro 7 and other policies, while still remaining positive. The CO_2 impact assessment indicated that the results in Figure 14 are primarily driven by a decrease in the energy savings due to higher electricity and fuel prices[158] following the revised EU ETS and Renewable Energy Directive and by an increase in avoided CO_2 emissions due to the combination of the policies.[159]

Figure 14 - Average net savings over the vehicle lifetime from a societal perspective (EUR/vehicle) resulting from the combination of policies (cars (l) and vans (r)) (see scenario TL_High)[160]



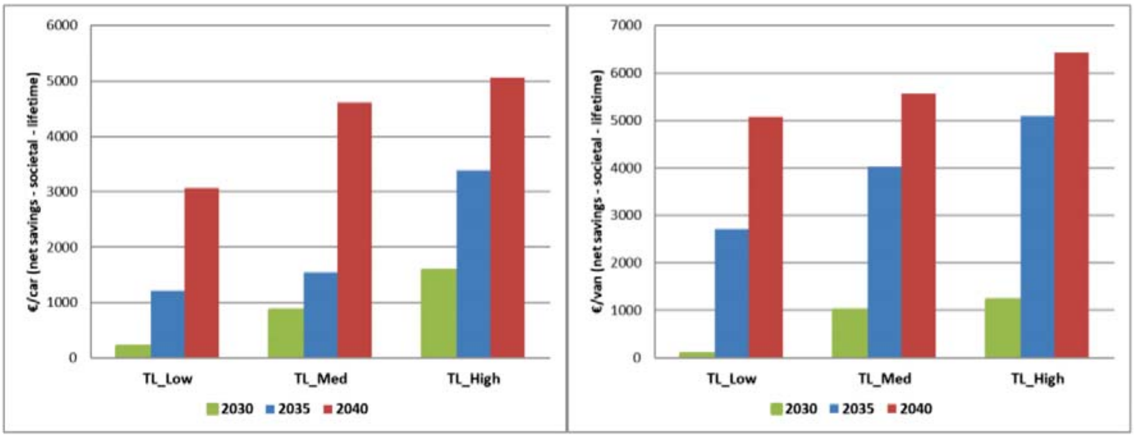
[157] SWD(2021) 613 final, Commission Staff Working Document, Impact Assessment, Accompanying the document Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition

[158] Where the Euro 7 impact assessment considers the regulatory costs of manufacturing and type-approving a new vehicle regarding pollutant emissions, the CO_2 impact assessment analysed the total cost of ownership also taking into account possible fuel savings for consumers which are not relevant following more stringent air pollutant emission standards.

[159] See footnote 157

[160] See footnote 157

Figure 15 - Average net savings over the vehicle lifetime from a societal perspective (EUR/vehicle) resulting from the CO_2 emission standards (in a MIX policy scenario context) (cars (l) and vans (r)) (see scenario TL_High)[161]



1.5.2. Cumulative impacts on consumers

When considering the impact of a 100% CO_2 target for cars and vans in 2035 on consumers, it is not solely the vehicle prices that are of concern. Since fuel and electricity savings from the use of zero-emission vehicles are significant for the consumers and exceed the higher upfront costs of more efficient and zero- and low-emission vehicles, the newly introduced CO_2 emission standards are expected to decrease the total cost of ownership (TCO) of such vehicles.[162] The third column in Table 32 shows the average net savings in TCO resulting from the CO_2 emission standards in Scenario TL_High from a first end-user perspective[163] in considering the first five years of a vehicle's lifetime for a new vehicle registered in 2030, 2035 and 2040.

With new internal combustion engine (ICE) cars and vans (including hybrids) still being introduced in the EU fleet until 2035, it is of interest to assess the effect of the different Euro 7 policy options on the net savings in TCO achieved through the new CO_2 standards. In addition, the two sets of limits introduced for brake emissions in PO2a, PO2b and PO3a also apply to zero-emission vehicles.[164] Therefore, the policy options are also expected to affect the TCO for cars and vans in 2035 and 2040.

To make the assessment, the total costs of the policy options in 2030, 2035 and 2040[165] were split up for cars and vans and divided by the new vehicle registrations expected in the respective year and segment taking into account the fleet developments. That way, fleet average costs per vehicle were calculated in line with the approach in the Impact

[161] See footnote 157
[162] See footnote 157
[163] While the CO_2 impact assessment also inspects the impacts on the total cost of ownership from the second user perspective, for this assessment an analysis of the first user perspective is deemed sufficient. The Euro emission standards mostly affect consumer affordability and the cost of ownership through the impact on the price of vehicles for first users. Impacts on the second users market will be limited since the increase is expected to be only a fraction of the price for first users, for all options.
[164] As illustrated in Table 20, the costs for including brake pads and filters to bring down harmful brake emissions is not the same for vehicles that are or are not primarily equipped with an internal combustion engine. Reason for this being that regenerative braking allows for reaching the brake emission limits at a lower cost per vehicle for PHEV and EVs.
[165] Supporting Impact Assessment Study, chapters 5.1.2, 5.2.2. and 5.3.2. Economic impacts

Assessment on CO_2. These costs per vehicle were subsequently subtracted from the net savings achieved by the CO_2 standards. The results for all policy options are presented in Table 32.

Table 32 – Cumulative impact of CO_2 standards (Scenario TL_High) and the Euro 7 policy options on the total cost of ownership (TCO) first users of new cars and vans

year	*vehicle*	Net savings in total cost of ownership (TCO) first users of new cars and vans				
		Only CO_2 standards[166]	CO_2 standards and PO1	CO_2 standards and PO2a	CO_2 standards and PO2b	CO_2 standards and PO3a
2030	€ per car	600	587	486	356	488
	€ per van	600	526	342	236	345
2035	€ per car	2 200	2 200	2 185	2 131	2 185
	€ per van	4 000	4 000	3 985	3 931	3 985
2040	€ per car	3 100	3 100	3 088	3 043	3 088
	€ per van	5 500	5 500	5 488	5 443	5 488

The table shows that the 1.7-2.3% increase in diesel vehicle prices in PO2a, PO2b and PO3a due to the mounting of pollutant emission control and sensor technology leads for the consumer to a decrease of the TCO savings from €600 per 2030 car when only the effect of the CO_2 emission standards is taken into account to €356-€488 per 2030 car when additionally the effect of PO2a, PO2b and PO3a are taken into account. For vans the decrease in savings is more extensive moving from €600 per 2030 vans to €236-€345 for PO2a, PO2b and PO3a. From 2035 on PO2a, PO2b and PO3a continue to have a small impact on the TCO for the consumer through the costs associated with complying with the limits for brake emissions for zero-emission vehicles. In 2035, TCO savings are expected to decrease from €2 200 per car - when only the effect of the CO_2 emission standards are taken into account - to €2 131-€2 185 - when additionally the effect of PO2a, PO2b and PO3a are taken into account. For vans, these policy options are expected to lead to a decrease in TCO savings from €4 000 to €3 931-€3 985 per van. Following learning effects related to hardware costs (see Annex 4 chapter 1.3), this impact is expected to further decrease in 2040.

Even though the policy options are expected to decrease the net savings in TCO for first users of new cars and to a larger extent for new vans, the overall cumulative effect of the CO_2 standards and the large share of policy options is still expected to be positive for the European consumer.

Considering the high regulatory costs for PO2b and cumulative impacts on consumers with the CO_2 emission standards, PO2a and PO3a are considered most proportionate for cars and vans to reach the zero-pollution and climate ambition of the European Green Deal.

1.5.3. Cumulative impacts on employment

In the CO_2 impact assessment[167], macro-economic models (i.e. E3ME and GEM-E3) were used to quantify the impacts of the targets on the wider economy, including employment. The new CO_2 standards for cars and vans were found to positively affect

[166] See footnote 157
[167] See footnote 157

the economic-wide GDP and employment due to the significant sector transformation from combustion-engine to zero-emission vehicles. The number of jobs are expected to increase by 39 000 in 2030 (0.02% increase in all relevant sectors) and by 588 000 in 2040 (0.3% increase in all relevant sectors) in Scenario TL_High.[168]

Since the Euro 7 policy options are generally based on existing technologies that do not require sector transformation, their impacts on GDP, sectoral output and employment are expected to be limited. In particular, the average annual additional investments (see also section 1.5.4) to reach the 100% CO_2 target in 2035 are estimated to amount up to €19 billion between 2021 and 2040. The Euro 7 policy options, however, are estimated to only result in average annual investments of €0.2, €1.2 or €2.4 billion during this same period (see Table 33 below). Hence, the policy options require investments one to two orders of magnitude below the investment required for CO_2. Since investments of this size are not likely to have any appreciable macroeconomic impact, the impacts on employment in Chapter 6 have been evaluated in a qualitative manner.

While PO1 and PO2a are expected to have a neutral impact on employment (i.e. no appreciable differences are expected), the qualitative assessment in Chapter 6 expected the more ambitious to have a low positive impact over the period 2025-2050. Indicatively, a low positive impact in employment was expected to correspond to far less than 0.1% of jobs concerned. The International Energy Agency has estimated that for every $1 million investment in ICE car manufacturing 5.2 to 9.2 jobs are created.[169] Taking into account that such employment multipliers are usually at the lower side for more advanced economies[170], the annual investment in 2030 of €1.5 billion for PO3a and of €2.5 billion for PO2b could approximately lead to 9 161 – 15 269 jobs[171].

Taking into account the estimated positive impact of the CO_2 standards and the low positive impact of PO2b and PO3a, the cumulative impact on the number of jobs in 2030 could be approximated by an increase of 0.024-0.027%. This translates in a total increase in the number of jobs of 48 161 – 54 269 in 2030.[172] Hence, the cumulative impact of CO_2 and the Euro 7 policy options on employment is expected to be limited with positive impacts mainly seen in the sectors supplying to the automotive sector as well as in the power sector. Other sectors experience some positive second order effects, e.g. as a result of overall increased consumer expenditure. Despite this estimated growth in employment, the impact assessment still foresees a loss in jobs in sectors associated to the production of internal combustion engines. Therefore, a certain level of reskilling of workers will be necessary to facilitate the sectoral transition.[173]

1.5.4. Cumulative impacts on industry

In the context of industry competitiveness, it can be interesting to look into the cumulative investments to comply both with the 100% CO_2 targets for cars and vans in 2035 and the policy options considered for a Euro 7 standard for these vehicles. Table 33 presents additional the average annual investments associated to the new CO_2 standards

[168] See footnote 157
[169] IEA, 2020. Sustainable Recovery World Energy Outlook Special Report: Transport
[170] IMF, 2021. The Direct Employment Impact of Public Investment.
[171] Considering the EUR/USD exchange rate of 17 August 2021 recorded at 1.1745.
[172] These numbers are merely indicative considering the difficulties in modelling macroeconomic impacts of this magnitude.
[173] See footnote 157

over the baseline in Scenario TL_High for the period 2021-2030 and 2021-2040 in billion euro[174] as well as the cumulative investments for the CO_2 standards and PO1, PO2a, PO2b and PO3a respectively.

Table 33 - Average annual additional investments over 2021-2030 and 2021-2040 in € billion (in 2021 values) (Scenario TL_High for CO_2 standards) [175]

	Period 2021-2030	Period 2021- 2040	% increase of PO on additional cost 2021-2040
Only CO_2 standards[176]	**2.6**	**19.0**	**NA**
CO_2 standards and PO1	3.0	19.2	1%
CO_2 standards and PO2a	4.6	20.2	7%
CO_2 standards and PO2b	6.2	21.4	13%
CO_2 standards and PO3a	4.6	20.2	7%

The table illustrates that in period 2021-2030 for all policy options, expect for PO1, similar or higher average annual investments are expected than for meeting the new CO_2 targets (€2.6 billion). This can be explained by the fact that most regulatory costs associated to Euro 7 will occur closely after 2025. For the CO_2 standards, on the other hand, the most stringent target of 100%, will only come into force in 2035.

For 2021-2040, the average annual investments induced by the new CO_2 standards increase to €19 billion. The annual increase of the Euro 7 policy options varies from €0.2 billion for PO1 to €2.4 billion for PO2b, further increasing the annual investments by 1-13%. In total, the average investments over 2021-2040 increase from €19 billion for the 100% CO_2 target in 2035 to €19.2-€21.4 billion when the effect of PO1, PO2a, PO2b and PO3a are taken into account.

This investment challenge for the automotive sector to reach the climate and zero-pollution ambition was already recognised in the European Green Deal[177], which stated that "Delivering additional reductions in emissions is a challenge. It will require massive public investment and increased efforts to direct private capital towards climate and environmental action, while avoiding lock-in into unsustainable practices. […] This upfront investment is also an opportunity to put Europe firmly on a new path of sustainable and inclusive growth. The European Green Deal will accelerate and underpin the transition needed in all sectors." Clear regulatory signals to the automotive sector are considered crucial for delivering climate and zero-pollution investment decisions.

Another important aspect to assess are the cumulative impacts on international competitiveness. As cleaner technologies have developed rapidly, new players focusing on clean vehicles have emerged across the globe, some of which have started entering the EU market. Policy developments towards have been a key driver for investments in zero-emission and zero-pollution technologies. Hence, the cumulative investments are expected to lead to benefits for the competitiveness of the automotive industry in a context where zero-emission and zero-pollution technologies will be more and more

[174] See footnote 157
[175] Calculated based on Table 4, Table 6 and Table 9 in Chapter 6
[176] See footnote 157
[177] COM(2019) 640 final. The European Green Deal

demanded on the global market.

Figure 12 (Annex 4 Chapter 1.4.1.) illustrates that after the UK, the United States and China represent two of the biggest export markets for the EU automotive industry with 1 million and 460 000 cars exported in 2019 to the US and China respectively, resulting in €59 billion.[178] The United States recently re-joined the Paris agreement and currently works on a proposal for more stringent emission rules. China is progressing with an ambitious China 7 emission standards and recently pledged to achieve climate neutrality by 2060. They can be expected to continue to accelerate the deployment of zero-emission vehicles through regulatory action and to tackle the serious air quality concerns in cities.

Next to China, East Asian countries South-Korea and Japan make up for a smaller 7 and 5 percent of the EU export in cars in 2019. Both countries have proclaimed their ambitions to cut greenhouse gas emissions in the coming years to achieve carbon neutrality by 2050.[179][180] While South Korea has been following the European precedent for diesel vehicle emission standards since 2002 and the Euro 6 standard entered into force in 2020[181], Japan's emission control requirements for vehicles are the strictest in Asia.[182]

Also Norway, Switzerland, Turkey and, more recently, the United Kingdom are important destinations for European car exports. In 2019, 2.2 million motor vehicles (including also heavy-duty vehicles) were exported from the EU-27 to the United Kingdom, representing 30% of the total EU vehicle exports.[183] While these nations have put together action plans towards battling climate change, all of them follow the current EU rules regarding the emissions from cars and vans and are expected to continue to do so (see 1.4.1.).

Trade partners that are currently of somewhat less importance for the Union, but are expected to become more relevant in the near future for cleaner vehicles include India and the ASEAN countries. The vehicle fleet in these countries has so far been relatively small in comparison to their respective populations. However, they are growing rapidly, making them a possible export destination for European manufacturers. Since India and most ASEAN countries are grappling with high pollution levels, they have adopted Euro emission standards. On the other side, nations like India are expected to be slower in bringing fully electric vehicles to the market considering their higher cost and will instead focus on compressed natural gas and hybrid vehicles for at least another decade.[143,144]

Taking into account all of the above developments, stimulating innovation in zero-emission technologies as well as in pollutant emission control and sensors technology the EU would allow access to international markets to be maintained while improving the competitive position of the EU automotive sector over the baseline.

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178 ACEA, 2020. EU passenger car exports, top 10 destinations (by value)
179 AP News, 2021. Japan raises emissions reduction target to 46% by 2030
180 European Parliament Think Tank, 2021. South Korea’s pledge to achieve carbon neutrality by 2050.
181 Transport Policy, 2021. South Korea: Light-duty emissions
182 ICCT, 2021. Japan
183 ACEA, 2020. EU-UK Automobile Trade: Facts and Figures

2. Baseline

Since the Euro 6/VI evaluation and the Euro 7 impact assessment were performed in parallel, two baselines have been considered to assess on the one hand the achievements of the current Euro 6/VI standards and on the other hand the impacts of a new initiative.

2.1. Evaluation Baseline

In the Euro 6/VI evaluation (see Annex 5) which covers the time period 2013/2014 until 2050, the proposed baseline represents what would have happened in the absence of the intervention. Without the introduction of Euro 6/VI emission standards, the previous emission standards – Euro 5 for cars and vans; and Euro V for lorries and buses – would have remained in place (see Annex 5, Table 35).[184] More specifically, the following assumptions were made in the evaluation baseline[185]:

For cars and vans, the baseline assumes that Euro 5 standards would remain in place and that, in the absence of the Euro 6 intervention, there would have been no further changes to pollutant emissions limits for new vehicles and no further changes to the relevant testing procedures.

However, the evaluation analysis also examined a second Euro 6 pre-RDE baseline for cars and vans. Considering the specific implications of the stepwise process of the Euro 6 implementation and, in particular, the significant changes to the testing procedures introduced with the adoption of RDE testing in the wake of Dieselgate, this second baseline reflects the evolution of the legal framework up to the point of the introduction of RDE testing. Hence, the Euro 6 pre-RDE baseline corresponds to the Euro 6b/c standards and assumes that RDE testing would not have been introduced. Therefore, the analysis examines the impacts that are only associated with the introduction of RDE testing in Euro 6d(-temp).

For lorries and buses, the continuation of the Euro V standard is assumed. As such, the assumption is that there would be no further changes to the emission limits or testing requirements. All new lorries or buses entering the market after 2013 would be Euro V vehicles. In this case, no additional changes to the testing procedures are considered as part of the baseline.

Next to the assumptions related to the Euro standards, the evaluation baseline considers the following key policy developments:

- CO_2 standards for cars and vans (Regulation (EC) No 433/2009 and (EU) No 510/2011, both since 1 January 2020 repealed and replaced by Regulation (EU) 2019/631) and for heavy-duty vehicles (Regulation (EU) 2019/1242). This development has led to the adoption of new technologies to achieve fuel efficiency and the reduction of greenhouse gas emissions. Hence, these standards are assumed to have affected the share of new diesel vehicles and the vehicle fleet in general.
- Relevant national policies, for instance on the development of low-emission zones (LEZ). In the baseline it is assumed that LEZs would have been based on the most recent standard, which would have been Euro 5/V in the absence of Euro 6/VI.

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[184] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 2.6 Baseline definition and point of comparison.
[185] See footnote 184.

The baseline for the evaluation makes the assumption that in the absence of the Euro 6/VI emission standards, vehicle manufacturers would not have introduced technologies to decrease pollutant emissions beyond what was required in the Euro 5/VI standards. Considering the cost of emission control technologies, supported by evidence gathered during the Dieselgate, it is not expected that any of the external trends would have resulted in manufacturers voluntarily adopting additional technologies. In contrast to the CO_2 emissions standards where fuel efficiency represents a possible purchase criterion for consumers, differences in the pollutant emissions levels are not expected to significantly drive consumer choices.

Next to its impact on policy developments, Dieselgate is also assumed to have had an impact on consumer awareness in the baseline, especially when it comes to pollution resulting from diesel vehicles. Between 2015 and 2018, the share of diesels sold in the EU (as a percentage of the total market for new passenger cars) declined from 52% to 36%.[186]

The evolution in the cost of raw materials is also relevant in terms of the costs of emission control technologies, particularly for precious metals such as palladium or rhodium which are used in catalytic converters. These raw materials have seen a significant increase in unit price since 2015, which is also taken into account in the baseline.

The macroeconomic assumptions for the baseline scenario follow the macroeconomic trends over the evaluation period. During this time period, the EU experienced a small but positive growth rate (in the range of 1.5-3% per year)[187] following the decline during the financial crisis. The number of new vehicle registrations also increased on an annual basis since 2013 following the significant decline in the 2008-2013 period.[188] In addition, the impact of COVID-19 is also included in the baseline and will be further discussed in Annex 6.

At the time of the adoption of Euro 6/VI, there were significant air quality problems throughout the EU, especially in urban areas and in densely populated regions. Road transport was responsible for a significant share of this pollution problem. According to the Euro 6/VI impact assessments, it contributed to 43% of total NO_x emissions, and 27% of total volatile organic compounds (VOCs) in 2002. In the Euro 5/V evaluation baseline, however, Euro 6/VI would not have entered into force which means that all new vehicles entering the market since 2014 (in the case of Euro 6) and 2013 (in the case of Euro VI) would have continued to be type-approved under the Euro 5/V standards. In the case of the Euro 6 pre-RDE baseline, Euro 6d(-temp) would not have been adopted, meaning that all cars and vans entering the market since 2018 would have continued to be type-approved under Euro 6c.

On the basis of the assumptions for the evaluation baseline, the SIBYL and COPERT models were used to develop projections of the expected evolution of the key variables in the baselines, including the evolution of new vehicle registrations and the evolution of emission factors per Euro standard/step.

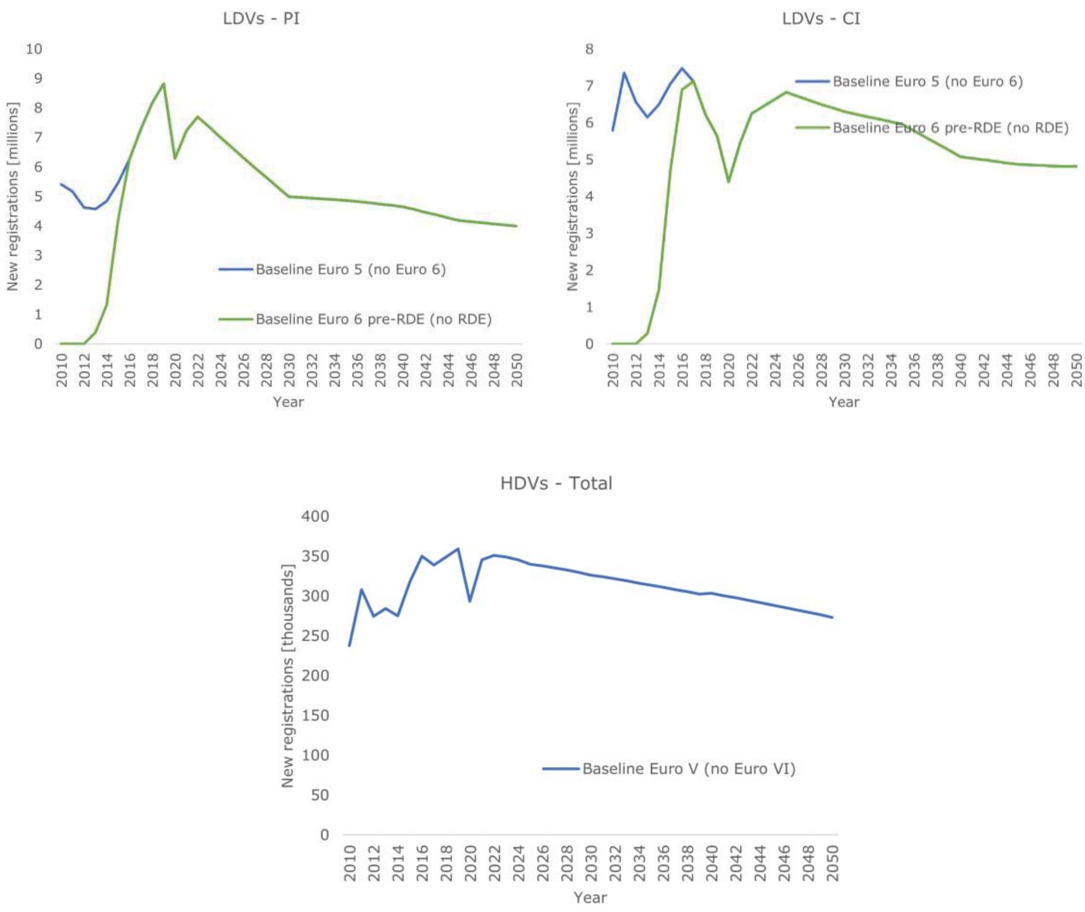
The number of new vehicle registrations under Euro 5/V or Euro 6b and its evolution

[186] ACEA, 2019. Share of Diesel in New Passenger Cars
[187] Eurostat, 2021. Real GDP growth rate - volume [TEC00115]
[188] OECD, 2019. Passenger car registrations Total, Percentage change

based on the SIBYL model are presented in Figure 16. For cars and vans, the blue curve represents the number of new registrations under the Euro 5 baseline, while the green curve represents the registration under the Euro 6 pre-RDE baseline. After 2018, the two curves converge since the total number of new vehicles registered coincide at that point in both baselines. The figures show that the number of new diesel and petrol cars and vans was expected to decline over time as more vehicles with an alternative powertrain (e.g. electric and hybrid vehicles) will enter the European fleet. This is effect is less for lorries and buses for which the number of new registrations of traditional vehicles are projected to remain stable.

The emission factors for each regulated air pollutant are expected to remain the stable over time (within a margin of error) for each vehicle category. Equation 1 demonstrated that the values for the emission factors are used to calculate the total emissions of a specific pollutant by multiplying the values with the number of vehicles in operation and the annual mileage per vehicle. The emission factors as used in the COPERT model for both the baseline and the evaluated Euro 6/VI standard are summarized in Table 7 in section 1.2.[189]

Figure 16 - Expected evolution in the number of new vehicle registrations under the Euro 5/V and the Euro 6 pre-RDE baseline[190]



[189] Emission factors for PN are not provided, due to the lack of such data in COPERT and because of the lack of trustworthy test data.
[190] CLOVE, 2022. Euro 6/VI Evaluation Study. Annexes 1:6 ISBN 978-92-76-56522-2. Annex 2: Development of the baseline scenarios, 9.2.6 Evolution of key pollutants.

2.2. Impact Assessment Baseline

The baseline to assess impacts of the policy options takes the following into account: a) the Euro 6/VI emission standards, b) the impact of COVID-19 on road transport activity[191] and c) the impact of the new 55% (cars) and 50% (vans) CO_2 targets by 2030 and 100% CO_2 targets for cars and vans by 2035[192] and the projected fit-for-55 HDV fleet evolution to contribute to the 55% net greenhouse gas emission reduction by 2030 and the 2050 climate neutrality objective[193] .

The baseline cannot take into account the effect of future potentially more stringent air quality targets which may trigger more city bans of combustion-engine vehicles and therefore modify road transport activity or vehicle sales. Such possible effect of future air quality targets would be difficult to quantify since it will depend on local actions taken at Member States level and will not be uniformly applied throughout the EU. However, this additional effect from the planned revision of Ambient Air Quality Directive in 2022 is estimated limited compared to the effects of CO_2 emission standards.

The baseline is a "no policy change" scenario which implies that the relevant EU-level legislation, addressing air pollutant emissions resulting from road transport will continue to apply without change. That means that Euro 6/VI applies, taking into account impact of the CO_2 targets for vehicles, including the aforementioned new CO_2 targets for cars/vans, and COVID-19 on road transport activity. It is referred to in chapter 6 as the baseline.

a) Euro 6/VI emission standards

The provisions laid down in the Euro 6/VI emission standards[194] and in particular the air pollutant emission limits and real-driving testing conditions set out therein are summarised in Annex 5, Table 34 and 35). This is the relevant EU-level legislation to reduce air pollutant emissions from road transport in Europe, which is assumed to remain in force.

Over time fleet renewal would lead to an increased share of Euro 6/VI vehicles in the EU fleet. As only 20% of cars and vans, and 34% of lorries and buses are type-approved to Euro 6/VI in 2020, including RDE testing for cars and vans introduced under final Euro 6d step, the benefits of cleaner Euro 6/VI vehicles compared to previous Euro vehicles will continue to be felt in the next decades on EU road as older vehicles are replaced by

[191] Road transport activity is the volume-km driven by vehicles on EU roads and is projected by the estimated evolution of vehicle sales.

[192] A linear interpolation was used for the year 2030 for both the activity and shares of vehicles between the two existing scenarios in the CO_2 Impact Assessment (TL_Med and TL_High), while the TL_High scenario was used for the year 2035. This approach is the estimated representation of the impact of the Commission proposal for CO_2 targets for cars/vans.

[193] For heavy-duty vehicles, the activity and fleet shares of vehicles are based on the SWD(2020) 176 final, Impact Assessment on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people (part 1) and SWD(2020) 176 final (part 2), supplemented for buses by CLOVE, 2022.

[194] Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and its implementing Regulation (EU) 2017/1151; Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and its implementing Regulation (EU) No 582/2011

these new cleaner vehicles[195].

b) Impact of COVID-19 on automotive industry and of transport activity

The COVID-19 pandemic continues to have significant effects on the automotive sector, which have the potential to shape the sector for years to come. In the short, the sector has been affected by the containment measures and other restrictions throughout this period (e.g. full-scale lockdowns) as well as uncertainty about the future which had an unprecedented impact on car sales across the EU.

In the first six months of 2020, EU-wide cars and vans production losses due to COVID-19 related factory shutdowns amounted to more than 3.5 million vehicles, around 20% of total production in 2019. Following the trend of the EU's GDP, demand for new passenger and commercial vehicles dropped by respectively 23.7% (to 9.9 million units) and 18.9% (to 1.7 million units) in 2020 as a direct result of the pandemic.[196] The long-term effects on the industry will only become clear after the pandemic has come to an end and will largely depend on the pace of the economic recovery. EU economic activity is set to pick up again in the first half of 2021[197], but it may remain constrained by virus containment measures. Similarly, EU automotive manufacturing should continue to recover in 2021, provided that supply chains remain functional. Demand, however, is only expected to return to the 2019 levels by 2023.[198] Please see Annex 7 for more details on the impact of COVID-19 on automotive industry.

The baseline takes into account the indirect impact of the COVID-19 pandemic on vehicle emissions, mostly through its effect on transport activity and fuel consumption. Estimations from the impact assessment on the 2030 climate target plan[199] estimated that the projected decrease in total fuel consumption of road transport was about 17% in 2020 compared to 2019. In addition, the JRC estimated that between February and April 2020 a total drop in vehicle activity of 60-90% was realised for passenger cars compared to a 15% drop for freight transport.[200]

Based on this evidence and taking into account the impacts of COVID-19 on GDP[201], the impact of the pandemic on activity in the different vehicle segments has been estimated over the time period considered in the baseline. The short-term estimates point to a sharp activity drop of 15% in 2020, followed by significant recovery in 2021. Nevertheless, by 2030 the pandemic and following crisis are projected to result to a permanent loss in total activity of 6% compared to the pre-COVID levels. Figure 7 in chapter 5.1 presents the comparison of the evolution in transport activity taking into account the COVID-19 drop. Moreover, a decreased transport activity is assumed by promoting public means of transport over private vehicles and advancing modal shifts to other transport means than road transport, especially when it comes to passenger transport.[202] The total activity for

[195] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1 Effectiveness, Evaluation question 1.
[196] ACEA, 2021. Press release: Passenger car registrations: -23.7% in 2020; -3.3% in December 2020; ACEA, 2021. Press release: Commercial vehicle registrations: -18.9% in 2020; -4.2% in December 2020
[197] European Commission, 2021. Spring 2021 Economic Forecast: Rolling up sleves
[198] BCG, 2020. COVID-19's Impact on the Automotive Industry
[199] SWD(2020) 176 final, Impact Assessment on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people (part 1) and SWD(2020) 176 final (part 2)
[200] JRC, 2020. Future of Transport: Update on the economic impacts of COVID-19
[201] See footnote 199
[202] See footnote 199

passenger transport in 2050 is projected to 6.4% lower, whereas the activity levels for freight transport are not assumed to differ.

c) CO_2 emission performance standards

The CO_2 emission performance standards[203] for light- and heavy-duty vehicles are a relevant EU-level measure which also reduce air pollutant emissions. This is due to the increased sales of zero- and low-emission vehicles that are triggered by stringent CO_2 targets for light- and heavy-duty vehicles. Battery and fuel cell electric vehicles do not have tailpipe emissions of air pollutants such as NO_x and particles but do emit non-tailpipe particles from brakes and tyres. Low-emission vehicles, such as plug-in hybrids, also have less tailpipe air pollutant emissions.

The CO_2 targets, including the new CO_2 targets proposed for cars/vans and the fit-for-55 projections for heavy-duty vehicles, and their impact on the vehicle fleet, are included in the Euro 7 baseline. As can be seen in Figure 7 in chapter 5.1, the share of new zero- and low-emission vehicles in the European vehicle fleet is projected to increase substantially over time, for light-duty vehicles much faster than for heavy-duty vehicles up to an end-date of 2035 for placing new combustion-engine cars and vans in the EU market.

[203] COM(2021) 556 final. Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition, Regulation (EU) 2019/1242 CO_2 emission performance standards for new heavy-duty vehicles

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PART 3/3

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

ANNEX 5-8

Accompanying the document

PROPOSAL FOR A REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on type-approval of motor vehicles and of engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009

{COM(2022) 586 final} - {SEC(2022) 397 final} - {SWD(2022) 358 final} - {SWD(2022) 360 final}

Contents

Annex 5: Evaluation Euro 6/VI emission standards

1. Introduction

The Euro emission standards were put in place in order to address ongoing concerns for public health and the environment related to air pollution caused by road transport and to also address risk of fragmentation of the European Single Market by the adoption of national standards and restrictions introduced by Member States. Vehicle emission standards for light-duty vehicles (i.e. cars and vans) and heavy-duty vehicles (i.e. lorries and buses) were implemented since 1992 through a series of Euro emission standards reflecting technical progress while addressing the emerging air quality issues. These standards are part of the type-approval framework in which new vehicle models are tested and granted type-approval to meet a minimum set of regulatory and technical requirements before entering into service on the EU market. Over the years, not only the specific limits for air pollutants were tightened over the successive Euro emission standards, but also the testing procedures were gradually modernized.

The current Euro emission standards which entered into force in 2013 for lorries and buses (Euro VI) and in 2014 for cars and vans (Euro 6), are referred to as Euro 6/VI emission standards in the following[1]. In comparison to Euro 5/V[2], the new standards introduced more demanding emission limits for some categories of pollutants (nitrogen oxide NO_x, particulate matter (PM), hydrocarbon (HC)), while other pollutants remained at the same level. In addition, significant changes to the testing procedures for emissions have been introduced in the implementing Regulations.

In September 2015, it was revealed that some European car manufacturers were using illegal defeat devices which recognise that the car was being tested and changed the car's behaviour to reduce emissions during the test, while on the road, the cars emitted much more. The scandal became widely known as Dieselgate and shook the confidence of the citizens in the Euro 6 regulations. Together with the European Parliament and the Member States, the Commission has since changed the European regulatory framework to restore the confidence of EU citizens in the type-approval system and in European car manufacturers and to include controls during market surveillance. Regulation (EU) 2018/858 has introduced from September 2020 new related EU type-approval rules (better quality and independence of vehicle type-approval and testing authorities, more controls of technical services, more checks on the roads, new EU wide recalls and penalties). Important progress was also made with the adoption of implementing regulations to ensure that emissions of cars are tested not only in the laboratory (the

[1] Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and its implementing Regulation (EU) 2017/1151. To ensure a smooth transition from the previous Directives to this Regulation, certain exceptions for vehicles designed to fulfil specific social needs were foreseen in the Euro 5 stage. These exceptions ceases with the entry into force of the Euro 6 stage; Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and its implementing Regulation (EU) No 582/2011

[2] Directive 2005/55/EC on the approximation of the laws of the Member States relating to the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous pollutants from positive-ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles, referred to as Euro V in the following

Worldwide Harmonised Light Vehicle Test Procedure – WLTP) but also on the road (the Real Driving Emissions testing – RDE).

1.1. Purpose of the evaluation

The purpose of this evaluation of the Euro 6/VI emission standards is to analyse to what extend the Euro 6/VI emission standards have achieved their specific objectives of setting harmonised rules on pollutant emissions from cars, vans, lorries and buses and improving the air quality by reducing pollutants emitted by the road transport sector and their operational objective of setting the next stage of emission limit values in a cost-effective way with specific focus on NO_x, PM and HC[3]. In line with the Better Regulation Guidelines[4], the evaluation examines the five evaluation criteria, namely: the effectiveness, efficiency, relevance, coherence and EU added-value of the measures established under both Euro 6 emission standards for cars and vans, and Euro VI emission standards for lorries and buses.

This evaluation is being carried out following the presentation of the European Green Deal[5] in December 2019 as a new growth strategy that will foster the transition to a climate-neutral, resource-efficient and competitive economy and the move towards zero-pollution in Europe. To accelerate the shift to sustainable and smart mobility, transport should become significantly less polluting, especially in cities. The EU automotive industry must lead the global transition to zero-emission vehicles, rather than follow the lead of others. This will allow the industry to take advantage of the business opportunities offered.

Significant efforts have been made over the last 5 years to reduce emissions of air pollutants, in particular in the wake of the Dieselgate. The European Parliament Inquiry Committee into Emission Measurement in the Automotive Sector (EMIS) also made several recommendations in order to improve the compliance with emission rules as well as a recommendation to proceed with the development and proposal of new emission rules, i.e. Euro 7[6]. Most of the recommendations were also repeated in the Briefing Paper[7] of the European Court of Auditors on the EU's response to the "dieselgate" scandal.

In parallel, new power trains – battery electric and hydrogen – are emerging as an alternative to the combustion engine. However, although the roll out of such technologies is accelerating, it is still slow. In the meantime, more needs to be done to "clean" the combustion engine to ensure protection of human health in urban areas and to prevent the Single Market from fragmenting due to individual national initiatives (e.g. diesel bans, petrol bans). The European Green Deal roadmap therefore includes a proposal for more stringent air pollutant emissions standards for combustion-engine vehicles by 2021.

The Commission decided to follow a back-to-back approach in which the evaluation and

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[3] SEC(2005) 1745 Commission Staff Working Document, Impact Assessment on Euro 5/6 emission standards; SEC(2007) 1718 Commission Staff Working Document, Impact Assessment on Euro VI emission standards; together referred to as Euro 6/VI impact assessments in the following

[4] https://ec.europa.eu/info/sites/info/files/better-regulation-guidelines-evaluation-fitness-checks.pdf

[5] COM(2019) 640 final, The European Green Deal

[6] EMIS, 2017. European Parliament recommendation of 4 April 2017 to the Council and the Commission following the inquiry into emission measurements in the automotive sector

[7] European Court of Auditors, 2019. The EU's response to the "Dieselgate" scandal

impact assessment are conducted in parallel as a single process. The findings of the evaluation will be used to inform further reflection on whether the Euro 6/VI emission standards continue to provide the appropriate legislative framework to provide high level environmental protection in the EU and to ensure proper functioning of the Single Market for vehicles.

This back-to-back evaluation and impact assessment requires to work with all stakeholders involved in emission standards to gather lessons learnt and optimise future emissions standards for vehicles in a short period of time. A first stakeholder conference in October 2018[8] took place in order to frame the needs. The Commission put together an Advisory Group on Vehicle Emission Standards (AGVES)[9], in which all relevant expert groups working on emission legislation involving industry, NGOs, academia and Member States were combined to discuss the Euro 6/VI emission standards and their future development. Potential issues or pitfalls of the back-to-back approach were identified continuously, such as the adjustment of problems identified and preliminary policy options following the evaluation, and subsequently targeted in the impact assessment of the Euro 7 initiative.

1.2. Scope of the evaluation

The evaluation covers the Euro 6/VI emission standards and their respective implementing measures:

- Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and its implementing Regulation (EU) 2017/1151;
- Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and its implementing Regulation (EU) No 582/2011.

The evaluation covers the period since the entry into force of the regulations, namely 2014 for Euro 6 and 2013 for Euro VI, up until now (2020). Considering that the steps Euro 6d and Euro VI E have yet to enter into force for all vehicles, that Euro 6/VI vehicles on the market are expected to remain on EU roads for a significant period of time and that the vehicles fleet is expected to be composed out of 100 percent Euro 6/VI vehicles in 2050, the impacts of Euro 6/VI are expected to last until 2050.[10] Therefore, the evaluation also covers the expected impacts of the adopted measures in the future.

Geographically, the evaluation focuses on the achievements of Euro 6/VI emission standards in the European Union. Hence, the evaluation covers the EU-27 Member States and additionally considers the implementation in former Member State, the United Kingdom. However, the EU automotive sector is not an isolated sector, since many of the manufacturers and their suppliers selling vehicles on the EU market are global players. These players come in direct contact with similar requirements in terms of pollutant emissions on other major market, which will be taken into account throughout the analysis.

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[8] https://ec.europa.eu/growth/content/stakeholder-event-preparing-future-european-emission-standards-light-and-heavy-duty-vehicles_en

[9] AGVES CIRCABC

[10] CLOVE, 2022. CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, hereinafter referred to as supporting Euro 6/VI evaluation study

This evaluation addresses the following key topics: the effectiveness of the Euro 6/VI emission standards on clean vehicles on EU roads, the effectiveness of newly introduced testing requirements, the Euro 6/VI regulatory costs for automotive industry, public authorities and consumers and its proportionality to the achieved benefits, the current and future need for rules on vehicle emissions, coherence within the Euro emission standards and with other relevant legislation – such as the CO_2 emission standards, Air Quality Directives and Roadworthiness Directives – and the continued need for harmonisation at EU level. Hence all relevant elements regarding effectiveness, efficiency, relevance, coherence and EU added-value are assessed.

This evaluation notably builds on a 18-week public stakeholder consultation carried out between 6 July and 9 November 2020 as well as a 14-week targeted stakeholder consultation on Euro 6/VI evaluation between 4 March to 8 June 2020, expert meetings between October 2018 and February 2021, see details in Annex 2, and extensive desk research.

This staff working document is supported by a study on post-Euro 6/VI emission standards in Europe - PART B: Retrospective assessment of Euro 6/VI vehicle emission standards, referred to as supporting Euro 6/VI evaluation study in the following, which was carried out from January 2020 to July 2021.

