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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}

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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.

[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]

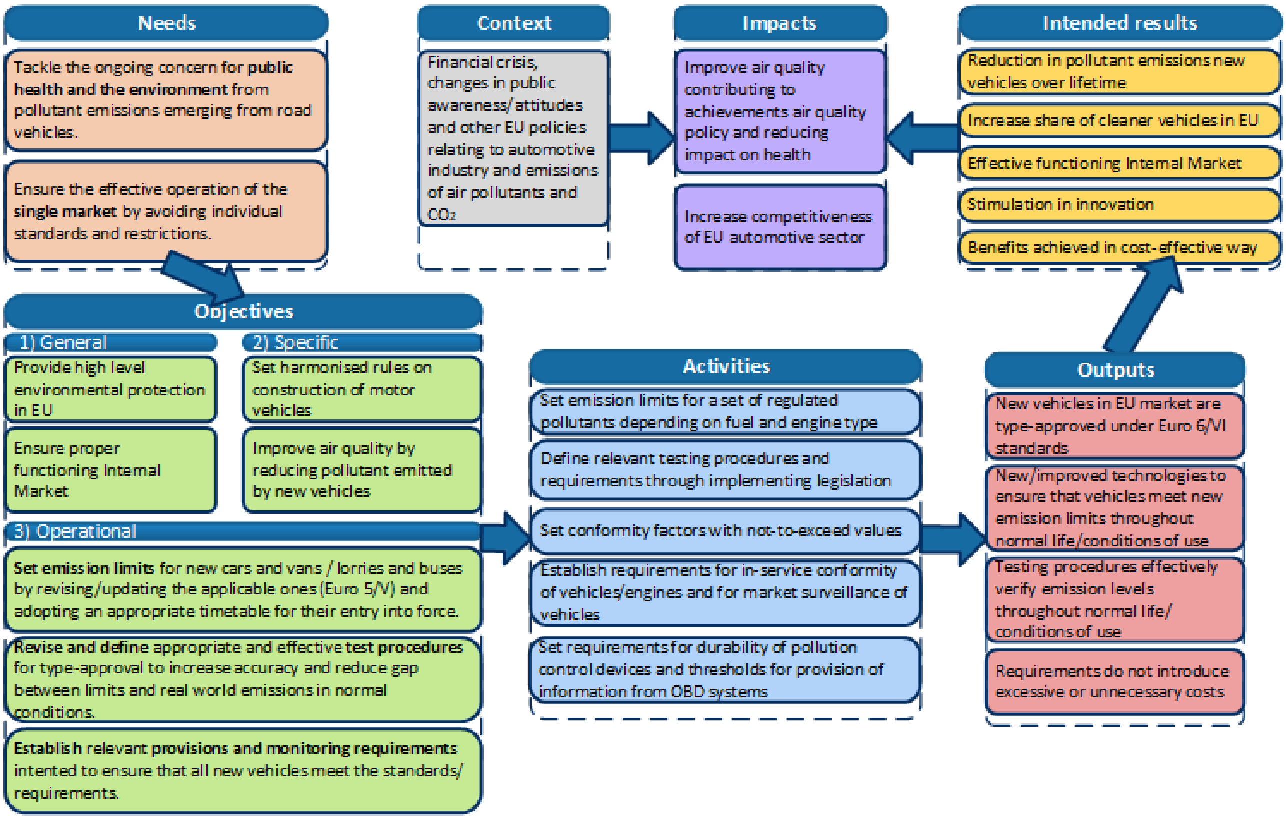
[11] See footnote 3

[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

[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.

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[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 – 30°C | Extended: -7 – 0°C & 30 – 35°C	-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

[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

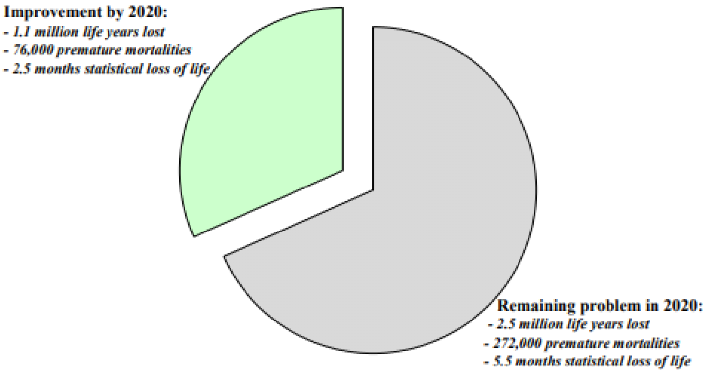
[33] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011;