2. BACKGROUND TO THE INTERVENTION

2.1. Description of Euro 6/VI emission standards and its objectives

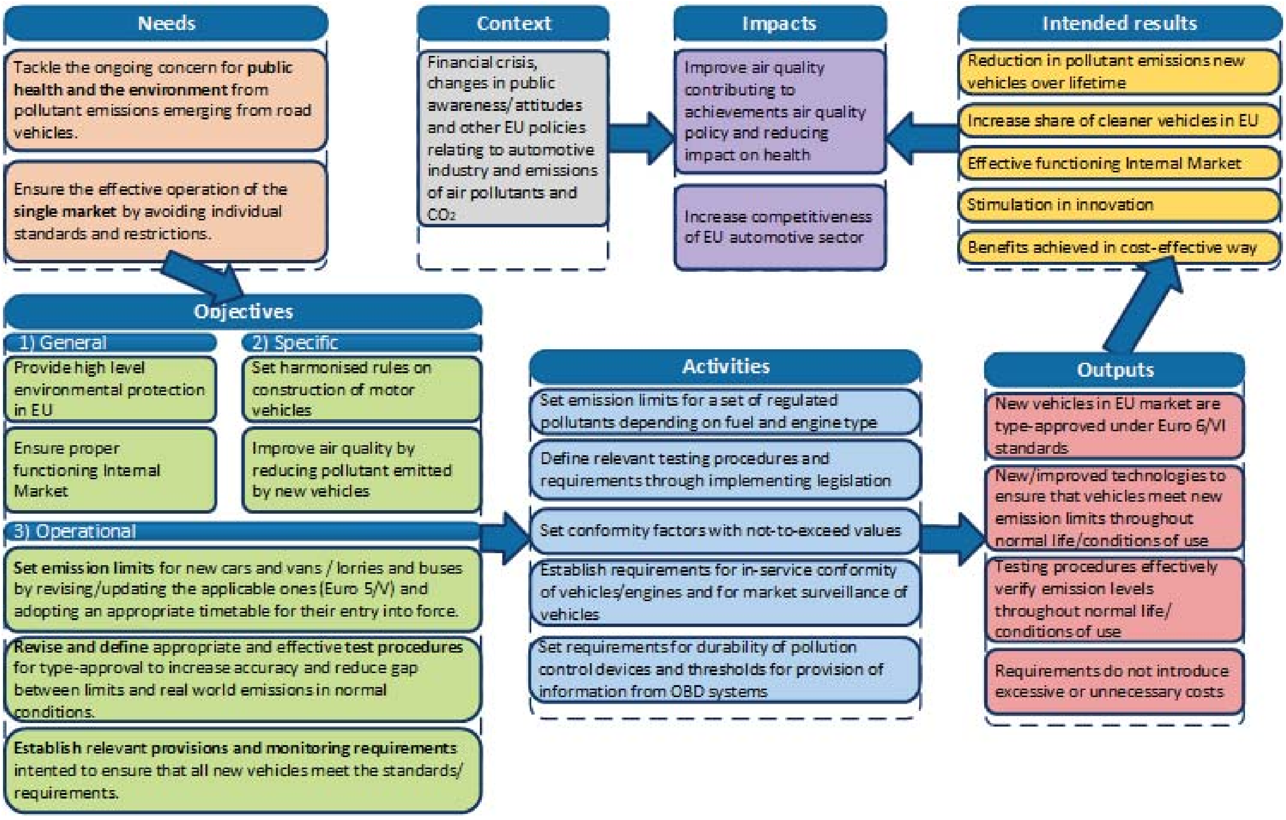
The vehicle emissions standards in Europe, also known as the Euro standards, are guided by the overarching need to reduce air pollution emerging from road transport and subsequently minimise harmful effects on human health and environment. In addition, harmonised technical requirements over the Member States were considered essential to ensure the proper functioning of the Single Market for vehicles[11]. That way, the pathway for control of emissions has commenced in 1992 with the introduction of Euro emission standards and has gradually progressed over 28 years with more stringent provisions.

While progress was made in the emission performance of vehicles moving from Euro emission standards 1/I to 5/V[12], the concern for public health and environment in combination with the risk of the emergence of varying product standards across the EU and the imposition of unnecessary barriers to intra-EU trade continued to be relevant. In particular, particulate matter (PM) as well as ozone precursors such as nitrogen oxide (NOx) and hydrocarbons (HC) were considered problematic due to their adverse effects to the health and the environment. A wide range of different stakeholder groups were affected by the problem: EU citizens were affected by poor air quality, manufacturers and their suppliers by necessary development and introduction of better pollution-control devices, consumers by potential price changes of new vehicles and national authorities by granting new emission type-approvals for vehicles.[13]

[11] See footnote 3
[12] Arabic numerals refer to Euro emission standards for cars and vans, Roman numerals refer to Euro emission standards for lorries and buses. Euro 1/I to 4/V emission standards were adopted as Directives, which had to be transposed into each Member State. Euro 5 and 6/VI emission standards were adopted as Regulations directly applicable to all EU Member States.
[13] See footnote 3

Figure 17 provides an overview of how these overarching needs or problems were translated into general, specific and operational objectives for the Euro 6/VI emission standards which were in line with the aims of both the Lisbon strategy[14] and the Sustainable Development strategy[15]. These objectives were on their turn translated into specific activities at EU level. That way, the Euro 6/VI emission standards aimed at ensuring the dual objectives of (i) ensuring the proper functioning of the Single Market for vehicles and (ii) providing high level of environmental protection in the EU. The intervention logic how Euro 6/VI standards were expected to work can be summarised along three main operational elements.

Figure 17 – Intervention logic of Euro 6/VI vehicle emission standards[16], supplemented by the supporting Euro 6/VI evaluation study



The Euro 6/VI vehicle emission standards set emission limit values for new cars, vans, lorries and buses, in two separate Regulations for cars/vans and lorries/buses with an almost identical legal structure. The Euro 6/VI emission limits are compared to the previous Euro 5/V emission limits in Table 35. Euro 6 introduced for cars and vans more demanding emission limits for NOx, HC and particulates - more stringent limits for particulate mass (PM) and new limits for particulate number (PN). Since the switch from Euro 4 to Euro 5 emission standards already resulted in significant reductions to the limits for gasoline cars and vans, the decrease in limits are mainly found in diesel vehicles. Also, Euro VI emission standards introduced for lorries and buses tighter limits for NOx, HC and particulates. Following the tightening of NOx, emission limits were

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[14] SEC(2010) 114 final, Commission Staff Working Document, Lisbon Strategy evaluation document
[15] COM(2001)264 final, Communication from the Commission, A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development
[16] See footnote 3

introduced in Euro VI for ammonia (NH_3) for diesel lorries and buses, to control the expected release of NH_3 as by-product to the use of NOx pollution-control devices. In addition, methane (CH_4) limits were tightened for gasoline lorries and buses.

The Euro 6/VI emission standards revised and subsequently defined appropriate and effective test procedures for controlling and verifying that the tailpipe and evaporative emissions are effectively limited (see Table 34)[17]. Through implementing legislation, significant changes were made compared to Euro 5/V to the testing procedures with the intention to reduce the gap between laboratory and real-world emissions. For cars and vans, this meant the replacement of the laboratory New European Driving Cycle testing (NEDC) by the laboratory Worldwide harmonised Light vehicles Test Procedure (WLTP) and introducing the Real Driving Emissions testing (RDE) on the road against temporary and final conformity factors[18][19]. For lorries and buses, off-cycle emissions (OCE), in-service conformity (ISC) and Portable Emission Measurement Systems (PEMS) testing were introduced in several steps[20]. In addition, Euro 6 emission standards revised the procedures for testing evaporative emissions, such as extension of the test procedure from 24 to 48 hours. That way, the Euro 6/VI emission standards were introduced in various steps, i.e. Euro 6 b-d(-temp) and Euro VI A-E.

Lastly, Euro 6/VI emission standards establishes appropriate provision and monitoring requirements to make sure that all new vehicles meet the standards. Depending on the specific vehicle type, the Euro 6/VI emission standards set or tightened requirements for manufacturers to check in-service conformity and durability of their vehicles for certain period or mileage. This ranges from five years or 100 000 km for cars and vans (no change compared to Euro 5)[21] up to 700 000 km or 7 years for heavy lorries and buses (500 000 km under Euro V)[22]. In addition, Euro 6/VI emission standards tightened the thresholds for the provision of information from on-board diagnostics (OBD) systems. These thresholds are intended to monitor the functioning of powertrain systems and components for reducing tailpipe emissions in order to identify possible areas of malfunction. In comparison to Euro 5/V emission standards, the OBD systems should be more sensitive to minor irregularities in the pollution-control devices. That way, malfunctions can be detected and corrected earlier.

[17] Tailpipe emissions means the emission of gaseous and particulate pollutants (see emission limits in Table 1). Evaporative emissions means the hydrocarbon vapours emitted from the fuel system of a vehicle other than those from tailpipe emissions. Euro 5 and 6 emission standards set an emission limit for the evaporative emissions test at 2.0 g evaporative emissions/test.

[18] Regulation (EU) 2017/1151 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)

[19] The conformity factor introduces for the respective pollutant a margin that is a parameter taking into account the measurement uncertainties introduced by the PEMS equipment, which are subject to an annual review and shall be revised as a result of the improved quality of the PEMS procedure or technical progress.

[20] Regulation (EU) No 582/2011 implementing and amending Regulation (EC) No 595/2009 of the European Parliament and of the Council with respect to emissions from heavy duty vehicles (Euro VI)

[21] Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6). Durability testing of pollution control devices undertaken for type-approval shall cover 160 000 km.

[22] Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI). For light buses and lorries, the durability period should be 160 000 km (100 000 km under Euro V) or 5 years. For medium lorries and buses the durability period should be 300 000 km (200 000 km under Euro V) or 6 years.

Table 34 – On-road testing conditions set out in Euro 6d/VI E[23]

Parameter	RDE (cars and vans)	PEMS (lorries and buses)
Ambient temperature	Moderate: 0 – 30ºC | Extended: -7 – 0ºC & 30 – 35ºC	-7°C to 35°C
Average speed	Urban: 15-40 km/h +Limitations for trip distance and duration, and speed range coverage	Test evaluation from $t_{coolant}$ > 30°C on; cold start weighted with 14%
Maximum speed	145 km/h (160 km/h <3 % of motorway)	-
Auxiliaries	No limitation	None
Trip characteristics	90-120 min, 34% urban, 33% rural, 33% highway	> 4x WHTC work depending on class of vehicle
Engine loading	Speed based limits on the basis of v*a[95th] [W/kg]	Only work windows > 10% valid
Maximum altitude	Moderate: 0 – 700m | Extended: 700 – 1 300m	1 600 m
Positive elevation gain	Total: <1 200 [m/100km] Urban: <1 200 [m/100km]	-
Vehicle age	ISC 100 000 km/5 years | MaS 160 000 km	N2, N3 < 16t, M3 < 7.5t: 300 000 km N3 > 16t, M3 > 7.5t: 700 000 km

[23] On-road test conditions, as set in latest step Euro 6d (Regulation (EU) 2017/1151) and Euro VI E (Regulation (EU) No 582/2011)

Table 35 – Emission limits set out in Euro 5/V and Euro 6/VI emission standards (changes in bold)[24]

A) Cars and vans

Air pollutants (mg/km)	**Positive ignition vehicles**						**Compression ignition vehicles**					
	Cars		**Vans category 1**		**Vans category 2**		**Cars**		**Vans category 1**		**Vans category 2**	
	Euro 5	**Euro 6**	**Euro 5**	**Euro 6**	**Euro 5**	**Euro 6**	**Euro 5**	**Euro 6**	**Euro 5**	**Euro 6**	**Euro 5**	**Euro 6**
NOx	60	60	75	75	82	82	180	**80**	235	**105**	280	**125**
PM	5.0	**4.5**	5.0	**4.5**	5.0	**4.5**	5.0	**4.5**	5.0	**4.5**	5.0	**4.5**
PN *(#/km)*[25]	-	**6×10^{11}**	-	**6×10^{11}**	-	**6×10^{11}**	6×10^{11}	6×10^{11}	6×10^{11}	6×10^{11}	6×10^{11}	6×10^{11}
CO	1 000	1 000	1 810	1 810	2 270	2 270	500	500	630	630	740	740
THC	100	100	130	130	160	160	-	-	-	-	-	-
NMHC	68	68	90	90	108	108	-	-	-	-	-	-
THC+NOx	-	-	-	-	-	-	230	**170**	295	**195**	350	**215**

[24] Positive ignition engine vehicles includes mainly petrol vehicles but also CNG and LPG vehicles, while compression ignition engine vehicles include diesel vehicles.
[25] PN emission limits for positive ignition vehicles are applicable only for direct injection engines.

B) Lorries and buses[26]

Air pollutants (mg/kWh)	**Positive ignition vehicles (Gas)**		**Compression ignition vehicles (Diesel)**			
	Euro V Transient testing (ETC)	**Euro VI** Transient testing (WHTC)	**Euro V** Transient testing (ETC)	**Euro VI** Transient testing (WHTC)	**Euro V** Steady-state testing (ESC and ELR)	**Euro VI** Steady-state testing (WHSC)
NOx	2 000	**460**	2 000	**460**	2 000	**400**
PM	30	**10**	30	**10**	20	**10**
PN *(#/kWh)*	-	**6.0×10^{11}**	-	**6.0×10^{11}**	-	**8.0×10^{11}**
CO	4 000	4 000	4 000	4 000	1 500	1 500
THC	-	-	-	**160**	460	**130**
NMHC	550	**160**	550	-	-	-
NH_3 *(ppm)*	-	**10**	-	**10**	-	**10**
CH_4	1 100	**500**	-	-	-	-
Smoke	-	-	-	-	500	-

[26] See footnote 3. From the collected data for the Euro VI impact assessment, two representative test cycles, the World Harmonized Transient driving Cycle (WHTC) and the World Harmonised Steady state Cycle (WHSC), have been created covering typical driving conditions in the European Union, the United States of America and Japan. The WHTC and WHSC replaced the Euro V test cycles consisting of a sequence of test points each with a defined speed and torque to be followed by the engine under steady state (European Steady state Cycle (ESC) test) or transient operating conditions (European Transient Cycle (ETC) test, European Load Response (ELR) test).

2.2. Baseline and points of comparison

Before Euro 6/VI emission standards came into place, pollutant emissions emerging from road transport had already been targeted since 1992 by five previous generations of standards. The Thematic Strategy on air pollution[27] already showed significant progress in the reduction of main air pollutants in 2000 for Europe. Nevertheless, road transport was still considered a significant source of pollution, as it was responsible for 43% of total NOx emissions and 27% of total volatile organic compound (VOCs)[28] emission in 2002. In addition, the total transport sector (which also includes shipping, aviation and rail) accounted for 29% of total $PM_{2.5}$ emissions in 2000.[29]

In a baseline scenario in which Euro 6/VI emission standards were not implemented, the previous Euro 5/V emission standards would have remained in place. Therefore, the performance of Euro 6/VI entails the additional or marginal effects of the intervention against a scenario in which Euro 5/VI was still in full force. In addition, the baseline scenario assumes that in the absence of the Euro 6/VI emission standards no further changes would have been made to the Euro 5/V emission limits and relevant testing procedures for the emission type-approval of new vehicles.[30] Next to this baseline scenario, an alternative baseline scenario is considered for cars and vans that assumes that the RDE test procedure was not introduced (i.e. effects of implementation of Euro 6 up to Euro 6c compared to Euro 6d). Hence, this alternative baseline scenario aims at evaluating and comparing the performance of Euro 6 emission standards before and after the implementing legislation introducing on-road RDE testing (see chapter 1.1).

The new Euro 6/VI emission limits have triggered a change in pollution-control devices compared to Euro 5/V, as manufacturers do not voluntary fit additional pollution-control devices to improve the pollutant emissions performance of their vehicles beyond those required to comply with the Euro 5/V emission standards.[31] Although the Roadworthiness Directives[32] have objectives similar to Euro 6/VI, they primarily aim at detecting and removing from circulation vehicles which are over-polluting due to technical defects. Hence, the Roadworthiness Directives could not have triggered the use of additional pollution control devices in new vehicles.

In order to assess the reduction of pollutant emissions from new vehicles until 2020 and further until 2050 when the combustion-engine vehicle fleet will consist of Euro 6/V vehicles only, other external factors or relevant developments that could have potentially affected these pollutant emissions are taken into account as counterfactual. The CO_2 emission performance standards for cars, vans, buses and lorries[33][34] might have played a

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[27] COM(2005) 446 final Thematic Strategy on air pollution

[28] Hydrocarbons (HC) and Volatile Organic Compounds (VOC) are used in this staff working document interchangeably.

[29] See footnote 3

[30] That means, the points of comparison are the Euro 5/V emission limits against the Euro 6/VI emission limits. The original points of comparison of the preferred option in the Euro 6/VI impact assessment has been updated to take on-board the changes made between the Commission's impact assessment and the adoption of the Euro 6/VI emission standards.

[31] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 2.6 Baseline definition and point of comparison

[32] Directive 2014/45/EU on periodic roadworthiness tests for motor vehicles and their trailers; Directive 2014/47/EU on the technical roadside inspection of the roadworthiness of commercial vehicles circulating in the Union

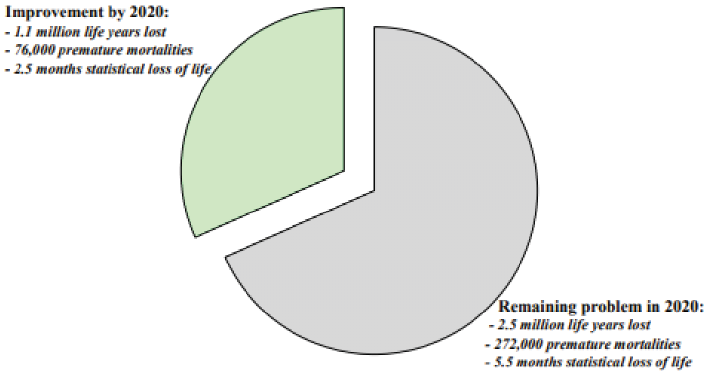
[33] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011;

role through the introduction of requirements that led to the adoption of new technologies to achieve fuel efficiency and reductions in CO_2 emissions. The adoption of such technologies may positively (e.g. more electric vehicles) or negatively (i.e. potential trade-offs for combustion-engine vehicles) affect the effectiveness of certain technologies used for combatting air pollutant emissions. That way, the quantitative analysis presents the maximum that can be assigned to the Euro 6/VI emission standards and takes into account the possibility that other external factors have played a role. These CO_2 standards affect the vehicle fleet and in particular the penetration of zero- or low-emission vehicles (e.g. electric vehicles, hybrids) in Europe. To fully account for the impacts of these climate policies on the air pollution emission resulting from road transport, the resulting vehicle fleets are taken into account for assessing Euro 6/VI effectiveness and efficiency.

In 2005, the Thematic Strategy on air pollution for 2000-2020 forecasted what was expected to happen in a scenario where no further policy action related to air pollution was taken. With no policy changes related to air pollution and its respective sources after 2005, health impacts from air pollution across the EU were still projected to be considerably high in 2020. Without further reductions of ozone (which is formed by reaction between HC and NOx), the health impacts related to this pollutant were expected to result in 20 000 premature deaths in the year 2000. Figure 18 demonstrates that for particulates, the average loss in statistical life expectancy without further EU action was expected to reach five months by 2020.

Apart from the impact of no further action on public health and the environment from pollutants from new vehicles, also the Single Market for vehicles would have been at risk without the introduction Euro 6/VI emission standards. In a scenario where emissions from road transport emitted by new vehicles remained an issue, the use of other measures by Member States, such as bans on certain types of vehicles entering urban areas or low emission zones were expected to become widespread. That way, the proper functioning of the Single Market for vehicles could have been hampered.[35]

Figure 18 – Effects of particles on mortality in 2000 and 2020 (with fixed 2005 policies)[36]



Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles

[34] SWD(2017) 650 final Commission Staff Working Document, Impact Assessment on setting emission performance standards for new passenger cars and for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light-duty vehicles; SWD(2018) 185 final Commission Staff Working Document, Impact Assessment on setting CO_2 emission performance standards for new heavy-duty vehicles

[35] See footnote 3

[36] COM(2005) 446 final Thematic Strategy on air pollution

On the other side, the Euro 6/VI impact assessment estimated the expected results of the preferred policy options for the Euro 6/VI initiative.[37] The new Euro 6 limits for cars and vans were expected to result in a 24% reduction in NOx emissions and no further reduction in PM and HC emissions, compared to Euro 5 by 2020. For Euro VI for lorries and buses, the new limits were expected to deliver a 37% reduction in overall NOx emissions, 22% reduction in PM emissions and no further reduction in HC emissions, compared to Euro V by 2020.

3. IMPLEMENTATION / STATE OF PLAY

3.1. Current situation

In order for the Euro 6/VI emission standards to have an impact on air pollution, vehicles type-approved under these standards should have a larger penetration in the European fleet of vehicles. Therefore, the Euro 6/VI evaluation considers not only the current situation in 2020 but also the further evolution of the penetration of Euro 6/VI vehicles in the fleet by estimating the sales of Euro 6/VI vehicles until 2050.

The Euro 6/VI impact assessments suggested that the monitoring of the effect of the Euro 6/VI emission standards should be undertaken by type-approval authorities who oversee the compliance processes to ensure that requirements of the regulations are met. However, no such reporting requirements or specific monitoring indicators have been included in the Euro 6/VI emission standards. Therefore, data from the SIBYL model, complemented by data from type-approval authorities and vehicle sales statistics, was applied.[38] The SIBYL model is a vehicle stock, activity and emissions projection tool that allows to make estimations and projections up to 2050 and will be further discussed in Sections 4 and 5. The number of emissions type-approvals reflects the compliance with the respective vehicle pollutant emissions. The estimation from the SIBYL model for the projected development of the European vehicle fleet is represented in Figure 19.

Figure 19 – Projected development of EU-27+UK[39] vehicle fleet[40]

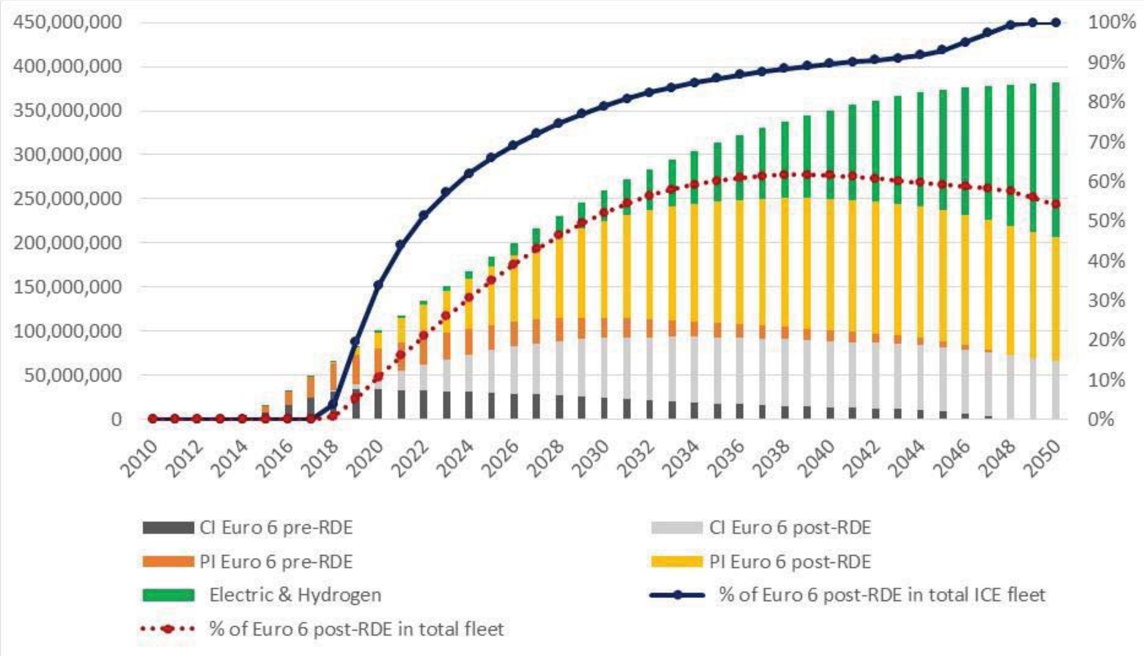
A) Cars and vans (Euro 6 pre- and post-RDE), Source: CLOVE based on data from SIBYL model

[37] For cars and vans, the preferred Euro 6 policy option included a NOx limit of 75 mg/km and a PM limit of 5 mg/km for diesel vehicles, which deviated from the actual limits adopted (see Table 1). For lorries and buses, the preferred Euro VI policy option included a NOx limit of 400 mg/kWh and a PM limit of 10 mg/kWh for diesel and gas engines, which also deviated from the actual limits adopted (see Table 1).

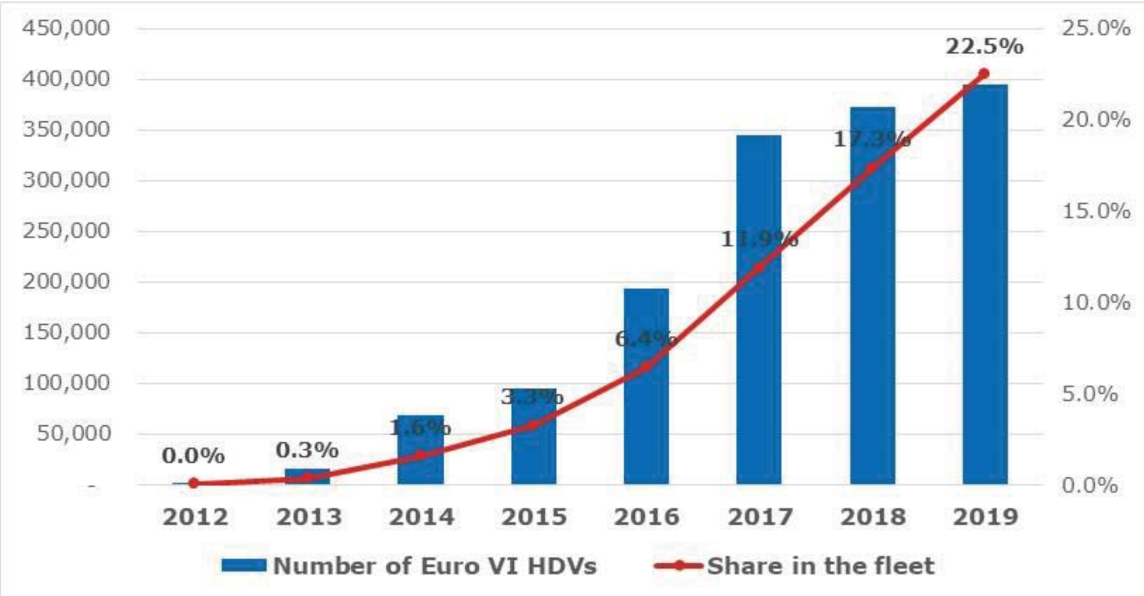
[38] SIBYL: Ready to go vehicle fleet, activity, emissions and energy consumption projections for the EU 28 member states. The SIBYL model was updated with data on emission type-approvals from 10 Member States, data on vehicle sales in the EU-28 from 2013-2020 from IHS Markit and vehicle fleet projections by the impact assessments for CO_2 emission standards for cars, vans, lorries and buses (SWD(2017) 650 final, SWD(2018) 185)

[39] The Euro 6/VI evaluation covers the period 2013 to 2020 and hence the geographical coverage is EU-28. However, as the impact of Euro 6/VI vehicles is projected until 2050, EU-27+UK is considered from 2021.

[40] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 3.5.1 Evolution of sales of Euro 6/VI vehicles over time



B) Lorries and buses (Euro VI), Source: CLOVE based on KBA, 2020[41]



According to Figure 19, the penetration of Euro 6 cars and vans is still limited to 20% of the total fleet in 2020. This indicates that the introduction of Euro 6 vehicles – and particularly of vehicles type-approved to the latest two steps including RDE testing – is still at its initial stages. However, by 2026 the cars and vans fleet is expected to consist of 50% Euro 6 type-approved vehicles, from which the large majority will be subject to RDE testing. This includes both diesel- and petrol-fuelled combustion-engine vehicles, but also alternative-fuelled vehicles. As can be seen in Figure 19, the latter are expected to take over the European combustion-engine fleet in the long run.

[41] KBA, 2020: Data extracted from multiple tables provided in vehicle statistics dataset https://www.kba.de/DE/Statistik/Fahrzeuge/fahrzeuge_node.html, Themensammlungen (FZ 13) and Themensammlungen (FZ 14)

While the SIBYL model suggests a rather fast uptake of RDE tested vehicles in the Euro 6 fleet with a share of over 50% by 2018, observed evidence from the Netherlands and Germany where RDE Euro 6 vehicles only represent a small share of vehicles on EU roads indicates that the SIBYL estimate might be an overestimation.[42]

For Euro VI lorries and buses, SIBYL model suggests that their share in the total fleet across the EU will reach 34% by the end of 2020. As shown in Figure 19, lorries and buses type-approved to Euro VI are expected to completely take over the fleet by 2040. Data from Germany (KBA) on vehicle registrations and stock of vehicles for 2013-2018 confirm the rapid uptake of newer Euro VI vehicles since 2017, reaching 17% of the heavy-duty fleet by 2018.[43]

3.2. Implementation Euro 6/VI emission standards

The Euro 6/VI emission standards outline the responsibilities of different actors, including for manufacturers to ensure that their vehicles meet the emission limits and durability requirements, and for Member States' type-approval authorities to grant type-approval if the requirements are fulfilled. Since the Euro 6/VI emission standards are legislated through Regulations[44], these requirements are binding in their entirety and directly applicable in all Member States. The actual implementation of Euro 6/VI emission standards is characterized by the gradual development of testing procedures and technical requirements introduced in the implementing Regulations through different steps, i.e. Euro 6b-d(-temp) and Euro VI A-E summarised in Table 36.

As already outlined in chapter 1.1, Dieselgate has occurred as important unexpected event during the implementation of the Euro 6 emission standard for cars. At the same time Euro 6d(-temp) was introduced with on-road Real Driving Emissions (RDE) NOx and PN testing with temporary and final conformity factors.

Table 36 – Overview of the implementation of Euro 6/VI emission standards

A) Cars and vans (Euro 6)

Regulation (EC) 715/2007
- Emission limits covering NOx, PM, PN, CO and THC for diesel vehicles and NOx, PM, PN, CO, THC and NMHC for petrol vehicles (see Table 35) - In-service conformity of vehicles and engines - Durability of pollution-control devices - On-board diagnostic (OBD) systems - Measurement of CO_2 emissions and fuel consumption
Commission Regulation (EC) 692/2008 – Euro 6b
- Implementing regulations as in Euro 5 plus the following: - Full OBD requirements with OBD thresholds - Revised measurement procedure for PM and PN (preliminary values for petrol direct injection)

[42] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 3.5.1 Evolution of sales of Euro 6/VI vehicles over time
[43] https://www.kba.de/DE/Statistik/Fahrzeuge/fahrzeuge_node.html
[44] See footnote 1

Commission Regulation (EU) 2017/1151 – Euro 6c
- Replacement of the laboratory New European Driving Cycle testing (NEDC) by a new laboratory test procedure - the World Harmonised Light Vehicle Test Procedure (WLTP) for measuring CO_2 emissions and fuel consumption - Introduction of the on-road Real Driving Emissions (RDE) NOx testing for monitoring only - Revised evaporative emissions test procedure - All else as in Commission Regulation (EC) 692/2008
Commission Regulation (EU) 2017/1151 – Euro 6d-temp
- Introduction of the on-road Real Driving Emissions (RDE) NOx and PN compliance with temporary conformity factors[45] - Full Euro 6 tailpipe emission requirements, 48H evaporative emissions test procedure and new in-service conformity (ISC) procedure
Commission Regulation (EU) 2017/1151 – Euro 6d
- Introduction of the on-road Real Driving Emissions compliance (RDE) with final conformity factors - More advanced emissions checks of cars for In-Service Conformity and testing by member states, independent and accredited third parties - Improved World Harmonised Light Vehicle Test Procedure (WLTP) procedure by eliminating test flexibilities - Introduction of devices for monitoring the consumption of fuel and/or electric energy, thereby making it possible to compare laboratory WLTP results for CO_2 emissions with the average real driving situation

B) Lorries and buses (Euro VI)

Regulation (EC) 595/2009
- Emission limits covering NO_x, PM, PN, CO, THC and NH_3 for diesel vehicles and NO_x, PM, PN, CO, NMHC, NH_3 and CH_4 for gas vehicles (see Table 35) - In-service conformity of vehicles and engines - Durability of pollution-control devices - On-board diagnostic (OBD) systems - Measurement of CO_2 emissions and fuel consumption
Commission Regulation (EU) 582/2011 – Euro VI A-C
- Specific technical requirements for emissions type-approval - Introduction of the worldwide harmonised transient driving cycle (WHTC) and the worldwide harmonised steady state driving cycle (WHSC)

[45] The conformity factor (2.1 to 1.43) introduces for the respective pollutant a margin that is a parameter taking into account the measurement uncertainties introduced by the PEMS equipment, which are subject to an annual review and shall be revised as a result of the improved quality of the PEMS procedure or technical progress. For example, a conformity factor of 2.1 means 168 mg/km NOx instead of 80 mg/km.

- Procedures for the measurement of in-service conformity (ISC) requirements - NH_3 measurement procedure - Measurement of CO_2 emissions and fuel consumption - Introduction of requirements with respect to the off-cycle in-use emissions testing procedures - Engine installation
Commission Regulation (EU) 582/2011 – Euro VI D
- Refined requirements for in-service conformity testing of engines using Portable Emission Measurement System (PEMS) testing - Trip requirements
Commission Regulation (EU) 582/2011 – Euro VI E
- Measurement of emissions during cold engine start periods - Use of PEMS for measuring PN

Since the Euro 6/VI emission standards were implemented in different steps, the standards are characterised by different application dates for Euro 6b-d(-temp) and Euro VI A-E. Furthermore, there are different application dates for new types of vehicles and new vehicles, which can be found in Annex I, Appendix 6 of Regulation (EC) 2017/1151 for cars and vans and in Annex I, Appendix 9 of Regulation (EU) 582/2011 for lorries and buses. Table 37 attempts to summarise the main dates for the implementation roadmap for Euro 6/VI emission standards. It shows that the most recent steps of Euro 6 (Euro 6 d) and of Euro VI (Euro VI E) have yet to be implemented for several vehicle categories.

Table 37 – Simplified implementation roadmap Euro 6/VI emission standards

A) Cars and vans

		Euro 6b	Euro 6c	Euro 6d-temp	Euro 6d
Cars	New types of vehicles	09/2014		09/2017	01/2020
	New vehicles	09/2015	09/2018	09/2019	01/2021
Vans	New types of vehicles	09/2015		09/2018	01/2021
	New vehicles	09/2016	09/2019	09/2020	01/2022

B) Lorries and buses

		Euro VI A	Euro VI B (diesel)	Euro VI B (gas)	Euro VI C	Euro VI D	Euro VI E
Lorries and buses	New types of vehicles	01/2013	01/2013	09/2014	01/2016	09/2018	01/2021
	New vehicles	01/2014	01/2014	09/2015	01/2017	09/2019	01/2022

As of these application dates, manufacturers of vehicles are responsible for ensuring that their vehicles meet the pollutant emission limits set out in the Euro 6/VI emission standards. To make sure that the vehicles actually comply with the Regulations, the emission tests are performed at several phases and monitored by national type-approval authorities, as follows:

Firstly, **type-approval testing** is done on pre-production vehicle models to ensure that the set emission limits are met and is granted by type-approval authorities in the Member States in collaboration with technical services acting on their behalf. The latter either carries out the testing at their facilities or supervises it at the manufacturers' facilities. That way, Certificates of Conformity (CoC) are granted for all vehicles for which the pre-production model has confirmed compliance with the emission limits.

Secondly, testing in the **Conformity of Production (CoP)** procedure aims at ensuring that the newly produced vehicles continue to comply with the limits as required by the legislation. Concretely, the manufacturer has to select a sample of vehicles from the production facility (i.e. not registered vehicles) that will undergo the same testing procedure as for type-approval. The type-approval authority audits the relevant tests performed by the manufacturers for which it may bring in a technical service.

Thirdly, **In-Service Conformity (ISC)** is applied to make sure that the emissions remain below the Euro 6/VI limits over the normal lifetime of the vehicles. For this compliance check, the manufacturer is generally responsible for performing the relevant tests, while the respective granting type-approval authority is required to test a number of selected vehicle types each year and is responsible for enforcement. Moreover, in the wake of Dieselgate, ISC testing by independent and accredited third parties is possible.

Lastly, **Market Surveillance (MaS)** should be performed by authorities that are independent from the authorities responsible for type-approval. These market surveillance authorities should assess the continued conformity with the limits, by testing registered vehicles against all the requirements of the Regulation. However, until 2020 Market Surveillance checks by Member States were not required by the Regulation. From 1 September 2020, the new EU vehicle type-approval framework[46] is applicable that demands Member States to test a minimum number of vehicles and requires that the market surveillance authorities reserve sufficient funds to perform the checks. Hence, Market Surveillance checks have been improved fundamentally.

Member States have the discretion to decide on penalties to infringements by manufacturers and technical services, including the level of penalties, and recalls of vehicles if they do not comply with the Euro 6/VI emission standards. Typically Member States have introduced a range of penalties levels depending on the type of infringement of the Regulations. What level of sanctions is applied within that bracket is at the Member State's discretion and is decided case by case.

In the wake of Dieselgate, the Commission has coordinated recalls of vehicles equipped with illegal defeat devices[47] organised by the Member States since January 2018 through

[46] Regulation (EU) 2018/858 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC

[47] A defeat device is defined in Regulation (EC) No 715/2007 as "any element of design which senses temperature, vehicle speed, engine speed (RPM), transmission gear, manifold vacuum or any other parameter for the purpose of activating, modulating, delaying or deactivating the operation of any part of

the Platform on Recall Actions related to NOx emissions[48]. Since then, the Commission has been regularly monitoring progress of recall actions and remind Member States of their obligation to recall the vehicles with illegal defeat device and to bring them into conformity with the type-approval rules. From 1 September 2020, the new EU vehicle type-approval framework empowers also the Commission to initiate EU-wide recalls and impose fines of up to €30 000 per non-compliant vehicle if no fine is being imposed by the Member State. In addition, the Commission may also fine technical services if they fail to carry out the test rigorously. The level of fines depends on an assessment of the gravity and extent of the non-compliance and are specified by a Commission delegated act.[49] The existing obligation for Member States to lay down rules for effective, proportionate and dissuasive penalties is maintained. With the new EU vehicle type-approval framework, Member States have to report to the Commission every year on the penalties they have imposed in the preceding year, and the Commission shall elaborate each year a summary report on the penalties imposed by Member States and submit it to the Forum for Exchange of Information on Enforcement composed of representatives appointed by the Member States representing their approval authorities and market surveillance authorities.

4. METHOD

4.1. Short description of methodology

The evaluation of the Euro 6/VI emission standards was carried out in 2020-2021 by the Commission and guided by a combined evaluation roadmap and inception impact assessment[50] that described potential issues in the Euro 6/VI emission standards and how the evaluation will provide a detailed analysis on the basis of the Better Regulation evaluation criteria. For this purpose, eight overarching evaluation questions were formulated to assess the regulations' effectiveness (three questions), efficiency (two questions), relevance (one question), coherence (one question) and EU-added value (one question). To inform the responses to these eight evaluation questions, a supporting Euro 6/VI evaluation study carried out by CLOVE consortium in 2020-2021[51] analysed a total of fourteen evaluation (sub-) questions which have been summarized into the eight questions considered here. Table A.1 in Appendix shows how the responses to the sub-questions in the supporting study have been re-aggregated in the Staff Working Document.

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the emission control system, that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use". The use of defeat devices that reduce the effectiveness of emission control systems is prohibited. The prohibition does not apply where the need for the device is justified in terms of protecting the engine against damage or accident and for safe operation of the vehicle, the device does not function beyond the requirements of engine starting or the conditions are substantially included in the test procedures for verifying evaporative emissions and average tailpipe emissions.

[48] Platform on Recall Actions related to NOx emissions, Compilation of information and data received from Member States' authorities on the progress of recall actions carried out in their territories for improving the performance of vehicles in use as regards their pollutant emissions. As recall actions are currently still on-going, updated data will be provided on a regular basis.

[49] Commission Delegated Regulation (EU) 2022/1209 of 5 May 2022 supplementing Regulation (EU) 2018/858 of the European Parliament and of the Council as regards the procedure for the imposition of administrative fines and the methods for their calculation and collection, OJ L 187, 14.7.2022, p. 19–22

[50] Combined Evaluation Roadmap / Inception Impact Assessment: Development of post-Euro 6/VI emission standards for cars, vans, lorries and buses

[51] See footnote 10

The supporting Euro 6/VI evaluation study helped collecting evidence and data through different channels, including several means for gathering stakeholder views and expertise.

As a first step for the evaluation an extensive literature review and analysis of data were undertaken through the supporting Euro 6/VI evaluation study focussing on the impacts of pollutant emission from new road vehicles. This included literature reviews of and data from the Euro 6/VI impact assessment[52], the study on post-Euro 6/VI emission standards in Europe carried out by the CLOVE consortium compromising key experts in Europe from the Laboratory of Applied Thermodynamics of the Aristotle University of Thessaloniki (LAT) (GR), Ricardo (UK), EMISIA (GR), TNO (NL), TU Graz (AT), FEV (DE) and VTT (FI)[53], other relevant studies and databases, and automotive market studies[54]. The literature review contributed to establishing the baseline and to collecting information on all evaluation questions.

As presented in Annex 2, the public and targeted stakeholder consultations in 2020 and AGVES expert meetings from 2019-2021 collected evidence and views from a broad range of stakeholders, in order to assess the relevance, effectiveness, efficiency, coherence and EU added value of the Euro 6/VI emission standards. In total, 32 contributions were received from public authorities, 6 from type-approval authorities, 8 from technical services, 38 from vehicle manufacturers, 64 from component suppliers, 80 from other industry stakeholders (including associations and fuel and energy industry), 11 from consumer organisations, 17 from environmental NGOs, 64 from citizens and 12 from other stakeholders to the targeted and public consultations regarding Euro 6/VI evaluation.

Nevertheless, limited data were provided by stakeholders during the targeted consultation on the evaluation. For the assessment of Euro 6/VI's effectiveness and efficiency (and to a lesser extent relevance), additional data from publicly available sources, namely the EEA NECD database[6] OECD statistics[8], the handbook on external costs and emission factors of Road Transport[9] and data on structural business statistics from Eurostat[10]; additional data on emission type-approvals from 10 type-approval authorities[55] and on Euro 6/VI vehicle sales in the EU-28 from IHS Markit[56] and cost estimations by CLOVE experts validated by key stakeholders[57] were therefore of great importance to supplement the limited data provided in the stakeholder consultation.

The assessment of Euro 6/VI's effectiveness and efficiency and the quantification of the impacts of the Euro 6/VI emission standards were supported by the use of the COPERT and SIBYL model. The SIBYL and COPERT model were updated with the data collected, latest emission factors and literature reviews as outlined in the previous paragraphs. More details on the COPERT and SIBYL model are provided in Annex 4.

For this evaluation, no case studies were conducted. Reason for this being that in view of

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[52] See footnote 3

[53] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[54] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, Chapter 7 References

[55] Type-approval authorities provided emission type-approval data at the request of the European Commission

[56] IHS Markit, 2021. Provision of data on vehicle sales in the EU-28 for Evaluation of Euro 6/VI vehicle emission standards

[57] CLOVE, 2022. Euro 6/VI Evaluation Study. Annexes 1-6 ISBN 978-92-76-56522-2, Annex 4: Presentation of Cost-Benefit Analysis Model

the limited data provided by stakeholders during the stakeholder consultation (only 3 manufacturers contributed, no contributions from automotive associations or suppliers), no representative stakeholder from the most important stakeholder group, the automotive industry, could be identified to carry out a case study. Instead, the comprehensive data collection procedures outlined above were chosen as the best way forward.

4.2. Limitations and robustness of findings

The evaluation of the Euro 6/VI emission standards entails certain limitations that might have certain implications on the validity of the conclusions. This section will discuss the main limitations, the related repercussions and how the issues are addressed.

The main limitation in the analysis is related to the efficiency criterion. A limited provision of cost data occurred during the targeted stakeholder consultation with data from 3 manufacturers and 3 approval-authorities only, which were not representative for EU-28. The shortcoming was tried to overcome without success by follow-up interviews and extension of the consultation by 6 weeks, also due to COVID-19. This lack of cost information had implications on the robustness of findings from Euro 6/VI's efficiency and hampered the credibility of the answers on the efficiency questions and related conclusions. This potential weakness has been addressed through the additional collection of data from numerous public sources and the Commission requested additional data from type-approval authorities and bought additional data on Euro 6/VI vehicle sales. Furthermore, cost estimates have been developed based on scaled-up desk research and input provided by CLOVE experts to fill in the remaining gaps and have been validated by key stakeholders. By these means, robust conclusions could be achieved on the efficiency criterion.

A second limitation is related to discrepancies that have occurred between different information sources. While limited data from type-approval authorities have been made available in the first place, these data were not always in line with the estimations provided by the SIBYL model. For example, when it came to the penetration of Euro 6/VI vehicles in the vehicle fleet, the SIBYL estimations seemed to overestimate the uptake of the most recent steps of Euro 6/VI vehicles and the related timing. Since this inconsistency could give wrong impression on the effectiveness of the Euro 6/VI emission standards, the SIBYL model was updated with new data on emission type-approvals from 10 Member States and vehicle sales in the EU-28 from 2013-2020 provided by IHS Markit. This approach is considered as appropriate mitigation measure.

A third limitation is the lacking implementation of monitoring requirements in the Euro 6/VI emission standards as suggested by Euro 6/VI impact assessments. Thus, neither Member States have reported on the compliance processes to ensure that requirements of the regulations are met, nor specific monitoring data on type-approval of vehicles, air pollution levels and epidemiology on health impacts from road transport were available. This problem was tried to overcome with the above-mentioned data collection, including existing data on air quality from the European Environment Agency (EEA), and literature review in 2020 and use of the updated SIBYL and COPERT model but could not fully compensate the non-availability of monitoring data for Euro 6/VI emission standards.

Overall, and despite the limitations presented above, the analysis underpinning this evaluation is sufficient to formulate answers to the evaluation questions. As regards to the monetised cost for industry and type-approval authorities, it is unlikely that further analysis based on available data would yield considerably different results or would significantly influence the overall findings.

5. ANALYSIS AND ANSWERS TO THE EVALUATION QUESTIONS

5.1. Effectiveness

Evaluation question 1: To what extent and through which factors has Euro 6/VI made cleaner vehicles on EU roads a reality? Which obstacles to cleaner vehicles on EU roads remain taking into account possible unintended consequences on the environment?

Overall conclusion: Evidence from literature and pollutant modelling shows that Euro 6/VI emission limits have contributed to cleaner vehicles on EU roads for NO_x and particulate (PM and PN) emissions. For the other pollutants CO, HC (THC and NMHC) and, for lorries and buses, NH_3 and CH_4 the impact of Euro 6/VI emission limits seems less positive. When considering other factors than emission limits, the enhanced Euro 6/VI testing procedures appear to have contributed most to cleaner vehicles on EU roads, in particular the RDE testing introduced in the last Euro 6d step.

Several obstacles to cleaner vehicles on EU roads have been detected which have negative consequences on the environment: Evidence suggests that unregulated NH_3, N_2O and NO_2 emissions have emerged as unintended consequences by Euro 6/VI emission limits and the related changes in emission control technologies. In the targeted stakeholder consultation, Member States and civil society underlined that problems still exist with OBD monitoring resulting in high pollutant emissions and that different limits for petrol and diesel vehicles did not have the positive effect that was envisaged. Industry considered different application dates for the stepwise Euro 6/VI approach and for new vehicle types and new vehicles as an obstacle. All stakeholder groups pointed out that Euro 6/VI testing procedures have become too complex and that Euro 6/VI provisions are not effective to prevent tampering.

Effect of Euro 6/VI emission limits on cleaner vehicles on EU roads

Since providing a high level of environmental protection is one of Euro 6/VI's objectives, the impact of the Euro 6/VI emission standards[58] on actually achieving cleaner vehicles on EU roads is an important measure for its effectiveness. In this context, the overall impact of the Euro 6/VI emission standards should depend on both the emission performance of Euro 6/VI vehicles and on their share in the fleet.

Emission levels per vehicle:

Following the introduction of Euro 6/VI limits[59], large reductions in NO_x emissions were realised compared to Euro 5/V vehicles and with the Euro 6/VI vehicles becoming progressively cleaner towards Euro 6d and Euro VI E[60]. Evidence from PEMS tests and remote sensing[61], comparing Euro 5/V and Euro 6/VI vehicles, has demonstrated that

[58] See footnote 1
[59] The changes in the emission limits moving from Euro 5/V to Euro 6/VI are summarized in Table 1 in Section 2.
[60] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.2.2 Are Euro 6/VI vehicles cleaner (i.e. less polluting) in relation to Euro 5/V vehicles?
[61] Remote sensing is an emissions measurement technique that evaluates emissions from passing motor

NO_x emissions from Euro 6 diesel cars have reduced by more than 50%, while NO_x emissions from diesel vans have almost reduced by 70%.[62][63] Also, the NO_x emissions from Euro VI lorries and buses have reduced significantly in comparison to their Euro V counterparts with the actual reduction depending on the specific heavy-duty category (between 58 and 88%).[64] Additionally, large reductions in PN emissions were realised for Euro 6 petrol vehicles with the introduction of PN limits making the use of Gasoline Particulate Filters (GPF) for Gasoline Direct Injection (GDI) vehicles inevitable.[65] This introduction in combination with more stringent PM limits also resulted in significant PM reductions for petrol cars and vans, while the changes are less evident for diesel vehicles.[66] Also, PEMS measurements on a bus in urban operation found PM to be approximately 85% lower.[67]

For the other pollutants CO, THC, NMHC and CH_4 no similar information was found in the literature.[68] For this reason, the COPERT model[69] was used to estimate potential reductions to learn whether vehicles have become less polluting.[70] For THC and NHMC, these results indicated emission reductions of 38 and 33% for Euro 6 vehicles and 30 and 30% for Euro VI vehicles. Also for CO emissions from Euro 6/VI vehicles considerable decreases were found in comparison to the emission from Euro 5/VI vehicles. While CO limits did not change for Euro 6/VI, Euro 6 vehicles were found to pollute 70% less CO in comparison to 86% less for Euro VI vehicles. These reductions can be explained by the introduction of diesel particulate filters (DPF). CH_4 emissions for new lorries and buses decreased by 27% with the introduction of Euro VI. For NH_3 emissions, however, Euro VI buses were found to emit 70% more NH_3 and Euro VI lorries even 75%[71]

Overall, this evidence is largely supported by all stakeholder groups that participated in the targeted consultation: close to all stakeholders from automotive industry, Member States and civil society[72] strongly agreed that Euro 6/VI standards have led to cleaner vehicles on the market.[73] Similar results were found for the public consultation in which the stakeholders from all groups including citizens indicated that air pollution originating from new vehicles decreased slightly or even significantly over the past 10 years.[74]

Fleet Emission levels:

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vehicles in real-world driving

[62] O'Driscoll, et al., 2018. Real world CO_2 and NO_x emissions from 149 Euro 5 and 6 diesel, gasoline and hybrid passenger cars.

[63] Ricardo Energy & Environment, 2017. The Joy of (Euro) Six?

[64] See footnote 63

[65] AECC, Concawe, Ricardo, 2017. Real-World Emissions Measurements of a Gasoline Direct Injection Vehicle without and with a Gasoline Particulate Filter

[66] Giechaskiel, B., et al., 2019. European Regulatory Framework and Particulate Matter Emissions of Gasoline Light-Duty Vehicles: A Review

[67] TNO, 2014. NO_x and PM emissions of a Mercedes Citaro Euro VI bus in urban operation

[68] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.2.2 Are Euro 6/VI vehicles cleaner (i.e. less polluting) in relation to Euro 5/V vehicles?

[69] COPERT: The industry standard emissions calculator and Annex 4

[70] Since this model also takes into account aspects such the effect of cold start phase, operation under hot engine or after treatment system conditions, the degradation of emission control systems and the impact of malfunctions or tampering, this analysis deviates from the approaches from the literature discussed above.

[71] See footnote 60

[72] In this context, civil society includes stakeholders from environmental NGOs, consumer organisations and research organisations.

[73] See footnote 60

[74] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 3)

While the Euro 6/VI emission standards have succeeded in progressively making new vehicles cleaner, these benefits are not yet fully felt on the EU roads.[75] In 2020 less than half of the EU vehicle fleet is type-approved to the Euro 6/VI emission standards (20% Euro 6 cars and vans, 34% Euro VI lorries and buses)[76]. Hence, the actual contribution of the Euro 6/VI emission standards towards realizing cleaner vehicles on EU roads appear to be a work in progress that will depend on the rate of uptake of cleaner Euro 6/VI vehicles replacing more polluting Euro 5/V vehicles.

Taking into account these findings per vehicle, the COPERT model[77] has quantified the expected level of total emissions from all vehicles until 2050[78] and the emission saving achieved to determine the impact of Euro 6/VI emission standards on the total level of emissions of the regulated pollutants. Given the emission reductions per vehicle and the fleet composition, considerable reductions in emission levels for NO_x have been realized, in particular for diesel vehicles.[79] For cars and vans, NO_x emission levels decreased by 22% between 2014 and 2020, while for lorries and buses a decrease by 36% was realised between 2013 and 2020. Figure 20 presents the emission savings resulting from Euro 6/VI in comparison with the previous Euro standards with its specific focus on NO_x, PM and HC. It shows that the emission reductions for Euro 6 have been mainly realised after the introduction of RDE testing, in the wake of Dieselgate. Significant savings have been also realised for PM emissions emerging from cars and vans , especially for exhaust PM emissions (28%). The emission savings achieved from lorries and busses were slightly less with a 14% decrease in exhaust PM emissions which is normal considering the low PM levels already achieved. For cars and vans, THC and NMHC emission levels have decreased by 13 and 12%, while for lorries and buses THC decreased 14%.[80]

Although the emission limits were not changed for CO, significant savings have been realised for CO emissions which were linked to the use of DPF. Following the new limit for NH_3 in Euro VI, emissions from this pollutant emerging from road transport actually increased by approximately 30%. The emission limit seems not to be strict enough to reduce NH_3 emissions effectively.[81]

In the targeted stakeholder consultation on the evaluation, stakeholders across all groups[82] considered that the Euro 6/VI limits were highly or somewhat successful in reducing actual pollutant emissions with only two stakeholders disagreeing on the success of the limits for cars[83]. Similarly, among the respondents to the public consultation almost everyone indicated that the standards have been appropriate for

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[75] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.2.3 Are vehicles on the EU roads cleaner?

[76] SIBYL: Ready to go vehicle fleet, activity, emissions and energy consumption projections for the EU 28 member states

[77] For more information see Annex 5 Evaluation Euro 6/VI emission standards: chapter 4.2. Limitations and robustness of findings and Annex 4

[78] See chapter 1.2: The vehicles fleet is expected to be composed out of 100 percent Euro 6/VI vehicles in 2050, hence the impacts of Euro 6/VI are expected to last until 2050.

[79] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.2.4 What was the impact of Euro 6/VI on the total level of emissions?

[80] See footnote 79

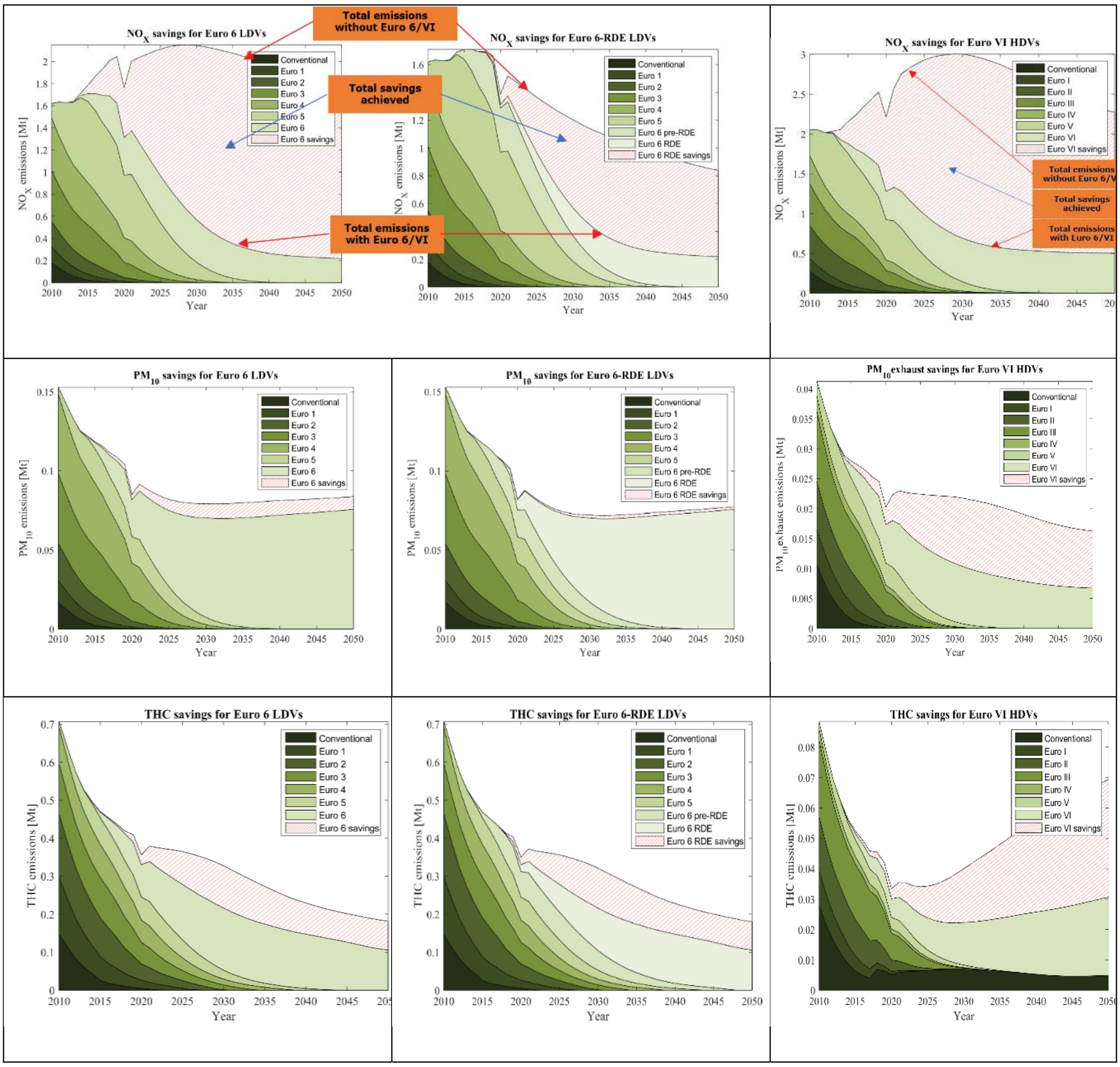
[81] See footnote 79

[82] The stakeholder groups are civil society (research organisations, consumer organisations, environmental NGOs), industry (manufacturers, suppliers) and Member States (public authorities, type-approval authorities, technical services).

[83] One supplier and one technical service

reducing pollutant emissions from road transport.[84] In particular, the new PN limit was considered an important step to better regulate fine particles and for Europe to take a leading role in this. Nevertheless, there still seems to be room to lower the limits for solid particles without large investment costs nor significant technical modifications.[85] When the stakeholders were asked in the public consultation whether the Euro 6/VI limits are sufficiently strict, the majority of Member States' and civil society stakeholders somewhat or completely disagreed.[86] Especially the limits for NO_x and PM/PN were considered not sufficiently low by the respondents that expressed discontent about the strictness of the limits.[87]

Figure 20 – NO_x, PM and HC savings for Euro 6 cars and vans, and Euro VI lorries and buses[88]



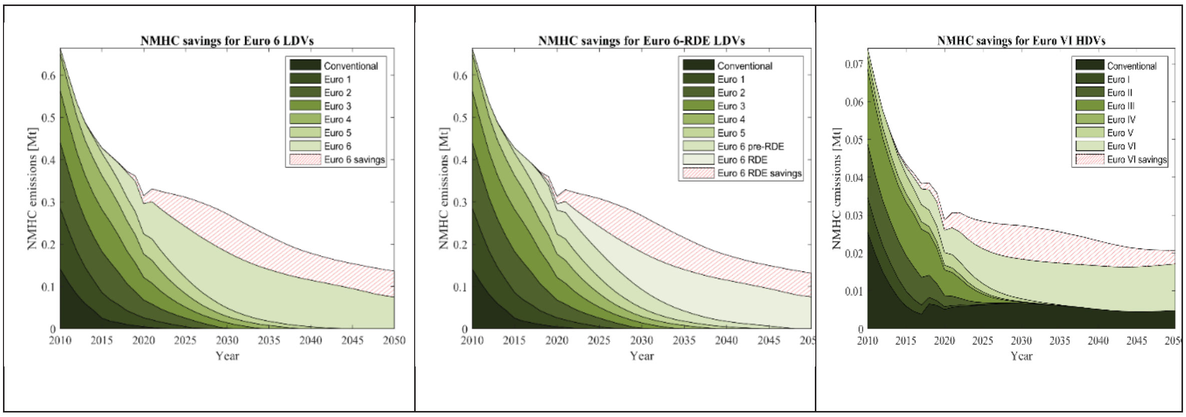
[84] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 5)

[85] See footnote 79

[86] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 12)

[87] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 12.1)

[88] CLOVE, 2022. Euro 6/VI Evaluation Study. Annexes 1-6. ISBN 978-92-76-56522-2, Annex 3. 9.3.3 Total emission savings



Effect of other Euro 6/VI factors on cleaner vehicles on EU roads

When considering other factors than Euro 6/VI emission limits that positively affected the achievements of cleaner vehicles on EU roads, the enhanced Euro 6/VI testing procedures appear to have contributed the most.

In-service conformity (ISC) testing including RDE testing for cars and vans and PEMS testing for lorries and buses are widely reported effective in ensuring low emissions.[89] During the EMIS committee[90], the JRC emphasised the ability of ISC testing and market surveillance to ensure compliance and subsequently emission reduction.[91] In addition, stakeholders from most groups generally consider RDE and the introduction of conformity checks through PEMS to be very successful and effective. Several environmental NGOs expect that third party ISC testing will have a significantly positive impact for tackling emissions but argue that it is too early to assess this for cars and vans.[92]

The introduction of cold-start emissions to testing procedures is also considered highly effective in ensuring that most emissions are accounted for cars, vans, lorries and buses. Before these emissions were regulated, the first five minutes of a trip – in which emissions are generally higher – were excluded from the data and hence not accounted for. When adding cold-start to the PEMS data, the importance of this aspect of testing becomes very clear.[93] While diesel cars can contribute up to 38% more to the total NO_x emissions when cold-start is included, cold-starts contribute up to 86% of PN emission of petrol vehicles without a particulate filter.[94]

Unintended consequences and obstacles of Euro 6/VI to cleaner vehicles on EU roads

While the Euro 6/VI emission standard aims at reducing the regulated pollutant emissions from new vehicles, evidence suggests that emissions of other unregulated air pollutants could be affected by Euro 6/VI and the related changes in emission control technologies. There is no NH_3 emission limit for cars and vans, despite the fact that cars

[89] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.4.2 To what extent have specific provisions/aspects of the legal framework played a role in terms of achieving the objective of reducing pollutant emissions?
[90] See footnote 6
[91] JRC, 2016. EMIS hearing on 19 April 2016: Replies to the Questionnaire to the Joint Research Centre (JRC), Committee of Inquiry into Emission Measurements in the Automotive Sector
[92] See footnote 89
[93] See footnote 89
[94] Hooftman, N., et al., 2018. A review of the European passenger car regulations – Real driving emissions vs local air quality

are actually the largest contributors to NH_3 emissions from transport in Europe.[95] The reason is that emission control technologies used to restrict NO_x emissions in line with the Euro 6 requirements cause an ammonia slip due to dosing of urea.[96] As a result, the use of ammonia slip catalysts (ASC) has been increased in recent Euro 6d diesel vehicles, in which N_2O may be produced as a by-product. For gasoline vehicles, particularly high NH_3 and N_2O emissions have been observed on positive ignition (PI) engines equipped with three-way catalysts.[97] Additionally, aftertreatment systems to reduce NO_x in Euro 6/VI have increased the NO_2 to NO_x ratio of vehicle exhaust.[98] However, this effect seems to have been mitigated in the latest Euro 6/VI steps. These unintended consequences on the environment by new NH_3, N_2O and NO_2 emissions will be further discussed under the relevance criterion (see chapter 5.3).

Some obstacles of Euro 6/VI emission standards to cleaner vehicles on EU roads have been detected in the targeted stakeholder consultation on the evaluation[99]:

- *Threshold OBD* – While many industry stakeholders consider the threshold for on-board diagnostics (OBD) to have been successful, non-industry stakeholders (e.g. public authorities, technical services, environmental NGOs) identified that problems still exist with OBD due to unclear requirements for monitoring and occurring failures in identifying malfunctions resulting in high emissions. In addition, the majority of respondents from all stakeholder groups to the public consultation indicated that the limited effect of OBD at least contributes somewhat to an increase in pollutant emissions. For industry, however, 28 of the 57 respondents indicated that the limited effect of OBD only contribute very little or not at all to this increase.[100]

- *Differences in Euro 6/VI limits based on technology and fuel* – Differences such as different limits for diesel, petrol and CNG cars did not have the positive effect that was envisaged, but it actually prevented greater achievements[101]. In the public consultation, 87 of 124 stakeholders from all groups indicated that developing fuel- and technology-neutral limits would be (very) important to improve the effects of emission limits for vehicles[102].

- *Different application dates for the stepwise Euro 6/VI approach and for new vehicle types and new vehicles* – Industry stakeholders were the most sceptical regarding these different application dates, indicating that it is important to introduce common dates to ensure regulatory planning reliability. This concern was emphasised in public consultation were 101 out of 128 stakeholders from all groups indicated that the different application dates for the stepwise approach were considered complex or very complex. For the different application dates for new types and vehicles, 88 out

[95] EEA, 2020. National Emission Ceilings Directive emissions data viewer 1990-2018
[96] ICCT, 2019. Recommendations for post-Euro 6 standards for light-duty vehicles in the European Union (submitted through AGVES)
[97] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.4 Do the standards properly cover all relevant/important types of pollutant emissions from vehicles that pose a concern to air quality and human health?
[98] See footnote 96
[99] See footnote 89
[100] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 15)
[101] Suarez-Bertoa et al., 2019. On-road emissions of passenger cars beyond the boundary conditions of the real-driving emissions test. Environmental Research, Volume 176
[102] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 13)

of 128 from all groups indicated that this feature of the legislation is at least somewhat complex.[103]

- *Complexity of Euro 6/VI emission tests* – Stakeholders from all groups, except environmental NGOs, indicated in the targeted consultation that the complexity of emission tests has played a negative role as it resulted in errors in performing the emission tests and calculations and significantly increased the capacity needed by manufacturers to comply with the Regulations, which in its turn increased prices and slowed down the uptake of Euro 6/VI vehicles. Moreover, the introduction of temporary and final conformity factors[104] are expected to have had a negative effect on the achievements of Euro 6/VI so far. This result was also confirmed in the public consultation where 98 out of 126 respondents from all stakeholder groups considered that the standards are complex or even very complex.[105] Especially the procedures of the emission tests and the number of emissions are considered (highly) complex by most respondents. Only civil society was less convinced of the complexity related to the number of tests, which they consider appropriate to achieve effective emission standards.[106]

- *Tampering* – Stakeholders from all groups indicated that the Euro 6/VI provisions taken to prevent tampering[107] with the emission control computer, odometer or other vehicle control unit are not effective and are expected to have had a negative effect on the achievements of Euro 6/V so far. A similar result was found in the public consultation in which a substantial majority across all stakeholder groups indicated that tampering still contributes to an increase in emissions.[108]

Evaluation question 2: How effective are the Euro 6/VI testing procedures to verify the emission standards?

Overall conclusion: The new on road RDE testing introduced under Euro 6d-temp for cars and vans reduced the gap between type-approval and real-world emissions. The Portable Emission Measurement Systems (PEMS) testing introduced under Euro VI D for lorries and buses was less effective. While cold start emissions is already addressed in the last Euro VI E step that still has to enter into force, the gaps in low-speed driving conditions and idle vehicles with low loads identified for Euro V vehicles continued in Euro VI vehicles.

Euro 6/VI testing procedures have made a gradual progress towards increasing the level of representativeness of the considered driving cycles and conditions of use, especially in urban driving conditions. Nevertheless, despite these improvements, important emissions remain unaccounted under Euro 6/VI emission testing. In particular, test boundaries for cars and vans still exclude short trips, high mileage

[103] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 9)
[104] See footnote 19
[105] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 8)
[106] See footnote 102
[107] Regulation (EC) No 595/2009 defines tampering as “inactivation, adjustment or modification of the vehicle emissions control or propulsion system, including any software or other logical control elements of those systems, that has the effect, whether intended or not, of worsening the emissions performance of the vehicle”
[108] See footnote 103

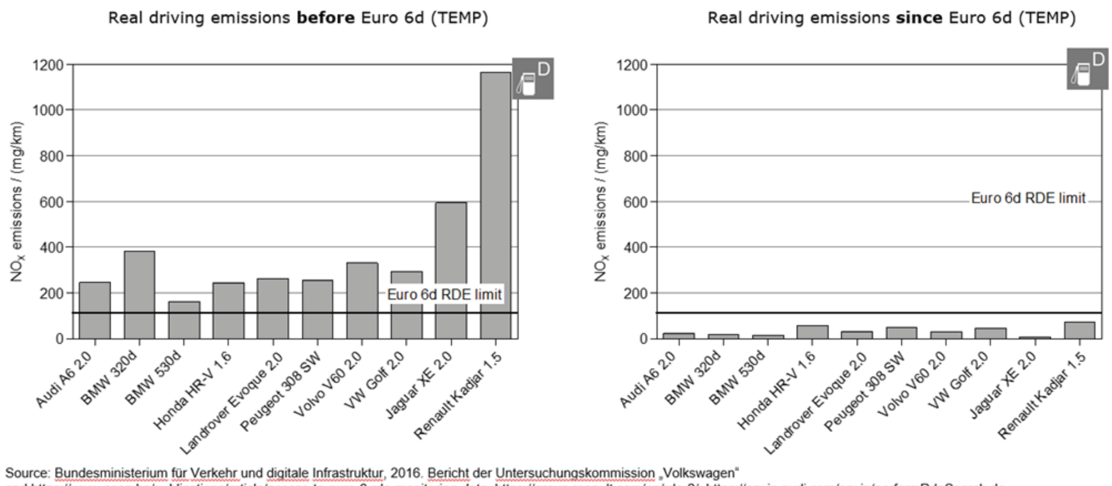
and high altitude circuits, and severe temperature conditions; and test boundaries for lorries and buses low loads, low speed and idle times that are of great importance in urban areas. Hence, a complete coverage of real-world driving cycles and all conditions of use is still missing in Euro 6/VI emission standards.

The response to evaluation question 1 already indicated that the enhanced Euro 6/VI testing procedures have been of great importance for making cleaner vehicles on EU roads a reality. In particular, ISC testing with RDE and PEMS testing, and the introduction of cold-start emissions to testing procedures are considered to be important factors for making cleaner vehicles on EU roads a reality. Now, this question evaluates the new Euro 6/VI testing procedures to check whether they reduced the gap between real-world emissions and type-approved emissions and whether they are actually representative for real-world driving cycles and conditions of use.

Gap between real-world emissions and type-approved emissions

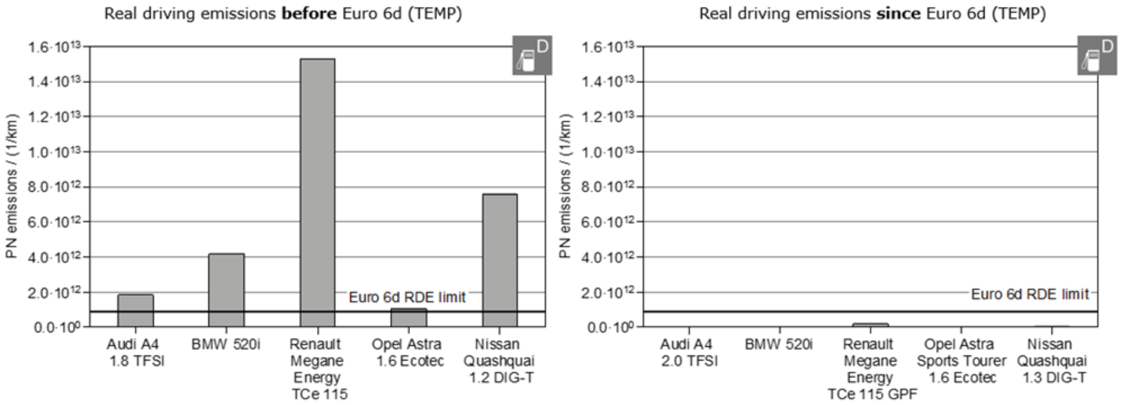
For cars and vans, before Euro 6 emission standards, and in particular before the introduction of RDE testing, significant levels of deviation between real-world and type-approved emissions were reported. The JRC demonstrated that pre-RDE Euro 6 diesel vehicles (Euro 6b) emit on average almost three times as much NO_x emissions and 40% more CO emissions than the respective emission limits allow.[109] This level of deviation decreased somewhat with the introduction of WLTP testing (Euro 6c)[110] and much more with the introduction of RDE testing (Euro 6d-Temp).[111] The impact of RDE testing on the gap between real-world and type-approved emissions is demonstrated in Figure 21 for NO_x and PN emissions.

Figure 21 – NO_x and PN emissions on a sample of vehicles before and after the introduction of RDE testing[112]



Source: Bundesministerium für Verkehr und digitale Infrastruktur, 2016. Bericht der Untersuchungskommission „Volkswagen"
and https://www.acea.be/publications/article/access-to-euro-6-rde-monitoring-data, https://group.renault.com/en/rde-2/, https://erwin.audi.com/erwin/performRdeSearch.do

[109] JRC, 2018. Joint Research Centre 2017 light-duty vehicles emissions testing: Contribution to the EU market surveillance: testing protocols and vehicle emissions performance
[110] WLTP was primarily introduced to reduce the gap between real-world and type-approved CO_2 emissions and fuel consumption
[111] JRC, 2019. Joint Research Centre 2018 light-duty vehicles emissions testing: contribution to the EU market surveillance: testing protocols and vehicle emissions performance
[112] See footnote 53



Source : http://www.duh.de/uploads/media/Hintergrundpapier_GDI-Pressegespraech.pdf
and https://www.acea.be/publications/article/access-to-euro-6-rde-monitoring-data, https://group.renault.com/en/rde-2/, https://erwin.audi.com/erwin/performRdeSearch.do, https://www.nissanrde.eu//,

Except for some reservations due to incompleteness in the RDE coverage for urban driving conditions, the majority of stakeholders from all groups participating in the targeted consultation agreed with the above findings for Euro 6 emission testing stating that the introduction of RDE testing reduced the gap between type-approval and real-world emissions. However, in the public consultation only a majority of industry and citizen respondents indicated that RDE testing ensures that cars and vans are compliant with the pollutant limits in all driving conditions.[113] In addition, a majority across all stakeholder groups, excluding industry, indicated that shortcomings in the existing on-road test at least contributed somewhat to an increase in emissions.[114]

For lorries and buses, the introduction of new Euro VI testing procedures and on-road testing procedures - WHTC, WHSC and PEMS testing - had limited positive results in reducing the existing gap between real-world and type-approved emissions. In particular for NO_x emission, the large gaps in low-speed driving conditions and idle vehicles with low loads identified for Euro V vehicles continued in Euro VI vehicles.[115] Thus, the driving cycle coverage proves to be insufficient and the margin for optimisation of vehicle's engine to the test remains.

However, stakeholders from all stakeholder groups broadly agreed in the targeted stakeholder consultation on the effectiveness of the Euro VI new testing procedures, which is not fully in line with the above findings. Especially for the introduction of on-road testing procedures for in-service conformity testing (i.e. PEMS), this is perceived to have reduced the gap between type-approval and real-world emissions by 44 out of 45 stakeholders that answered this question.[116] Also in the public consultation a majority of industry and citizen respondents indicated that PEMS testing ensures that lorries and buses are compliant with the limits in all driving conditions.[117] Hence, progress was reported towards narrowing the gap between real-world emissions and type-approved emissions. Nevertheless, stakeholders - mostly from Member States and civil society - replied to the public consultation and the Combined Evaluation Roadmap/Inception

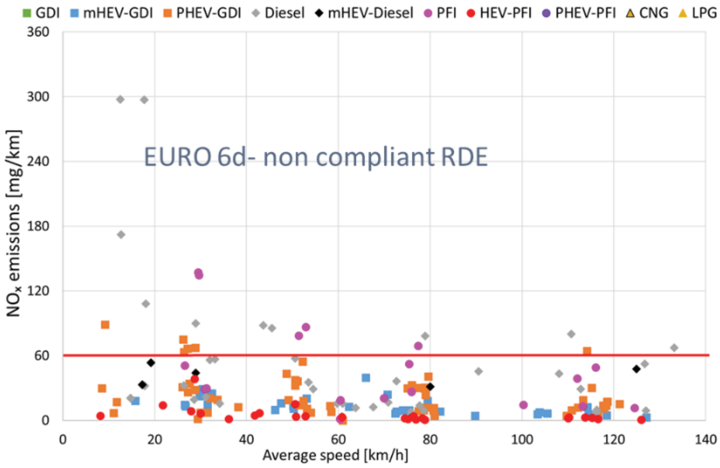
[113] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 14)
[114] See footnote 108
[115] Grigoratos, T., et al., 2019. Real world emissions performance of heavy-duty Euro VI diesel vehicles; TNO, 2018. Tail-pipe NOx emissions of Euro VI buses in the Netherlands
[116] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.3.2. What has been the impact of the changes to the testing procedures in terms of reducing the gap between real emissions and type-approval emissions?
[117] See footnote 113

Impact Assessment[118] by saying that there is still a wide gap, especially in urban driving conditions, which confirms the above findings on WHTC, WHSC and PEMS testing.

Coverage of actual real-world driving cycles and conditions of use

Moving from Euro 5 emission testing with laboratory NEDC testing to Euro 6c with laboratory WLTP testing and Euro 6d-TEMP with a combination of WLTP and RDE testing, gradual progress has been made towards increasing the level of representativeness of the considered driving cycles and hence conditions of use and the robustness against defeat strategies. This follows from the shift in requirements through RDE testing requiring the inclusion of urban, rural and motorway driving cycles and expanding boundary conditions by accounting for differences in ambient temperature and altitude which deviates from the repeatable and reproducible testing cycles of NEDC and WLTP testing. Nevertheless, despite these improvements, important emissions remain unaccounted under Euro 6/VI emission testing. The test boundaries for cars and vans still exclude short trips, high mileage and high altitude circuits, and severe temperature conditions. Since pollutant emissions are generally higher in such driving cycles and conditions of use, a large part of the overall emissions remains unaccounted for.[119] Figure 22 illustrates how driving cycles with a very low average speed – and hence not covered in RDE testing – tend to result in NO_x emissions far above the current emission limit for petrol cars.

Figure 22 - Emission performance of Euro 6d vehicles for NO_x for different average speeds (NO_x limit for petrol cars = 60 mg/km)[120]



Moving from Euro V emission testing with ESC/ETC/ELR testing to Euro VI A with WHTC/WHSC testing and Euro VI D with the addition of PEMS testing to ISC testing, improvements were made to the reliability of testing for lorries and buses. New driving cycles and hence conditions of use include urban, rural and motorway operations and cover a wide range of load and speed operations. In addition, the new requirements hamper defeat strategies by manufacturers through removing the possibilities for prior-calibrating the emission control system to meet the limits. Nevertheless, the test boundaries still exclude important emissions measured at low loads, low speed and idle

[118] See footnote 50

[119] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.3.3 Have the testing procedures increased reliability in terms of the measurement of the vehicles' emissions and verification of the level of emissions in comparison to the emissions limits?

[120] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

times that are of great importance for lorries and buses operating in urban areas. In addition, an important level of tampering is still reported under Euro VI, following lacking third-party verification and the fact that ISC is undertaken by the manufacturer.[121]

Hence, a complete coverage of real-world driving cycles and all conditions of use is still missing in Euro 6/VI emission standards. As the cycles and conditions that are not yet included also result in extensive pollutant emissions, it is of great importance for human health and environment to review the testing boundaries.

Evaluation question 3: What are the benefits of Euro 6/VI emission standards and how beneficial are they for industry, the environment and citizens?

Overall conclusions: For industry, Euro 6/VI emission standards had overall neither a clear positive nor a clear negative impact. It is difficult to determine whether the increased regulatory costs, in particular for cars and vans after the necessary introduction of RDE testing in the wake of Dieselgate, have affected the respective profit margins and the overall profitability. Clearly, it cannot be determined if a price increase of cars since 2014 is associated to regulatory costs associated with the Euro 6 emission standards, it could also be the result of various other factors affecting prices (e.g. difficult economic conditions, increased installation of comfort equipment or changes in fleet composition towards more heavy and expensive vehicles). The regulatory costs also do not necessarily imply a direct negative impact on the competitiveness of the EU manufacturers compared to non-EU competitors, as the latter are faced with similar costs. In the contrary, to ensure the competitiveness of the EU automotive industry, it is of great importance that stricter Euro 6/VI emission limits and testing procedures help to ensure access to external markets for European manufacturers, which have adopted stricter limits, in particular the United States and China. Considering the number of R&D projects directly linked to Euro 6/VI emission standards, it is expected that the standards had a positive impact on research activities in the EU. On the other hand, some stakeholders suggested that most of the technologies were already available on the market and the standards only fostered innovation through improving existing technologies and subsequently decreasing their costs. Lastly, industry reports differences in interpretation of Euro 6/VI emission standards at national level which seems to hamper the full achievement of the objective to achieve harmonised rules on the construction of vehicles.

For the benefit of the environment, Euro 6/VI emission standards reduced pollutants emitted by the road transport sector, especially from NOx and particulates emissions. However, no changes are observed in the share of road transport emissions to total emissions from all sectors. Next to directly achieving benefits for the environment, the Euro 6/VI emission standards could also benefit the environment by raising public awareness on vehicle-related air pollution problems and in that way, influencing public attitude.

For the benefit of citizens, Euro 6/VI emission standards curbs health impacts by reducing pollutants emitted by the road transport sector that could cause respiratory

[121] See footnote 119

and cardiovascular diseases upon inhalation, for example bronchitis, asthma or lung cancer. On the other hand, there is no compelling evidence suggesting that the Euro 6/VI emission standards have had a positive or negative impact on employment.

Benefits for industry

1) Impact on harmonised rules on the construction of vehicles

A specific objective for the creation of Euro 6/VI emission standards was to achieve harmonised rules on the construction of motor vehicles to limit distortions in competition across Europe that would be realised by the Member States. That way, this harmonised approach should benefit industry.

While there is an overall understanding amongst most stakeholders groups[122] that the introduction of the Euro 6/VI emission standards has resulted in a level of harmonisation that would not have been achievable at the level of the Member States, several concerned industry representatives do not agree that Euro 6 emission standards have ensured harmonised rules (7 out of 30).[123] They report discrepancies in the form of differences in interpretations of the Regulations by different type-approval authorities. For example, there would still be differences in interpretations in the authorisation to disable pollution-control devices to protect components and in measurement devices' errors. This situation makes it possible for manufacturers to select the type-approval authority with the least stringent interpretation of existing rules.[124][125] Overall a small majority of respondents to the public consultation indicated that the complexity in the current standards leads to misinterpretation amongst type-approval authorities. Especially stakeholders from civil society seem to be convinced of the occurrence of such misinterpretations.[126] Due to these reported differences in interpretation, full harmonisation on the construction of motor vehicles seems not to be achieved yet.

2) Impact on competitiveness of the EU automotive industry

a. Impact on cost and price competitiveness

For cars and vans, the introduction of Euro 6 emission standards resulted in significant equipment costs for emission control technologies (see detailed cost assessment in section 5.2). In particular, the introduction of RDE testing required improvements of existing equipment and installation of new equipment. Moreover, the introduction of the new standards also entailed considerable other costs during implementation phase for vehicle testing and type-approval (see detailed cost assessment in section 5.2). While there is uncertainty surrounding the exact rise in costs, it is clear that the actual regulatory costs were higher than initially anticipated[127][128].

[122] See footnote 82

[123] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.5.2. To what extent has the adoption of the standards ensured the presence of harmonised rules on the construction of motor vehicles?

[124] de Sadeleer, N., 2016. Reinforcing EU testing methods of air emissions and the approval processes of vehicle compliance in the wake of the VW scandal

[125] Gieseke and Gerbrandy, 2017. Final report on the inquiry into emission measurements in the automotive sector A8-0049/2017- Committee of Inquiry into Emission Measurements in the Automotive Sector

[126] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 10)

[127] For cars and vans, the estimated equipment costs are higher than the ones that were identified in SEC(2005) 1745 (Euro 6 Impact Assessment). In addition, no other compliance costs were considered in

The transmitted regulatory costs by change in vehicle prices for consumers is less clear. For cars, real prices have on average increased since 2014. While this increase could be linked to the increase in regulatory costs associated with the Euro 6 emission standards, it could also be the result of various other factors affecting prices (e.g. difficult economic conditions, increased installation of comfort equipment or changes in fleet composition towards more heavy and expensive vehicles).[129][130] Stakeholders from all groups participating in the targeted consultation suggest that Euro 6/VI has resulted in a small increase in vehicle prices with industry respondents generally indicating a more extensive rise in prices. Similar input was provided to the public consultation where 121 out of 139 respondents from all stakeholder groups (including citizens) considered that Euro 6/VI has led to an increase in the prices of cars, vans, lorries and buses.[131]

The profitability of the EU automotive sector was analysed. However, it is difficult to determine whether the increased regulatory costs have affected the respective profit margins and the overall profitability. According to industry stakeholders, the introduction of Euro 6/VI emission standards had a significant or limited negative impact on the profitability of the EU automotive sector. Since the Euro 6/VI emission standards apply to all vehicles sold on the EU internal market, the regulatory costs do not necessarily imply a direct negative impact on the competitiveness of the EU manufacturers compared to non-EU competitors, as the latter are faced with similar costs. Therefore, competitive disadvantages referred to by EU manufacturers are expected to be rather indirect through the relatively higher compliance costs for EU manufacturers in comparison to their competitors in lower cost countries.[132]

b. Impact on international competitiveness

To ensure the competitiveness of the EU automotive industry, it is of great importance that stricter Euro 6/VI emission limits and testing procedures help to ensure access to external markets for European manufacturers. When comparing the emission requirements in Europe today with those in place in other key markets (i.e. the United States and China), however, the EU appears to be lagging behind its main competitors. Figure 23 demonstrates that with the exception of PM emissions, both the United States and China have adopted more ambitious limit values for cars and vans. Also when it comes to the testing procedures, the United States currently takes the lead through the creation of detailed standards and OBD enforcement mechanisms that eliminate loopholes.[133]

SEC(2005) 1745 and SEC(2007) 1718 (Euro 6/VI Impact Assessments)

[128] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.7.3. What has been the impact of the Euro 6/VI standards on the competitiveness of the EU automotive industry?