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]

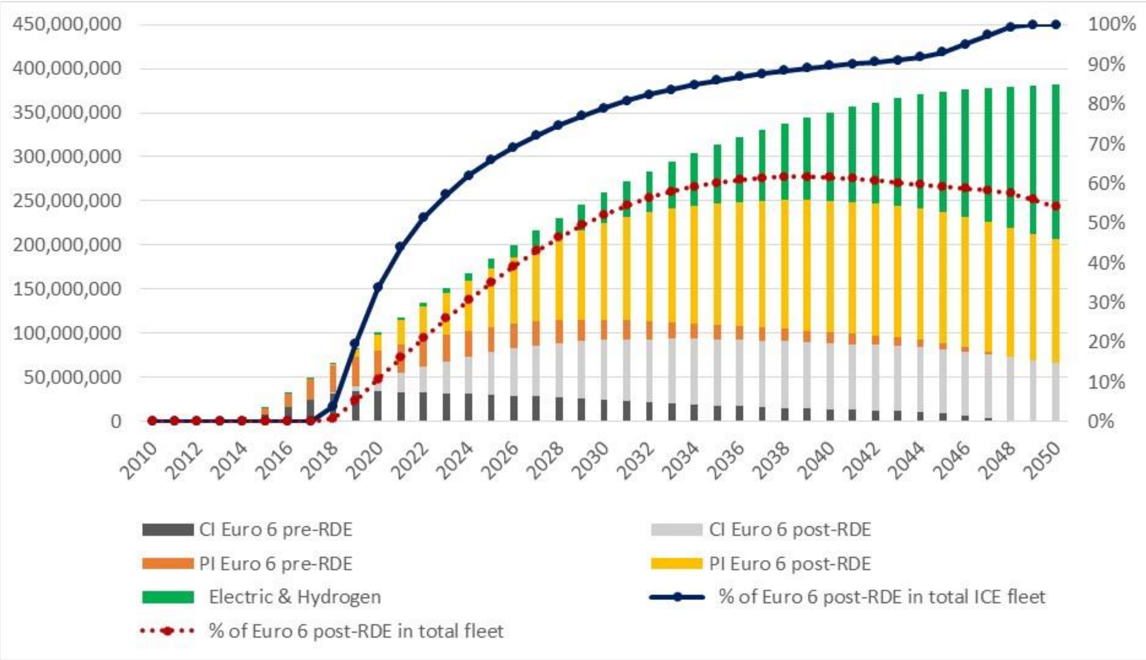
A) Cars and vans (Euro 6 pre- and post-RDE), Source: CLOVE based on data from SIBYL model

[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).

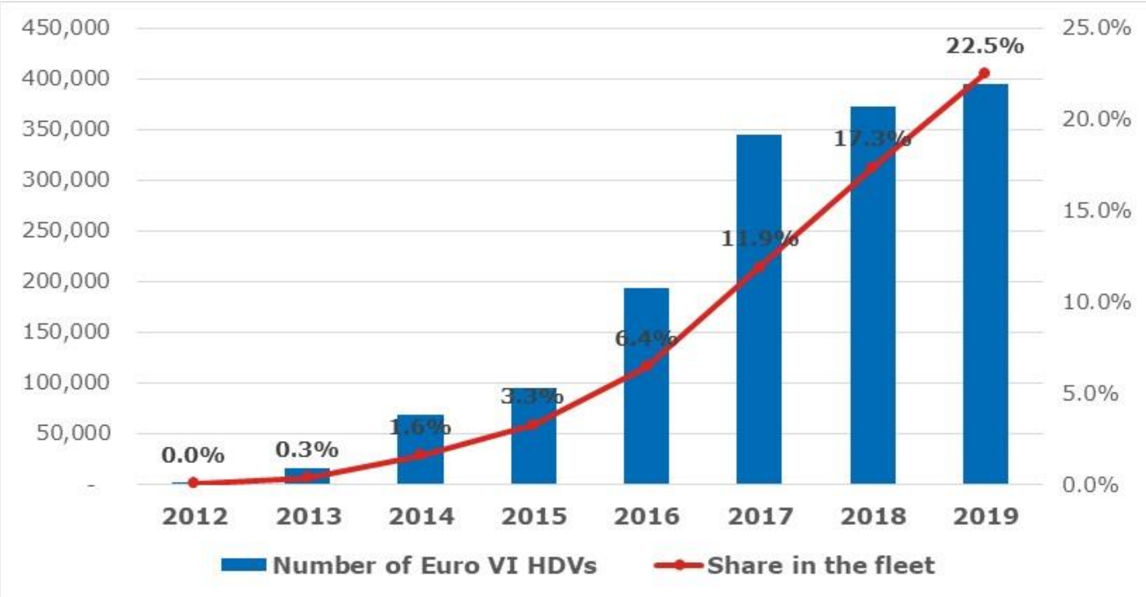
[38] SIBYL: Ready to go vehicle fleet, activity, emissions and energy consumption projections for the EU 28 member states. The SIBYL model was updated with data on emission type-approvals from 10 Member States, data on vehicle sales in the EU-28 from 2013-2020 from IHS Markit and vehicle fleet projections 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.