[129] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, Chapter 5.1.6.2. Have there been any impacts from the Euro 6/VI in relation to: prices of vehicles, CO2 and other emissions?

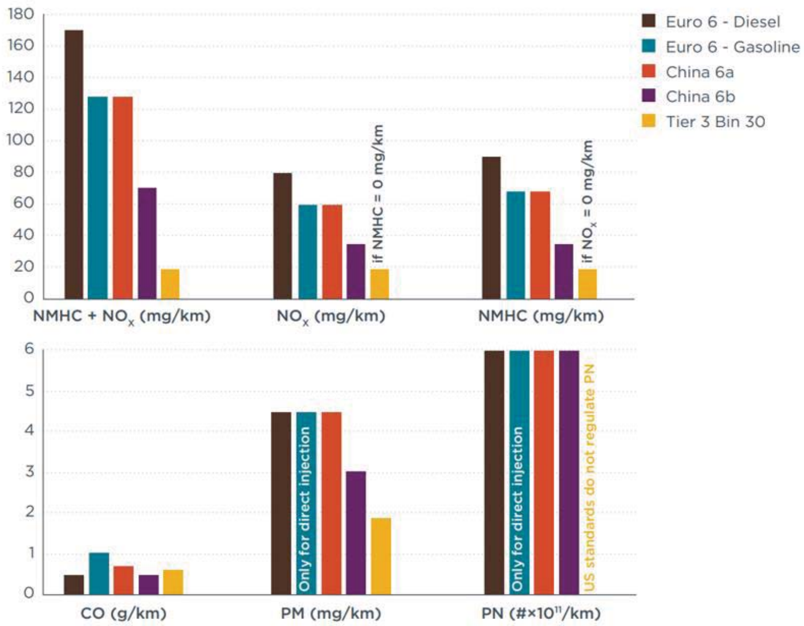
[130] AEA, 2011. Effect of regulations and standards on vehicle prices. Report to the European Commission – DG Climate Action

[131] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 3.1)

[132] See footnote 128

[133] ICCT, 2015. Comparison of US and EU programs to control light-duty vehicle emissions

Figure 23 – Comparison of latest emission limits in the EU, United States and China for light-duty vehicles, Source: ICCT, 2019[134]



Hence, the more stringent emission limits introduced in Euro 6/VI are not sufficient to result in competitive gain for the European manufacturers given that their global counterparts are implementing stricter standards.[135] Nevertheless, the Euro 6/VI emission standards are expected to have an impact on the access to markets by reducing the emission reductions required to sell vehicles on other markets with even stricter requirements.[136] In addition, the stakeholders from all groups participating in the targeted consultation widely indicated that the Euro 6/VI emission standards have actually realised a positive effect on the EU automotive industry's competitiveness, with industry being slightly hesitant in their reply. Feedback from the ICCT indicated that without the Euro 6/VI emission standards, European manufacturers could have lost the ability to develop and produce desirable vehicles for the US and Chinese market.

c. Impact on the capacity to innovate

Considering the number of R&D projects directly linked to Euro 6/VI emission standards, it is expected that the standards had a positive impact on research activities in the EU.[137] For example, the European Investment Bank (EIB) confirmed that loans amounting to €13.6 billion were provided to car manufacturers for the development of pollution-control devices between 2005 and 2015.[138] These research activities were mainly focussed on improvements in existing technologies rather than on the development of completely new technologies. These findings are confirmed by all the

[134] See footnote 96
[135] Wells, P. et al., 2013. Governmental regulation impact on producers and consumers: A longitudinal analysis of the European automotive market.
[136] See footnote 128
[137] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.8.2 To what extent did the introduction of Euro 6/VI incentivise public and private research activity towards the development of new clean vehicle technologies and emissions control technologies?
[138] See footnote 125

stakeholder groups participating in the targeted consultation: 64 of 73 respondents across all groups indicated that the Euro 6/VI emission standards have provided an incentive for research activities towards the development of new clean vehicle technologies. In addition, multiple stakeholders, mostly from civil society, stress that for Euro 6, there was an acceleration in R&D activities following the introduction of RDE testing. On the other hand, some stakeholders from industry suggested that most of the technologies were already available on the market and the standards only fostered innovation through improving existing technologies and subsequently decreasing their costs.[139] In a similar way, there are now technologies available on the market allowing for further emission reductions than currently required under the Euro 6/VI emission standards.[140]

Although emission control technologies similar to the ones required for the Euro 6/VI emission standards were already adopted in other major markets, their adoption in Europe would most likely not have happened at a similar rate without the introduction of Euro 6/VI emission standards in Europe. While the technology was largely available, its voluntary uptake in Europe would have depended on costs and customer demand. With emission control technologies only adding costs with little perceived value for consumers, it is clear that manufacturers would most likely not have voluntarily adopted the technology required under Euro 6/VI.[141]

To encourage technology advances and improvements following the introduction of Euro 6/VI emission standards, support instruments were put in place at EU and Member State level. At EU level, manufacturers and suppliers were able to make use of Horizon 2020 projects focusing on the development of cleaner engine and aftertreatment technologies. Next to that, EU support instruments – such as the above-mentioned loans from the European Investment Bank - were available to finance related R&D activities. Member State support occurred either through nationally funded R&D support projects or through financial incentives. With 16 out of 30 industry stakeholders indicating in the targeted consultation that they made use of national projects, this support mechanism has been employed most frequently. Financial incentives by Member States, which have been encouraged in the Euro 6/VI emission standards[142], have only been used by 6 out of 25 industry stakeholders that responded to this question in the targeted consultation.[143] In general, the responses to the public consultation suggest that the standards have encourage the development of innovative technologies for cleaner vehicles, as this was indicated by more than 90 percent of the respondent with no remarkable differences between the stakeholder categories.[144]

These mixed results on the competitiveness of the automotive industry are reflected in the responses to the public consultation. Most respondents from all stakeholder groups considered that Euro 6/VI had at least somewhat of an impact on reinforcing the competitiveness of the industry, while the majority of respondents from Member States

[139] See footnote 137
[140] See footnote 53
[141] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.8.3 To what extent did the introduction of Euro 6/VI incentivise the adoption of new clean vehicle technologies and emissions control technologies?
[142] Article 12 Regulation (EC) No 715/2007; Article 10 Regulation (EC) No 595/2009
[143] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, Chapter 5.1.8.5 Were there relevant mechanisms in place to support the development of relevant technologies?
[144] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 4)

believe Euro 6/VI to be a great or very great contributor here.[145]

Benefits for environment

A specific objective for the creation of Euro 6/VI emission standards was to improve air quality by reducing pollutants emitted by the road transport sector. In addition, the Euro 6/VI impact assessments[146] indicated that monitoring data on air pollution levels and the epidemiology on health impacts (see below) will point to the wider success of the policies.

Euro 6/VI vehicles have realized large emission savings for NO_x and particulate (PM and PN) emissions, in combination with small savings for CO, HC (THC and NMHC) and increasing emissions of NH_3 (see evaluation question 1). All these pollutants are regulated under the National Emission Ceilings Directive (NECD)[147], which requires Member States to set national emission reduction commitments. That way, the emission savings brought by Euro 6/VI emission standards for road transport sector have contributed to efforts for achieving the NECD targets from all sectors. However, no changes are observed in the share of road transport emissions to total emissions from all sectors[6]. This result could be influenced by the increasing trend in the number of motor vehicles on EU roads, increasing mileage per vehicle or decreasing emission levels in other polluting sectors.[148] Most stakeholders from all groups agree that the Euro 6/VI emission standards have improved air quality. However, one environmental NGO stresses that road transport is still an important contributor to the total emission in the EU, which limits the Euro 6/VI objective to improve air quality by reducing pollutants emitted by the road transport sector.

Next to directly achieving benefits for the environment, the Euro 6/VI emission standards could also benefit the environment by raising public awareness on vehicle-related air pollution problems and in that way, influencing public attitude. Nevertheless, the direct contribution of the Euro 6/VI emission standards in this context appears to be limited. While the last Eurobarometer survey[149], which was conducted in 2017, illustrated that the public seems to be more aware of air pollution issues and the role of motor vehicles in creating those, it is possible that other trends might have a larger impact. In particular, the growing use of Low Emission Zones (LEZs) in urban areas are likely to have positively affected public awareness in this context.[150] While the creation of LEZs could have also taken place in the absence of the Euro 6/VI emission standards (i.e. continuation of Euro 5/V emission standards), the further development of LEZs does depend on the continuation of the Euro standards as Euro 6/VI vehicles allow local

[145] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 6)
[146] See footnote 3
[147] Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants. The Directive establishes the emission reduction commitments for the Member States' anthropogenic atmospheric emissions of SO2, NOx, NMVOC, NH3 and PM2,5 and requires that national air pollution control programmes be drawn up, adopted and implemented and that emissions of those pollutants and the other pollutants referred to in Annex I, including CO, as well as their impacts, be monitored and reported. NMHC can be considered equivalent to NMVOC.
[148] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.5.3 What has been the contribution of the standards to achieving National Emission Ceilings Directive (NECD) targets?
[149] Special Eurobarometer 468, November 2017. Attitudes of European citizens towards the environment
[150] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.8.6 Have the standards contributed towards raising awareness on vehicle-related air pollution and influenced public attitude?

authorities to impose access restrictions on up to Euro 5/V vehicles. That way, the introduction of Euro 6/VI could have raised awareness on air pollution issues through allowing cities to strengthen their LEZ. However, it is not possible to quantify this possible benefit.

Benefits for citizens

1) *Reduced impact on health*

By reducing pollutants emitted by the road transport sector, the Euro 6/VI emission standards provided also a benefit to citizens by curbing health impacts from road transport emissions that could cause respiratory and cardiovascular diseases upon inhalation, for example bronchitis, asthma or lung cancer. Combatting such health impacts from road transport could result in a reduction in the external costs, that means, medical treatment costs, production losses due to illnesses and even deaths.[151]

Table 38 shows the analysis carried out by the SIBYL model (see Annex 4), confirming that the Euro 6/VI emission standards generated a decrease in external costs through the reduction of health impacts originating from road transport. Euro 6 has resulted in a €31 billion decrease in external costs up to 2020 through the reduction of NO_x and PM emissions from cars and vans. While the largest share of the benefits were realized in the early steps of Euro 6 following the new emission limits, additional benefits were realized through the introduction of RDE testing and these benefits are expected to increase significantly when more Euro 6d vehicles will be sold after 2020. With a total of €67 billion, health benefits of a different scale were realised with the introduction of Euro VI, mainly from reduction of NO_x emissions from lorries and buses. While health benefits have already been realised at this point, they are expected to increase exponentially over the next thirty years, exceeding external cost savings of €1.8 trillion.[152]

These positive health impacts are validated in the responses to the public consultation. A majority of stakeholders from industry, citizens and especially Member States indicated that Euro 6/VI contributed to protecting human health.[153] Next to that, these impacts are largely confirmed in the literature[154], remaining health risks related to certain regulated and unregulated pollutant emissions remain a concern. Mainly emissions during regeneration at short intervals, especially for PN emissions[155] or emissions of unregulated yet hazardous pollutants, such as NO_2, present serious health risks.

Table 38 – Reduced health impact of Euro 6/VI emission standards: Changes in external costs (in € billion)[156]

Vehicle Category	Benchmark for savings	2014- 2020	2021-2050
NOx			
Cars and vans	Euro 6 pre-RDE compared to Euro 5	26.4	446.3
	Euro 6 RDE compared to Euro 6 pre-	2.1	305.8

[151] European Commission, 2019. Handbook on the external costs of transport
[152] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.7.2 Have there been any changes in the levels of observed health impacts as a result of Euro 6/VI?
[153] See footnote 145
[154] European Commission 2019. Handbook on the external costs of transport; Grigoratos, T., et al.., 2019. Real world emissions performance of heavy-duty Euro VI diesel vehicles.
[155] Giechaskiel, B., 2020. Particle Number Emissions of a Diesel Vehicle during and between Regeneration Events. Catalysts; Valverde, V. & Giechaskiel, B., 2020. Assessment of Gaseous and Particulate Emissions of a Euro 6d-Temp Diesel Vehicle Driven >1300 km Including Six Diesel Particulate Filter Regenerations.
[156] See footnote 152

Vehicle Category	Benchmark for savings	2014- 2020	2021-2050
NOx			
	RDE		
	Total Euro 6 compared to Euro 5	28.5	752.2
Lorries and buses	Euro VI compared to Euro V	65.1	979.8
Total monetised benefits from NOx reduction		**93.6**	**1 732.0**
PM10			
Cars and vans	Euro 6 pre-RDE compared to Euro 5	1.9	31.4
	Euro 6 RDE compared to Euro 6 pre-RDE	0.1	7.8
	Total Euro 6 compared to Euro 5	2.0	39.2
Lorries and buses	Euro VI compared to Euro V	1.4	40.0
Total monetised benefits from PM10 reduction		**3.4**	**79.2**

2) Direct impact on employment

Employment in the automotive industry, both for manufacturers and suppliers, could have been positively and negatively affected by the Euro 6/VI emission standards. However, there is no compelling evidence suggesting that Euro 6/VI has had a positive or negative impact on employment.

The introduction of Euro 6/VI emission standards could have resulted in a short-term increase in labour costs, induced by the requirements to implement emission control systems. Since the regulatory costs would have diminished over the application and hence evaluation period, the short-term negative employment effects would follow this trend and could even be transformed into a positive long-term employment effect. This was demonstrated in the GEAR 2030 Strategy 2015-2017 study[157] which used modelling to understand the impact of EU regulations on the wider economy. The results from this exercise showed that small changes in the industry's composition of GDP, of development of wages and labour productivity over time can change employment numbers, while the total wage ratio remains constant. That way, employment effects can turn significantly positive. Nevertheless, it should be stressed that the effect caused by the Euro 6/VI emission standards cannot be disentangled from other factors that may have affected labour costs in the automotive sector, including other environmental and safety legislations.

In addition, positive employment effects could have been realised in the automotive sector and in the type-approval authorities through the creation of new jobs in R&D related activities or in activities associated with the implementation of the Euro 6/VI emission standards. This assumption was confirmed by a number of type-approval authorities and manufacturers that participated in the targeted stakeholder consultation.[158][159]

[157] European Commission, 2017. GEAR 2030 Strategy 2015-2017. Comparative analysis of the competitive position of the EU automotive industry and the impact of the introduction of autonomous vehicles

[158] 4 out of 20 manufacturers that provided responses and 2 industry associations reported costs for staff hired; 2 out of 4 type-approval authorities reported costs incurred for new staff and inspectors.

[159] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.7.4 Has there been any direct impact (positive/negative) on employment?

5.2. Efficiency

Evaluation question 4: What are the regulatory costs related to the Euro 6/VI emission standards and are they affordable for industry and consumers? Have Euro 6/VI achieved a simplification of vehicle emission standards? **Overall conclusions:** The Euro 6/VI emission standards have led to considerable regulatory costs for automotive industry, which were mainly driven by the emission control technologies and are to a great extent passed through to the consumers. The total regulatory costs compared to Euro 5/V are €21.1 to €55.6 billion for Euro 6 (2014-2020) and €5 to €20.4 billion for Euro VI (2013-2020). These regulatory costs result to 95-99% from direct compliance costs (hardware costs, R&D and related calibration, facilities and tooling costs) and to 1-5% from costs during implementation phase (testing and witnessing costs, type-approval fees) and administrative costs. The introduction of more demanding on-road RDE and PEMS testing procedures has led to an increase of costs during implementation phase, namely testing and witnessing costs increased by €150-€302 thousand per model family for Euro 6d(-temp) and by €95.7-€232 thousand per engine family for Euro VI. The related reporting procedures have increased the administrative costs by €16-€52 thousand per type-approval for Euro 6d (-temp) and by €17.5-€27.5 thousand per type-approval for Euro VI. These regulatory costs are considered affordable to industry, approval authorities and consumers, with the exception of vehicle price increases for small diesel cars and vans. It is safe to assume that vehicle manufacturers pass through their regulatory costs to consumers to a great extent and that any cost implication for industry will only be for a short period until extra costs are recovered through increased prices. Also suppliers pass through their hardware costs largely – if not fully – to their clients, the vehicle manufacturers, and most type-approval authorities pass through their costs to vehicle manufacturers by type-approval fees. The average vehicle price increase due to Euro 6/VI is less than 2% for cars and vans, in the range of 4.2-5% for lorries and of 2.1-3% for buses. However, for the most recent step in Euro 6, the share of the cost for small segment cars and vans is found to be significantly higher in the case of diesel vehicles – 4.3% for the small segment vehicles, compared to 2.7% for the large segment vehicles. No simplification was realised in the Euro 6/VI emission standards. Instead, the emission tests introduced over the steps of Euro 6/VI increased the complexity significantly resulting in a text of more than 1 300 pages with multiple references to other pieces of legislation, different application dates of Euro 6/VI steps and the above-mentioned increased costs during implementation phase. For stakeholders from civil society this complexity is seen as, at least partly, justified in view of the need to ensure that vehicles are clean on the basis of more demanding testing and in-service conformity requirements.

Regulatory costs for automotive industry

In order to analyse the regulatory costs of Euro 6/VI emission standards borne by automotive industry, different cost categories were identified in accordance with the

Better Regulation guidelines[160] (see Table 39).

Table 39 – Description of cost categories, based on CLOVE, 2022[161]

Regulatory costs for automotive industry		
Direct compliance costs		
Substantive compliance costs	***Equipment costs***	
	• **Hardware costs**	*Recurrent* costs arising from the need to install engine and emission control technologies on vehicles to meet the emission limits. As these needs will continue as long as Euro 6/VI is into force, the hardware cost will carry on after 2020. However, they are expected to decrease gradually following a strong learning effect.
	• **R&D and related calibration costs including facilities and tooling costs**	*1) One-off* costs related to the development of new emission control systems or the necessary upgrades for existing systems intended to ensure compliance with the new requirements, including for new facilities, tools and logistics investments required to support R&D and calibration directly linked to Euro 6/VI. *2) Recurrent* costs in terms of calibration costs and related testing for each new vehicle model or new engine to ensure that it meets the Euro 6/VI requirements. These costs will continue after 2020, but at a gradually decreasing level on the basis of a learning effect.
	Costs during implementation phase	
	• **Testing and witnessing costs**	*Recurrent* costs for testing in the context of type-approval, in-service conformity and conformity of production performed or witnessed by type-approval authorities in the facilities of the manufacturers.
	• **Type-approval fees**	*Recurrent* costs including the fees for granting type-approval paid to type-approval authorities, excluding the cost of witnessing above.
Administrative burden	***Administrative costs***	
	Recurrent costs including costs for reporting and to fulfil other information provision obligations as part of the process for granting type-approval.	

The costs for automotive industry were collected through questionnaires and interviews in the first targeted stakeholder consultation on the evaluation and CLOVE expert estimates (for more information on data collection, see method chapter 4) and have been analysed in a bottom-up approach. That way, the cost per unit (e.g. per vehicle or engine) were first verified for each cost category.[162] These costs were then scaled up to estimate the cost for the whole stakeholder group using relevant data including new vehicle registrations per year, number of manufacturers affected, number of engine/model families and number of emission type-approvals.[163]

In this context, the evaluation on the efficiency was faced with certain limitations (see Chapter 4). In particular, the limited provision of cost data during the targeted consultation – only 3 manufacturers and 3 type-approval authorities provided data – has been an implication. However, major efforts have been made to tackle this problem through extending data sources and estimating costs through a scaled-up desk research using input provided by CLOVE experts. These cost estimates were then sense checked

[160] European Commission, 2020. Better Regulation Toolbox, Tool #58. Typology of costs and benefits.
[161] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.3 Analysis of regulatory costs for industry
[162] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.1 Introduction
[163] See footnote 161

using data at the sector level (e.g. total turnover, total R&D expenditure) to ensure that the estimates were plausible and to assess to which extent the regulatory cost are reasonable for the respective stakeholders. Next to that, a conservative approach was adopted using broad cost ranges allowing for a higher margin of error. Lastly, the main assumptions on the unit costs per cost category were presented to the stakeholders participating in the AGVES meeting of 26 November 2020, including more than 100 industry participants. Three industry stakeholders, one manufacturer, one supplier and one association, reacted after the meeting and provided further input that has been reflected in the analysis. Hence, robust conclusion should be achieved for the efficiency section. [164]

The analysis focused on identifying and quantifying the costs generated through the new requirements of Euro 6/VI emission standards. Hence, the evaluation considered the incremental change in regulatory costs related to Euro 6/VI in comparison to those related to Euro 5/V. Additionally, for cars and vans the change in regulatory costs moving from the first steps of Euro 6 to the later steps including RDE testing, i.e. Euro 6d(-temp), is considered. For Euro 6 (cars and vans), the variation in the costs per vehicle type is accounted for by differentiating the costs for petrol vehicles and diesel vehicles.[165] To account for the variation incurred depending on the vehicle type, size and manufacturer (higher/lower end), different cost ranges (low/moderate/high) were considered.[166]

1) *Costs for vehicle manufacturers*

Table 40 presents estimates of costs borne by vehicle manufacturers with the introduction of Euro 6/VI emission standards, as net increases in the different costs for manufacturers in total and per unit (vehicle or model/engine family).

Table 40 – Estimates of costs borne by vehicle manufacturers with the introduction of Euro 6/VI emission standards, compared to Euro 5/V[167]

<table>
<tr><th rowspan="3"></th><th colspan="3">Petrol cars and vans</th><th colspan="3">Diesel cars and vans</th><th>Lorries and buses</th></tr>
<tr><th rowspan="2">Euro 6b-c</th><th colspan="2">Introduction RDE testing</th><th rowspan="2">Euro 6b-c</th><th colspan="2">Introduction RDE testing</th><th rowspan="2">Euro VI</th></tr>
<tr><th>Euro 6d-temp</th><th>Euro 6d</th><th>Euro 6d-temp</th><th>Euro 6d</th></tr>
<tr><td colspan="8">1) Equipment costs</td></tr>
<tr><td colspan="8">• Hardware costs</td></tr>
<tr><td>Cost per vehicle (€)</td><td>0</td><td>84-103</td><td>228-465[168]</td><td>341-937</td><td>630-1 536</td><td>751-1 703</td><td>1 798-4 200</td></tr>
<tr><td>Total cost (€ billion)</td><td>0</td><td colspan="2">1.9-3.2</td><td colspan="3">15.3-40</td><td>4.1-9.5</td></tr>
<tr><td colspan="8">• R&D and related calibration costs including facilities and tooling costs</td></tr>
<tr><td>Cost per vehicle (€)</td><td colspan="3">36-108</td><td colspan="3">43-156</td><td>1 900-3 800</td></tr>
<tr><td>Total cost (€ billion)</td><td colspan="3">1.3-4</td><td colspan="3">1.8-6.7</td><td>5.35-10.7</td></tr>
</table>

164 See footnote 162
165 This is not necessary for Euro VI (lorries and buses), consisting mainly of diesel vehicles.
166 See footnote 161
167 CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.3.1 Costs for vehicle manufacturers
168 Following the presentation in the AGVES meeting of 26 November 2020, one automotive association suggested that hardware costs were higher than this figure. However, no specific evidence or other figures were provided to support this.

2) Costs during implementation phases					
• **Testing costs**					
Cost per model / engine family (€ thousand)	0-34	138-286	0-34	138-286	93-227
Total cost (€ million)	0-118	360-747	0-118	360-747	51-126
• **Witnessing costs**					
Cost per model / engine family (€ thousand)	3-4	12-16	3-4	12-16	2.7-5
Total cost (€ million)	10-14	31-42	10-14	31-42	1.5-2.8
• **Type approval fees**					
Cost per type-approval	0		0		0
Total cost (€ million)	6-10		6-10		0
3) Administrative costs					
Cost per type-approval (€ thousand)	4-12	16-52	4-12	16-52	17.5-27.5
Total cost (€ million)	40-120	207-674	40-120	207-674	26-41
Total costs					
Total cost until 2020 (€ billion)	21.1-55.6				9.5-20.4
Total cost until 2050 (NPV in € billion - 2010 values)	80.6-186.6				16-35

Equipment costs - Hardware costs

To comply with the Euro 6/VI requirements, manufacturers had to introduce and integrate new emission control technologies. To estimate the hardware costs that were realised moving from Euro 5/V to Euro 6/VI, typical technology packages used to meet the new requirements were considered.[169] Table 40 shows that for Euro 6 diesel cars and vans, the hardware costs were significant at the pre-RDE steps. This was mainly driven by the introduction of the selective catalytic reduction (SCR) emission control technology. With the introduction of RDE testing, hardware was also required for a share of petrol vehicles, including the use of gasoline particulate filter (GPF) which introduced with €69 moderate costs per vehicle. Thus, the hardware costs for cars and vans mostly increased as a result of the introduction of RDE testing.[170]

Next to the hardware cost per vehicle, Table 40 also presents the net increase in total hardware cost. In comparison with the other cost categories presented in the table, it becomes clear that for cars and vans the rise in hardware costs is the most extensive. For cost per vehicle in comparison to Euro 5, the costs of hardware installed in the most recent Euro 6d vehicles are estimated at €228-€465 for petrol and at €751-€1 703 for diesel vehicles. These estimates are higher than the estimation of the Euro 6 impact assessment[171], in which the weighted average cost per diesel vehicle was estimated at €213 (€280 in 2020 prices). This follows from the fact that analysis in the Euro 6 impact assessment only focused on the cost of the key technology expected to be needed to comply with the limits (SCR or LNT) and did hence not cover other aspects such as the

[169] The Euro 6 diesel technology package includes lean NOx trap (LNT) in initial steps, selective catalytic reduction (SCR) with Urea kit, SCR with a soot filter (SCRF), advanced exhaust gas recirculation (EGR) and on-board diagnostics (OBD) sensors; the Euro 6 petrol technology package includes gasoline particulate filter (GPF), second three-way catalytic converters (TWC), combustion optimisation and OBD sensors. The Euro VI technology package includes diesel particulate filters (DPF), zeolite SCR, ammonia slip catalyst (ASC) and OBD sensors.

[170] See footnote 167

[171] See footnote 3

costs of sensors and other supporting hardware (e.g. Lambda or NO_x sensors)[172]. In addition, RDE testing was not yet taken into consideration, meaning that the estimates from the IA are only comparable with the Euro 6 pre-RDE costs.[173]

For lorries and buses, however, the hardware cost per vehicle is estimated to be between €1 798 and €4 200, which is comparable to the estimates of the Euro VI impact assessment which were in the range of €2 539-€4 009 (€2 817-€4 419 in 2020 prices).[174]

Equipment costs - R&D, calibration, facilities and tooling costs

Estimating R&D, calibration, facilities and tooling costs was challenging considering the limited availability of relevant data and the fact that R&D projects for the development of new vehicles rarely focus on just one legal requirement such as the Euro 6/VI emission standards. However, uncertainty has been addressed in the estimates by allowing a wide cost range for which the high cost estimates were based on the input from a high-end manufacturers and the low cost estimates stem from the literature.[175] The combined cost estimations are presented in Table 40.

For Euro 6, the costs for R&D, calibration, facilities and tooling costs is estimated at €36-€108 per vehicle for petrol and at €43-€156 per vehicle for diesel. In total, this makes up for a cost ranging from €3.1 to €10.7 billion for the period 2014-2020. Calibration costs, which should be considered as recurrent costs since new models brought to the market will have to be calibrated to ensure compliance, are expected to represent more than 50% of the total R&D cost estimate for cars and vans.[176]

For Euro VI, it is assumed that only part of the reported R&D costs by manufacturers through the targeted consultation are directly linked to Euro VI, since the R&D activity was also relevant for the US EPA 10 standards[177]. Hence, the R&D costs related to Euro VI are estimated at €1.1 billion for large manufacturers and €0.3 billion for smaller ones. The total R&D, calibration, facilities and tooling costs are presented in Table 40, together with the costs per vehicle. The estimates suggest that the total costs in this context are comparable to the total hardware costs incurred in the period 2013-2020. On a per vehicle basis, they represent a cost of €1 900 and €3 800 per vehicle sold in this period. While this high cost per vehicle in comparison to the cost for cars and vans can be expected given the smaller volume of lorries and buses sold in the internal market, these estimates based on data from manufacturers[178] seem to be on the higher side compared to results from an ICCT study[179], which suggested this cost to be 8 to 12 times lower.[180] Similar to Euro 6, the calibration costs have also increased moving from Euro V to Euro VI. In particular, expert estimates indicated that calibration costs have increased from

[172] While the pollutants monitored by OBD did not change between Euro 5 and Euro 6, the threshold for the provision of information from on-board diagnostics (OBD) systems did change both with the introduction of Euro 6 and before the introduction of Euro 6d. Hence, additional sensors were still needed to effectively control emissions (e.g. multiple Lambda or NOx sensors) for RDE compliance.

[173] See footnote 167

[174] See footnote 3

[175] ICCT, 2012. Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles.

[176] See footnote 167

[177] US EPA standards are structured and tested quite differently to EU standards so direct comparisons are not possible, but in practice a similar level of technology is considered necessary to meet either standard, even if application and calibration approaches differ.

[178] 7 large manufacturers representing 90% of the HDV market and 10 small manufacturers representing the remaining 10% of the market.

[179] ICCT, 2016. Costs of emission reduction technologies for heavy-duty diesel vehicles

[180] See footnote 167

€1.8 million to €3.5 million for a lead engine application.[181]

Costs during implementation phase – Testing and witnessing costs

The introduction of the Euro 6/VI emission standards has led to some changes to the testing requirements and procedure for granting type-approval – including type-approval, ISC and CoP – that were not applicable under Euro 5/VI (see chapter 3). As such, the sixth generation of Euro standards is associated with net increases in the testing costs, as well as increases in the time and effort type-approval authorities spend on witnessing these tests. In this context, increases in testing activity and the number of emission type-approvals is closely linked to the stepwise introduction Euro 6/VI. Moreover, a manufacturer indicated that the level of effort in this context and the associated costs for testing doubled between Euro 5 and Euro 6 pre-RDE, while it increased by a factor 5 between Euro 5 and Euro 6d. The introduction of Euro VI for lorries and buses, on the other hand, has increased the time and effort needed for testing and witnessing by a relatively lower extent of 50%.[182]

On the basis of the information made available by manufacturers and type-approval authorities during the targeted stakeholder consultation on the evaluation, the cost estimates for the testing and witnessing costs following the introduction of Euro 6/VI emission standards are summarised in Table 40.[183] Since not every vehicle needs to go through the implementation procedures explained above, not the costs per vehicle are relevant in this context, but the cost per model family for cars and vans, and per engine family for lorries and buses. For Euro 6, the testing costs per model family are estimated at €0-€34 thousand before the introduction of RDE testing and at €138-€286 thousand after the introduction. For Euro VI, these costs per engine family are expected to be between €93 and €227 thousand. As can be seen in the table, the increase in witnessing costs moving from Euro 5/V to Euro 6/VI are expected to be less important.[184]

Costs during implementation phase – Type-approval fees

Type-approval authorities participating in the first targeted stakeholder consultation provided input on the fees they charge on vehicle manufacturers, excluding the costs to cover witnessing discussed above. Their input suggested that the fees charged by authorities are generally very small ranging from €0 to €2 000 per type-approval to Euro 6 and ranging from €0 to €460 per type-approval to Euro VI depending on the specific authority. Table 40 presents the changes in the fees moving from Euro 5/VI to Euro 6/VI. There is no indication that these fees have systematically increased as a result of the introduction of Euro 6/VI. However, a small increase has been detected in the total cost associated with the fees for type-approval due to an increase in the number of emission type-approvals to the Euro 6 standard.[185] The Euro 6 requirements and the changes in specific aspects of the testing procedures meant that manufacturers had to re-test and request new type-approvals for existing models, while the introduction of CO_2 related monitoring and reporting obligations based on WLTP have led to an increase in the number of type-approvals.[186]

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[181] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.3.1.2 Regulatory costs of Euro VI
[182] See footnote 167
[183] See footnote 167
[184] See footnote 167
[185] See footnote 167
[186] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 3.4 Implementation of

Administrative costs

Detailed input on administrative costs in the form of costs for reporting and to fulfil other information provision obligations as part of the process for granting type-approval is not generally available. The administrative costs are estimated at €20 to €64 thousand per type-approval to Euro 6 and at €17.5 to €27.5 thousand per type-approval to Euro VI (see Table 40). Given the limited input provided by manufacturers, however, there is uncertainty which is partly covered in the range of the upper and lower cost estimates in the calculation. Further to that, the significant increase in administrative costs moving from Euro 5/V to Euro 6/VI still represent a relatively small share of the total costs.

Total regulatory costs for vehicle manufacturers

The total regulatory costs for manufacturers resulting from Euro 6 and Euro VI are presented in Table 40. The Euro 6/VI emission standards have resulted in a total regulatory cost estimated at €31-€76 billion. When looking into how these regulatory costs will develop after 2020 and considering a social discount rate of 3.8%[187] and a learning effect[188], the total net cost associated with the Euro 6/VI emission standards up to 2050 are estimated at €97-€222 billion. The weighted average of the total regulatory cost for the period up to 2020 is estimated at around €357-€929 per diesel vehicle and by €80-€181 per petrol vehicle for Euro 6 (cars and vans). For Euro VI for lorries and buses, the weighted average of the total regulatory costs is €3 717-€4 326 per vehicle.[189]

2) *Costs for component suppliers*

Next to the cost implications for vehicle manufacturers, the regulatory costs for component suppliers are also expected to be affected by Euro 6/VI emission standards. In general terms, these costs may include R&D costs to ensure that components are in compliance with the new requirements. In the case of aftertreatment technologies, this would mean development and testing costs to ensure that technologies guarantee that vehicles will be able to meet the new requirements. In the case of suppliers of engines requiring type-approval, certain costs during implementation phase will also be applicable.[190]

Suppliers participating to the targeted stakeholder consultation on the evaluation reported varying levels of costs[191], while in general higher costs were identified for the larger suppliers. Nevertheless, the feedback from three important suppliers to the targeted consultations shows that these costs for suppliers should be largely – if not fully – reflected in the increased costs for equipment paid by their client, the vehicle manufacturers. The increased costs for manufacturers, capturing also the costs for

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the legislation – Type-approval activity

[187] This rate is taken equal to 4%, as recommended by the Better Regulation Toolbox, Tool#61. The inflation rate within the EU was also taken into account in the calculations, which was -0.2% in October 2020, resulting to a total discount rate of 3.8%.

[188] For hardware and calibration costs a linear reduction of costs over a six-year depreciation period was assumed leading to a gradual reduction to 50% of the initial costs estimated.

[189] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.8 Conclusions

[190] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.3.2 Costs to suppliers

[191] Respondents indicated one-off costs ranging from less than 1 million to over 100 million for testing and product development and typically to less than 0.1 million for the administrative costs. In terms of recurrent costs, there were typically around 10% of the one-off costs.

suppliers, were already presented in Table 40.[192]

Regulatory costs for type-approval authorities

Apart from automotive industry, type-approval authorities are targeted by the Euro 6/VI emission standards as they are in charge of granting type-approval. Therefore, these authorities are expected to have been confronted with the following costs during implementation phase[193]:

- *One-off* costs for investment in new facilities and equipment as well as preparatory action taken in the form of training, development of guidance documents or other system updates.
- *Recurrent* costs associated with the increased need for human resources following the introduction of Euro 6/VI emissions standards, including the time needed for witnessing of type-approval, ISC and CoP tests and for reviewing documentation provided by vehicle manufacturers.

Input from type-approval authorities to the targeted stakeholder consultation on the evaluation showed that these authorities were faced with an increase[194] in costs during implementation phase following the introduction of Euro 6/VI emission standards.[195] Similar to the case for component suppliers, the costs for authorities are expected to be largely covered by vehicle manufacturers in the form of costs for witnessing the type-approval, presented in Table 40.

Indirect regulatory costs for consumers, including citizens and business users of vehicles

In evaluation question 3, the transmitted regulatory costs and its potential effect on the vehicle prices for consumers, either being professional (business users such as transport companies) or private, were already discussed. While it was difficult to identify evidence showing that the observed increase in prices of cars is directly linked to the Euro 6 emission standards, it is generally expected that manufacturers would have passed on the costs to consumers in the long term considering the monopolistic competition characteristics of the automotive market.[196] Assuming that manufacturers indeed pass on the full cost to consumers through increased prices, the relative impacts of this can be examined by comparing the vehicle prices with the net increase in costs per vehicle to assess what share of a vehicle price they actually represent. In order to do this properly, the lower cost estimates of Table 40 were compared to the weighted average of prices of vehicles in the smaller size segments, while the high cost estimates were compared with prices of vehicles in the higher segments.

As can be seen in Table 41, the estimated total costs per vehicle (2014-2020) in most

[192] See footnote 190

[193] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.4 Costs to type approval authorities

[194] For the recurrent cost, a large type-approval authority reported costs of up to €1 million, while another large authority that a total of 20 new staff member has to be hired. The latter also reported an increase of around 30% of the workforce responsible for granting type approvals. Also the smaller type-approval authorities reported an increase in the number of staff ranging between 2 and 4 new staff members.

[195] CLOVE, 2022. Euro 6/VI Evaluation Study. Annexes 1-6. ISBN 978-92-76-56522-2, Annex 6 chapter 9.6.8 Costs to Type-Approval authorities

[196] Mamakos, A. et al., 2013. Cost effectiveness of particulate filter installation on Direct Injection Gasoline vehicles

cases represent less than 2% of the average price for cars and vans. For the most recent step in Euro 6, the share of the cost for small segment cars and vans is found to be significantly higher in the case of diesel vehicles (4.3% for the small segment vehicles, compared to 2.7% for the large segment vehicles). This is mainly driven by the higher hardware costs linked to the technologies to ensure compliance with Euro 6d. For lorries, these costs are in the range of 4.2-5% for the average lorry price and for the typically more expensive buses, these costs should represent no more than 3% of the total purchase price.[197]

Table 41 – Regulatory costs of Euro 6/VI in comparison to average purchase prices per vehicle segment[198]

	Vehicle segment	Regulatory cost per vehicle (in €)	Average vehicle price (in €)	Share of vehicle price
Cars and vans	Small	265	17 209	1.5%
	Medium	377	31 933	1.2%
	Large	700	68 082	1%
Lorries	Small	4 195	100 000	4.2%
	Medium	6 447	130 000	5.0%
	Large	8 998	200 000	4.5%
Buses	Small	4 195	200 000	2.1%
	Medium	6 447	250 000	2.6%
	Large	8 998	300 000	3%

In all, there is no evidence suggesting that the impact of the regulatory costs associated with Euro 6/VI are not affordable for consumers. When stakeholders were asked in the public consultation to indicate what was the impact of Euro 6/VI on vehicle prices, the large majority of respondents from all stakeholder groups – industry, Member States, civil society and citizens – indicated that there has been an increase in the vehicle prices for all categories (cars, vans, lorries and buses). However, when asked if they agree that EU legislation makes cars unduly expensive a majority over all groups disagreed or even strongly disagreed. Hence, the impact on vehicle prices and consumers is not expected to have been significant or disproportionate.[199]

Are the costs affordable and justified?

While the affordability for consumers was already described above, also for automotive industry the costs are generally expected to be affordable. As the regulatory cost will be passed on to consumers to a great extent, any cost implication will only be for a short period until manufacturers manage to recover the extra costs through increased prices. But even in the absence of such a recovery, the total cost estimate for the period 2013-2020 as a combined result of Euro 6 and Euro VI represents no more than 2% of the total turnover of the sector (estimated at around €3.5-€4 trillion).[200] This is partly confirmed

[197] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.5 Impact of costs on consumers
[198] See footnote 197
[199] See footnote 197
[200] According to Eurostat Structural Business Statistics data (SBS_NA_IND_R2) for the manufacturer of motor vehicles (NACE 29.1), the total turnover of the sector increased from €600 billion in 2013 to €820 billion in 2018, the last year available. Assuming the same level per year for 2019-2020, the total turnover of the sector is around €5 trillion (2013 values) that includes revenues from the aftersales market and other

by the results of the public consultation: the majority of respondents from Member States and civil society indicated that the costs of complying with the Euro 6 limits and tests are affordable. Overall, industry seems to be more sceptical on the affordability. When splitting the industry group further, the majority of respondents from component suppliers and LNG fuel industry disagree with the affordability of the Euro 6/VI standard. The majority of manufacturers does not provide a clear answer as they neither agree nor disagree with the standards being affordable.[201] Nevertheless, the costs related to the legislation might be a challenge to some manufacturers with small production volumes who may only be able to recuperate these costs over a longer period.[202]

The rise in costs is seen as a result of the multiple stages in the introduction of RDE testing and the increasing complexity in the legislation. One manufacturer, for example indicated that the changes to the testing provisions often come at short notice leading manufacturers to change type-approval projects, leading to duplication of effort and increases in the type-approval activity since 2017, resulting in higher costs. Thus, it can be argued that some of these costs were unnecessary and could have been avoided if a more streamlined approach had been adopted, possibly over a longer period. However, this should be balanced against the benefits from the introduction of the RDE testing in decreasing vehicle pollutant emissions.[203]

Was simplification achieved by Euro 6/VI emission standards?

The description of the implementation of the Euro 6/VI emission standards in chapter 3.2 already gives a strong indication that the legislation is quite complicated. Hence, no tangible simplification has been achieved moving from Euro 5/V to Euro 6/VI. On the contrary, the legislative text has built on the previous texts adding new elements and additional requirements which has resulted in a text of more than 1 300 pages with multiple references to other pieces of legislation. In addition, the Euro 6/VI emission standards consist of several pieces of legislation, that are separate for light-duty (cars and vans) and heavy-duty vehicles (lorries and buses). That way, requirements have been introduced in various steps (Euro 6b-d(-temp) and Euro VI A-E) with different application dates depending on the vehicle types. Next to that, the complexity has increased as result of the new and more demanding testing requirements. In addition to the numerous lab-based test, on-road testing of vehicles has been introduced in Euro 6 in four different pieces of legislation via different enforcement mechanisms (type-approval, CoP, ISC).[204]

These observations indicating that Euro 6/VI emission standards have not led to simplification are widely supported by stakeholders from all groups. This is illustrated by the responses to the public consultation in which 98 out 128 stakeholders considered Euro 6/VI as very complex or complex. [205] A majority across all stakeholder groups

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services. Data on turnover from the main activity of the sector is only available for some Member States. Assuming a similar share of turnover from main activity to the total reported for all Member States, it leads to a total turnover of €3.5-€ 4 trillion for the period 2013-2020. This does not include the turnover of suppliers of components and equipment.

[201] See footnote 86

[202] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.6 Are the costs affordable for industry?

[203] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.1.7 Are there any of the costs that are unjustified/unnecessary?

[204] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.3 EQ10 Has Euro 6/VI achieved a simplification of vehicle emission standards in relation to EURO 5/V?

[205] See footnote 105

considered the emission test procedures to be complex. Also, the number of emission tests were perceived to be complex or even very complex across a majority of stakeholders. However, civil society representatives consider the more demanding emission tests and in-service conformity requirements as justified in view of the need to ensure that vehicles are clean. Lastly, 101 out of 128 stakeholders from all groups indicated that the different application dates for the stepwise Euro 6/VI approach, as described above, are complex to very complex. [206]

This identified complexity of Euro 6/VI emission standards is also seen in Table 40 as contributing to the costs during implementation phase for type-approval testing and witnessing, which increased between €153 000 and €368 000 per model family moving from Euro 5 to Euro 6 for cars and vans and between €95 700 and €232 000 per engine family moving from Euro V to Euro VI for lorries and buses. 88 out of 117 respondents to the public consultation from all stakeholder groups agreed or strongly agreed that complexity leads to significant costs[207].

Evaluation question 5: To what extent has Euro 6/VI been cost-effective? Are the costs proportionate to the benefits attained?

Overall conclusions: The Euro 6/VI emission standards are in general cost-efficient and have generated net economic benefits to society. The positive net benefits are estimated at €192-€298 billion for Euro 6 cars and vans. In particular diesel cars and vans have a high benefit associated with the emission savings for these vehicles. On the other hand, petrol cars and vans seems to have negative net benefits due to the limited NO_x emission savings and compliance costs for gasoline particulate filters. For Euro VI lorries and buses, very positive net benefits of estimated €490-€509 billion have been realised.

The regulatory costs of Euro 6/VI emission standards have been considered justified and proportionate in the public and targeted stakeholder consultation by a large majority across all stakeholder groups – industry, Member States and civil society – to ensure the necessary decrease in air pollutant emissions emerging from road transport and hence prevent negative effects on human health and environment.

Industry stakeholders however were somewhat sceptical, indicating that consumers do not really appreciate the improvements in aftertreatment technologies in vehicles, in contrast to the situation for fuel efficiency. On the other hand, the majority of stakeholders across all groups, including citizens, indicated that Euro 6/VI, and in particular the introduction of RDE testing in the wake of Dieselgate, at least contributed somewhat towards ensuring consumer trust in the type-approval system and automotive products.

The evaluation question 4 analysed the regulatory costs related to the introduction of Euro 6/VI emission standards and the related benefits of the intervention in terms of emission savings and reduced environmental health impacts were discussed under effectiveness (see chapter 5.1). In the following both will be compared to determine whether the intervention has achieved its operational objective of setting the next stage of emission limit values in a cost-effective way with specific focus on NO_x, PM and HC[208].

[206] See footnote 102
[207] See footnote 126
[208] See footnote 3

Hence, it will be determined whether the costs are proportionate to the benefits attained.

Since the benefits of the Euro 6/VI emission standards will continue in the future with the further penetration of Euro 6/VI vehicles in the European vehicle fleet, the analysis of the cost-effectiveness considers the period from the entry into force of Euro 6/VI in 2013/2014 until 2050, while considering a social discount rate of 3.8%[209]. On the basis of the damage costs for air pollutants[210], the benefits have been monetised for the main pollutants NO_x, PM and NMHC. The proportionality of these benefits to the costs for these three pollutants have been analysed using two indicators: the net present value[211] and benefit-cost ratio[212]. In addition, a third indicator - abatement cost per tonne of most dominant NO_x emissions avoided[213] - is used to further evaluate the cost-effectiveness of the realized NO_x savings over the discussed period.

Table 42 shows the results of the cost-effectiveness analysis. For Euro 6 and especially for Euro VI, high net present values are realised when comparing to Euro 5/V emission standards, meaning that the net present value of the benefits realised through Euro 6/VI outweigh the net present value of the costs. When looking into Euro 6, this appears to be driven by the high benefits associated with the emission savings for diesel cars and vans resulting in benefit-cost ratio of 2.5-5.9. The cost-effectiveness of the final steps of Euro 6, which introduced RDE testing, is found to be lower (2.5-4.7 for diesel vehicles and 1.6-3.1 in total). This is mainly a result of the higher costs associated with the RDE testing (see Table 40), (part of which are expected to continue in the future) as well with the significant emissions savings already achieved with the introduction of Euro 6 before RDE.

Table 42 – Analysis of cost-effectiveness of Euro 6/VI emission standards[214]

	Euro 6 (RDE) to Euro 5	Euro 6 RDE to Euro 6 pre-RDE	Euro VI to Euro V
	Total cars and vans		**Total lorries and buses**
Net Benefits (€ billion)	192-298	54-96	490-509
Benefit-cost ratio	2-4.7	1.6-3.1	15-33
Abatement costs for NOx [€/ton]	1.8-4.1	2.5-4.9	0.2-0.5
	Only diesel cars and vans		
Net Benefits (€ billion)	219-303.5	80-105.8	
Benefit-cost ratio	2.5-5.9	2.5-4.7	

209 See footnote 187

210 European Commission, 2019. Handbook on the external costs of transport

211 The net benefits are the monetary difference between the present value of the benefits and costs, considering base year 2013 for lorries and buses and 2014 for cars and vans. Thus, a positive value for this indicator (i.e. > 0) means that the net present value of the monetary benefits are greater than those of the costs. The net benefits consider the effectiveness of the initiative in absolute terms (thus the larger the difference between benefits and costs, the better).

212 The benefit-cost ratio is the ratio of the present value of the total monetised benefits in comparison to the present value of the total regulatory costs for the automotive industry. If the ratio is greater than 1, the net present value of the benefits outweighs the net present value of the costs. The ratio considers the effectiveness of the initiative independent from the scale (thus larger benefits can have the same ratio as smaller benefits when the costs are equally larger).

213 Abatement cost per tonne of NO_x emissions avoided is found by dividing the regulatory costs over the emission savings of NO_x, which was found to be the most dominant pollutant in terms of the monetised benefits. It has not been possible to disentangle the costs of focusing only on those covering NO_x emissions. The abatement cost is therefore underestimated to a certain extent.

214 CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.2.2.2 Analysis of cost-effectiveness

	Euro 6 (RDE) to Euro 5	Euro 6 RDE to Euro 6 pre-RDE	Euro VI to Euro V
Abatement costs for NOx [€/ton]	1.4-3.2	1.6-3.1	
	Only petrol cars and vans*		
Net Benefits (€ billion)	-26.7 / -5.3	-27 / -9.8	
Benefit-cost ratio	0.3-0.7	0.2-0.4	
Abatement costs for NOx [€/ton]	/	/	

*Not including benefits related to savings of PN emissions

While the cost-effectiveness indicators showed that the benefits achieved by the Euro 6/VI emission standards generally outweigh the costs for stakeholders, the analysis shows that this is not the case for petrol cars and vans. This is a reflection of the fact that the analysis does not capture the benefits of reduced PN emissions due to the absence of relevant data on emission factors, while it does take into account the moderate hardware costs for the related gasoline particulate filter (GPF) technologies (see above). As such, the monetised benefits for petrol cars and vans have been underestimated. Next to that, these petrol vehicles only realise limited NO_x emission savings under Euro 6 since the emission limits for petrol cars and vans remained unchanged in Euro 6. As a consequence, the negative net benefits are expected to underestimate the benefits for these vehicles. On this matter, other literature sources performed ex-ante analysis on the cost-effectiveness of the GPF technologies[215] from which we can reasonably expect that the total cost-effectiveness is higher than what is presented in Table 42, even though it might still be the case that the net benefits are negative, which means that the costs might not be proportionate to the benefits achieved for petrol cars and vans.[216]

The overall conclusion of a positive cost-effectiveness of Euro 6/VI emission standards is also supported by the targeted and public consultation. When asked in the targeted stakeholder consultation to evaluate the costs of Euro 6/VI emission standards in proportion to the benefits for human health and environment, a large majority across all stakeholder groups – industry, Member States and civil society – considered that the costs were quite or very low. Environmental NGOs, national authorities, a consumer organisation and a research institution argued that the benefits for human health and environment from the reduction of emissions are so great, that the regulatory costs, even if relatively high, are very well justified. In addition, two environmental NGOs stressed that considering the large external costs of air pollution from road transport in the EU-28 – calculated at around €49 billion for cars and vans and at €18 billion for lorries and buses in 2019[217] – reported in the Handbook on the external costs of transport[218], any emission savings can lead to significant reductions in the total external costs of air pollution to society.[219]

Stakeholders were less positive when asked to compare the regulatory cost of Euro 6/VI

[215] Mamakos, A. et al., 2013. Cost effectiveness of particulate filter installation on Direct Injection Gasoline vehicles. Considering hardware and indirect costs and not accounting for the impact of non-regulated sub-23 nm particles, the ex-ante study found that overall societal effect associated with the installation of a GPF would be anywhere between a net benefit of €78 per vehicle and a net cost of €217 per vehicle.

[216] See footnote 214

[217] In the EU-28 alone the external costs of air pollution from passenger cars has been calculated at €33.36 billion and for light commercial vehicles (vans) at €15.49 billion in 2019. For heavy goods vehicles (lorries), these external costs have been calculated at €13.93 billion, while for buses and coaches these were calculated at €4.02 billion in 2019.

[218] See footnote 210

[219] See footnote 214

with the benefits for their own organisation. For cars and vans, 6 industry stakeholders (including 4 manufacturers and 2 component suppliers), 3 Member States and 1 research institute out of the 27 respondents perceived the cost-effectiveness of Euro 6 for their organisation as negative. For lorries and buses, this were 4 respondents from industry (including 2 manufacturers and 2 component suppliers) and 2 from Member States out of the 19 stakeholders consulted.[220]

When comparing the regulatory costs of Euro 6/VI with the benefits realised for consumers, in the context of cars and vans 3 manufacturers and 2 suppliers were somewhat sceptical, while for lorries and buses this was 1 manufacturer. One component supplier and a research institution indicated that consumers do not really appreciate a direct benefit from pollutant emissions reduction and the respective improvements in aftertreatment technologies in vehicles, in contrast to the situation for fuel efficiency. That way, they indicate that consumers would not consider higher prices of vehicles related to Euro 6/VI as justified. In contrast, several stakeholders over all groups considered that the regulatory costs are justified by the benefits. One environmental NGO pointed out that the introduction of RDE testing has also been significant in addressing the important issue of consumer trust, which was severely affected in the wake of Dieselgate. This result was also found in the public consultation in which the majority of stakeholders across all groups – industry, Member States, civil society and citizens – indicated that Euro 6/VI at least contributed somewhat towards ensuring consumer trust in the type-approval system.[221] In addition, local initiatives in the form of restrictions for access to urban areas, such as Low Emission Zones, are also expected to change consumer perception of the importance of a vehicle's emissions performance.[222]

5.3. Relevance

Evaluation question 6: To what extent do the Euro 6/VI objectives of ensuring that vehicles on EU road are clean correspond to the current needs? Is there a demand/potential for cleaner vehicles on EU roads over their whole lifetime?

Overall conclusions: The Euro 6/VI objectives to improve air quality by reducing pollutants from road transport and to set harmonised rules on the construction of motor vehicles are still highly relevant. Progress has already been made to a certain level but air quality issues associated to road transport remain a persistent issue in European urban areas. Also new pollutant emission species being harmful for health or environment have arised since the adoption of Euro 6/VI more than a decade ago with the introduction of new engines, exhaust aftertreatment technologies, fuels and additives. Harmonised rules on the construction of motor vehicles are necessary to avoid the fragmentation of the Internal Market for vehicles by individual emission standards and to allow industry and public authorities to take advantage from economies of scale. There is also a demand for cleaner vehicles on EU roads over their whole lifetime as the average age and lifetime mileage of vehicles on EU roads have changed since the adoption of Euro 6/VI. The Euro 6/VI durability requirements appear to be significantly lower than the average fleet age and lifetime mileage for all vehicle types.

Recent policy developments, that means the European Green Deal and the New

[220] See footnote 214
[221] See footnote 145
[222] See footnote 214

Industrial Strategy for Europe, support the Euro 6/VI objectives and the relevance to improve air quality by reducing emissions from road transport. These policy developments emphasise the need to make transport significantly less polluting, especially in cities, in order to accelerate the shift to sustainable and smart mobility and thus support the competitiveness of the EU automotive industry on the global market. The European Green Deal roadmap therefore includes a proposal for more stringent air pollutant emissions standards for combustion-engine vehicles by 2021. At the same time, the European Green Deal underlines the EU's objective of achieving climate neutrality by 2050 and the roadmap includes a proposal for strengthened CO_2 standards for cars and vans by June 2021. The interplay of both emission initiatives will provide a pathway to zero-emission vehicles, while at the same time it will ensure that the remaining internal combustion engines are as clean as they can be.

Today's relevance of the objectives of Euro 6/VI emission standards

1) *Improving air quality by reducing pollutants emitted by the road transport sector*

Creating a toxic-free environment is of great importance to protect Europe's citizens and ecosystems. To realise this, it is vital to clean and remedy pollution, such as air pollution, but also to take action to prevent pollution from being generated in the first place. According to the World Health Organization (WHO), air pollution still represents the biggest environmental risk to health as it is still responsible for many premature deaths.[223] In 2018, PM concentrations were responsible for around 379 000 premature deaths in EU-28, NO_2 for 54 000 and O_3 for 19 400 deaths.[224][225] Since most activities that actively increase air pollutant emissions are situated in urban areas, they also suffer from higher ambient concentrations and greater exposure to such pollutants. While air quality in European urban areas has improved over the last decade, in 2017 a significant proportion of the urban population was still exposed to concentrations above the threshold defined by the Ambient Air Quality Directive (AAQD)[226]. When considering the more stringent guideline values of the WHO, an even larger proportion of people were exposed to exceeded levels, while these levels will be even higher with the revised 2021-WHO guidelines. Table 43 presents the significant, but still insufficient progress, towards diminishing the populations exposed to air pollution. In addition, road transport is still a major cause of this pollution, particularly when looking into NO_2 and NO_x emissions. In a JRC study focussing on European urban areas, the contribution of road transport to overall NO_x emissions was found to be 47% on average.[227] While a minimum contribution of 20% percent was found in Lisbon, maximum values of more than 70% were found in Athens and Milan.

[223] WHO, 2016. Ambient air pollution: A global assessment of exposure and burden of disease
[224] Emissions of NMVOCs, NOx, CO, which are regulated by Euro 6/VI emission standards, contribute to the formation of tropospheric ozone (O_3).
[225] EEA, 2020. Air quality in Europe 2020
[226] Directive 2008/50/EC on ambient air quality and cleaner air for Europe
[227] JRC, 2019. Urban NO2 Atlas

Table 43 – Percentages of the EU urban population exposed to air pollution levels exceeding the AAQD thresholds or the previous WHO guideline values in 2008 and 2018, based on data from EEA, 2020[228]

	Exceedance levels in urban population based on Ambient Air Quality Directive (%)		Exceedance levels in urban population based on WHO guidelines (%)	
Pollutants	**2008**	**2018**	**2008**	**2018**
NO_2	12.3	3.6	12.3	3.6
PM_{10}	23.9	15.0	74.9	48.3
$PM_{2.5}$	12.5	3.6	86.8	73.6
O_3	15.3	34.1	98.5	98.6

On the other hand, pollutant emissions from road transport have decreased considerably for key pollutants over the last two decades[229], even though gradual increases in transported passenger and freight volumes were realized during this period. [230] The majority of stakeholders from all groups – including industry, Member States and civil society – consulted through the targeted consultation considers emission standards to be a relevant mechanism to encourage a reduction in vehicle emissions that offsets potential increases in the demand for transport.[231]

Amongst the stakeholders, there is a wide consensus when it comes to the general relevance of air pollution issues and the respective role of road transport. 56 of 61 stakeholders from all groups confirm that there are ongoing issues, while 57 agree that there is an ongoing need to limit vehicle emissions from vehicles. When looking into the relevance of Euro 6/VI emission standards to reduce vehicle emissions, a majority across all stakeholder groups strongly agrees that there is a further need to set and enforce Euro emission standards. These stakeholders argue that air pollution is an externality that is not captured in the economic incentives of consumers and producers. If not for the Euro 6/VI emission standards, there would be no incentives for the development and deployment of pollution-control devices. Nevertheless, 5 stakeholders – mostly from industry – disagree that there is a further need for Euro emission standards to reduce vehicle emissions. These stakeholders point to other needs in this area, including the need to promote fleet renewal by Euro 6/VI vehicles and the need to ensure the interplay between pollutant and CO_2 emission standards.[232]

2) *Setting harmonised rules on the construction of motor vehicles*

As the previous Euro emission standards, Euro 6/VI sets and enforces emission standards in a harmonised way across the EU. This approach was considered necessary to prevent the emergence of different product standards across Member States as they would negatively affect the Internal Market. Through the creation of barriers to intra-EU trade, individual national emission standards are expected to result in the fragmentation of the Internal Market for vehicles. Up until now, no changes have occurred to the operation of either the EU internal market or the automotive sector that would suggest that a

[228] EEA, 2020. Exceedance of air quality standards in Europe
[229] The decrease in pollutant emissions emerging from road transport, however, slowed down since 2014.
[230] EEA, 2020. Air pollutant emissions data viewer (Gothenburg Protocol, LRTAP Convention) 1990-2018
[231] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.2.1 Need to take action in terms of reducing pollutants emitted by the road transport sector in order to improve air quality
[232] See footnote 231

harmonised approach in setting and enforcing vehicle standards is no longer relevant.[233]

Stakeholders of all groups that participated in the targeted consultation widely confirm the relevancy of tackling vehicle emissions in a harmonised manner. The majority indicated that both the effectiveness and strictness of standards would be lower if they were not developed at the EU level. According to three environmental NGOs, rules on emissions would be less strict if set by each Member State individually, as they would be incentivised to decrease the cost of compliance for their home industry and hence drive a race to the bottom. In addition, stakeholders confirm the need for harmonised rules to allow industry and public authorities to take advantage from economies of scale. One supplier emphasised that a harmonised approach allows for efficiency of development and certainty for product planning, while individual rules by Member States would have led to a patchwork of initiatives requiring industry to manage their emission technologies and fleets accordingly.[234]

Developments affecting the relevance of Euro 6/VI emission standards

Considering the recent policy developments at EU level, the relevance of the Euro 6/VI emission standards has not been compromised. On the contrary, the European Green Deal[235] presented in December 2019 is a new growth strategy that will foster the transition to a climate-neutral, resource-efficient and competitive economy and the move towards zero-pollution in Europe. It includes key elements on a zero pollution ambition for a toxic-free environment and on accelerating the shift to sustainable and smart mobility. To protect Europe's citizens and ecosystems, more action is required to prevent pollution from being generated as well as measures to clean and remedy it. Transport should become drastically less polluting, especially in cities. The European Green Deal roadmap therefore includes a proposal for more stringent air pollutant emissions standards for combustion-engine vehicles by 2021. These policy developments underline that it is still relevant to improve air quality by reducing emissions from road transport as they remain an issue for the EU. The New Industrial Strategy for Europe[236] presented in March 2020 lays the foundations for an industrial policy that will help Europe's industry to make this ambition a reality and further emphasises the relevance of setting and enforcing the environmental rules in a harmonised manner across the EU. This follows from the need for EU industry to become more competitive as it becomes greener.

The policy developments at local level also stress the relevance of the Euro emission standards. This is shown by the adoption of Low Emission Zones (LEZs) in more than 250 European cities for which a large proportion use the Euro emission standards as a basic criterion for granting access or determining the charge to be applied. Some cities (e.g. Amsterdam, Brussels, London, and Paris) go even further with their zero-pollution ambitions and have already announced different forms of Zero Emission Zones (ZEZs). For example, there are ideas to tighten the restriction rules in certain high-traffic zones that will result in a ban of diesel and petrol vehicles through a combination of access restrictions and charging for non-zero emission capable vehicles. Both applications by local authorities confirm the usefulness of Euro emission standards for kind of "labelling" purposes in access regulations. Additionally, the ambition for ZEZs in certain cities suggests that there is actually a need to update the Euro emission standards in line

[233] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.2.2 Need to set harmonised rules on the construction of motor vehicles
[234] See footnote 233
[235] See footnote 5
[236] COM(2020) 102 final, A New Industrial Strategy for Europe

with a zero-pollution target.[237]

Next to these developments, the EU's climate ambitions have been progressing over the last years leading to the recent 2030 Climate target plan[238] presented in September 2020, which put forward an increase of the climate target for 2030, to reduce greenhouse gas emissions by at least 55% by 2030. For road transport, CO_2 vehicle standards have proven to be an effective policy tool. By June 2021, the Commission will therefore revisit and strengthen the CO_2 standards for cars and vans for 2030.

This climate policy development goes hand in hand with the most relevant technological and market development that potentially affects the relevance of the Euro emission standards: the increasing uptake of electric and other alternative fuelled vehicles[239] that contribute to the decarbonisation of transport. Some of these vehicles (i.e. electric and hydrogen fuelled vehicles) do not generate CO_2 and tailpipe pollutant emissions, which makes them very important for reaching zero-emission targets. Hence, the uptake of such vehicles has been actively encouraged through a number of policy initiatives, including the Alternative Fuels Infrastructure Directive[240], the Clean Vehicles Directive[241] and CO_2 emission standards for new road vehicles[242]. Since the entry into force of Euro 6/VI emission standards, there has been a clear rise in the share of electric and hybrid cars and vans sold in the EU. This increase is illustrated in Table 44 and according to data reported by ACEA[243] for the third quarter of 2020, these percentage are still on the rise with almost 1 in 10 cars sold in the EU being battery electric or plug-in hybrid. Also for buses there is a clear trend towards alternative fuels with electric and CNG buses being already widely deployed in many EU cities. Electric and hydrogen lorries, compared to CNG/LPG lorries, are still in the development and testing phase, with commercial solutions expected in the coming years with the pace depending vehicle operations and weight.[244] [245]

Table 44 – Share of electric vehicles in new vehicles registered in the EU, based on data from European Alternative Fuels Observatory, 2020[246]

	Share of battery electric vehicles (BEV) in total new vehicles sold (%)		Share of plug-in hybrid electric vehicles (PHEV) in total new vehicles sold (%)	
Vehicle type	**2014**	**2019**	**2014**	**2019**

[237] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.3.2 Policy developments at local level

[238] COM(2020) 562 final, Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people

[239] As defined in the Directive 2014/94/EU, 'alternative fuels' means fuels or power sources which serve, at least partly, as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to its decarbonisation and enhance the environmental performance of the transport sector. This includes electricity, hydrogen, biofuels, synthetic and paraffinic fuels, natural gas, including biomethane, in gaseous form (compressed natural gas (CNG)) and liquefied form (liquefied natural gas (LNG)), and liquefied petroleum gas (LPG).

[240] Directive 2014/94/EU on the deployment of alternative fuels infrastructure

[241] Directive 2019/1161/EU on the promotion of clean and energy-efficient road transport vehicles

[242] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles; Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles

[243] ACEA, 2020. Press release 05/11/2020, Fuel types of new cars.

[244] European Alternative Fuels Observatory, 2020. Vehicles and fleet

[245] T&E, 2019. E-trucks: European automakers' third and final chance to get electrification right

[246] See footnote 244

	Share of battery electric vehicles (BEV) in total new vehicles sold (%)		Share of plug-in hybrid electric vehicles (PHEV) in total new vehicles sold (%)	
Cars	0.3%	2.1%	0.3%	1.2%
Vans	0.6%	1.2%	0.0% (0 vehicles)	0.0% (115 vehicles)

Considering this technological and market development, one might raise the question as to whether the need to introduce cleaner combustion engine vehicles through stricter emission standards is still relevant when a large proportion of the fleet emits no tailpipe emissions. When asked about this, stakeholders across all groups widely indicated that cleaning combustion engine vehicles is relevant to protect the environment and reduce air pollution (59 out of 64). Only 2 stakeholders from industry believed that the emergence of electric vehicles made the need for cleaning combustion engine vehicles irrelevant.[247]

While the market is changing fast, internal combustion engine vehicles are still expected to remain a significant part of the European fleet for several years, not only for heavier long-haul lorries. Therefore, the zero-pollution ambition for a toxic-free environment, introduced by the European Green Deal, can only be achieved with more stringent emission standards for these vehicles. As long as vehicles equipped with internal combustion engines - including hybrids (HEV, PHEV), CNG, LNG and any other alternative fuel - are sold, there will still be a need to make them as clean as possible in order to avoid adverse effects to human health and environment.

Changing needs for air pollutants and the considered lifetime of vehicles

The required coverage of air pollutants limits has potentially changed since the adoption of Euro 6/VI emission standards more than a decade ago. The air pollutant limits covered in the Euro 6/VI emission standards are presented in Table 35 (see section 2). While many pollutants are covered, some new pollutant emission species are arising with the introduction of new engines, exhaust aftertreatment technologies, fuels and additives.[248] In addition, the majority of respondents from all stakeholder groups, including industry, Member States, civil society and citizens, to the public consultation agreed that the Euro 6/VI emission limits do not cover all relevant pollutant.[249] This majority, however, is less convincing amongst industry respondent. 23 out of 68 industry respondents disagreed that not all relevant air pollutants are covered in the legislation. Industry stakeholders were especially reticent when asked whether there are currently unregulated pollutants emerging from road transport. While in total, the majority of stakeholders agree with this statement, 19 out of 52 industry stakeholders disagree and 16 neither agree nor disagree.[250]

Table 45 presents an overview of air pollutants that are not covered in the Euro 6/VI emission standards, while being harmful for health or environment. Some of these pollutants are aggregated in regulated wider pollutant categories and should be assessed separately if more precise pollution control is necessary (e.g. NO_2, NMOG and HCHO). Others pollutants, such as NH_3, ultrafine particles, brake emissions, evaporative

[247] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.3.3 Technological and market developments
[248] See footnote 53
[249] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 2)
[250] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 12)

emissions and CH_4 require new measurement methods. Many of these pollutants also came up in the public consultation, in which respondents that indicated that the current list of regulated pollutants is insufficient were asked which air pollutants should be added. 61 stakeholders answering this question from all stakeholder groups indicated that adding brake and tyre emissions, ultra-fine particles and NH_3 and CH_4 for cars and vans is most relevant. While also N_2O was pointed out by the majority of stakeholders answering this question, NO_2, HCHO and NMOG were considered less relevant.[251]

Table 45 – Non-regulated pollutants related to road transport relevant to health and environment[252]

Air pollutants	Why of concern
Nitrogen dioxide (NO_2)	The use of aftertreatment systems could cause an increase in the NO_2 to NO_x ratio of vehicle exhaust. However, this effect seems to have been mitigated in the later steps of Euro 6/VI as the SCR systems preferentially digest NO_2, and the remaining NOx tends to be dominated by NO.
Ammonia (NH_3)	Current technologies used for restricting NOx emissions in line with the Euro 6/VI requirements cause an "ammonia slip", while high NH_3 emissions are also seen in gasoline vehicles.[253] However, the use of ammonia slip catalysts (ASC) has mitigated this effect in later steps of Euro 6/VI.
Formaldehyde (HCHO)	Formaldehyde emissions are the result of the incomplete burning of the alcohol content of the fuel. Therefore, they increase with high ethanol content in the fuel. Gasoline with higher ethanol content (E10) seems to be gaining momentum.[254]
Non-methane organic gases (NMOG)	Oxygenated hydrocarbons, including alcohols and aldehydes, are not adequately quantified under the NMHC limits and are ozone precursors. Exposure to ozone levels is still clearly exceeding recommended values (see Table 43).
Ultra-fine particles[255]	PN limits only take into account solid particles larger than approximately 23 nm, that means only non-volatile particles; while smaller particles have detrimental health effects.
Brake emissions	Brake wear has been recognized as the leading source of non-exhaust particles, contributing up to 21% of all PM_{10} emissions related to traffic.[256] A measurement procedure is under discussion in the GRPE Particle Measurement Programme.[257]
Evaporative emissions	Evaporative VOC emissions from vehicles account for an increasing proportion of total vehicle emissions.[258] This is due to improvements in NMVOC tailpipe emissions but also to increasing share of petrol engines, ethanol content and high temperature episodes.[259]

[251] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 12.2)
[252] See footnote 97
[253] See footnote 96
[254] See footnote 253
[255] Volatile, semi-volatile and solid particles smaller than 23 nm from vehicle exhaust
[256] Grigoratos, T. & Martini, G., 2015. Brake wear particle emissions: a review
[257] See footnote 253
[258] EEA, 2020. Air pollutant emissions data viewer (Gothenburg Protocol, LRTAP Convention) 1990-2018
[259] See footnote 53

Methane (CH_4)[1]	Methane emissions become especially concerning when methane is used as a fuel (natural gas, bio-methane, synthetic methane). Less than 1% of the EU vehicle fleet is powered with CNG. However, it is expected that natural gas vehicles will have a role in the decarbonisation agenda, especially if blended with bio-methane.[260]
Nitrous oxide (N_2O)	The use of aftertreatment systems could cause an increase in N_2O emissions, which is an important greenhouse gas. For gasoline vehicles, particularly high N_2O emissions have been observed on positive ignition (PI) engines equipped with three-way catalysts.[261]
Tyre emissions	Similar to brake emissions, this unconventional source of emissions contributes to the formation of PM and PN. As emissions arising from these sources have also amplified through the increasing popularity of large and fast-accelerating vehicles (e.g. SUVs and electric vehicles), these emissions become more concerning. However, measurement procedures are still lacking for tyre emissions.[262]

[1] NH_3 and CH_4 are regulated for lorries and buses

Furthermore, the average age and lifetime mileage of vehicles on EU roads might have changed since the adoption of Euro 6/VI emission standards in a way that the durability provisions, which set requirements for manufacturers to check the in-service conformity and the durability of their vehicles, no longer reflect the average lifetime and mileage of vehicles.

In Table 46, a comparison is made of the Euro 6/VI provisions and the actual situation on EU roads. Based on this evidence, the time limits and the durability requirements appear to be significantly lower than the average fleet age and lifetime mileage for all vehicle types. Especially when considering the recent upward trend in the average vehicle lifetime for all vehicle types.[263] In addition, the increasingly complex pollution-control devices have introduced more complex engineering approaches in today's vehicles which require a more complete demonstration of durability. Also, recent developments in the field of on-board monitoring introduce a need for more comprehensive monitoring which is not properly reflected in the Euro 6/VI durability requirements.[264]

These finding are supported by the results of the public consultation. When asked to evaluate the statement pointing out that real-world emissions are not adequately limited over the entire lifetime of vehicles, the majority of respondents from Member States, civil society and citizens indicated that that they somewhat or completely agreed. Within the industry, 29 out of 59 respondents were of the opinion that emissions are adequately monitored.[265] In addition, a very strong majority of stakeholders from all groups indicated that both vehicle ageing and the costs of vehicle maintenance contribute somewhat or even to a (very) great extent to an increase in air pollutant emissions.[266]

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[260] ACEA, 2020. Natural and renewable gas: Joint call to accelerate the deployment of refuelling infrastructure
[261] See footnote 97
[262] See footnote 253
[263] ACEA, 2020. Average age of the EU motor vehicle fleet, by vehicle type
[264] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.3.1.5 Are there any developments that have introduced a need for action to appropriately monitor the emissions performance of vehicles over their complete lifetime?
[265] See footnote 113
[266] See footnote 103

Table 46 – Comparison Euro 6/VI durability requirements and average fleet in 2020, based on data from ACEA, 2020 and Ricardo Energy & Environment, 2020 (see columns)

Vehicle type	Euro 6/VI durability requirement	Average EU fleet[267]	Euro 6/VI durability requirement	Average EU fleet[268]
Cars	5 years	10.8 years	160 000 km	225 000 km
Vans	5 years	10.9 years	160 000 km	200 000 km
Light / medium lorries and buses	5 / 6 years	12.3 years	160 000 / 300 000 km	510 000 / 570 000 km
Heavy lorries and buses	7 years	12.3 years	700 000 km	800 000 km

[1] In-service conformity measures: 100 000 km

5.4. Coherence

Evaluation question 7: Are the Euro 6/VI emission standards coherent internally and with other legislation pieces applying on the same stakeholders and with similar objectives? Are there any inconsistencies, overlaps or gaps?

Overall conclusions: Stakeholders from all groups - including industry, national authorities, technical services and civil society - confirm in the targeted consultation that, overall, vehicle manufacturers are provided with a coherent policy and legal framework to reduce vehicle emissions. Nevertheless, there are some inconsistencies as follows.

Regarding internal coherence within Euro 6/VI emission standards, stakeholders from all groups indicate that there are inconsistencies in the Euro 6 standards for cars and vans, and to a lesser extent in the Euro VI standards for lorries and buses, when it comes to different emission limits for diesel and petrol vehicles, deadlines for compliance and the testing procedures. Moreover, ammonia and methane are regulated in Euro VI only and there seems to be a lack of clear border between Euro 6 and Euro VI.

Regarding external coherence with other EU legislation, the Air Quality Directive, CO_2 emission standards and Roadworthiness Directive are of relevance.

Stakeholders from all groups indicated the existence of consistency issues between Euro 6/VI emission standards and the Air Quality Directive. The main problem seems to be that Euro 6/VI emission limits were based upon the best available technology to provide cost-effective solutions, while there was too little consideration of the actual air quality problems they should help to overcome. There are some differences in the pollutants regulated in both legislations but this is substantiated by Euro 6/VI covering tailpipe emissions from road transport and Air Quality Directive covering all air pollution sources.

Mixed views and evidence are found for the relationship between Euro 6/VI and the CO_2 emission standards. While trade-offs could exist, no significant evidence was found to suggest that Euro 6/VI emission standards resulted in unintended negative

[267] ACEA, 2020. Average age of the EU motor vehicle fleet, by vehicle type
[268] Ricardo Energy & Environment, 2020. Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA

consequences for CO_2 emission standards. It can, however, be expected that the separate frameworks lead to some inefficiencies, both in terms of cost and in the processes to develop and deploy technologies.

The Euro 6/VI emission standards and the Roadworthiness Directives on Periodic Technical Inspections (PTI) and Roadside Inspections (RSI) do not yet operate in the complementary way necessary to ensure the best possible level of environmental and health protection by reducing air pollutant emissions from road transport. To guarantee protection against degradation, failure or tampering of pollution-control devices during the lifetime of vehicles, improvements in the requirements for on-board diagnostics systems in the Euro 6/VI emission standards are important that can be used for emission testing during PTI and RSI.

Regarding external coherence with other policy developments, it should be noted that taxation is applied inconsistently across the EU for different types of vehicles, that the competitive position of the EU industry is still undermined through the lower stringency of the requirements in Euro 6/VI emission standards compared to other key markets (i.e. US, China) and that arising local Low- and Zero Emissions Zones are using Euro 1/I to 6/VI as "labelling" criteria in a different manner and timing.

Stakeholders from all groups – including industry, national authorities, technical services and civil society – confirm in the targeted consultation that, overall, vehicle manufacturers are provided with a coherent policy and legal framework to reduce vehicle emissions (in total 38 out of 47).[269] Most stakeholders that responded negatively to this statement include industry representatives, suggesting that the automotive industry has more negative views when it comes to coherence in an emission standards context.

Internal coherence within Euro 6/VI emission standards

The assessment of internal coherence looks into the different components from Euro 6/VI emission standards and examines how they operate together and to which extent there are any inconsistencies, overlaps or gaps within and between the four Euro 6/VI Regulations[270].

A large share of industry stakeholders indicate that there are inconsistencies in the Euro 6 standards for cars and vans when it comes to the emissions limits (16 out of 19), and the testing procedures (17 out of 20). When it comes to the testing procedures, consistency issues are for example identified in RDE and PEMS error margins, the use of WLTP for heavy vans, differences in obligations for ISC and type-approval for specific vehicles and redundancies of certain low-temperature requirements. Next to these testing issues, differences in other provisions for cars and vans are indicated as causing internal inconsistencies for Euro 6. Differing treatment for these types of vehicles in terms of deadlines for compliance and emission limits could result in environmental costs to society, as vans are allowed to pollute more than comparable cars. There are also persistent differences based on fuels. While a PN limit was established in Euro 6, this limit does not apply to all petrol vehicles, excluding port fuel injection (PFI) petrol engine vehicles. Additionally, several stakeholders from industry, national authorities

[269] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.4.1.1.2 Internal coherence issues on Euro 6
[270] See footnote 1

and one research organisation point out that by setting different emission limits for diesel and petrol vehicles, the Euro 6 emission standards are lacking in fuel- and technology neutrality. Also in the public consultation, a majority of stakeholder across all groups – industry, Member States, civil society and citizens – indicated that these differences in limits result in some complexity.[271] While this lack of fuel-and technology neutrality can be perceived as an internal coherence issue, it should be noted that the differences were partly justified as they took into account the cost-effectiveness of imposing certain limits for certain fuels. While these differences between diesel and petrol can have detrimental effects in achieving lower levels of air pollution, they are rather a limitation of the emission standard than an inconsistency.[272]

For the Euro VI emission standards for lorries and buses some stakeholders over all groups – including industry and some national authorities - indicate consistency issues with either emission limits (9 out of 20) or with testing procedures (7 out of 18). Nevertheless, the majority of vehicle manufacturers directly responsible for the implementation of Euro VI indicate that there are inconsistencies when it comes to testing (5 out of 6) and the limits (6 out of 7), providing examples such as differences in cold/warm weighing in WHTC and PEMS conformity factors. Also for Euro VI, some suppliers and testing organisations describe several limitations that are not necessarily inconsistencies, including the lack of fuel- and technology neutrality and the use of unclear terminology.[273]

The identified inconsistencies in Euro 6/VI emission standards are, however, not expected to result into costs for the manufacturers and type-approval authorities dealing with the legislation on a daily basis according to the majority of stakeholders from all groups. If negative effects on costs are identified, most stakeholders that provided specific information (including a public authority and a consumer organisation) often expect that these costs are likely to be borne by consumers or society at large.[274]

There are potential coherence issues between the Euro 6 emission standards for cars and vans and the Euro VI emission standards for lorries and buses. As a first issue, a testing organisation pointed to the fact that while Euro VI includes limits for ammonia (NH_3), Euro 6 does not. This pollutant is included in the Euro VI emission limits as the pollution-control devices used in diesel lorries and buses can lead to sizeable NH_3 emissions in case of malfunctioning or poor calibration. As already raised under Evaluation Questions 1 and 6, similar technologies for restricting NO_x emissions also cause a similar "ammonia slip" for cars and vans, which leads to high levels of NH_3 emissions. Nevertheless, no limit is in place for NH_3 in the Euro 6 standards.[275] The same issue applies to methane (CH_4) that is regulated under Euro VI but not under Euro 6, although all type of vehicles use natural gas to an increasing degree, the main source of CH_4 emissions.

A second issue is related to the lack of a clear border between Euro 6 emission standards for cars and vans and Euro VI emission standards for lorries and buses. The border cross-

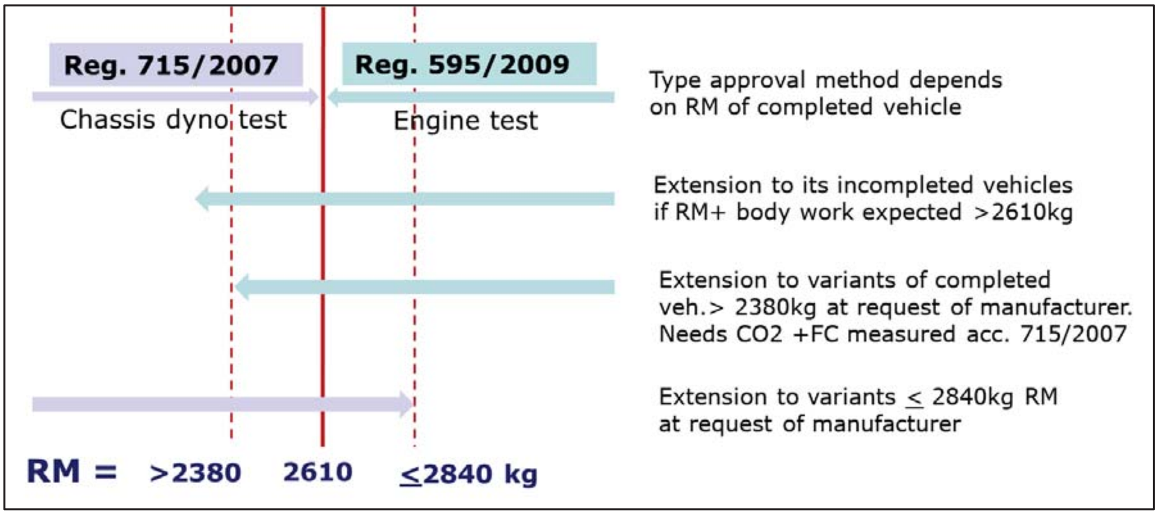
[271] See footnote 102
[272] See footnote 269
[273] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.4.1.1.6 Internal coherence issues identified on Euro VI
[274] See footnote 269
[275] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.4.1.1.8 Incoherence between Euro 6 and Euro VI

over from Euro 6 to Euro VI depends on the reference mass[276] of the vehicle. In principle, all vehicles with a reference mass exceeding 2 610 kg fall under Euro VI and its engine test procedure, while vehicles up to this reference mass fall under Euro 6 and its chassis dynamometer testing. However, there are some exceptions causing an overlap in the reference mass range between >2 380 kg and ≤2 840 kg resulting in a grey zone (see Figure 24). As pointed out by experts in the targeted stakeholder consultation on the evaluation and in AGVES, vehicles which fall in this grey zone may have to be tested under Euro 6 and Euro VI. Moreover, the use of reference mass prevents the alignment of vehicle categories M and N for cars, vans, lorries and buses with the EU vehicle type-approval framework[277] and the CO_2 emission performance standards for new heavy-duty vehicles[278], which use technically permissible maximum laden mass[279]. This coherence issue between the Euro 6 and Euro VI emission standards causes obscurity and prevents optimal environmental protection.[280]

The results from the public consultation show a gap between the industry respondents and the other stakeholder groups (Member States, civil society and citizens) on whether having a separate regulatory framework for cars/vans and lorries/buses brings any complexity to the Euro standards. While a large majority of stakeholders from Member States, civil society and citizens (49 out of 66) indicated that such a separate regulatory framework is at least somewhat complex, a majority of industry stakeholders (39 out 60) said that it was not complex at all.[281]

[276] As defined in Regulation (EC) No 715/2007 and Regulation (EC) No 595/2009, 'reference mass' means the mass of the vehicle in running order less the uniform mass of the driver of 75 kg and increased by a uniform mass of 100 kg.
[277] As defined in Regulation (EU) 2018/858, 'Category M consists of motor vehicles designed and constructed primarily for the carriage of passengers and their luggage, divided into: (i) Category M_1: motor vehicles with not more than eight seating positions in addition to the driver's seating position …; (ii) Category M_2: motor vehicles with more than eight seating positions in addition to the driver's seating position and having a maximum mass not exceeding 5 tonnes …; and (iii) Category M_3: motor vehicles with more than eight seating positions in addition to the driver's seating position and having a maximum mass exceeding 5 tonnes …; Category N consists of motor vehicles designed and constructed primarily for the carriage of goods, divided into: (i) Category N1: motor vehicles with a maximum mass not exceeding 3,5 tonnes; (ii) Category N2: motor vehicles with a maximum mass exceeding 3,5 tonnes but not exceeding 12 tonnes; and (iii) Category N3: motor vehicles with a maximum mass exceeding 12 tonnes. … Maximum mass means the technically permissible maximum laden mass.'
[278] See footnote 33
[279] As defined in Regulation (EU) No 1230/2012, 'technically permissible maximum laden mass' means the maximum mass allocated to a vehicle on the basis of its construction features and its design performances.
[280] AGVES, 2020. Ad hoc meeting on Simplification 16 November 2020; HDV CO2 Editing Board, 2019. HD CO_2 Light lorries and light buses, TNO, 2 December 2019
[281] See footnote 102

Figure 24 – Schematic picture of border between Euro 6 for cars and vans, and Euro VI for lorries and buses[282]



External coherence with other EU legislation and other policy developments

1) *External coherence with other EU legislation*

One Directive that will not be further discussed in this section is the Fuel Quality Directive[283]. While this piece of legislation also indirectly regulates certain air pollutants[284], these pollutants stemming from fuels, and not from tailpipe emissions, are not regulated in the Euro 6/VI emission standards. Hence, there is no overlap between the two legislations.

a. *Ambient Air Quality Directive and the National Emission Ceilings Directive*

The Ambient Air Quality Directive (AAQD)[285] and the National Emission reduction Commitments Directive (NECD)[286], which were already introduced in Evaluation Questions 3 and 6, aim to improve air quality across the EU by setting concentration limits in ambient air concerning specific air pollutants and long-term overall emission reduction targets concerning the main air pollutants from all relevant sources. Considering that Euro 6/VI emission standards focus on the reduction of tailpipe and evaporative pollutant emissions from road transport to improve air quality, the objectives of the different pieces of legislation and their intended achievements are connected.