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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

[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

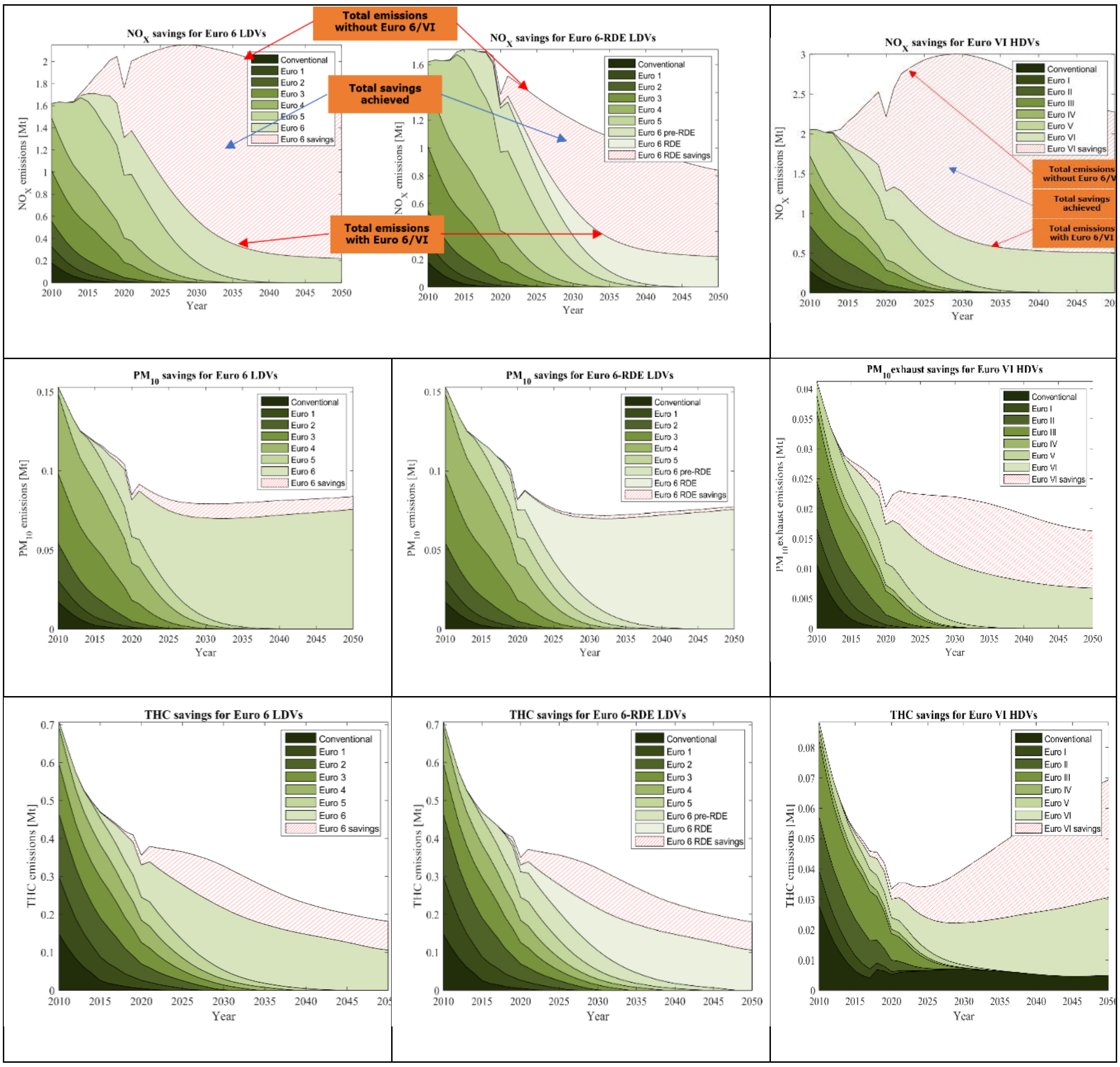
[81] See footnote 79

[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]



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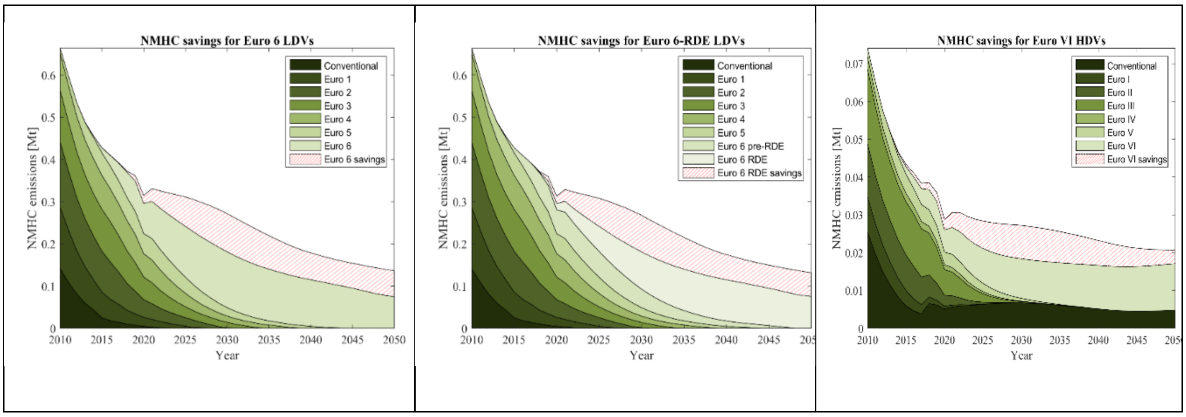
84 European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 5)

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

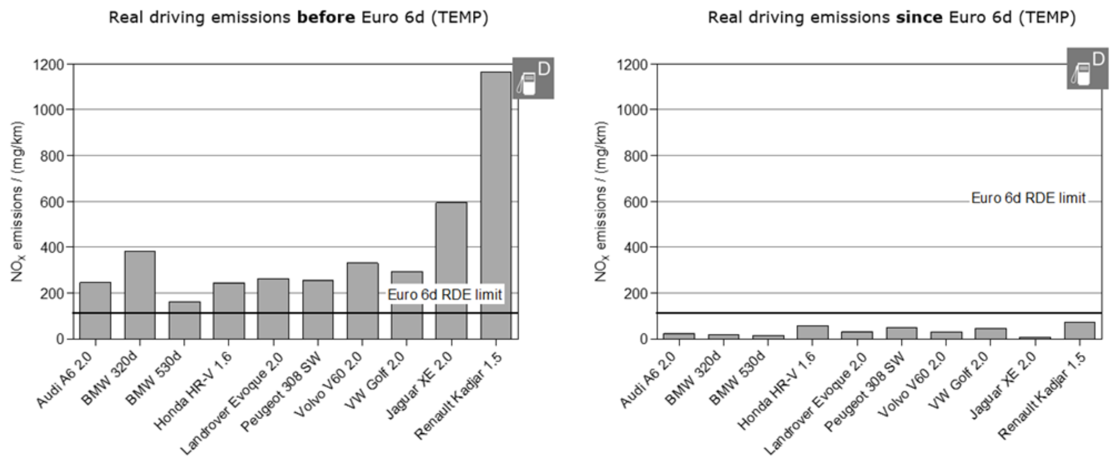
and high altitude circuits, and severe temperature conditions; and test boundaries for lorries and buses low loads, low speed and idle times that are of great importance in urban areas. Hence, a complete coverage of real-world driving cycles and all conditions of use is still missing in Euro 6/VI emission 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]