Stakeholders from all groups participating in the targeted consultation – industry, Member States and civil society – indicated the existence of consistency issues between Euro 6/VI emission standards and the AAQD (27 of the 39). Reflecting on the specific causes for this identified inconsistency, the following were mentioned. A type-approval authority and an environmental NGO noted that when the Euro 6/VI emission standards

[282] See footnote 53
[283] Directive 2009/30/EC amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels on Fuel Quality
[284] Hydrocarbons such as benzene and polycyclic aromatic hydrocarbon (PAH), oxygenates, sulphur content, lead content
[285] See footnote 226
[286] See footnote 147

were constructed, there was little consideration of the actual air quality problems they should help to overcome. On the contrary, the limits were based upon the best available technology to provide cost-effective solutions taking into account the implications on competitiveness. However, the environmental NGO underlined that a significant proportion of the EU's population is still exposed to air pollution and road transport is still an important contributor. As such, more stringent Euro emission standards are potentially needed to ensure coherence with the overall EU objectives on air quality. On the other hand, four industry stakeholders stressed that for AAQD targets to be achieved through the Euro standards a very large turnover of the fleet would be needed, which conflicts with the AAQD goal of turning non-compliance areas into compliance areas "as soon as possible".[287]

With the exception of CO which is regulated in the AAQD and the Euro 6/VI emission standards, there are differences in the species or in their specification in the different legislations. The Euro 6/VI emission standards regulate limits for THC, which is nearly – but not quite – the same as VOCs which is regulated in AAQD, for NO_x which is the sum of the harmful NO_2 regulated separately in AAQD and the much less harmful NO, and for PM rather than the more specific PM_{10} and $PM_{2.5}$ regulated in AAQD.[288] O_3 (ozone), which is regulated in AAQD, is not a tailpipe emission and hence not regulated in the Euro emission standards. Instead, O_3 precursors (NOx, THC, NMHC and CO), are regulated in Euro 6/VI. Other air pollutants regulated under the Ambient Air Quality Directives such as SO_2, benzene, lead, arsenic, cadmium, nickel, and benzo(a)pyrene are considered less relevant for tailpipe emissions of vehicles but important for pollutants emerging from other sources, as air quality targets cover all air pollution sources.

For road transport, the 2019 fitness check of the Ambient Air Quality Directives[289] indicated that challenges in the implementation and enforcement of the vehicles emission standards have had negative consequences for air quality. However, the changes introduced in European regulatory framework since 2015 in the wake of Dieselgate – including RDE testing – led to improvements and tighter EU supervision that should help the Euro emission standards to further support the AAQD goals.

b. CO_2 emission performance standards for cars, vans and heavy-duty vehicles

A narrow majority of industry stakeholders in the targeted consultation indicated to be aware of inconsistencies between the objectives of Euro 6/VI and CO_2 emission standards (11 out of 21). One consumer organisation implied that the inconsistency is due to the fact that pollutant and CO_2 emissions are treated separately.[290]

While the Euro 6/VI emission standards aim at reducing air pollutant emissions from

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[287] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.4.2 EQ 13 - To what extent is E6/VI consistent with other legislation pieces applying on the same stakeholders and with similar objectives? Are there any inconsistencies, overlaps or gaps?

[288] See footnote 287

[289] SEC(2019) 427 final, Commission Staff Working Document, Fitness Check of the Ambient Air Quality Directives (Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air and Directive 2008/50/EC on ambient air quality and cleaner air for Europe). The Ambient Air Quality Directives define and establish objectives and standards for ambient air quality for 13 air pollutants to be attained by all Member States across their territories against timelines laid out in the Directives. These are: sulphur dioxide (SO2), nitrogen dioxide (NO2) and nitrogen oxides (NOx), particulate matter (PM10 and PM2.5), ozone (O3), benzene, lead, carbon monoxide, arsenic, cadmium, nickel, and benzo(a)pyrene.

[290] See footnote 287

new cars, vans, lorries and buses, the CO_2 emission performance standards aim at reducing CO_2 emissions from the same vehicles.[291] Since both standards aim at reducing emissions from different species, there is no direct overlap between their objectives. Moreover, the Euro 6/VI emission standards set pollutant limits that each vehicle must comply with due to the local impact of pollutant, whereas the CO_2 emission standards set CO_2 targets for the vehicle fleet due to the global impact of CO_2.

A limited number stakeholders from industry, national authorities and technical services that participated in the targeted consultation consider that there are trade-offs between the CO_2 and Euro 6/VI emission standards (7 out of 64).[292] The reasoning behind this is that technologies for meeting Euro 6/VI emission limits could increase fuel consumption and that the CO_2 emission standards could increase pollutant emissions as they would encourage the use of diesel vehicles which are usually more fuel efficient, but emit higher NO_x emissions than petrol vehicles. However, the CO_2 standards also promote the adoption of zero- and low-emission vehicles, which supports the reduction of pollutant emissions and shows that synergies can also be realised in this context. Two industry stakeholders agreed on this matter by indicating that while there are trade-offs in some emission technologies, in others reductions in both air pollutant and CO_2 emission can be realised (e.g. for BEVs).[293] Taking this into account, it is possible that the legal frameworks provide somewhat inconsistent incentives for consumers. However, every new vehicle has to comply with both the Euro 6/VI and the CO_2 emission standards, therefore any trade-off between CO_2 and air pollutants – especially NO_x – is expected to be minimal.[294]

It should also be mentioned that consistency with the CO_2 emission standards is also realised through coherent CO_2 and pollutant measurement methods under Euro 6/VI emission standards. For cars and vans, the Euro 6 testing procedure WLTP is used for determining CO_2 and pollutant emissions. For lorries and buses, the CO_2 emissions are determined for the vehicle by the VECTO simulation tool due to the large number of variants in engine, transmission, axles and bodies.[295] The CO_2 emissions of the engine and the other components are input data to VECTO, and CO_2 and pollutant emissions of the engine are measured using the Euro VI testing procedures WHTC and WHSC.

Some stakeholder from industry also argued that in general there is limited coordination between the Euro and CO_2 emissions standards and that the duplication of legislative acts aimed at different emissions also adds to the costs that the industry has to incur. While the approach could affect the costs for industry, which also has to bear costs from other advancements in for example automated vehicles, there is still room for further cooperation to improve consistency between the standards to develop an integrated approach which would provide a more consistent message to industry and consumers.[296]

[291] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 setting emission performance standards for new passenger cars and (EU) No 510/2011 setting emission performance standards for new light commercial vehicles; Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles
[292] See footnote 292
[293] See footnote 287
[294] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapters 5.1.4.3.2 Role of CO_2 emission targets and 5.4.2.1.2 Coherence with vehicle CO_2 standards
[295] Regulation (EU) 2017/2400 implementing Regulation (EC) No 595/2009 as regards the determination of the CO2 emissions and fuel consumption of heavy-duty vehicles and amending Directive 2007/46/EC of the European Parliament and of the Council and Commission Regulation (EU) No 582/2011
[296] See footnote 287

However, no significant evidence was found to suggest that Euro 6/VI emission standards resulted in unintended negative consequences for CO_2 emission standards.[297] It can, however, be expected that the separate standards lead to some inefficiencies, both in terms of cost and in the processes to develop and deploy technologies.[298]

c. Roadworthiness Directives

The Directives on roadworthiness of vehicles[299] have the objective to contribute to the reduction of emissions from road transport through measures aiming at detecting more effectively and removing from circulation vehicles which are over-polluting due to technical defects. That way, roadworthiness testing for emissions is primarily focussed on ensuring that key pollution-control devices are present and operating correctly and are hence roadworthy. This is done through two types of inspections: the Periodic Technical Inspection (PTI) – which takes place at fixed intervals allowing the owner to prepare for a standard testing procedure – and the Roadside Inspections (RSI) – for which vehicles are selected on the road and the inspector can more freely determine what is inspected.

Nevertheless, stakeholders from all groups in the targeted consultation, including 7 (3 type-approval authorities, 3 public authorities and 1 technical service) out of the 8 authorities or technical services that answered this question, indicate that there are inconsistencies or conflicts between the Roadworthiness Directives and the Euro 6/VI emission standards. Two main sources of inconsistency between the legislations were discovered: the first one lies in the Roadworthiness Directives, while the second one is a problem of the Euro 6/VI emission standards.

The Roadworthiness Directives do not take into account a potential need to assess compliance with the emission limits set in the Euro 6/VI emission standards. Despite the objectives of roadworthiness emission testing (both PTI and RSI) towards reducing pollutant emissions, the limited nature of the unloaded tests results in poor alignment with the Euro 6/VI emission standards. In this context, one research organisation, two public authorities and one NGO[300] agreed that roadworthiness testing – and especially PTI – could and should be more directly correlated to the Euro 6/VI emission standards. One environmental NGO and a technical service association replying to the Combined Evaluation Roadmap/Inception Impact Assessment[301] stressed the importance of strengthening and improving PTI. In addition, the results of the public consultation stressed that the majority of the participating stakeholders from Member States, civil society and citizens indicated that inadequate PTI and RSI contribute to a great or even a very great extent to an increase in emissions.[302]

The Euro 6/VI emission standards tightened the thresholds for the provision of information from on-board diagnostics (OBD) systems that are used for emission testing during PTI. However, Euro 6/VI emission standards do still not include requirements on OBD that are sufficient to properly support emission testing during the lifetime of vehicles. This is due to the fact that OBD systems currently have limited capacity and are

[297] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.1.6.2 Have there been any impacts from the Euro 6/VI in relation to: prices of vehicles, CO_2 and other emissions?
[298] See footnote 287
[298] See footnote 287
[299] Directive 2014/45/EU and Directive 2014/47/EU
[300] Transport & Environment, 2020. Road to Zero: the last EU emission standard for cars, vans, buses and trucks
[301] See footnote 50
[302] See footnote 108

ineffective in detecting and diagnosing degradation, failure or tampering[303] of pollution-control devices. These issues may not only be technical but also behavioural. The issues with OBD result in, for example, PTI not being capable of detecting whether a good functioning particulate filter is in place in diesel vehicles.[304] Four stakeholders – one from industry, one type-approval authority, one research institution and one environmental NGO[305] – criticised the Euro 6/VI emission standards for not including sufficient PTI/RSI provisions that could require checks of vehicles during their lifetime and efficient tools, especially software, to prevent manipulation. As a result, the majority of respondents to the public consultation from Member States and civil society disagreed that OBD ensures that new vehicles are compliant with the pollutant limits over their entire lifetime.[306]

2) *External coherence with other EU and national policy developments*

a. *Other EU policy developments*

Considering other EU policies (i.e. taxation, industry and employment), most coherence issues were found in taxation policy. 11 out of 36 stakeholders from all groups identified issues in this area. Industry indicated that taxation is applied inconsistently across the EU for different types of vehicles[307]. While unified tax incentives and disadvantages would help manufacturers focus their efforts, this would also be beneficial for health and environment as similar taxation across Member States avoids that old and less clean vehicles are sold to Eastern Europe.[308] As set out in the European Green Deal roadmap, the Commission will propose by June 2021 to revise the Energy Taxation Directive[309], focusing on environmental issues, and proposing to use the provisions in the Treaties that allow the European Parliament and the Council to adopt proposals in this area through the ordinary legislative procedure by qualified majority voting rather than by unanimity.

While no stakeholders expressed concerns regarding potential inconsistencies between Euro 6/VI emission standards and EU employment policy, an environmental NGO voiced its concerns on the coherence with EU industrial policy. The stakeholder indicated that the unintended Dieselgate event negatively affected the reputation and competitiveness of European industries and while the introduction of RDE testing improved the industry's competitiveness, the competitive position of the industry is still undermined through the lower stringency of the requirements in Euro 6/VI emission standards compared to other key markets (i.e. US, China). This opinion shows that there might be some consistency issues between Euro 6/VI emission standards and industrial policy. In addition, through the New Industrial Strategy for Europe[310], which was already

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303 See footnote 107

304 Kadijk G., Spreen J.S. & van der Mark P.J., 2016. Investigation into a Periodic Technical Inspection test method to check for presence and proper functioning of Diesel Particulate Filters in light-duty diesel vehicles

305 See footnote 96

306 See footnote 113

307 ACEA, 2021. According to ACEA website accessed on 15 January 2021, there is still a huge variation in both the basis for taxation and tax levels across the European Union. Several Member States tax cars on their power, price, weight, cylinder capacity or a combination of these factors though, increasingly, countries are adopting CO_2-based taxation. Presently, 24 EU Member States tax vehicles on their roads according to their CO_2 emissions levels.

308 See footnote 287

309 Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity

310 COM(2020) 102 final, A New Industrial Strategy for Europe

discussed in Evaluation Question 6, some other coherence issues are found. The strategy introduced the need for a new industrial way that is fit for the ambitions of today and the realities of tomorrow, so the EU industry becomes more competitive as it becomes greener and more circular. As Evaluation Question 3 already confirmed, the more stringent requirements introduced in Euro 6/VI emission standards compared to Euro 5/V are not considered sufficient to result in competitive gain for the European manufacturers given that their global counterparts are implementing tighter standards. Hence, the Euro 6/VI emission standards appear not to be coherent with the New Industrial Strategy for Europe.

b. Other national policy developments

While Low- and Zero Emissions Zones (LEZs and ZEZs) and their benefits for raising public awareness and for supporting the relevance of the Euro emission standards were already discussed in Evaluation Question 3 and 6, this section looks into the coherence between these local initiatives and the Euro 6/VI emission standards.

As the Euro 6/VI emission standards, most local LEZs have the objective to improve air quality by reducing air pollution caused by road transport. Some cities (e.g. Amsterdam, Brussels, London, and Paris) go even further with their zero-pollution ambitions and have already set course toward different forms of ZEZs. A large proportion of these local initiatives use the Euro 1/I to 6/VI emission standards as a kind of "labelling" criterion for granting access or determining the charge to be applied to enter a certain area. Therefore, there is a consistency between both the objectives and the implementation of the initiatives needed.[311] However, manufacturers provided a coordinated response to the targeted consultation in which they indicated that the arising of local restrictions by local or regional authorities using Euro 1/I to 6/VI in a different manner and timing as "labelling" criteria are actually considered inconsistent between each other and they could result in the fragmentation of the EU internal market.[312]

5.5. EU-added value

Evaluation question 8: What is the added value of Euro 6/VI compared to what could have been achieved at merely national level? Do the needs addressed by Euro 6/VI continue to require harmonisation action at EU level?

Overall conclusion: Overall, a clear EU-added value and respect of the subsidiarity principle is confirmed for the Euro 6/VI emission standards, in line with the general objectives of the Treaty ensuring a proper functioning of the Internal Market and providing for a high level of environmental protection in the EU.

No indication was found of changing needs for the Internal Market suggesting that a harmonised approach for vehicle emission standards would no longer be necessary. If Member States were expected to act to reduce pollutant emissions, a fragmented approach would be realised, resulting in less effective intervention at significantly higher costs for industry and authorities. In addition, it continues to be more effective to tackle vehicle pollutant emissions at EU level considering that more can achieved there than at the national level. Hence, EU intervention is required to achieve the desired results.

[311] See footnote 237
[312] See footnote 287

The objectives of Euro 6/VI emission standards could be achieved at international level only to a much lower extent and at a much slower pace. Nevertheless, industry takes a more reserved position when it comes to EU-added value in comparison with what could be achieved at UN level.

EU-added value of Euro 6/VI emission standards

In the context of pollutant emissions emerging from road transport, there is a clear and persistent need for Euro 6/VI emission standards at EU level. A first reason for this is that both air pollution and road transport have a transboundary dimension. While air pollution from road transport is primarily a problem in Europe's urban areas, atmospheric modelling shows that the pollution emitted in one Member State also contributes to pollution in other Member States. In addition, neither freight nor passenger transport stops at the national borders.[313] Considering this, any efforts taken by Member States in the absence of harmonised EU action could be offset by other (neighbouring) Member States through cross-border spill-over effects, making it extremely difficult to achieve the same level of environmental and health protection as achieved on EU level. Hence, fulfilling the specific objective of Euro 6/VI emission standards to improve air quality by reducing pollutants emitted by the road transport sector could not be realised as effectively without EU action.[314]

The development and governing of Euro 6/VI emission standards at EU level is key to prevent harm to the functioning of the Internal Market. While local or national initiatives could in theory replace EU action, they would also create considerable obstacles for automotive industry to enter into national markets, as numerous standards are expected to arise. This shows that national action poses great risks for the Internal Market, which comprises an area without internal frontiers where the free movement of goods, persons, services and capital must be ensured. To safeguard the free movement of vehicles, common emission standards for cars, vans, lorries and buses can only be achieved at EU level. That way, a cobweb of technical requirements for different Member States would not achieve the second specific objective of Euro 6/VI emission standards of setting harmonised rules on the construction of motor vehicles in line with Article 114 of the Treaty of the Functioning of the European Union[315].[316] This shows that the needs and challenges addressed by the Euro 6/VI emission standards clearly correspond to the needs of the Internal Market.[317]

Both arguments emphasise that there is a clear case for a harmonised approach to combat vehicle pollutant emissions through the development of Euro standards at EU level. To

[313] See footnote 3
[314] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.5.1.3 Is there continued EU added value of requiring harmonisation at EU level? Could certain elements be added or dropped?
[315] The Treaty on the Functioning of the European Union, 2012. Article 114 stipulates "1. … The European Parliament and the Council shall … adopt the measures for the approximation of the provisions laid down by law, regulation or administrative action in Member States which have as their object the establishment and functioning of the internal market. … 3. The Commission, in its proposals envisaged in paragraph 1 concerning health, safety, environmental protection and consumer protection, will take as a base a high level of protection, taking account in particular of any new development based on scientific facts. …".
[316] See footnote 3
[317] See footnote 320

validate these arguments, the evaluation will look into the EU-added value compared to what could be achieved at both the national and the international level.

EU-added value of Euro 6/VI emission standards compared to action at national level

Member States are expected to take action if no Euro 6/VI emission standard were in place. At the same time, like-minded Member States would be likely to cooperate through harmonising their emission standards, either at a more or less stringent level, while smaller Member States are expected to adopt the emission standards of larger Member States. Hence, a collection of different emission standards would arise over the EU.

This scattered approach is not expected to be equally effective in achieving the above-mentioned objectives of the Euro 6/VI emission standards. Next to the cross-border issues discussed above, the expected difference in willingness of Member States to strictly regulate the emission from vehicles would contribute to this. These differences were striking in the adoption process for the Euro 6d step where some Member States were against the adoption of more stringent conformity factors[318] or testing procedures.[319] This shows that not all national emission standards are expected to be as ambitious as Euro 6/VI emission standards or may even not be in place at all. A large majority of stakeholders from all groups – industry, national authorities and civil society – agree in the targeted consultation with this conclusion, indicating that the strictness of limits would be either somewhat or significantly lower if action was taken at the national level. Also, they expect that Member State action would be less effective in bringing cleaner vehicles to the market and in reducing pollutant emissions. Hence, the high level environmental protection that is currently achieved at EU level could not be realized at national level. [320]

Action at national level could also not ensure the proper functioning of the Internal Market. According to an extremely large majority across all stakeholder groups in the targeted consultation, harmonisation in terms of placing vehicles on the EU market would have been lower if action was taken at Member State level. Similarly, in the public consultation 138 out of 160 respondents from all groups - industry, Member States, civil society and citizens - agreed that EU regulations on air pollutant emissions are more efficient than national regulations.[321]

In addition, compliance and administrative costs for industry and national authorities would be significantly higher in the absence of EU action, as confirmed by manufacturers and type-approval authorities concerned in the targeted stakeholder consultation. This could even trigger manufacturers to abandon certain Member State markets where the cost of compliance would be higher than the expected revenues. [322]

EU-added value of Euro 6/VI emission standards compared to action at international level

[318] See footnote 45
[319] Gieseke and Gerbrandy, 2017. Report on the inquiry into emission measurements in the automotive sector A8-0049/2017- Committee of Inquiry into Emission Measurements in the Automotive Sector
[320] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.5.1.2 What would have happened on the basis of action taken at national or regional level only?
[321] See footnote 144
[322] See footnote 320

Action at international level is often seen as an alternative for EU action by mostly stakeholders from industry. In the context of vehicle emission standards, international action would most likely take place through the UN's World Forum for Harmonization of Vehicle Regulations[323] which focusses on the establishment of global harmonisation of certain technical regulations for vehicles including mutual recognition of type-approval amongst its signatories and limits air pollutant emissions through Regulation No 83 for cars and vans, and Regulation No 49 for lorries and buses[324]. The EU, which is generally considered to be the driving force behind more stringent UN standards[325], has achieved that the before mentioned UN Regulations were aligned with the Euro 6/VI emission limits and testing procedures.[326]

The objectives of Euro 6/VI, however, could only be achieved to a much lower extent and at a much slower pace at UN level than would be the case at EU level. This follows from the fact that without the EU's driving force, the standards that would eventually be adopted at UN level would be based on the lowest common denominator and hence provide lower environmental and health protection, which is confirmed by stakeholders from civil society and public authorities. Additionally, the adoption of the international emission standards would take way more time compared to EU regulation. This slow progress for the development of UN regulations has been observed in the development of a whole vehicle type-approval system and in several safety-related initiatives.[327]

While most stakeholders agree that UN standards would be less effective in reducing pollutant emissions, industry seems less convinced. In addition, stakeholders from all groups expect costs in this scenario to be the same or slightly lower for national authorities, and slightly or significantly lower for industry. While no evidence was provided for these statements, several industry stakeholders argued that global standards could lead to cost-savings as they would provide room to achieve higher economies of scale.[328] In order to either confirm or refuse these statements from industry, a complex cost-benefit analysis covering the major global markets and market segments would be necessary.

Principle of subsidiarity and the Euro 6/VI emission standards

The principle of subsidiarity is defined in Article 5 of the Treaty on European Union[329]. It aims to ensure that decisions are taken as closely as possible to the citizen and that constant checks are made to verify that action at EU level is justified in light of the possibilities available at national, regional or local level.

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[323] WP29 World Forum for Harmonization of Vehicle Regulations (WP.29) is a permanent working party in the institutional framework of the United Nations and offers a unique framework for globally harmonized regulations on vehicles.

[324] UN Regulation No 83 — Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements; UN Regulation No 49 — Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles

[325] Norman, J., 2018. Vehicle Type Approval

[326] Transport Research Laboratory, 2014. Transposition of EC Euro 6 Regulation into UNECE Regulations

[327] SWD (2015) 138 final. Progress report on the 2014 activities of the World Forum for Harmonisation of Vehicle Regulations (UNECE WP.29)

[328] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.5.1.4 How do the results and impacts of Euro 6/VI compare with what would have been achieved by action taken at international level (i.e. the UNECE)?

[329] See footnote 315

In line with the Euro 6/VI impact assessments[330], this evaluation confirms that the Euro 6/VI emission standards respect the principle of subsidiarity. As discussed above, the majority of stakeholders considers the EU approach to be considerably more effective in tackling emissions from vehicles than both national or international action. In addition, a majority of stakeholders across all groups indicated that without EU action and with solely national action, harmonisation would have been significantly lower, which would be detrimental for the proper functioning of the Internal Market and the high level of environmental protection in the EU.[331] Considering this, action at EU level is justified and continues to be justified in light of what can be achieved at other levels of governance.

6. CONCLUSIONS

The Euro 6/VI emission standards – being the sixth generation of harmonised emission standards for cars, vans, lorries and buses – continued the progress toward enhancing the pollutant emission performance of vehicles on EU roads that started with Euro 1/I in 1992. This stepwise approach of introducing more stringent pollutant emission standards aimed at improving the contribution of new vehicles to air quality issues.

Considering the presentation of the European Green Deal[332] in December 2019 as a new growth strategy introducing a zero-pollution and climate-neutrality ambition, the Euro 6/VI emission standards have been evaluated through the five evaluation criteria.[333] The aim was to assess to what extend Euro 6/VI has achieved the objectives of setting harmonised rules on pollutant emissions from vehicles and improving the air quality by reducing pollutant emitted by road transport with specific focus on nitrogen oxide (NO_x), particle mass (PM) and hydrocarbon (HC). This evaluation covers the Euro 6 regulation for cars and vans, the Euro VI regulation for lorries and buses and their respective implementing measures, together referred to as Euro 6/VI emission standards.[334] It considers the EU-27 Member States and former Member State the United Kingdom and covers the period since the entry into force of the Regulations (2014 for Euro 6 and 2013 for Euro VI) up until 2020. However, given that the impacts of Euro 6/VI are expected to last after 2020 until the vehicle fleet consists of Euro 6/VI vehicles, the evaluation also refer to the expected impacts of the Euro 6/VI emission standards until 2050.

It should be mentioned that the Euro 6/VI evaluation entails some limitations in the form of limited provisions of cost data by automotive industry and type-approval authorities for the efficiency assessment, discrepancies between different information sources on the uptake of Euro 6/VI vehicles and lacking monitoring indicators for the Euro 6/VI emission standards. Despite these limitations, the initiated analysis underpinning this evaluation was sufficient to formulate answers to the evaluation questions.

Euro 6/VI realised partly cleaner vehicles on EU roads

[330] See footnote 3

[331] CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3, chapter 5.5.1.3 Is there continued EU added value of requiring harmonisation at EU level? Could certain elements be added or dropped?

[332] COM(2019) 640 final, The European Green Deal

[333] Effectiveness, Efficiency, Relevance, Coherence and EU-added value (in line with the Better Regulation Guidelines)

[334] Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and its implementing Regulation (EU) No 582/2011; Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and its implementing Regulation (EU) 2017/1151.

Since the entry into force of Euro VI emission limits in 2013 and Euro 6 emission limits in 2014 up until 2020, NO_x emissions on EU roads have decreased by 22% for cars and vans and by 36% for lorries and buses. In comparison with the estimates of the Euro 6/VI impact assessments[335], the NO_x savings linked to Euro 6/VI were only slightly lower than the 24% which was initially expected for Euro 6 and the 37% expected for Euro VI. In addition, exhaust PM emissions on EU roads have known a decrease of 28% for cars and vans, and a decrease of 14% from lorries and buses. These savings for lorries and buses were estimated somewhat higher in the Euro VI impact assessment at 22%.

Total hydrocarbons (THC) emissions from lorries and buses also went down by 14% with Euro VI, while THC and non-methane hydrocarbons (NMHC) emissions from cars and vans went down by 13 and 12%. However, for the other pollutant – including carbon monoxide (CO) for cars and vans, and methane (CH_4) for lorries and buses – no significant emissions savings were observed following the introduction of Euro 6/VI. For ammonia (NH_3) from lorries and buses, the emission were even found to increase with the introduction of Euro VI, which indicates that the limits for this pollutant are insufficiently low.

For the benefit of citizens, Euro 6/VI emission standards curbs health impacts by road transport that lead to long-term respiratory and cardiovascular diseases, for example bronchitis, asthma or lung cancer. However, several obstacles to cleaner vehicles on EU roads have been identified which have negative consequences on public health. Hence the Euro 6/VI objective to improve air quality by reducing pollutants from road transport is very relevant and requires actions as follows.

The Euro 6/VI emission limits for the above-mentioned regulated pollutants are found to be insufficient. New pollutant emissions from road transport have arised since the adoption of Euro 6/VI more than a decade ago with the introduction of new engines, exhaust aftertreatment technologies, fuels and additives. Current technologies to restrict NO_x emissions in Euro 6 cause a NH_3 slip, resulting in increasing emissions of NH_3 as this pollutant is not regulated in Euro 6. Euro 6/VI has also resulted in particularly high N_2O and NO_2 emissions. In addition, some pollutant are not controlled sufficiently precisely as they are currently aggregated in wider pollutant categories (e.g. NMOG, HCHO, NO_2). Other pollutants that are of concern today, but are not yet regulated include ultrafine particle emissions, CH_4 emissions for cars and vans and brake- and tyre wear.

There is technological potential to go further without large investment costs as many technologies to further decrease pollutant emissions are already on the market and partly in place in other key markets (i.e. United States and China). Vehicle manufacturers are not likely to adopt more effective emission control technologies to further combat emissions from new vehicles, solely because they are already available on the market.

Euro 6/VI testing procedures partly effective

The above-mentioned RDE testing reduced the gap between type-approval and real-world emissions for cars and vans. The Portable Emission Measurement Systems (PEMS) testing introduced under Euro VI D for lorries and buses was less effective. While cold start emissions was already addressed in the last Euro VI E step that still has

[335] SEC(2005) 1745 Commission Staff Working Document, Impact Assessment on Euro 5/6 emission standards; SEC(2007) 1718 Commission Staff Working Document, Impact Assessment on Euro VI emission standards

to enter into force, the gaps in low-speed driving conditions and idle vehicles with low loads identified for Euro V vehicles continued in Euro VI vehicles.

Euro 6/VI testing procedures have made a gradual progress towards increasing the level of representativeness of the considered driving cycles and conditions of use, especially in urban driving conditions. Nevertheless, despite these improvements, important emissions remain unaccounted under Euro 6/VI emission testing. Test boundaries for cars and vans still exclude short trips, high mileage, high altitude and severe temperature conditions; and test boundaries for lorries and buses low loads, low speed and idle times that are important in urban areas.

There is also a demand for cleaner vehicles on EU roads over their whole lifetime as the average age and lifetime mileage of vehicles on EU roads have doubled in average since the adoption of Euro 6/VI. The Euro 6/VI durability requirements appear no longer effective in capturing vehicles' real world emissions over their useful lifetimes, as they are significantly lower than today's average fleet age and lifetime mileage for all vehicle types.

Hence, a complete coverage of real-world driving cycles and all conditions of use is still missing in Euro 6/VI emission standards.

Euro 6/VI regulatory costs considerable but affordable

The Euro 6/VI emission standards have led to considerable regulatory costs for automotive industry, which were mainly driven by the emission control technologies and are to a great extent passed through to the consumers. The total regulatory costs compared to Euro 5/V are €21.1 to €55.6 billion for Euro 6 (2014-2020) and €9.5 to €20.4 billion for Euro VI (2013-2020). These regulatory costs result in average to 95-99% from equipment costs (hardware costs, R&D and related calibration, facilities and tooling costs) and in average to 1-5% from costs during implementation phase (testing and witnessing costs, type-approval fees) and administrative costs.

The weighted average of the total regulatory cost for the period up to 2020 is estimated at around €357-€929 per diesel vehicle and by €80-€181 per petrol vehicle for Euro 6 (cars and vans). However, these estimates hide the fact that the costs per vehicle have been significantly higher over the last few years since the introduction of RDE testing in year 2017. The largest part of these costs are hardware costs arising from the need to install emission control technologies on vehicles to meet the emission limits. While initially the hardware costs for petrol vehicles did not change moving from Euro 5 to Euro 6 (b-c), moving to the final step of Euro 6 (d) has resulted in an increase of €228-€465 per petrol vehicle. For diesel vehicles, the initial hardware costs for Euro 6 (b-c) were €341-€937, while the moving from Euro 5 to the final step of Euro 6 (d) increased the hardware costs by €751-€1 703. In all, the weighted average costs for Euro 6 are found to be higher than the expected costs in the Euro 6 impact assessment in which the weighted average cost per diesel vehicle was estimated at €213 (€280 in 2020 prices).[336]

For Euro VI for lorries and buses, the weighted average of the total regulatory costs increased by €3 717-€4 326 per vehicle. As was the case for Euro 6, the hardware costs represent the largest share of these costs and are mainly driven by the introduction of diesel particulate filter (DPF) technology. Moving from Euro V to Euro VI, the hardware costs for lorries and buses increased between €1 798 and €4 200 per vehicle. These cost

[336] See footnote 335

estimates are comparable with the costs in the Euro VI impacts assessment which were estimated in the range of €2 539-€4 009 (€2 817 to €4 419 in 2020 values).[337]

The analysis also pointed out sizeable R&D and related calibration costs including facilities and tooling costs related to the sixth generation of Euro standards, estimated at around €43-€156 per diesel vehicle and €36-€108 per petrol vehicle for Euro 6 (cars and vans) and €1 900-€3 800 per vehicle for Euro VI (lorries and buses). In particular the latter were higher than expected due to the lower sales number of heavy-duty vehicles.

The introduction of more demanding RDE and PEMS testing procedures has led to a sizeable increase of costs during implementation phase as a result of the more demanding testing regimes and the associated reporting procedures. Testing and witnessing costs increased by €150-€302 thousand per model family for Euro 6d(-temp) and by €96-€232 thousand per engine family for Euro VI. The related reporting procedures have increased the administrative costs by €16-€52 thousand per type-approval for Euro 6d(-temp) and by €18-€28 thousand per type-approval for Euro VI. A main area where unnecessary costs may have arisen is in the practical aspects of the introduction of the testing procedures under Euro 6d(-temp), increasing the number of type-approvals considerably.

Type-approval authorities incurred one-off costs as well as an increase in recurrent costs due to new staff and new testing facilities. However, these costs during implementation phase are expected to be covered mainly through type-approval fees charged to manufacturers.

These costs during implementation phase related to type approval and fees and administrative costs represent a smaller amount of the total regulatory cost for both Euro 6 (4-5%) and Euro VI (1%). The only exception are the costs for petrol cars and vans where, due to the fact that there was no need for new technologies in the initial stages, the overall share of the other costs elements was higher (19%).

The average vehicle price increase for consumers due to Euro 6/VI is less than 2% for cars and vans, in the range of 4.2-5% for lorries and of 2.1-3% for buses. However, for the most recent step in Euro 6, the average price increase for diesel cars and vans is significantly higher – 4.3% for the small segment vehicles, compared to 2.7% for the large segment vehicles.

In conclusion, the total regulatory costs resulting from the Euro 6/VI emission standards are significant. At the same time, there is no indication that they are not affordable for industry, approval authorities and consumers, with the exception of vehicle price increases for small diesel cars and vans.

Euro 6/VI was cost-effective

The Euro 6/VI emission standards are in general cost-effective compared to Euro 5/V and have generated net economic benefits to society. The positive net benefits are estimated at €192-€298 billion for Euro 6 cars and vans. In particular diesel cars and vans have positive net benefits of €219-€304 billion associated with the emission savings for these vehicles. On the other hand, petrol cars and vans seems to have negative net benefits due to the limited NO_x emission savings and high compliance costs for gasoline particulate filters. For Euro VI lorries and buses, very positive net benefits of estimated €490-€509 billion have been realised.

[337] See footnote 335

The regulatory costs of Euro 6/VI emission standards have been considered justified and proportionate in the public and targeted stakeholder consultation by a large majority across all stakeholder groups – industry, Member States and civil society – to ensure the necessary decrease in air pollutant emissions emerging from road transport and hence prevent negative effects on human health and environment.

Industry stakeholders however were somewhat sceptical, indicating that consumers do not really appreciate the improvements in aftertreatment technologies in vehicles, in contrast to the situation for fuel efficiency. On the other hand, the majority of stakeholders across all groups, including citizens, indicated that Euro 6/VI, and in particular the introduction of RDE testing in the wake of Dieselgate, at least contributed somewhat towards ensuring consumer trust in the type-approval system and automotive products.

Euro 6/VI did not impact the competitive position of automotive industry

For the competitiveness of industry, Euro 6/VI emission standards had overall neither a clear positive nor a clear negative impact on the targeted market segments. It is difficult to determine whether the increased regulatory costs, in particular for cars and vans after the introduction of RDE testing, have affected the respective profit margins and the overall profitability. Clearly, it cannot be determined if a price increase of cars since 2014 is associated to regulatory costs associated with the Euro 6 emission standards, it could also be the result of various other factors affecting prices.

The regulatory costs also do not necessarily imply a direct negative impact on the competitiveness of the EU manufacturers compared to non-EU competitors, as the latter are faced with similar costs. In the contrary, to ensure the competitiveness of the EU automotive industry, stricter emission limits and testing procedures would help manufacturers to ensure access to external markets, which have adopted stricter limits, in particular the United States and China.

Considering the number of R&D projects directly linked to Euro 6/VI emission standards, it is expected that the standards had a positive impact on research activities in the EU. On the other hand, some stakeholders suggested that most of the technologies were already available on the market and the standards fostered innovation through improving existing technologies and subsequently decreasing their costs.

There is no compelling evidence suggesting that the Euro 6/VI emission standards have had a sizeable impact on employment or on increasing consumer awareness of air pollution issues.

Recent policy developments make the Euro 6/VI objectives more relevant

Recent policy developments, that means the European Green Deal, support the Euro 6/VI objectives and the relevance to improve air quality by reducing emissions from road transport in a unified EU approach. The European Green Deal emphasises the need to make transport significantly less polluting, especially in urban areas, in order to accelerate the shift to sustainable and smart mobility and thus support the competitiveness of the EU automotive industry on the global market. The European Green Deal roadmap therefore includes a proposal for more stringent air pollutant emissions standards for combustion-engine vehicles by 2021. At the same time, the European Green Deal underlines the EU's objective of achieving climate neutrality by 2050 and the roadmap includes a proposal for strengthened CO_2 standards for cars and vans by June 2021. The interplay of both emission initiatives will have to provide a pathway to zero-emission vehicles, while at the same time it will have to ensure that the remaining internal combustion engines are as clean as they can be in accordance with the zero-pollution ambition of the European Green Deal.

Some coherence issues on vehicle emissions legislation

Stakeholders from all groups - including industry, national authorities and civil society - confirm in the targeted consultation on the Euro 6/VI evaluation that, overall, vehicle manufacturers are provided with a coherent policy and legal framework to reduce vehicle emissions. Nevertheless, there are some coherence issues as follows.

Regarding internal coherence within Euro 6/VI emission standards, there is a lack of fuel- and technology neutrality, when it comes to different emission limits for diesel and petrol vehicles or PN limits set for petrol vehicles only. Moreover, there is a lack of coherence between Euro 6 for cars and vans and Euro VI for lorries and buses, as there are different application dates of the steps of Euro 6/VI, i.e. Euro 6b-d(-temp) and Euro VI A-E, NH_3 and CH_4 are regulated in Euro VI only and there seems to be a lack of clear border between Euro 6 and Euro VI vehicles.

Regarding external coherence with other EU legislation, the main issue identified is that the Euro 6/VI emission standards and the Roadworthiness Directives on Periodic Technical Inspections (PTI) and Roadside Inspections (RSI) do not yet operate in the complementary way necessary. To guarantee protection against degradation, failure or tampering of aftertreatment systems during the lifetime of vehicles, improvements in the requirements for on-board diagnostics (OBD) systems in the Euro 6/VI emission standards are important that can be used for emission testing during PTI and RSI.

There are some differences in the pollutants regulated in the Air Quality Directive and Euro 6/VI emission standards but this is substantiated by Euro 6/VI covering tailpipe emissions from road transport and Air Quality Directive covering all air pollution sources. Some industry stakeholders raised concerns about trade-offs between CO_2 and NO_x combatting technologies. However, no significant evidence was found to suggest that Euro 6/VI emission standards resulted in unintended negative consequences for CO_2 emission standards.

Euro 6/VI has simplification and burden reduction potential

No simplification was realised in the Euro 6/VI emission standards. In the contrary, all stakeholder groups pointed out that Euro 6/VI testing procedures have become too complex. More demanding emission tests introduced gradually over the steps of Euro 6/VI increased the complexity significantly resulting in a text of more than 1 300 pages with increasing number of references to UN Regulations and different application dates for different vehicle categories, new vehicle types and new vehicles. This development increased the enforcement costs for industry and type-approval authorities. For stakeholders from civil society this complexity is seen as, at least partly, proportionate in view of the need to ensure that vehicles are clean on the basis of more demanding testing and in-service conformity requirements.

Euro 6/VI has clear EU-added value

The Euro 6/VI evaluation confirmed a clear EU-added value to take action on vehicle pollutant emissions through a harmonised approach at EU level, in order to avoid the fragmentation of the internal market for vehicles by incoherent, national emission standards and to allow industry and public authorities to take advantage from economies of scale.

No indication was found of changing needs for the internal market suggesting that a harmonised approach for vehicle emission limits would no longer be necessary. In the contrary, a unified EU approach to curbing harmful emissions and ensuring cleanest possible performance of a combustion engine during the transition phase towards zero-emissions road transport, is needed. A phase out of combustion engines should not be left to the decisions of individual Member States (e.g. ban of diesel and petrol vehicles), risking to cause damage to the internal market. Such uncoordinated actions would create inefficiencies for the automotive industry. Manufacturers would have to design, produce and commercialise different vehicles for different Member States.

The objectives of Euro 6/VI emission standards could be achieved at international level only at the cost of their effectiveness to a much lower extent and at a much slower pace. While most stakeholders agree that UN standards would be less effective in reducing pollutant emissions, industry seems less convinced. Several industry stakeholders argued that global standards result in larger economies of scale and in more level playing field. In order to either confirm or refuse these statements from industry, a complex cost-benefit analysis covering the major global markets and market segments would be necessary.

Lessons learned on monitoring and reporting

Some lessons can be learned from the lacking implementation of monitoring indicators identified in the Euro 6/VI impact assessments in the Euro 6/VI legislation, which considerably hampered the evaluation process.

The Euro 6/VI impact assessments identified the ‘number of vehicles which are successfully type-approved according to the Euro 6 or Euro VI standard’ as the core monitoring indicator. However, the Euro 6/VI legislation did not translate this monitoring indicator into a reporting requirement for the Member States. The Euro 6/VI evaluation had to rely on a limited number of contributions from Member States and industry through the first targeted consultation and on costly private data to proceed with the evaluation.

In addition, neither Member States have reported on the implementation to ensure that requirements of the regulations are met nor specific monitoring data on air pollution levels and epidemiology on health impacts from road transport were available.

Appendix: Details on methods and analytical models

The evaluation of Euro 6/VI emission standards and the impact assessment for Euro 7 emission standards were carried out in 2020/21 as back-to-back approach. Both used the same procedure (see Annex 1), stakeholder consultation (see Annex 2) and analytical methods (see Annex 4).