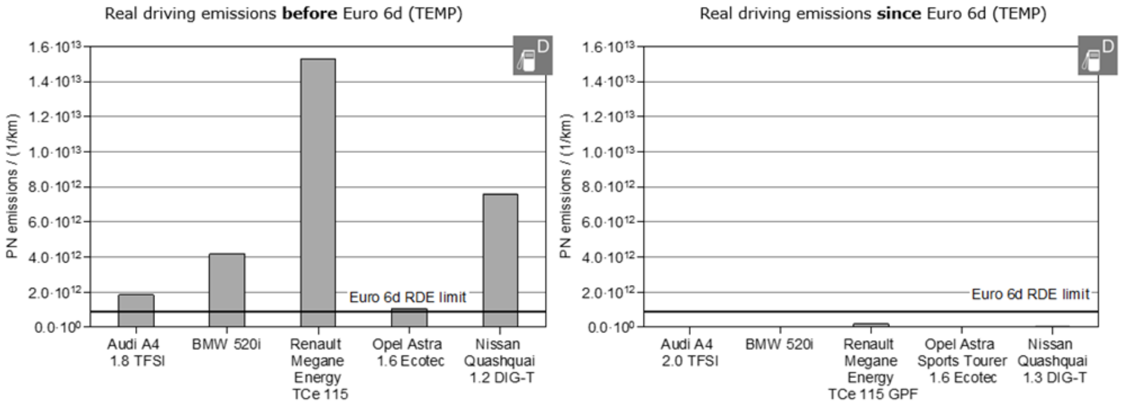
Source: Bundesministerium für Verkehr und digitale Infrastruktur, 2016. Bericht der Untersuchungskommission „Volkswagen"
and https://www.acea.be/publications/article/access-to-euro-6-rde-monitoring-data, https://group.renault.com/en/rde-2/, https://erwin.audi.com/erwin/performRdeSearch.do

[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



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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

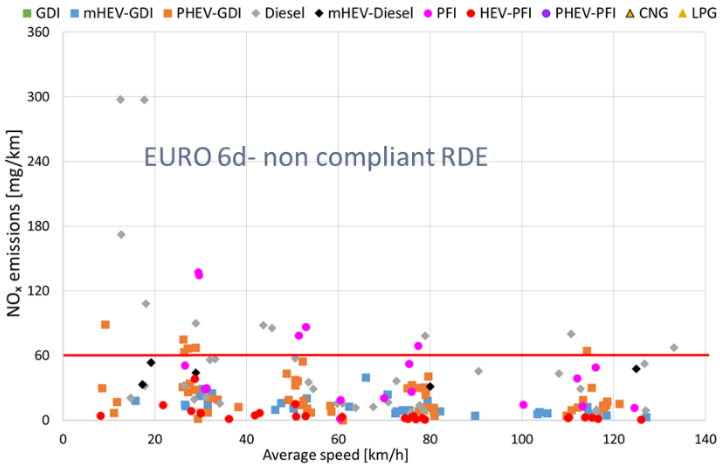
[113] European Commission, 2020. Presentation AGVES Meeting 26 November 2020: Post-Euro 6/VI public stakeholders consultation (Question 14)
[114] See footnote 108
[115] Grigoratos, T., et al., 2019. Real world emissions performance of heavy-duty Euro VI diesel vehicles; TNO, 2018. Tail-pipe NOx emissions 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].

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[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?

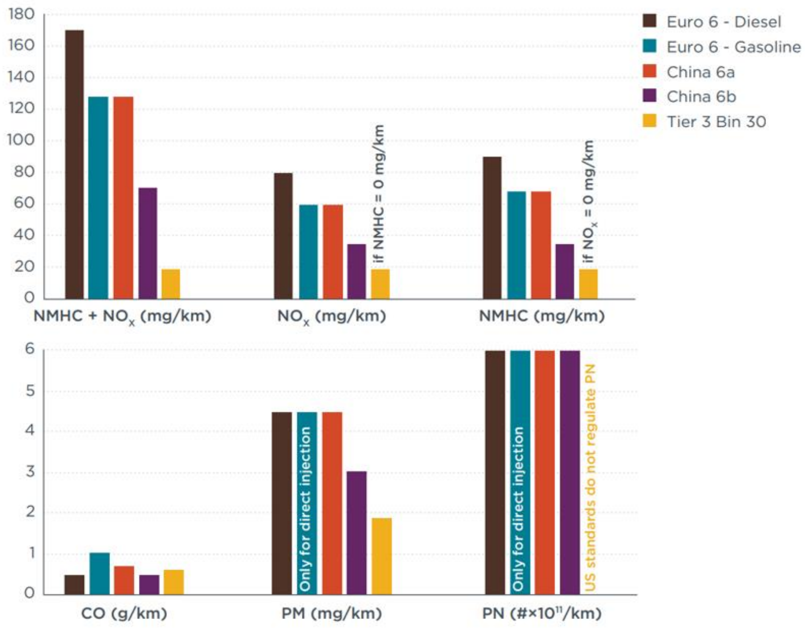
[130] AEA, 2011. Effect of regulations and standards on vehicle prices. Report to the European Commission – DG Climate Action