Supporting Euro 6/VI evaluation study

Eight overarching evaluation questions were formulated to assess the regulations' effectiveness (three questions), efficiency (two questions), relevance (one question), coherence (one question) and EU-added value (one question). To inform the responses to these eight evaluation questions, a supporting Euro 6/VI evaluation study carried out by CLOVE consortium in 2020/21[338] analysed a total of fourteen evaluation (sub-) questions which have been summarised into the eight questions considered here. Table A.1 shows how the responses to the sub-questions in the supporting study have been re-aggregated in the Staff Working Document.

Table A.1 – Mapping the nine evaluation questions of this staff working document (SWD) against the 14 evaluation sub-questions addressed in the supporting Euro 6/VI evaluation study

Criterion	Evaluation question (SWD)	Evaluation sub-question (supporting study)
Effectiveness	**(1)** To what extent and through which factors has Euro 6/VI made cleaner vehicles on EU roads a reality? Which obstacles to cleaner vehicles on EU roads remain taking into account possible unintended consequences on the environment?	EQ1 - To what extent has Euro 6/VI made cleaner vehicles on EU roads a reality? EQ3 - What are the factors that have influenced positively and negatively the achievements observed? In particular, which obstacles to cleaner vehicles on EU roads still remain? EQ5 - Has Euro 6/VI had unintended positive or negative consequences or collateral effects?
	(2) How effective are the Euro 6/VI testing procedures to verify the emission standards?	EQ2 - How effective are the existing testing procedures to verify the emission standards?
	(3) What are the benefits of Euro 6/VI and how beneficial are they for industry, the environment and citizens?	EQ4 - To what extent has Euro 6/VI achieved other specific objectives? EQ6 - What are the benefits of Euro 6/VI and how beneficial are they for industry, citizens and the environment? EQ7 - To what extent has Euro 6/VI supported innovative technologies and other technological, scientific or social development? Are adaptation mechanisms in place to allow this?

338 CLOVE, 2022. CLOVE, 2022. Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3.

Criterion	Evaluation question (SWD)	Evaluation sub-question (supporting study)
Efficiency	**(4)** What are the regulatory costs related to the Euro 6/VI emission standards and are they affordable for industry, type-approval authorities and consumers? Have Euro 6/VI emission standards achieved a simplification of vehicle emission standards?	EQ8 - What are the compliance and administrative costs? Is there evidence that Euro 6/VI has caused unnecessary regulatory burden? Are they affordable for industry and approval authorities? EQ10 - Has Euro 6/VI achieved a simplification of vehicle emission standards in relation to Euro 5/V?
	(5) To what extent has Euro 6/VI been cost-effective? Are the costs proportionate to the benefits attained?	EQ9 - To what extent has Euro 6/VI been cost-effective? Are the costs proportionate to the benefits attained? What are the factors influencing the proportionality of costs?
Relevance	**(6)** To what extent do the Euro 6/VI objectives of ensuring that vehicles on EU road are clean correspond to the current needs? Is there a demand/potential for cleaner vehicles on EU roads over their whole lifetime?	EQ11 - To what extent do the objectives of Euro 6/VI of ensuring that vehicles on EU road are clean correspond to the current needs? Is there a demand/potential for cleaner vehicles on EU roads over their whole lifetime?
Coherence	**(7)** Are the Euro 6/VI emission standards coherent internally and with other legislation pieces applying on the same stakeholders and with similar objectives? Are there any inconsistencies, overlaps or gaps?	EQ12 - To what extent do Euro 6/VI features work together sufficiently well? Are there inconsistencies, overlaps or gaps? EQ13 - To what extent is Euro 6/VI consistent with other legislation pieces applying on the same stakeholders and with similar objectives? Are there any inconsistencies, overlaps or gaps?
EU-added value	**(8)** What is the added value of Euro 6/VI compared to what could have been achieved at merely national level? Do the needs addressed by Euro 6/VI continue to require harmonisation action at EU level?	EQ14 - What is the added value of Euro 6/VI compared to what could have been achieved at merely national level? Do the needs and challenges addressed by Euro 6/VI correspond to the needs of the internal market? Do the needs and challenges addressed by Euro 6/VI continue to require harmonisation action at EU level?

Annex 6: Policy options

6.1. Policy option 1: Low Green Ambition

Policy option 1 implies a narrow revision of Euro 6/VI emission standards with high ambition on tackling the increasing complexity of the vehicle emission standards (problem 1) and low ambition to improve vehicle pollutant limits (problem 2) and insufficient control of vehicle real-driving emissions (problem 3). In line with the specific objective to reduce complexity of the Euro 6/VI emission standards, option 1 addresses key simplification and consistency challenges through refining the architecture of Euro 6 and Euro VI. It assumes that a single vehicle emission standard for cars, vans, lorries and buses is developed, multiple application dates of Euro 6/VI steps are avoided and the complexity of emission testing is reduced with obsolete tests removed.

Simplification measures

This option includes a number of measures to simplify and refine the legislative architecture of the emission standards and the emission testing (see Table 47). The simplification measures target a number of laboratory-based tests that have become less relevant with the move towards on-road testing.

Table 47 – Simplification measures in policy option 1

Simplification of legislative architecture	Reasoning
1. Merging the basic acts of Euro 6 (Regulation (EC) No 715/2007) and Euro VI (Regulation (EC) No 595/2009) into one basic act (Euro 7), while keeping obligations for emission testing for cars/vans and lorries/buses in separate implementing acts.[339]	At least the following implementing acts will be required: 1. Regulation on testing LDV vehicles (as in Regulation (EC) 2017/115, including rules for CoP, ISC and Market Surveillance) 2. Regulation on testing HDV vehicles (methodology and testing of whole vehicles with PEMS, part of Regulation (EU) 582/2011 including rules, for CoP, ISC and Market Surveillance, and expansion to new powertrains) 3. Regulation on engine type approval as a separate implementing legislation addressing engines, part of Regulation 582/2011) 4. Regulation on CO_2 determination for HDV vehicles 5. Regulation on replacement parts and components (brakes, replacement emission control systems, …)
2. Defining a new and unambiguous legislative border between cars/vans and lorries/buses based on total permissible maximum laden mass instead of the Euro 6/VI reference mass.[340]	In order to harmonise with type approval definitions of motor vehicles With the request of the manufacturer upward extension of the mass limit up to 4.0 tonnes may be taken

[339] CLOVE, 2022. Study on post-Euro 6/VI emission standards in Europe – PART B Potentials for simplification of vehicle emission standards (hereafter "supporting simplification study"), chapter 5.1.1 Merging the main regulations for cars/vans (LDV) and lorries and/buses (HDV)

[340] Supporting simplification study, chapter 5.1.2 Scope of regulation

3. Introducing a single application date per vehicle category for Euro 7.[341]	No need for two application dates, one for new vehicle types and one for new vehicles since new vehicle types may be type approved according to the rules from the moment of entry into force. The possibility to provide financial incentives for early introduction is foreseen.
4. Improved on-board diagnostics (OBD) as a support element to enable testing for in-service conformity (ISC) and market surveillance (MaS).[342]	Enhanced use of Malfunction Indicator Light (MIL) to facilitate testing and enforce repairs. Details to be defined in Implementing Regulations.
5. Aligning EU and international UN regulations by referencing UN regulations[343] in Euro 7 where appropriate.[344]	In support to international harmonisation of type approval rules, UN regulations developed with the consensus of the EU, shall be referenced in the Implementing Regulations.
6. Adopting appropriate verification procedures for conformity of production (CoP), in-service conformity (ISC) and market surveillance (MaS).[345]	Enhancing the rules of CoP, ISC, and introduce rules for MaS which were missing in Euro 6/VI, including the new role of testing by third parties and the Commission. A list of tests and actors responsibilities per stage of type approval will be included in the Annexes of the Regulation
Simplification of emission testing	**Reasoning**
Cars and vans	
1. Replacing the OBD, durability, and crankcase tests at type-approval with OEM declarations and checking them during market surveillance. Repeal idle and opacity tests as obsolete.[346][347]	Simplifying test regime during initial type approval by replacing tests with declarations by the manufacturer that they comply with the requirements. The compliance will be checked during market surveillance checks. The idle and opacity tests which were introduced for use during periodical technical inspections were proven not apt for recent vehicle technologies and are repealed. Reflect this in the list of tests (see point above).
2. Improved OBD provisions for malfunction detection with appropriate OBD threshold limits[348].[349]	Simplify and improve the OBD malfunction detection capabilities that could be checked also during market surveillance. For

[341] Supporting simplification study, chapter 5.1.3 One introduction date
[342] Supporting simplification study, chapter 5.1.4 Strengthening MIL (S-MIL)
[343] Regulation No 83 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements; Regulation No 49 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles
[344] Supporting simplification study, chapter 5.1.8 Alignment of EU and UNECE regulations
[345] Supporting simplification study, chapter 5.1.9 Alignment of CoP, ISC, MaS framework
[346] Supporting simplification study, chapter 5.1.6 Idle emissions, smoke opacity, crankcase emissions and OCE; chapter 5.1.7 Durability testing
[347] Supporting simplification study, chapter 5.2.1 Testing requirements overview
[348] In-use performance ratios (IUPR) currently give an idea of how often the conditions subject to monitoring occurred and how frequent the monitoring intervals occurred. For example, a minimum IUPR of 0,1 would mean that there should be at least one monitoring event during 10 trips.

	Implementing Regulations.
3. Substituting the laboratory-based ambient temperature correction test at type-approval and replace it with declared temperature correction which may be checked during market surveillance[350]	Analysis of CO2 between the ATCT at 14 °C and WLTP test at 23 °C showed that the difference between the two tests is minimal. Therefore it is not considered cost effective to repeat the ATCT test during type approval and the OEM may declare a Temperature correction. Such declaration may be checked during market surveillance tests.
Lorries and buses	
1. Shifting emphasis and emission limits to on-road testing of vehicles and keeping laboratory tests mainly for CO_2 evaluation.[351]	The true compliance of a heavy duty vehicle with emission limits will be checked during on-road testing during all phases of type approval, while laboratory tests of engines and components will still be required mostly for the determination of CO_2.
2. Replacing type-approval testing by declarations from the manufacturers for OBD, durability, crankcase emissions, NO_x control operation and reagent freeze protection, while testing them at Market Surveillance.[352]	Simplifying test regime during initial type approval by replacing tests with declarations by the manufacturer that they comply with the requirements. The compliance will be checked during market surveillance checks.
3. Improving OBD provisions for malfunction detection with appropriate OBD threshold limits [353]	Simplify and improve the OBD malfunction detection capabilities that could be checked also during market surveillance. For Implementing Regulations.

Technology-neutral emission limits

Another important driver for complexity in the Euro 6/VI emission standards follows from the fact that they are not technology-neutral. To tackle this, policy option 1 makes the Euro 6/VI emission limits coherent over the different ICE technologies in order to achieve technology-neutral limits (see Table 48). NH_3 limit is extended to cars and vans for the same reason it was already introduced for lorries and buses in Euro VI, i.e. to control ammonia slip from the current generation of catalysts.

Table 48 – Technology-neutral emission limits in policy option 1[354]

Air pollutants	Cars	Small vans	Large vans	Lorries and buses
	(mg/km)	(mg/km)	(mg/km)	(mg/kWh)
NO_x	60	75	82	460
PM	4.5	4.5	4.5	10
$PN_{>10nm}$ (#/km)	6×10^{11}	6×10^{11}	6×10^{11}	6×10^{11}
CO	500	630	740	4 000

[349] See footnote 342
[350] Supporting simplification study, chapter 5.1.5 Low temperature testing and ATCT
[351] Supporting simplification study, chapter 5.2.2 Euro 7 on-road testing
[352] Supporting simplification study, chapter 5.1.6 Idle emissions, smoke opacity, crankcase emissions and OCE; chapter 5.1.7 Durability testing, chapter 5.2.1 Testing requirements overview
[353] See footnote 342
[354] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

THC	100	130	160	660
NMHC	68	90	108	160
NH_3	20	20	20	10 (ppm)
Evaporative emissions	2 g/test (for gasoline only)	2 g/test (for gasoline only)	2 g/test (for gasoline only)	-

While the value of the emission limits are not stricter than the limits included in the Euro 6/VI regulations, the fuel-related specificities have been removed and the same pollutants are limited for all ICE vehicles. Hence, also the problem of untapped and lacking vehicle pollutant limits is partially addressed through this action. For example, option 1 introduces a common NO_x emission limit of 60 mg/km for all cars. This replaces the current NO_x limits of 60 mg/km for petrol cars and 80 mg/km for diesel cars. NH_3 and CH_4 limits are not only used for lorries and buses but also for cars and vans, as emission control technologies that are necessary to comply with NO_x emission limits may cause a so-called ammonia slip due to excessive dosing of urea[355] and CH_4 may be emitted by gaseous-fuelled vehicles. The threshold for particle numbers (PN) is lowered from 23 nm to 10 nm, in line with the international work at UN level[356]. Evaporative emissions remain as today.

Extended real-driving testing

The measures aim at refining and simplifying the emission testing (see Table 47) by moving towards extended real-driving testing with low ambition. Policy option 1 allows testing of vehicles beyond the normal Euro 6 d RDE and Euro VI E PEMS conditions, as presented in Table . No conformity factor is foreseen for this option as PEMS were already assessed to measure accurately at these levels. For conditions that extend beyond current RDE/PEMS, as depicted in Table 49, an emissions cap of 4× the emission limits defined in Table will apply for both light-duty and heavy-duty vehicles. Implications for what concerns vehicle technologies needed can be found in section 1.3.1 in Annex 4.

Table 49 – Normal and extended real-driving testing conditions in policy option 1 (low ambition boundaries)[354]

Parameter	Normal driving conditions	Extended driving conditions
	Cars and vans	
Emission Limit Multiplier	-	4 (applies once and only for the period when any of the conditions below apply)
Ambient temperature	-7°C to 35°C	-10°C to -7°C or 35°C to 45°C
Maximum speed	Up to 145 km/h	Between 145 km/h and 160 km/h
Trip characteristics	Any trip longer than 10 km	
$v \times a_{pos}$ [95th [W/kg]	As in current RDE	Outside current RDE
Towing, aerodynamic modifications	Not allowed	Allowed
Auxiliaries use	Possible as per normal use	-

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355 Heeb et al. 2005. Three-way catalyst-induced formation of ammonia—velocity- and acceleration-dependent emission factors

356 UNECE, 2020. 81st session Informal Documents: GRPE-81-10 Revisions to ECE/TRANS/WP.29/GRPE/2020/14: sub 23nm PN measurements, GRPE-81-11 of UN29: Clarification of points regarding "UN Regulation WLTP"

Maximum altitude	Up to 1 300 m	From 1 300 to 1 600 m
Positive elevation gain	No limitation	-
Minimum mileage	10 000 km	
Lorries and buses		
Emission Limit Multiplier	1	3 (applies once and only for the period when any of the conditions below apply)
Ambient temperature	-7°C to 35°C	-10°C to -7°C or 35°C to 45°C
Cold start	Test evaluation from engine start on; no weighting of cold start	-
Auxiliaries	Possible as per normal use	-
Minimum trip duration	More than 4 WHTC	Between 3 and 4 WHTC
Evaluation (MAW[357])	1x WHTC window	-
Engine loading	All	-
Payload	Between 10% and 100%	Less than 10%
Maximum altitude	Up to 1 300 m	From 1 300 to 1 600 m
Minimum mileage	10 000 km	-
Trip characteristics	Any	-

6.2. Policy option 2: Medium and High Green Ambition

Policy option 2 implies a wider revision of Euro 6/VI emission standards with high ambition to tackle the increasing complexity of the vehicle emission standards (problem 1) and to address untapped and lacking vehicle pollutant limits (problem 2) and medium ambition to address insufficient control of vehicle real-driving emissions (problem 3).

Policy option 2 builds on the same simplification measures as option 1 to reduce complexity of the Euro 6/VI emission standards. In addition, two stringency levels of stricter pollutant emission limits (called medium ambition and high ambition emission limits) are considered, to provide up-to-date limits for all relevant air pollutants. Similarly, two sets of extended real-driving testing are considered in policy options 2 (called medium ambition and high ambition boundary conditions) to control real-driving emissions throughout the vehicles' lifetime and in almost all conditions of use.

Simplification measures

Policy option 2 considers the same simplification measures as policy option 1, to simplify the legislative architecture and the emission testing (see Table 47) and to propose technology-neutral limits coherent over the different ICE technologies.

Medium and high ambition stricter emission limits

Policy option 2 considers two possible sub-options of stricter emission limits to take into account two levels of technological possibilities for achieving such emission levels and the related investment costs for vehicle manufacturers and component suppliers. Policy option 2a – Medium Green Ambition - considers strict air pollutant emission limits based on currently available emission control technologies; policy option 2b – High Green Ambition - considers more stringent air pollutant emission limits based on best available emission control technologies (see Table 50 and Table 51).

[357] Under the moving average window (MAW) method, the mass emissions are calculated for subsets of complete data sets, called windows. The window size is defined by the work over the window which must be equal to the work produced during the engine certification cycle. (WHTC).

Policy option 2a includes a reduction of the NO_x limit for cars to 30 mg/km and for underpowered[358] vans to 45 mg/km. This is because vehicles with low power to mass ratio, while needed for some applications, cannot handle emissions with the same effectiveness as the normally powered vehicles. For lorries and buses the need to control both cold and hot emissions leads to two limits expressed in mg/kWh (see Table 50). This policy option also lowers all other pollutants regulated in Euro 6/VI (PM, PN, CO, THC, NMHC, NH_3, CH_4) and introduces new ones (N_2O, HCHO and brake emissions). HCHO, CH_4 and N_2O emission limits are set at the level of today's emissions (i.e. a cap on emissions) to ensure that these emissions do not disproportionately increase beyond today's level with the introduction of new CO_2 limits or new emission control technologies in future vehicles or with new fuels but no new emission control technology is required or foreseen.

For evaporative emissions, the diurnal emission limits are strengthened, while a limit is also set for refuelling emissions. These reductions are achievable by emission control technology available already in the market today[359], which is described in Table 21, and addresses the problem driver of not exhaustive use of technological potential for reducing emissions.

Table 50 – Strict emission limits in policy option 2a and 3a based on available emission control technology[359]

Air pollutants	**Cars and vans**	**Large vans if underpowered**	**Lorries and buses Cold emissions[360]**	**Lorries and buses Hot emissions[361]**
	(mg/km)	(mg/km)	(mg/kWh)	(mg/kWh)
NO_x	30	45	350	90
PM	2	2	12	8
$PN_{>10nm}$ (#/km)	1×10^{11}	$1x10^{11}$	$5x10^{11}$	$1x10^{11}$
CO	400	600	3 500	200
NMOG	45	45	200	50
NH_3	10	10	65	65
CH_4+ N_2O	45	55	660	410
HCHO	5	10	30	30
Evaporative emissions[362]	0.5 g/worst day + ORVR[363]	0.7 g/worst day + ORVR	-	-
Brake emissions	7	7	Review	Review
Tyre emissions	Review	Review	Review	Review
Battery durability[364]	70%	70%	Review	Review

Policy option 2b includes a reduction of the Euro 6/VI limit for cars to even lower values (see Table 51). These reductions can be achieved only by integrating best available emission control technologies in the vehicle and related hardware and R&D costs for

[358] Large vans with power to test mass ratio less than 35 kW/t
[359] CLOVE, 2022. Technical studies for the development of Euro7: Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5
[360] Expressed as 100% of MAW
[361] Expressed as 90% of MAW
[362] With random preconditioning at any temperature up to 38 °C
[363] ORVR stands for "On-board Refuelling Vapour Recovery" and is a limit designed to avoid emissions during the refuelling of the vehicles. Limit to be set at 0.05 g/L.
[364] Expressed as Battery Energy Based. To be reviewed for lorries and buses and for inclusion of range metric.

technology system integration and calibration[365].

Table 51 - Stricter emission limits in policy option 2b based on best available emission control technology[359]

Air pollutants	**Cars and vans** (mg/km)	**Large vans if underpowered** (mg/km)	**Lorries and buses Cold emissions** (mg/kWh)	**Lorries and buses Hot Emissions** (mg/kWh)
NO_x	20	30	175	90
PM	2	2	12	8
$PN_{>10nm}$ (#/km)	1×10^{11}	1×10^{11}	$5x10^{11}$	$1x10^{11}$
CO	400	600	1 500	200
NMOG	25	25	150	50
NH_3	10	10	65	65
CH_4+ N_2O	20	25	660	410
HCHO	5	10	30	30
Evaporative emissions	0.3 g/worst diurnal test + ORVR	0.5 g/worst diurnal test + ORVR	-	-
Brake emissions	5	5	Review	Review
Tyre emissions	Review	Review	Review	Review
Battery Durability	80%	80%	Review	Review

Both sub-options include limits for two not yet regulated exhaust emissions that are of concern today: nitrous oxide (N_2O) and formaldehyde (HCHO). High N_2O emissions have been observed on gasoline vehicles equipped with three-way catalysts, while HCHO is a toxic and carcinogenic substance affecting human health which is released through the combustion process and becomes increasingly relevant as gasoline vehicles and higher ethanol content (E10) are gaining momentum.[366] Since the emission limits proposed for NO_x are considered sufficiently low to also restrict emissions of nitrogen dioxide (NO_2), regardless of their relative proportion within the NO_x group, policy option 2 does not include a separate limit for this pollutant.[367]

In addition to exhaust and evaporative emissions, both scenarios in option 2 introduce limits for brake emissions[368]. Brake wear has been recognized as the leading source of non-exhaust particles which are harmful to human health and the environment and emitted by all type of vehicles. A method and protocol is currently under development in the UN.[369] Progress has been made in developing a measurement method and protocol

[365] See footnote 359
[366]CLOVE 2022.Euro 6/VI Evaluation Study. ISBN 978-92-76-56398-3. 5.3.1.4 Do the standards properly cover all relevant/important types of pollutant emissions from vehicles that pose a concern to air quality and human health? Are there important types of pollutant emissions that are not covered?
[367]CLOVE, 2022. Euro 7 Impact Assessment Study. ISBN 978-92-76-58693-7, chapter 4.4.3 Policy Option 2: Improved air pollutant limits and advanced tests for cars, vans, lorries and buses in addition to policy option 1.
[368] Next to brake emissions, tyre emissions are found to be a source of non-exhaust emissions as they contribute to the formation of PM and PN. As it is not yet technologically feasible to develop limits or tests for tyre emissions, they cannot be assessed in this impact assessment and it is suggested to include a review clause in Euro 7.
[369] UNECE, 2021. UNECE to develop global methodology to measure particle emissions from vehicles' braking systems

for cars and vans[370], while the technologies to decrease brake emissions are already in the market or close to becoming commercial.[371] While the brake emission limits in sub-option 2a can be realised using better brake pad material, the limits in sub-option 2b also requires additionally a brake filter for the collection of the brake wear particles produced.[372] Brake emissions from heavy-duty vehicles will only be limited at a second phase when the methodology is extended to cover them as well.

Medium and high ambition real-driving testing boundaries

While emission limit sub-options are assumed to be complied with under normal driving conditions, a multiplier is needed in order to comply with the extended conditions of use in policy option 2. Where policy option 1 introduced a set of low ambition extended driving conditions, sub-option 2a and 2b are assumed to be complied with under a set of medium and high ambition extended driving conditions respectively. Hence, the more demanding conditions for the engine are taken into account (see Table 52 and Table 53). Furthermore, a cap is imposed by a maximum budget of pollutants allowed on trips that are smaller than a certain threshold required for the assessment to be made thoroughly (enough data need to be collected for a thorough assessment). In this manner, all possible trips are covered by a limit.

Policy option 2 will further expand the testing conditions of policy option 1, while policy options 2b will cover almost all real-driving testing conditions. This action addresses the driver of limited representativeness of on-road tests covering normal conditions of use. The sub-options for stricter emission limits presented in Table 50 and Table 51 are assumed to apply to the new normal driving conditions and extended driving conditions as presented in Table 52 and Table 53 respectively. The tables illustrate that several boundaries have been extended to cover more demanding normal circumstances for the vehicle which may result in significantly higher emissions, without however allowing for completely free and unbounded driving but limiting the conditions to those necessary to cover the widest part of driving under European conditions. A further extension of the testing conditions is designed to cover an even great part of the conditions of use, approaching full coverage of all relevant European conditions in policy option 2b.

For extended driving conditions an emission limit multiplier will be used to account for the harder conditions put on the engine and emission control system. The effect of such an emission limit multiplier is limited since it is only applied in rare occasions. Furthermore, the emission multiplier proposed here is milder than the one proposed in the CLOVE study, due to the fact that the boundaries are also milder compared to the CLOVE study and completely free driving is not allowed.

The ambient temperature conditions have been lowered to -10 °C and the maximum altitude to 2 000 m in option 2a and to 2 200 m in option 2b in order to cover the highest road elevations in Europe. As another example Figure 22 in Annex 5 illustrates how low-speed driving, which is not covered in the Euro 6d RDE tests, has been linked to high pollutant emissions.[373] The Euro 6/VI average speed boundary conditions (see Table) have therefore been removed. Implications for what concerns vehicle technologies

[370] A measurement method for brake emissions from lorries and buses is not developed yet. It is suggested to include a review clause in Euro 7.
[371] See footnote 367
[372] Supporting Euro 7 impact assessment study, Annex I, section 9.5 Cost modelling
[373] See Annex 5: Evaluation Euro 6/VI emission standards, Figure 16 – Emission performance of Euro 6d vehicles for NO_x for different average speeds, based on CLOVE, 2022

needed can be found in Table 21.

Table 52 – Comprehensive real-driving conditions in policy option 2a and policy option 3a, in normal and extended driving conditions (medium ambition boundaries)[374]

Parameter	Normal driving conditions	Extended driving conditions
Cars and vans		
Emission Limit Multiplier	1	2 (applies once and only for the period when one of the conditions below apply)
Ambient temperature	-7°C to 35°C	-10°C to -7°C or 35°C to 45°C
Maximum speed	Up to 145 km/h	Between 145 km/h and 160 km/h
Trip characteristics	Any trip, normal limits for tests longer than 10 km (budget approach for trips less than 10 km)	-
$v \times a_{pos}$ [95th [W/kg]	As in RDE	Any condition but extreme driving is prohibited
Towing, aerodynamic modifications	Not allowed	Allowed according to specification of OEM and up to the regulated speed
Auxiliaries use	Possible as per normal use	-
Maximum altitude	Up to 1 300 m	From 1 300 to 1 800 m
Positive elevation gain	No limitation	-
Minimum mileage	10 000 km	Between 3 000 km and 10 000 km
Lorries and buses		
Emission Limit Multiplier	1	2 (applies once and only for the period when one of the conditions below apply)
Ambient temperature	-7°C to 35°C	-10°C to -7°C or 35°C to 45°C
Cold start	Test evaluation from engine start on; no weighting of cold start	-
Auxiliaries	Possible as per normal use	-
Minimum trip duration	Any (for MAW evaluation 4× WHTC)	-
Evaluation (MAW[375])	1x WHTC window	-
Engine loading	All	-
Payload	Higher than or equal to 10%	Less than 10%
Maximum altitude	Up to 1 600 m	From 1 600 to 1 800m
Minimum mileage	5 000 km for <16t TPMLM 10 000 km for > 16t TPMLM	Between 3 000 km and 5 000 km for <16t TPMLM Between 3 000 km and 10 000 km for > 16t TPMLM
Trip characteristics	Any	-

Table 53 – Comprehensive real-driving conditions in policy option 2b, in normal and extended driving conditions (high ambition boundaries)[374]

Parameter	Normal driving conditions	Extended driving conditions

[374] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.
[375] Under the moving average window (MAW) method, the mass emissions are calculated for subsets of complete data sets, called windows. The window size is defined by the work over the window which must be equal to the work produced during the engine certification cycle. (WHTC).

Cars and vans		
Emission Limit Multiplier	1	3 (applies once and only for the period when any of the conditions below apply)
Ambient temperature	-7°C to 35°C	-10°C to -7°C or 35°C to 45°C
Maximum speed	Up to 160 km/h	Above 160 km/h
Trip characteristics	Any trip, normal limits for tests longer than 10 km	-
Towing, aerodynamic modifications	Not allowed	Allowed
Auxiliaries use	Possible as per normal use	-
Engine loading	Restriction for first 2 km	Any condition but extreme driving is prohibited
Maximum altitude	Up to 1 600 m	2 200 m
Positive elevation gain	No limitation	-
Minimum mileage	3 000 km	Between 300 km and 3 000 km
Lorries and buses		
Emission Limit Multiplier	1	2 (applies once and only for the period when any of the conditions below apply)
Ambient temperature	-7°C to 35°C	-10°C to -7°C or 35°C to 45°C
Cold start	Test evaluation from engine start on; no weighting of cold start	-
Auxiliaries	Possible as per normal use	-
Minimum trip duration	Any (for MAW evaluation 4× WHTC)	Any (for MAW evaluation 4× WHTC)
Evaluation (MAW[376])	1x WHTC window	-
Engine loading	All	-
Payload	Any	-
Maximum altitude	Up to 1 600 m	From 1600 to 2 200m
Minimum mileage	3 000 km for <16t TPMLM 6 000 km for > 16t TPMLM	Between 300 km and 3 000 km for <16t TPMLM 6 000 km for > 16t TPMLM
Trip characteristics	Any	-

Medium and high ambition durability, including security of emission control systems and anti-tampering

Policy option 2 also considers the need to address inadequate durability provisions. In the two sub-options and in policy option 3 the requirements to comply with the emission limits for vehicles in use, i.e. the durability provisions, are extended from the current inadequate period in Euro 6/VI. The Euro 6 durability provisions for cars which are limited to 5 years or 100 000 km[377] are extended to 10 years or 200 000 km, whichever comes first in policy option 2a and 3a to reflect the average lifetime of vehicles in Europe and extended further to 15 years or 240 000 km, whichever comes first in policy option 2b to reflect the maximum lifetime of vehicles in Europe[378][379]. Similarly ambitious

[376] Under the moving average window (MAW) method, the mass emissions are calculated for subsets of complete data sets, called windows. The window size is defined by the work over the window which must be equal to the work produced during the engine certification cycle. (WHTC).
[377] Or 160 000 km for checking the durability of the replacement emission control systems.
[378] Supporting Euro 7 impact assessment study, chapter 4.4.3 Policy Option 2: Improved air pollutant limits and advanced tests for cars, vans, lorries and buses in addition to policy option 1
[379] ACEA, 2020. In 2020, passenger cars in use were on average 11.5 years old, vans 11.5 years, lorries 13 years and buses 11.7 years.

provisions are introduced for lorries and buses. In all cases, for the period of the extended durability, i.e. between 160 000 km or 8 years and the periods in Table 55 below, a durability multiplier shall be used to take into account the natural degradation of both the emission control systems used for gaseous pollutants and the engine. This durability multiplier is needed only for gaseous pollutants, because particle filters do not have durability issues. They either work or fail, in which case they need to be replaced. The new durability provisions can be seen in Table 54.

Table 54 – Durability provisions in policy option 2a, 3a and 2b[380]

	Policy option 2a and 3a	Policy option 2b
Cars and vans	Durability multiplier for gaseous pollutants between 160 000 km/8 years and 200 000 km/10 years	Durability multiplier for gaseous pollutants between 160 000 km/8 years and 240 000 km/15 years
Lorries and buses	Durability multiplier] for gaseous pollutants For N2, N3<16t, M3<7.5t: between 300 000km and 375 000 km N3>16t, M3>7.5t: between 700 000 km and 875 000 km	Durability multiplier for gaseous pollutants For N2, N3<16t, M3<7.5t: between 300 000km and 450 000 km N3>16t, M3>7.5t: between 700 000 km and 1 050 000 km

The requirement for increased durability means further reduction of excess emissions created by older vehicles, but also helps to avoid the undesired effect of tampering of older vehicles, i.e. removing or otherwise circumventing the emission control systems of a vehicle. On top of the increased durability requirements, cybersecurity measures, such as the ones recommended by the JRC[381] and the European Parliament[382] in their respective reports, will be introduced as stronger requirements to protect the integrity of the emission control systems.

A further improvement in terms of durability is adding provisions for the durability of propulsion batteries of PHEVs and BEVs, according to the developments at UN level[383]. Such addition would not add any costs because the level of durability is currently set to the level already achieved by the average (not the best) batteries of today and the costs for the verification are already included in the other tests (i.e. no new test will be required).

6.3. Policy option 3a: PO2a and Medium Digital Ambition

Policy option 3a implies a profound revision of Euro 6/VI emission standards with high ambition to tackle the increasing complexity of the vehicle emission standards (problem 1), to address untapped and lacking vehicle pollutant limits (problem 2) and to address insufficient control of vehicle real-driving emissions (problem 3).

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[380] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

[381] JRC 2021 Technical Report: "Vehicles Odometer and Emission Control Systems - Digital Tampering and Countermeasures", Jose Luis Hernandez Ramos (JRC), L. Sportiello (JRC)

[382] European Parliament, 2014-2019, P8_TA-PROV(2018)0235, European Parliament resolution of 31 May 2018 with recommendations to the Commission on odometer manipulation in motor vehicles: revision of the EU legal framework

[383] UN 2021. ECE/TRANS/WP.29/GRPE/2021/18 (IWG on EVE) Proposal for a new UN GTR on In-Vehicle Battery Durability for Electrified Vehicles

Policy option 3a builds on the same simplification measures as option 1 to reduce complexity of the Euro 6/VI emission standards and on more stringent air pollutant emission limits and comprehensive real-driving conditions as policy option 2a to provide appropriate and up-to-date limits for all relevant air pollutants. In addition, new continuous emission monitoring of pollutants over the whole lifetime of the vehicle is added, based on improved versions of available sensor technologies. Synergies with the on-board fuel consumption meters (OBFCM) introduced under the CO_2 emission performance standards[384], in terms of reading and communicating the monitored emission data, will be exploited.[385] This option has the added benefit of further simplifying and improving compliance controls for type approval and also allowing future periodic technical inspections and roadworthiness tests to be performed online. A prerequisite for the introduction of CEM is stronger cybersecurity measures, as those described in the relevant JRC report[386]. It is expected that such measures will already be introduced under the baseline and therefore no cost will be necessary in this proposal.

Simplification measures

Option 3a considers the same simplification measures as option 1, to simplify the legislative architecture and the emission testing (see Table 47).

Medium ambition stricter emission limits

Option 3a considers the same strict emission limits as option 2a (see Table 50). The lowest emission limits of option 2b (see Table 51) are not considered since it is uncertain whether the lowest emission limits can be reliably measured with on-board sensors throughout the lifetime of vehicles.

Medium ambition real-driving testing boundaries

Policy option 3a considers the same real-driving testing conditions as option 2a, to cover normal driving conditions and extended driving conditions (see Table 52).

Medium ambition durability, including security of emission control systems and anti-tampering

This policy option considers the same durability provision as policy option 2a (see Table 54).

Continuous emission monitoring

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[384] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles and Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles both require in Article 12 that the Commission shall regularly collect data on the real-world CO_2 emissions and fuel or energy consumption of passenger cars, light commercial vehicles and heavy-duty vehicles using on-board fuel and/or energy consumption monitoring devices.

[385] Regulation (EU) 2017/1151, supplementing Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6); Regulation (EU) 2018/1832, amending Directive 2007/46/EC, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) 2017/1151 for the purpose of improving the emission type approval tests and procedures for light passenger and commercial vehicles, including those for in-service conformity and real-driving emissions and introducing devices for monitoring the consumption of fuel and electric energy, implementing Regulation (EU) 2021/392 on the monitoring and reporting of data relating to CO2 emissions from passenger cars and light-commercial vehicles

[386] JRC 2021 Technical Report: "Vehicles Odometer and Emission Control Systems - Digital Tampering and Countermeasures", Jose Luis Hernandez Ramos (JRC), L. Sportiello (JRC)

Option 3a introduces continuous monitoring of vehicle emission performance by means of continuous emission monitoring (CEM) systems. The CEM system make use of sensors installed inside the vehicles to measure or assess tailpipe emissions continuously. The use of CEM will improve compliance checks of vehicles types and may additionally provide a strong instrument to detect and therefore deter from tampering, especially if linked with appropriate cybersecurity measures[387][388]. Additionally, CEM may be used as a virtual periodic technical inspection/roadworthiness tool, to complement, or eventually substitute the need for yearly inspections.

CEM further provides a very handy tool for market surveillance authorities that could check thousands of emission data without direct access to the vehicles leading to further simplification of the emission type approval and prioritisation of tests to vehicle types that exhibit higher emission profiles. This leads to further savings in regulatory costs. For purposes of checking the compliance of vehicles against the emission requirements, detailed data of the vehicle owner, identification or geolocation will not be needed or acquired, in full respect of GDPR rules. For the purposes of vehicle type approval and market surveillance, the strength of this system lies in reading thousands of data from all vehicles belonging to the same type.

Policy option 3a is based on sensors which are commercially available today and could be introduced for NO_x, NH_3 and partly PM based on communication functionalities already installed on vehicles due to the OBFCM requirements (see Table 55). It also considers the possibility of geo-fencing that puts a vehicle automatically into zero-emission mode when entering zero-emission zones, such as cities, although no impacts can be assessed in regards to this option.

Table 55 – Continuous emission monitoring in policy option 3a based on available sensor technologies[389]

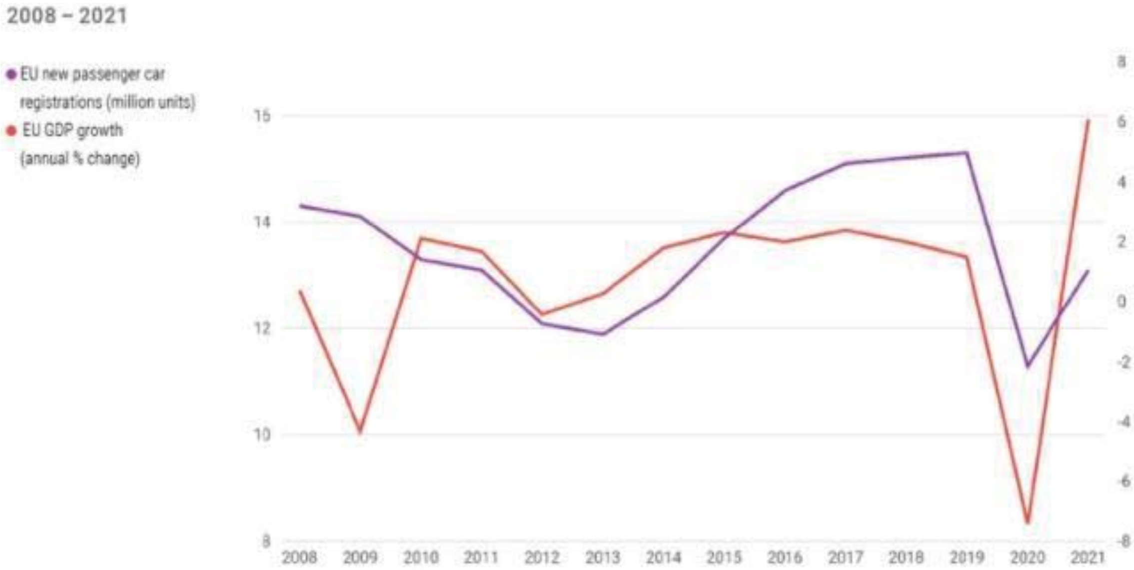
Element	CEM for cars, vans, lorries and buses
Pollutants CEM	**NO_x and NH_3** sensors: Monitoring of emission performance and identification of malfunctions of emission control systems. **PM** sensors: Filter diagnostics (no PM measurement)
Communication platform	Based on OBFCM protocol that brings data storage and data communication functionalities to the vehicle and intermittent signal transmission with no transmission of personal data.
Functionalities	1. Limits exceedances via MIL and limp/mode and inducement strategy to enforce repairs 2. Enhanced malfunction detection over OBD 3. Information available to authorities for ISC/MaS testing (potential future access also for purposes of PTI and roadworthiness and tampering detection) 4. Engine feedback to adjust emission control system performance (real-time calibration) 5. Possibility of enforcement of geo-fencing for zero emission mode for plugin vehicles

[387] CLEPA, 2021. CLEPA recommendations for Euro 7/VII, Statement on on-board monitoring during AGVES meeting of 24 February 2021
[388] Supporting Euro 7 impact assessment study, chapter 5.3.1. Environmental impacts
[389] CLOVE, 2022. Technical studies for the development of Euro 7. Testing, Pollutants and Emission Limits. ISBN 978-92-76-56406-5.

Annex 7: Impact of the COVID-19 crisis in automotive industry on policy options

The COVID-19 pandemic has heavily impacted the automotive sector world-wide, posing unprecedented challenges for the industry as a whole. In EU-27, registration of new passenger and commercial vehicles dropped by respectively by -23.7% and -18.9%, with a trend following the GDP curve in the European Union (see Figure 25), which shows that a close correlation between GDP and car registrations over the period in the EU, contrary to what happened during the previous 2008-2009 crisis with average GDP decline: -6.43% over 2020 in EU-27)[390]. For passenger cars, 9.9 million units were sold in 2020, which represents a drop of 3 million units compared to 2019[391]: For commercial cars, 1.7 million units were sold over the same period (i.e. 401 000 units less).

Figure 25 - New passenger cars and GDP growth in the EU 2008-2021 (source: ACEA, IHS Markit, and European Commission DG ECFIN retrieved from ACEA)[392]



This has to be placed in the broader context of the economic crisis worldwide both from the demand- and supply-side perspectives. The automotive market weighs heavily on global manufacturing and on economies with a high exposure to this sector.

The global GDP has contracted by 3.3% in 2020.[393] After an unprecedented sudden shock in the first half of 2020, the economy has recovered gradually in the third quarter as containment measures relaxed, allowing businesses and household spending to resume. Still, the global GDP in the second quarter of 2020, was 10% lower than at the end of 2019, which was immediately reflected in car sales globally.