[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

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[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

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[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

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[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]

<table>
<tr><th colspan="3">Regulatory costs for automotive industry</th></tr>
<tr><th colspan="3">Direct compliance costs</th></tr>
<tr><td rowspan="7">Substantive compliance costs</td><td colspan="2">Equipment costs</td></tr>
<tr><td>• Hardware costs</td><td>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.</td></tr>
<tr><td>• R&D and related calibration costs including facilities and tooling costs</td><td>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.</td></tr>
<tr><td colspan="2">Costs during implementation phase</td></tr>
<tr><td>• Testing and witnessing costs</td><td>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.</td></tr>
<tr><td>• Type-approval fees</td><td>Recurrent costs including the fees for granting type-approval paid to type-approval authorities, excluding the cost of witnessing above.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="2">Administrative burden</td><td colspan="2">Administrative costs</td></tr>
<tr><td colspan="2">Recurrent costs including costs for reporting and to fulfil other information provision obligations as part of the process for granting type-approval.</td></tr>
</table>

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]

	Petrol cars and vans			**Diesel cars and vans**			**Lorries and buses**
		Introduction RDE testing			Introduction RDE testing		
	Euro 6b-c	Euro 6d-temp	Euro 6d	Euro 6b-c	Euro 6d-temp	Euro 6d	Euro VI
1) Equipment costs							
• **Hardware costs**							
Cost per vehicle (€)	0	84-103	228-465[168]	341-937	630-1 536	751-1 703	1 798-4 200
Total cost (€ billion)	0	1.9-3.2		15.3-40			4.1-9.5
• **R&D and related calibration costs including facilities and tooling costs**							
Cost per vehicle (€)	36-108			43-156			1 900-3 800
Total cost (€ billion)	1.3-4			1.8-6.7			5.35-10.7

[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

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

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]

[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]

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[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.'

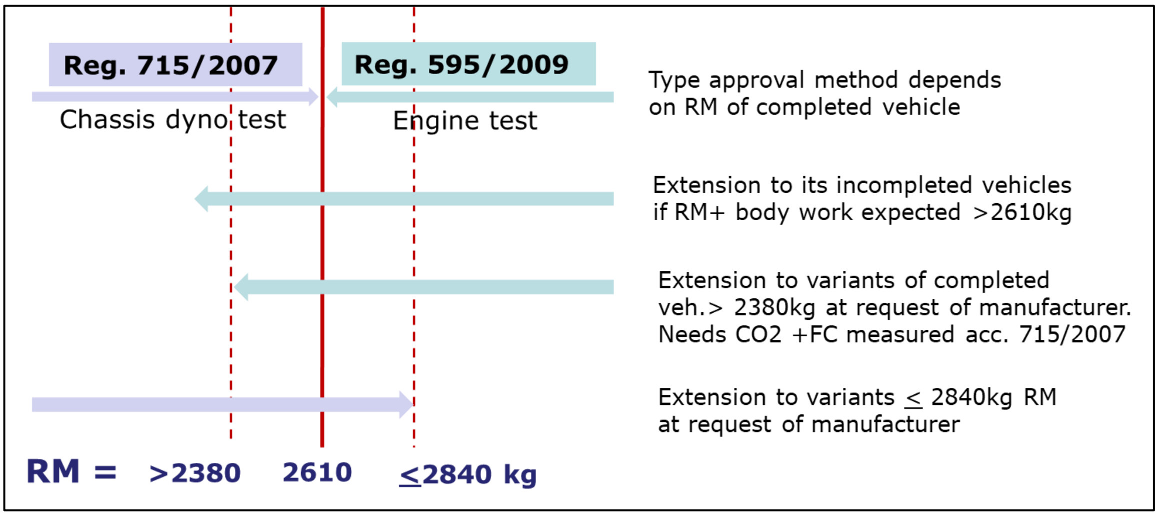
[278] See footnote 33

[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

[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]

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[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

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[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

[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.

[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	-

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**	**Large vans if underpowered**	**Lorries and buses Cold emissions**	**Lorries and buses Hot Emissions**
	(mg/km)	(mg/km)	(mg/kWh)	(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

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[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)	-
$v \times a_{pos}$ [95^{th} [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).

[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

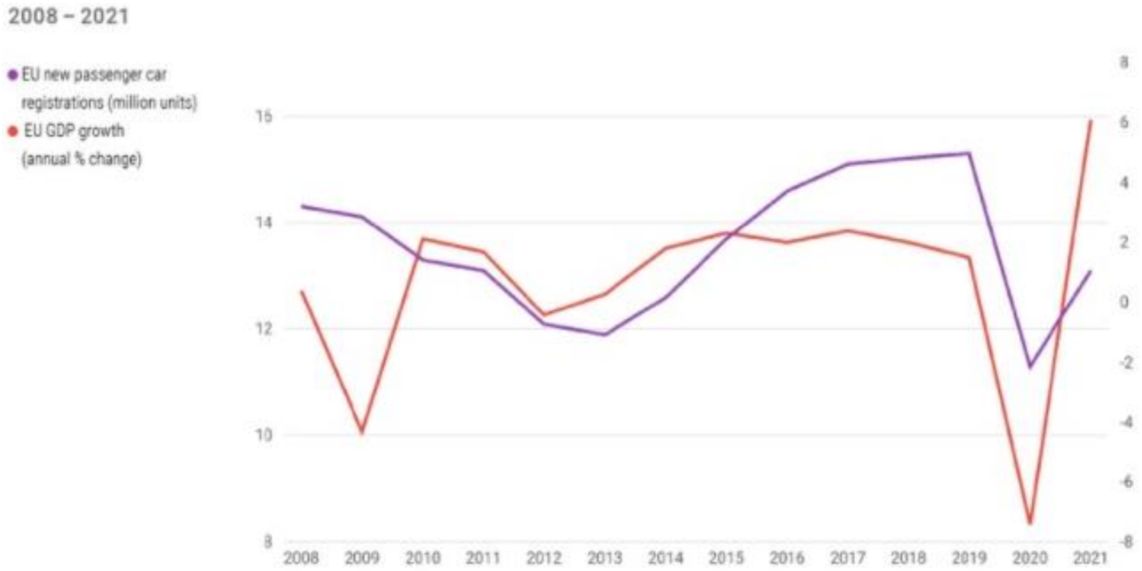
[388] Supporting Euro 7 impact assessment study, chapter 5.3.1. Environmental impacts