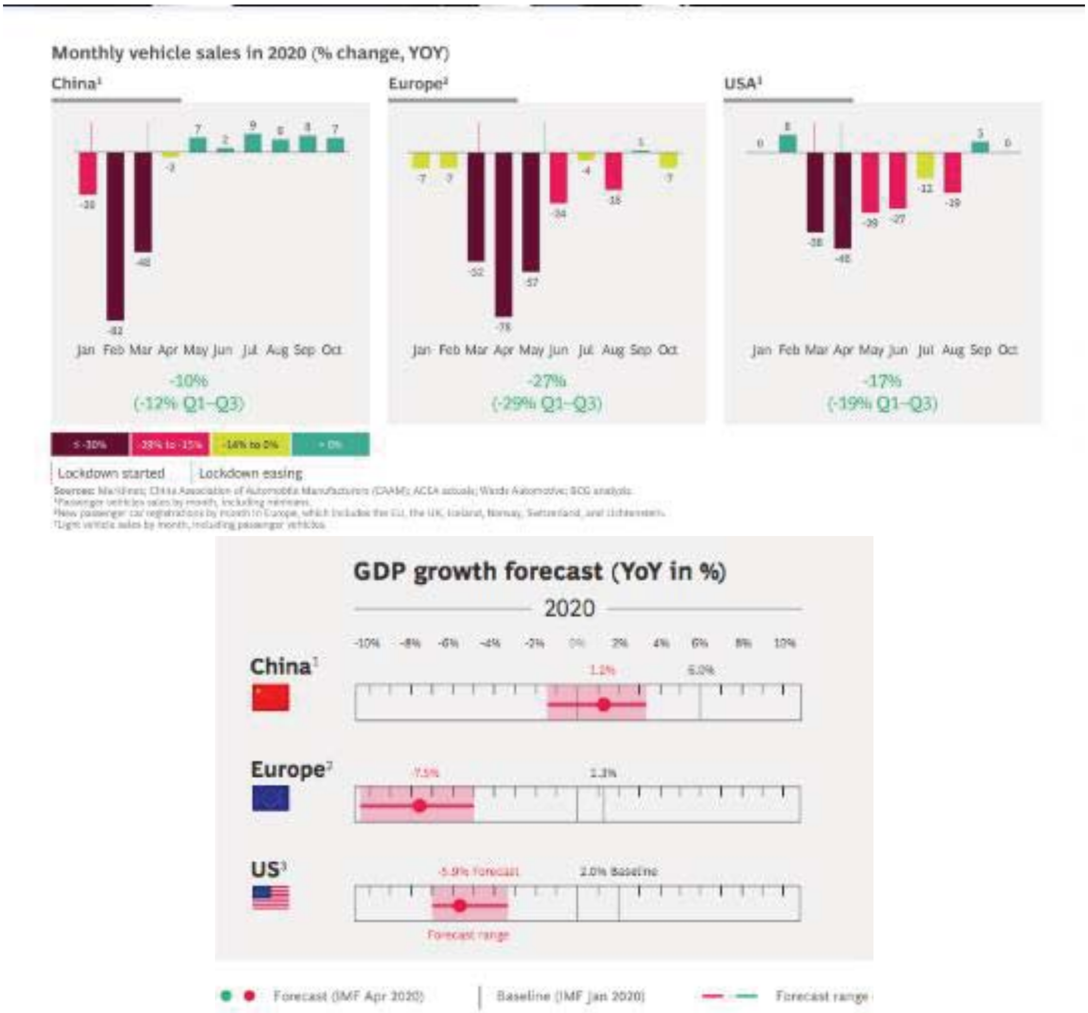
Global sales of vehicles have fallen under 77 million units in 2020, down from 89.7 million units in 2019 with a previous peak of 94.3 million units in 2017 following 10 years of continuous growth (in 2020, 17.3 million less vehicles have been sold and 15

[390] Eurostat, 2021. Newsrelease Euroindicators: GDP down by 0.7% in the euro area and by 0.5% in the EU (17/2021 – 2 February 2021).
[391] ACEA, 2021. Passenger car registrations: -23.7% in 2020; -3.3% in December
[392] ACEA, 2020 31 December. Available at https://twitter.com/acea_eu/status/1344629151916040195
[393] WEO IMF April 2021 p.7 , i.e. 1.1% smaller than projected in October 2020 – Also estimated contraction of real global GDP (excluding the EU) by -3.4% and in the EU by -6.3% (European Economic Forecast Winter 2021 (interim)) – Institutional Paper 144 February 2021

million units less have been produced compared to 2019)[394].

The impact on sales and recovery pace differed for each key regional bloc and automotive market, respectively in China, Europe and the USA - as reflected in Figure 26 below -, also depending on the disease progression, overall sanitary situation and of the status and level of lockdown measures.

Figure 26 - Monthly sales in 2020 (% change, Yoy) vs. GDP growth forecast in China, Europe and USA (source: BCG)[395]



The EU economy contracted by 6.3% in 2020[396] economic forecast projecting growth of 3.7% in 2021 and 3.9% in 2022[397]. All economic aggregates have been significantly impacted by the pandemic evolution and the containment measures with a direct effect on the automotive industry: for instance, a decline in consumer spending was foreseen in May 2020, up to 40% -50%, with numerous second- and third- order effects[398]. Besides decreasing sales and demand, this resulted in massive losses, liquidity shortages and changes in customers' behaviours. This was compounded by the already rapidly

394 IHS Markit, 2020. Daily Global Market Summary - 31 December 2020

395 BCG, 2020. COVID-19's Impact on the Automotive Industry

396 European Commission, 2021. European Economic Forecast – Winter 2021 (Interim) – European Commission Institutional Paper 144 February 2021

397 European Commission, 2021. European Economic Forecast – Winter 2021 (Interim) – European Commission Institutional Paper 144 February 2021

398 Mc Kinsey, 2020. The-impact-of-COVID-19-on-future-mobility-solutions

advancing technology shift in a competitive environment which required significant investment and strategic realignments.

In the EU, the economic consequences materialised through three main channels. First, the partial or full shut down of entire sectors due to the measures put in place to contain contagion has severely disrupted service sectors, including transport and mobility. Second, such disruptions also affected production and distribution activities and the access to extra-EU supply chains. Third, the consequent loss of income led to diminishing demand. Mobility patterns and customers behaviours have been also significantly modified in the long run.

Impact on transport services –As a consequence of global lockdown measures due to the Covid-19 crisis, mobility fell by an unprecedented amount in the first half of 2020[399]. Road transport in regions with lockdowns in place dropped between 50% and 75%, with global average road transport activity almost falling to 50% of the 2019 level by the end of March 2020. Immediately after the crisis outbreak, public-transit ridership has fallen 70 to 90% in major cities across the world, and operations have been significantly impacted by uncertainty and strict hygiene protocols—such as compulsory face masks and health checks for passengers or restricting the number of riders in trains and stations to comply with space requirements. Ride hailers have also experienced declines of up to 60 to 70%, and many micro-mobility and carpooling players have suspended their services. As well, fleet leasing and car rental have been hit harder than most by the travel bans to stem the spread of Covid-19.

Road freight transport has been significantly and negatively impacted by the epidemic outbreak, at global level and in Europe in particular. Sales in the land transport sector (which also includes freight and passenger rail transport in addition to road transport) in the EU and other Western European countries contracted by 10.3% in 2020, in real terms[400]. The greatest disruption occurred during the first wave of the pandemic in spring 2020 but the sector recovered from the summer, with the lifting of border closures and the return of business activity and household consumption. However, the activity underwent another slowdown as the virus spread for a second time and many countries in the region were forced to implement new guidelines, partially closing economies once more. The impact through the year was greater for international than for domestic transport. A difference according to the transported products can also be observed, with the trade in pharma and ICT products having remained significant through last year. As an exception, e-commerce and last-mile delivery have increased, which seems to correspond to a long term trend.

Standstill in production and supply disruption – The impact of the COVID-19 crisis has been sudden and universal. For Original Equipment Manufacturers (OEM), initial concerns over a disruption in Chinese parts exports quickly pivoted to large-scale manufacturing interruptions across Europe. Global production stopped and the supply chain was critically disrupted. The most immediate and visible effect in the traditional

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[399] Compared to the period between 3 January and 6 February 2020 - before the outbreak of the pandemic in Europe - average mobility in the EU was about 17% lower in the fourth quarter of 2020, and declined further (to -26%) in January 2021. This compares to -25% and -9% on average in the second and third quarters of 2020, respectively. See: European Commission, 2021. European Economic Forecast – Winter 2021 (Interim) – European Commission Institutional Paper 144 February 2021 – also Google Mobility Index and Finish Ministry of Finance, 2021. Economic Effects of the COVID-19 Pandemic – Evidence from Panel Data in the EU Discussion papers

[400] See footnote 394

automotive sector was subsequently the standstill of many OEM and supplier factories.

The COVID-19 pandemic has had a severe impact on Europe's vehicle manufacturing sector[401]. During the first half of 2020 alone, EU-wide production losses (cars and vans) due to COVID-19 amounted to 3.6 million vehicles[402], worth around €100 billion and around 20% of the total production in 2019. These losses were the result of both factory shutdowns (especially during the 'lockdown' months of March, April and May) and the fact that production capacity did not return to pre-crisis levels once the lockdown measures have been eased[403].

Approximately, 24 million less vehicles are expected to be produced globally between 2020 and 2022.[404] The industry would thus be hit two times harder by the coronavirus pandemic than during the 2008-2009 financial crisis: indeed, benchmarked against pre-COVID 19 forecasts made in January 2020, COVID-19 led to over 12 million units of losses.

At the height of the crisis, over 90 percent of the factories in China, Europe, and North America closed. With the stock market and vehicle sales plummeting, automakers and suppliers have laid off workers or relied on public intervention, particularly short-time work schemes and similar arrangements to support paying employees.

Several carmakers[405] had to be bailed out due to liquidity problems. The massive use of furlough schemes did not prevent the announcement of several plant closures/job losses[406] at manufacturer or supplier level.

Most factories and plants have reopened and relaunched production after the first lockdown and have remained in operation.

Impact on demand – The sanitary COVID-19 crisis also had a direct impact on consumer demand and distribution channels. The exogenous shock of the pandemic has indeed exacerbated the already present downshift in the global demand. Dealers were subject to regulations imposing an immediate closure of showrooms and retail network. For customers, the impact was multifaceted as people, facing financial uncertainty, reduced their purchasing, stayed home and postponed major investments. The confidence indicator of the Transport-Mobility-Automotive Ecosystem was one of the most hit[407] amongst all EU Industrial Ecosystems. Significantly the purchase intent for both new cars and used cars remains low across all countries in the Union, with the least impact in France (e.g. new car purchase intent decrease by -11% (France), -21% (Germany) and -25% (Italy) compared to pre-COVID-19 crisis intent whereas used car purchase intent decreased respectively by 11% (France), -31% (Germany) and -28% (Italy)). There was still a positive net impact in maintenance and repair.

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[401] SWD (2020) 98 final, Commission Staff Working Document, Identifying Europe's recovery needs

[402] ACEA, 2021. Coronavirus / COVID-19

[403] ACEA, 2020. Interactive map: COVID-19 impact on EU automobile production, first half of 2020

[404] See footnote 394

[405] FCA and Renault received state aid under the Temporary Framework to support the economy in the context of the coronavirus outbreak.

[406] Examples include plants operated by car manufacturers such as Nissan, Renault, Bridgestone, Continental, etc.

[407] SWD (2020) 98 final, Commission Staff Working Document, Identifying Europe's recovery needs: Chart 1 Confidence Indicator of EU industrial Ecosystems: Current and Expected Supply and Demand Factors

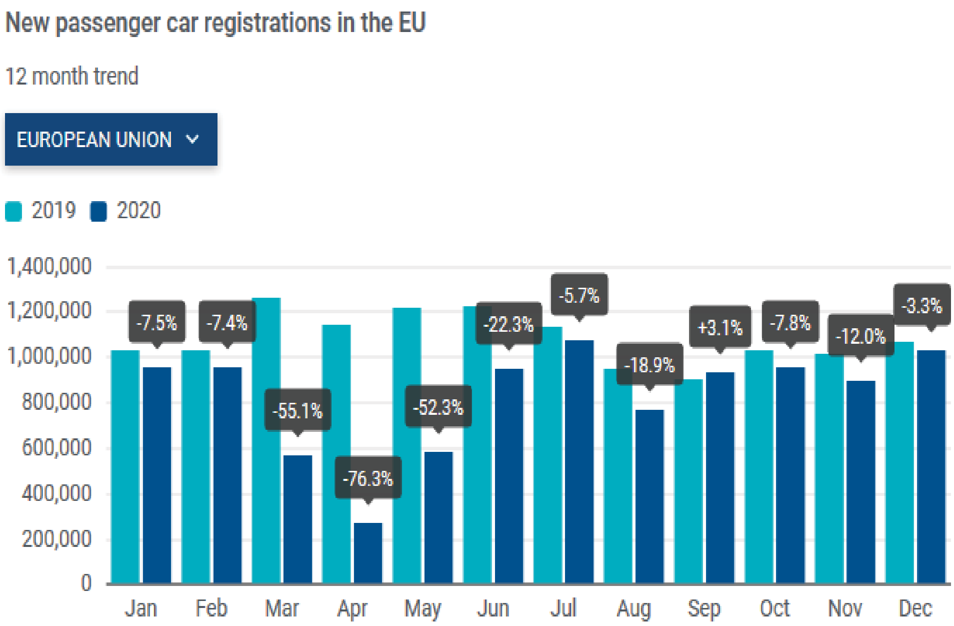
Consequently, the **automotive market**, that was already on a downward trend, facing structural challenges (CO_2, pollutant emissions, electrification), was hard-hit and suffered an unprecedented 23.7%[408] decrease of passenger car sales in 2020. It is expected that COVID-19 will negatively affect sales volumes for years to come.

In more details:

In April 2020 alone, vehicle sales in Europe dropped by 84% compared to the same period in 2019. It also followed a decline of sales and production over the previous period in 2019-2018: car sales had seen their steepest year-over-year decline in 2019 (-4%)[409] since the 2008/2009 Financial Crisis as consumer demand from the U.S. to China softened.

- Passenger Cars: Demand for new vehicles slumped during the peak of the crisis, with new registrations of passenger cars down 32% in the first 8 months of 2020 compared to the previous year[410].

Figure 27 - New passenger car registrations in the EU 2020 vs. 2019 (monthly registrations – source: ACEA)[411]



Spain posted the sharpest drop (-32.3%), followed closely by Italy (-27.9%) and France (-25.5%), while full-year losses were significant but less pronounced in Germany (-19.1%).

Despite uncertainties in the near term, demand still showed some signs of recovery after the summer 2020, with new registrations higher in September by 3.1% (cars) and 13.3% (vans) compared to 2019. New car registrations in Germany, EU's largest market, were 8.4% above levels of September 2019[412], with impressive growth in all electrified

[408] See footnote 391
[409] See footnote 394
[410] ACEA, 2020. Passenger car registrations: -32.0% eight months into 2020; -5.7% in July and -18.9% in August
[411] See footnote 410
[412] KBA, 2020. Pressemitteilung Nr. 23/2020 - Fahrzeugzulassungen im September 2020

segments, thanks in particular to government stimulation measures aimed at electric and hybrid vehicles. However, demand declined again in October, with EU-wide registrations down 7.8% in October. New restrictions put in place in several EU countries in autumn 2020, due to the resurgence of the virus, put the recovery of economies under question.

The downwards trend continued for the whole October- December period despite incentives and recovery packages: in December, high, double-digit losses were seen in countries such as France (down 11.8%), Italy (down 14.7%), Portugal (down 19.6%). Germany showed the best performance, with a solid gain of 9.9%, followed by Spain, with a tiny loss of 0.01%.

All other segments have been impacted with un-even performances and recovery trends from one EU Member State to the other:

- **New light commercial vehicles (LCV) up to 3.5t**: From January to December 2020, new van registrations declined by 17.6% across the European Union, standing at 1.4 million units. Spain recorded the sharpest drop (-26.5%) so far this year, while losses were less strong in France (-16.1%), Italy (-15.0%) and Germany (-12.2%).

In November, demand for new light commercial vehicles in the EU remained stable (-0.5%) compared to same period in 2019, whereas it weakened in December 2020 compared to December 2019 (-6%). Results in the EU's top four markets were mixed: in November 2020, registrations in Italy and Germany were positive, growing by 10.3% and 6.2% respectively, while LCV demand contracted in Spain (-8.1%) and France (-3.8%). In December 2020, registrations fell by 10.4% and 2.3% respectively in Italy and France, while Germany (+2.5%) and Spain (+1.6%) recorded modest gains.

- New heavy commercial vehicles (HCV) of 16t and over: all through 2020, 198 352 new heavy commercial vehicles were registered across the European Union, a decline of 27.3% compared to 2019. Despite the 2 last months' positive performance, each of the 27 EU markets recorded double-digit drops so far this year, including Germany (-26%), France (-25.8%) and Spain (-22.1%).

The two last months of the year showed positive results: in November 2020 alone, the EU market for heavy lorries improved, with new registrations up by 6.0% to 20.620 units. Central European countries (+28.6%) largely contributed to this result. Among the largest Western European markets however, only Italy (+28.5%) managed to post growth. During the month of December, 16 839 new heavy commercial vehicles were registered across the EU, a year-on-year rise of 11.8%. Central European markets continued to provide a strong boost to this growth; Poland, one of the leading markets, saw a 48.4% increase in heavy-lorry registrations in December 2020. Among the largest Western European markets, Germany also made a sizeable contribution (+27.4%), followed by Spain (+8.3%) and France (+2.6%).

- **New medium and heavy commercial vehicles (MHCV) over 3,5t**: 2020, registrations of new lorries declined sharply across the European Union including in the four major markets: France (-24.1%), Germany (-24.0%), Spain (-21.7%) and Italy (-14.0%). This contributed to a cumulative decline of 25.7% to a total of 247 499 lorries registered in 2020.

In December 2020, demand for new medium and heavy lorries posted a solid growth (+7.1%) following a modest upturn (+3.7%) in November 2020, benefiting from the positive performance of the heavy-duty segment (which makes up the bulk of total lorry demand). As for the biggest EU markets, Germany saw the highest percentage growth

(+12.3%), followed by Spain (+3.8%) and France (+2.9%). By contrast, MHCV registrations slid fell slightly in Italy (-1.8%).

- New medium and heavy buses & coaches (MHBC) over 3,5t: from January to December 2020, EU demand for buses and coaches contracted by 20.3%, counting 29 147 new registrations in total. Among the largest EU markets, Spain (-35.9%) and Italy (-24.9%) ended the year in negative, while losses were more limited in France (-10.8%) and Germany posted a slight growth over the same period (+0.4%).

In December 2020, new bus and coach registrations in the EU increased by 13.4% compared to December 2019. With the exception of France (-20.9%), all major EU markets gave a significant boost to the overall performance of the region: Italy (+13,4%), Germany (+22.1%) and Spain (+60.9%) in particular.

Impact of Incentives and recovery packages - Member States and the Commission announced a series of measures to support the economic recovery of the private sector, including the automotive segment. Noticeably, the recession was finally not as deep as expected in 2020[413] despite reintroduction and tightening of containment measures by Member States in response to the 2nd wave. Stimulus packages and recovery measures have also been instrumental for attenuating the recession.

Lessons have been learned from the 2008-2009 crisis in this respect[414]: electric vehicle targeted measures have been designed in countries such as Austria, France, Germany, Greece, Italy, Romania and in the Netherlands whereas other measures already in place and targeting also clean vehicles (e.g. *bonus malus* in Sweden) have been continued. They were all cornerstones of the respective demand stimulus packages, aimed at stimulating the recovery of the automotive sector, in particular through demand and supply of zero and low emission vehicles and recharging infrastructure.

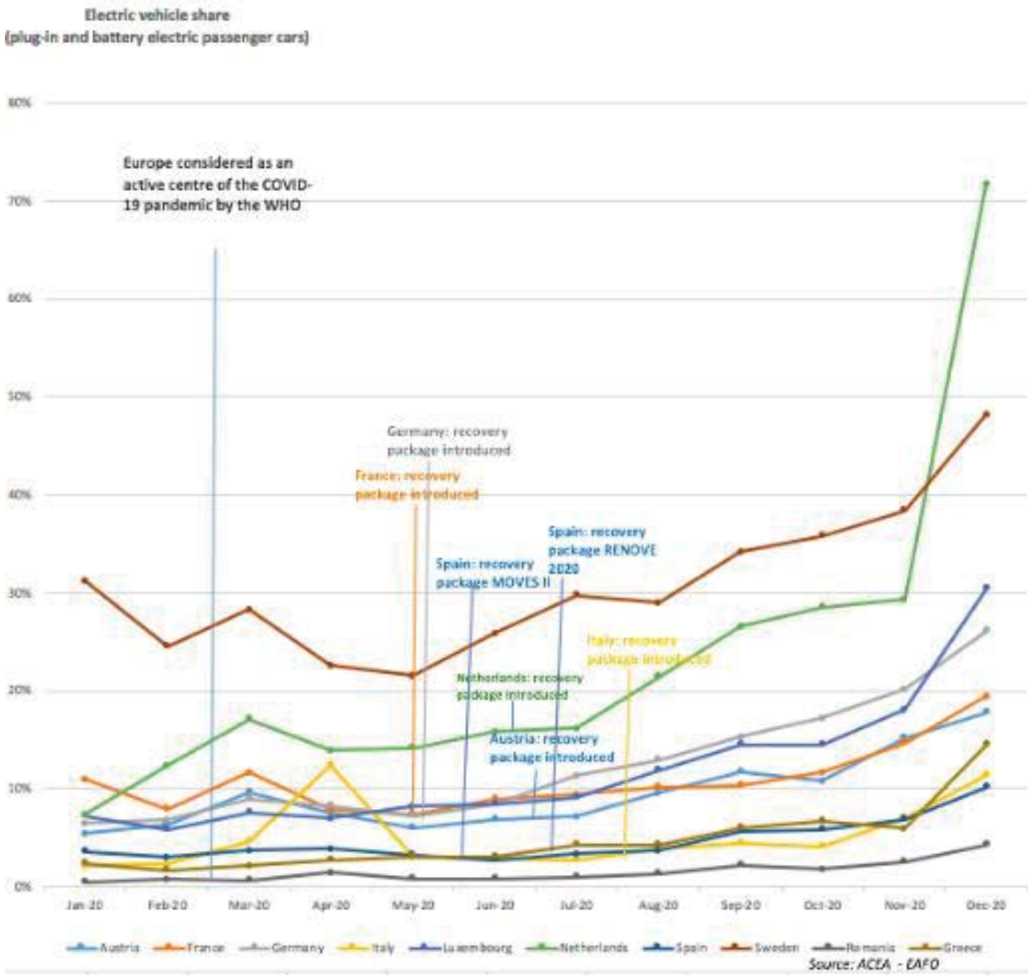
These measures may have contributed to avoiding steeper drops in demand of vehicles in the EU: indeed, contrary to other markets, the electric passenger car markets in Europe has not collapsed since the outbreak of the COVID-19 pandemic. On the contrary, in March and April when mobility was most limited in many European countries, electric vehicles still recorded high registration shares, up to 12% in France and Italy, as shown in the Figure below. Even with fluctuations over 2020, electric passenger car registrations recorded all-time highs.

Up to the end of May, before the introduction of the first recovery packages, this was likely partially a result of more favourable taxes or cost benefits for electric vehicles in markets. After June 2020, electric passenger car shares have rebounded the most in France and Germany after a slight downfall since April 2020. Both countries introduced recovery packages for electric car purchases in June, which had a positive effect on consumer choices. There seems to be similar effects with the Spain's program MOVES II introduced in June 2020 as well as with the stimulus packages in Austria, Spain (RENOVE 2020 Program), and Italy, introduced after June 2020, as well as in other EU Member States having introduced similar measures (Greece, the Netherlands, Romania - see Figure below).

413 European Commission, 2021. Press release: Winter 2021 Economic Forecast: A challenging winter, but light at the end of the tunnel

414 International Council on Clean Transportation, 2020. Briefing: Green vehicle replacement programs as a response to the COVID-19 crisis: Lessons learned from past programs and guidelines for the future

Figure 28 - Electric Vehicle shares in the EU and EU Member States' Recovery packages (Summer 2020) (based on ACEA[415] and EAFO[416])



Outlook and perspectives

Global new-vehicle sales will return to double- digit growth in 2021, but will fail to recover fully[417]. EU economy would barely return to pre-pandemic levels in 2022[418].

Figure 29 - New Vehicle Sales 2020-2021 (source: The Economist Intelligence Unit)[419]

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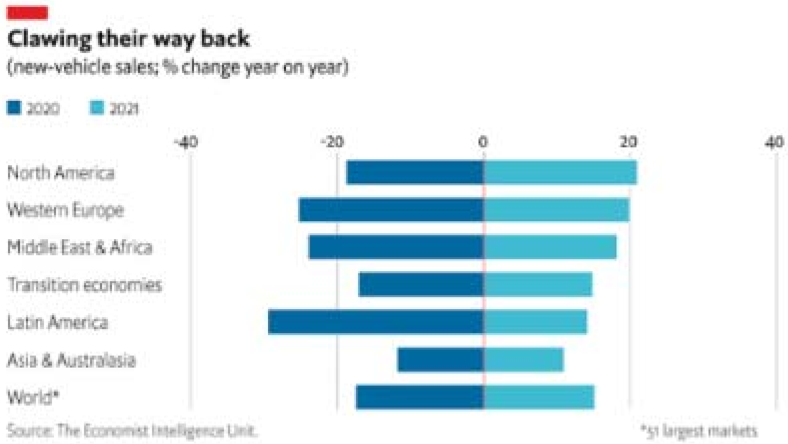
[415] ACEA, 2021. Consolidated registrations – by country
[416] EAFO, 2021. Vehicles and fleet – passenger cars
[417] The Economist Intelligence Unit, 2021. Industries in 2021
[418] European Commission, 2021. European Economic Forecast – Winter 2021 (Interim)
[419] See footnote 417



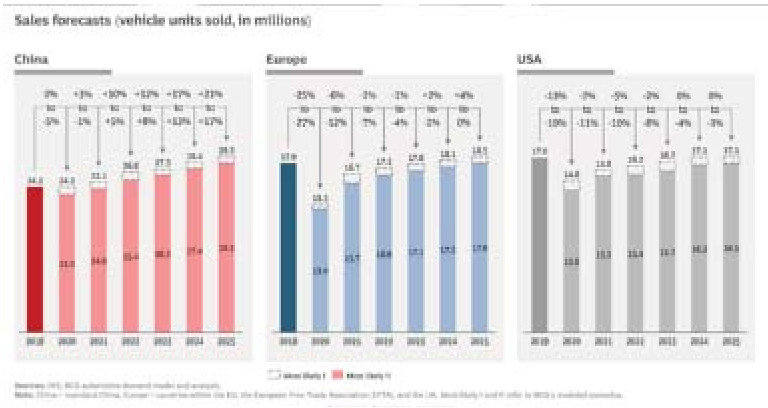
As regards new vehicle sales, a recovery of demand in the EU at the same level as 2019 is foreseen by 2023 only[420]. It is anticipated that the unprecedented shift away from fossil fuel vehicles, in favour of low- emission or electric vehicles will continue and that Europe's share of global Electric Vehicle market will keep increasing. Global Electric Vehicle sales are expected to rise sharply in 2021, to around 3.4 million units, supported by the above-mentioned generous government incentives, and new launches.

The Figure 30 below illustrates the perspectives of recovery respectively in China, USA and Europe:

- A significant demand rebound was recorded in China already, with 2020 corresponding to 23.6 million units, down by 4.9% compared to 2019. 2021 forecast is set at 24.9 million units (+5.6% compared to 2020).[421]
- Despite adverse COVID-19 trends, the automotive demand should continue to recover in the USA, supported by OEM and dealer incentives, online sales, government stimulus and improving economics. A positive trend of demand should continue in 2021 with a forecast of 16 million units for 2021 (+10% compared to 2020). Risks remain, notably from weak fleet sales and tight inventories; restocking efforts, which remain vulnerable to any further potential virus restrictions.
- European recovery prospects are mixed, with worrying virus resurgences, varied economic and stimulus support, ongoing restrictions and uncertainties as regards the sanitary situation (potential third wave). It is anticipated that the Western and Central European automotive demand for 2021 achieves 15.3 million units for 2021[422], with a 11% growth compared to 2020[423]. Governmental support measures should be maintained in the EU Member States with major automotive markets (e.g. France, Germany, Italy, Spain).

Figure 30 - Sales forecast for China, EU and USA (2019-2025) (source BCG, IHS Markit)[424]

[420] See footnote 395
[421] IHS, 2021. Financial Services Commentary and Analysis
[422] See footnote 421
[423] See footnote 421
[424] See footnote 395



Impact on mobility patterns and behaviours

Many uncertainties also exist on how the COVID-19 crisis may affect future mobility, from the capacity of governments and companies to promote transport electrification to what consuming and behavioural changes could potentially be expected from it. The long-lasting impact of the crisis may differ significantly though from other earlier crisis circumstances, particularly 2008-2009 as the automotive industry was already facing multiple huge transformations across global markets when hit by the pandemic outbreak.

Still, beside challenges and economic immediate downturn, the COVID-19 has undoubtedly led to an acceleration of the twin transition in the automotive sectors and to some positive outcome:

- **There is evidence already that the current crisis will not slow down the current ongoing move to electrification**. On the contrary, industry and technological innovation experts expect the crisis to become a catalyst for the transformation. Experts anticipate that "*the next two or three years will be weak years for sales of still-prevalent ICE (internal combustion engine) vehicles on traditional technology platforms.*" And "*demand for the current car line-up will be sluggish due to economic impairments and, at the point demand recovers, customers will return to a more favourable environment for xEVs (battery electric and plug-in hybrid) and demand 2023/2024 state-of-the-art technology*."[425]
- **Reinforced individual mobility**: in the short term, the COVID-19 crisis has raised the importance of safety and the sense of security for consumers. There is thus anecdotal evidence that car ownership will remain very important for individuals in a market which remains on the rise overall. On the other hand, long lasting trends to be noted towards more flexible models of use, financing and subscriptions of cars, and mobility, also with effects on automotive after-sales.
- **Powertrain electrification**: Demand and supply were already shifting towards electric and electrified vehicles, driven by CO_2 regulation and technological progress, e.g., improved battery chemistry, increased range, high-performance charging.
- **Digitalisation of automotive sales and services**: Consumer trends are changing the way we buy and drive cars and consume mobility, e.g., connected cars, assisted driving.
- **e-Commerce.** Widespread confinement has given a massive boost to e-commerce and home deliveries. More people are shopping online, accelerating a pre-existing long-term trend which should last.

[425] Arthur D Little, 2020. Win the automotive COVID-19 rebound

- **Last mile delivery and autonomous cargo transportation.** Companies involved in last mile delivery, which were quite active prior to the pandemic crisis, are set to gain from the Retail, e-commerce and logistics companies should increase investment in technologies and innovation. The positive impact of the crisis on the long-term e-commerce trend should also drive more investment in autonomous driving tech and complete solutions for goods deliveries, in particular for last mile delivery.
- **Customer experience and dealership tools.** During this period there was a push towards pure online sales and contactless deliveries. Customers will likely benefit from less friction in the sales process. Customer behavioural shift towards more online is expected to last, as it parallels other shopping experiences. Most dealers and repair shops are trying to adapt extremely
- **Push to cross-sectorial innovation towards smart and green mobility.** Combined with strengthened charging station infrastructure and innovation in battery technologies, there will be opportunities for uptake of advanced technologies and new entrant technologies and new entrant players with new business models and consumers opportunities at stake (e.g. Vehicle to Grid, Smart grids).

Annex 8: Alternative set of assumptions on emission limits and durability

In the stakeholder consultations, automotive industry and civil society representatives raised concerns and expressed divergent opinions regarding the emission limits, length of the durability requirements and the technological potential for reducing emissions over the lifetime of the vehicles. Emission limits and durability are in particular relevant for air quality benefits. In addition to the different emission limits and durability assumed in the policy options 1, 2a, 2b and 3a for low, medium and high green ambition (see Table 2 in chapter 5), two alternative set of assumptions were assessed to evaluate the effect of changes in emission limits and of durability.

8.1 Alternative set of assumptions on emission limits

An alternative set of emission limits was developed (see Table 56). In this alternative scenario, slightly less strict emission limits are assumed for NO_x, PM, PN, CO, NMOG and NH_3, for light-duty vehicles as well as for heavy-duty vehicles when compared to the medium ambition emission limits in policy option 2a (see Table 50). The conclusions drawn for this alternative are valid also for PO3a, since PO3a is based on the same emission limits as PO2a.

Table 56 – Alternative set of emission limits to Policy Option 2a based on available emission control technology

Air pollutants	Cars and vans	Large vans if underpowered	Lorries and buses Cold emissions[426]	Lorries and buses Hot emissions[427]
	(mg/km)	(mg/km)	(mg/kWh)	(mg/kWh)
NO_x	35	45	440	110
PM	3	3	12	8
$PN_{>10nm}$ (#/km)	3×10^{11}	$3x10^{11}$	$9x10^{11}$	$2x10^{11}$
CO	450	600	5 300	300
NMOG	50	50	225	56
NH_3	15	15	80	80
CH_4+ N_2O	40	50	660	410
HCHO	5	10	30	30
Evaporative emissions[428]	0.5 g/worst day + ORVR[429]	0.7 g/worst day + ORVR	-	-
Brake emissions	7	7	Review	Review
Battery durability[430]	70%	70%	Review	Review

The environmental impacts of the alternative set of emission limits in terms of emission reductions of air pollutants were assessed for light- and heavy-duty vehicles and are presented together with the environmental impacts of the policy option 2a in Table 57 and Table 58.

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[426] Expressed as 100% of MAW
[427] Expressed as 90% of MAW
[428] With random preconditioning at any temperature up to 38 °C
[429] ORVR stands for “On-board Refuelling Vapour Recovery” and is a limit designed to avoid emissions during the refuelling of the vehicles. Limit to be set at 0.05 g/L.
[430] Expressed as Battery Energy Based. To be reviewed for lorries and buses and for inclusion of range metric.

Table 57 – Assessment of the environmental impacts of policy option 2a and alternative medium green ambition compared to the baseline: reduction of emissions of air pollutants in 2035 for cars and vans, Data source: SIBYL/COPERT 2021

Pollutant	Latest available emissions	Baseline	Alternative 2a with less strict emission limits	2a – Medium Green Ambition
	2018 in kt	2035 in kt, % compared to baseline		
NO_X	1 689.67	389.40	**234.58 (-40%)**	224.40 (-42%)
$PM_{2,5,brake\ emissions}$	14.90	16.04	**11.82 (-26%)**	11.82 (-26%)
$PM_{2,5,exhaust}$	43.85	1.50	**1.29 (-14%)**	1.28 (-15%)
PN_{10} [in #]	$6.55x10^{25}$	$1.92x10^{24}$	**$1.29x10^{24}$ (-33%)**	$1.06x10^{24}$ (-45%)
CO	2 796.13	584.50	**482.68 (-17%)**	414.90 (-29%)
THC	412.22	146.10	**116.03 (-21%)**	113.20 (-23%)
NMHC	369.70	119.20	**96.61 (-19%)**	93.80 (-21%)
NH_3	38.41	23.85	**17.44 (-27%)**	16.15 (-32%)
CH_4	42.52	26.85	**19.42 (-28%)**	19.42 (-28%)
N_2O	16.34	41.26	**28.91 (-30%)**	28.91 (-30%)

Table 58 – Assessment of the environmental impacts of policy option 2a and alternative medium green ambition compared to the baseline: reduction of emissions of air pollutants in 2035 for lorries/buses, Data source: SIBYL/COPERT 2021

Pollutant	Latest available emissions	Baseline	Alternative 2a with less strict emission limits	2a – Medium Green Ambition
	2018 in kt	2035 in kt, % compared to baseline		
NO_X	1 689.73	705.40	**354.20 (-51%)**	316.10 (-55%)
$PM_{2,5,brake\ emissions}$	-	-	**-**	-
$PM_{2,5,\ exhaust}$	23.45	8.81	**5.37 (-39%)**	5.37 (-39%)
PN_{10} [#]	$3.70x10^{25}$	$7.49x10^{23}$	**$5.17x10^{23}$ (-31%)**	$4.06x10^{23}$ (-46%)
CO	412.92	111.50	**99.30 (-11%)**	97.90 (-12%)
THC	43.38	26.55	**32.41 (-12%)**	23.06 (-13%)
NMHC	36.71	16.66	**13.31 (-20%)**	12.95 (-22%)
NH_3	6.46	9.64	**9.64 (-0%)**	6.45 (-33%)
CH_4	6.67	9.89	**10.10 (+2.1%)**	10.10 (+2.1%)
N_2O	57.13	97.80	**58.30 (-40%)**	58.30 (-40%)

Conclusion: In line with the assumed alternative emission limits which are less strict than those in PO2a, there are 1-2% less emission savings of NO_x, $PM_{2.5}$ and NMHC and

5% less emission savings of NH_3, compared to policy option 2a for light-duty vehicles. However, for heavy-duty vehicles, there are 4% less emission savings of NO_x and 33% less emission savings of NH_3.

Although the alternative assumption has been developed on the basis of less strict emission limits, **the regulatory costs** associated with it are the same as in policy option 2a, for light- and heavy-duty vehicles.

This is explained by the fact that the same emission control systems will need to be deployed in policy option 2a and in the alternative assumption.

More specifically, the choice of technology as shown in Table 21, is determined by the level of emission limits of NO_x and PN for all types of vehicles. For the emission levels of NO_x (30 mg/km for PO2a and 35 mg/km for the alternative) and for PN ($1x10^{+11}$ for PO2a and $3x10^{+11}$ for the alternative), the required technology is the same. The hardware cost, which is the most important cost category, is therefore the same in PO2a and the alternative. The appropriate level of emissions will be reached through the use of software and appropriate calibration. The calibration costs do not change with the level of emission limits, therefore the total regulatory costs remain the same in PO2a and the alternative.

Therefore, not only the alternative assumption leads to lower emission savings when compared with policy option 2a, but it still results in the same regulatory costs.

Table 59 below presents the efficiency of the alternative assumption as it was done in Table 13 in chapter 7 for the policy options 1, 2a, 2b and 3a.

Table 59 – Assessment of efficiency compared to baseline* for medium-ambition policy option 2a and alternative option 2a with less strict emission limits, 2025-2050, Introduction of Euro 7 in 2025, Data source: SIBYL/COPERT 2021

Policy option	Alternative 2a with less strict emission limits	2a – Medium Green Ambition
Cars and vans		
Health and environmental benefits, 2025 NPV in billion €	**52.41**	54.82
Regulatory costs savings, 2025 NPV in billion €	**3.45**	3.45
Regulatory costs, 2025 NPV in billion €	**33.73**	33.73
Net benefits, 2025 NPV in billion €	**22.13**	**24.55**
Benefit-cost ratio**	1.7	1.7
Lorries and buses		
Health and environmental benefits, 2025 NPV in billion €	**124.94**	132.54
Regulatory costs savings, 2025 NPV in billion €	**0.38**	0.38
Regulatory costs, 2025 NPV in billion €	**16.82**	16.82
Net benefits, 2025 NPV in billion €	**108.50**	**116.10**
Benefit-cost ratio**	7.5	7.9

** The baseline considers an end-date of combustion-engine cars/vans in 2035, see section 5.1.*
*** The benefit-cost ratio gets disproportionally high when costs are low which gives an unjustified advantage to low-cost options (here lorries and buses) and has the potential to mislead policy makers. The benefit-cost ratio is disregarded to choose one option based on benefits and costs in absolute terms only and included in this table for completeness purposes only.*

Conclusion: Compared to policy option 2a, the **alternative assumption leads to lower health and environmental benefits and no cost changes**. The net benefits for the alternative assumption of the medium green ambition are for light- and heavy-duty vehicles lower than policy option 2a due to the smaller reduction in harmful air pollutants.

8.2 Alternative set of assumptions on durability

Most new vehicles that are purchased by a first user eventually end up on the second-hand market. In addition, large flows of used cars are reported from Western to Central-Eastern EU countries with the import of used cars exceeding the number of domestic new registrations in almost all Central-Eastern EU countries.[431] These flows are expected to be an important contributor to the difference in the average age of vehicles in Western and Central-Eastern EU countries raised by stakeholders from civil society. While the lowest average ages of cars are found in Luxemburg, Austria, Ireland, Denmark and Belgium (7-9 years), the highest average age are found in Lithuania, Estonia, Romania and Greece (16-17 years).[432]

Used vehicles exported to other regions, like Africa or Middle East may remain in circulation even longer. Such vehicles often comply with below Euro 4/IV standard and they often present problems with the emission control technologies leading to high emissions of PM and NO_x.[433] Despite efforts by several African countries, a lack of adequate fuel quality in most African countries still prevents the optimal use of recent advanced emission control technologies.[434]

The revision of the End-of-Life Vehicle Directive[435] planned for 2022 is looking into the problem of circulation and of export of used vehicles outside the EU in order to address environmental and health problems created by them.

Since the Euro 6/VI durability provisions were found to be inadequate, all policy options considered in the impact assessment were based on increased durability with different levels of ambition (see Table 2 in chapter 5 and Table 54). This was done in order to ensure good performance of the vehicle throughout their lifetime.

Policy option 2a on the medium green ambition reflects the average lifetime of vehicles in EU-27. An alternative to option 2a was analysed where higher durability was introduced to reflect the need for increased car performance in order to limit emissions beyond the average lifetime (see Table 60). Since the durability assumptions are the same in PO2a and PO3a, the conclusions drawn are also valid for PO3a.

Table 60 - Assessment of efficiency compared to baseline* for medium-ambition policy option 2a and alternative option 2a with increased durability, 2025-2050, Introduction of Euro 7 in 2025, Data source: SIBYL/COPERT 2021

Policy option	2a – Medium Green Ambition	Alternative 2a with increased durability
Cars and vans		

[431] Transport & Mobility Leuven, 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
[432] ACEA, 2021. Average age of the EU vehicle fleet, by country.
[433] Dutch Ministry of Infrastructure and Water Management – Human Environment and Transport Inspectorate, 2020. Used vehicles exported to Africa: A study on the quality of used export vehicles
[434] United Nations Environment Programme (UNEP), 2020. Global Trade in Used Vehicles Report
[435] Directive 2000/53/EC on end-of life vehicles

Durability	200 000 km or 10 years	**240 000 km or 15 years**
Health and environmental benefits, 2025 NPV in billion €	54.82	**55.78**
Regulatory costs savings, 2025 NPV in billion €	3.45	**3.45**
Regulatory costs, 2025 NPV in billion €	33.73	**34.66**
Net benefits, 2025 NPV in billion €	**24.55**	**24.58**
Benefit-cost ratio**	1.7	1.7
Lorries and buses		
Durability lorries < 16t, buses < 7.5t / lorries > 16t, buses > 7.5t	375 000 km / 875 000 km	**450 000 km / 1 050 000 km**
Health and environmental benefits, 2025 NPV in billion €	132.54	**133.55**
Regulatory costs savings, 2025 NPV in billion €	0.38	**0.38**
Regulatory costs, 2025 NPV in billion €	16.82	**18.06**
Net benefits, 2025 NPV in billion €	**116.10**	**115.87**
Benefit-cost ratio**	7.9	7.4

** The baseline considers an end-date of combustion-engine cars/vans in 2035, see section 5.1.*

*** The benefit-cost ratio gets disproportionally high when costs are low which gives an unjustified advantage to low-cost options (here lorries and buses) and has the potential to mislead policy makers. The benefit-cost ratio is disregarded to choose one option based on benefits and costs in absolute terms only and included in this table for completeness purposes only.*

Conclusion: The alternative set of durability assumptions results in slightly higher health and environmental benefits for both cars/vans and lorries/buses while increasing hardware costs lead to slightly higher regulatory costs. For light- and heavy-duty vehicles, only minimal changes occur with regard to the net benefits moving from the average durability assumptions in policy option 2a to increased durability.

This cost-benefit result is explained by the fact that the additional emission savings with increased durability assumptions are only expected to occur towards the end of the assessed period. Hence, the net present value of the health and environmental benefits does not increase much. In a contrary manner, the additional hardware costs mostly occur at the beginning of the vehicles lifetime, which increases the net present value of the regulatory costs relatively more.

In conclusion, the alternative set of durability assumptions to reflect a longer lifetime of vehicles in the EU-27 is not expected to be a more efficient solution for either cars/vans or lorries/buses.