[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

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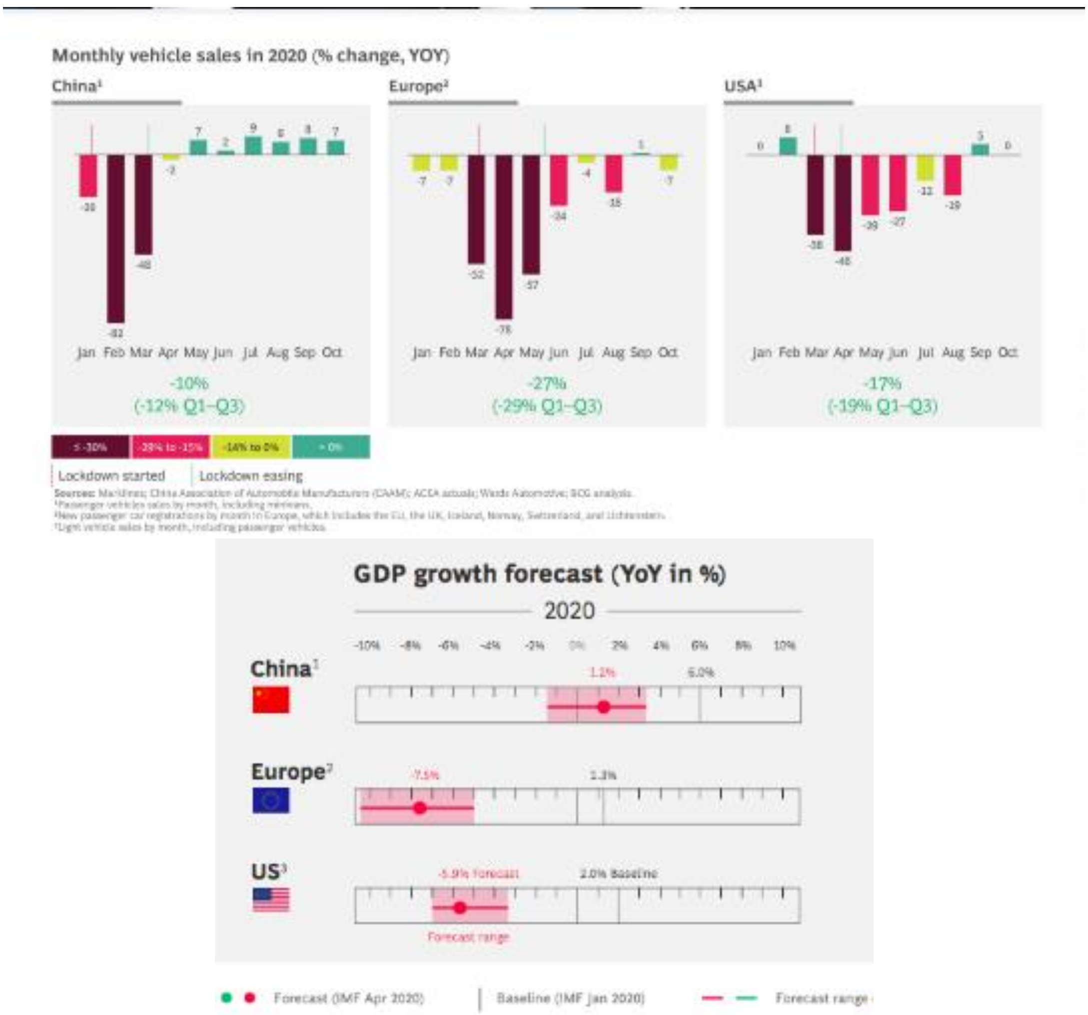
[390] Eurostat, 2021. Newsrelease Euroindicators: GDP down by 0.7% in the euro area and by 0.5% in the EU (17/2021 – 2 February 2021).
[391] ACEA, 2021. Passenger car registrations: -23.7% in 2020; -3.3% in December
[392] ACEA, 2020 31 December. Available at https://twitter.com/acea_eu/status/1344629151916040195
[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

[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.

[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

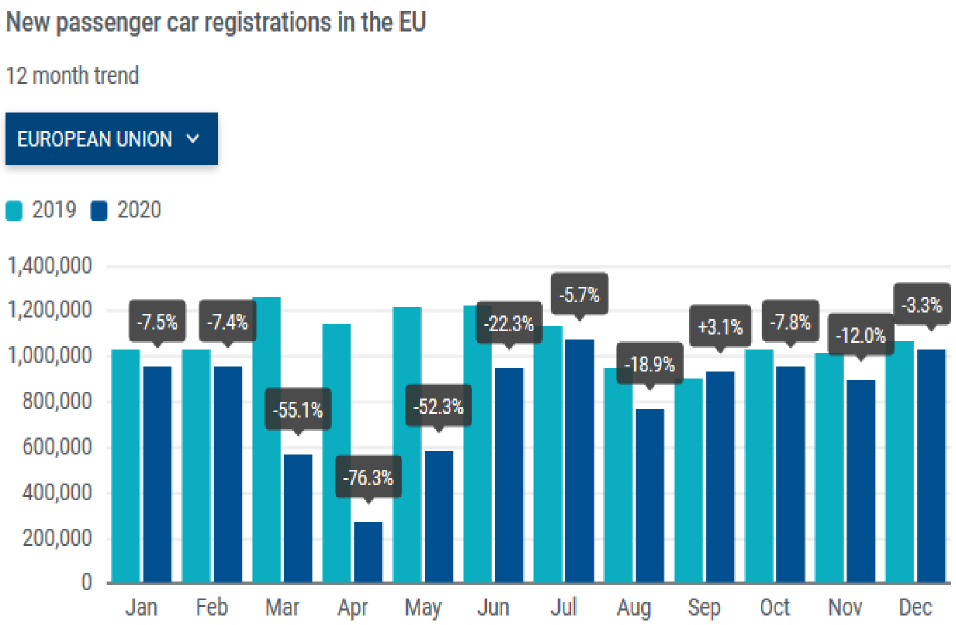
Consequently, the **automotive market**, that was already on a downward trend, facing structural challenges (CO_2, pollutant emissions, electrification), was hard-hit and suffered an unprecedented 23.7%[408] decrease of passenger car sales in 2020. It is expected that COVID-19 will negatively affect 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.

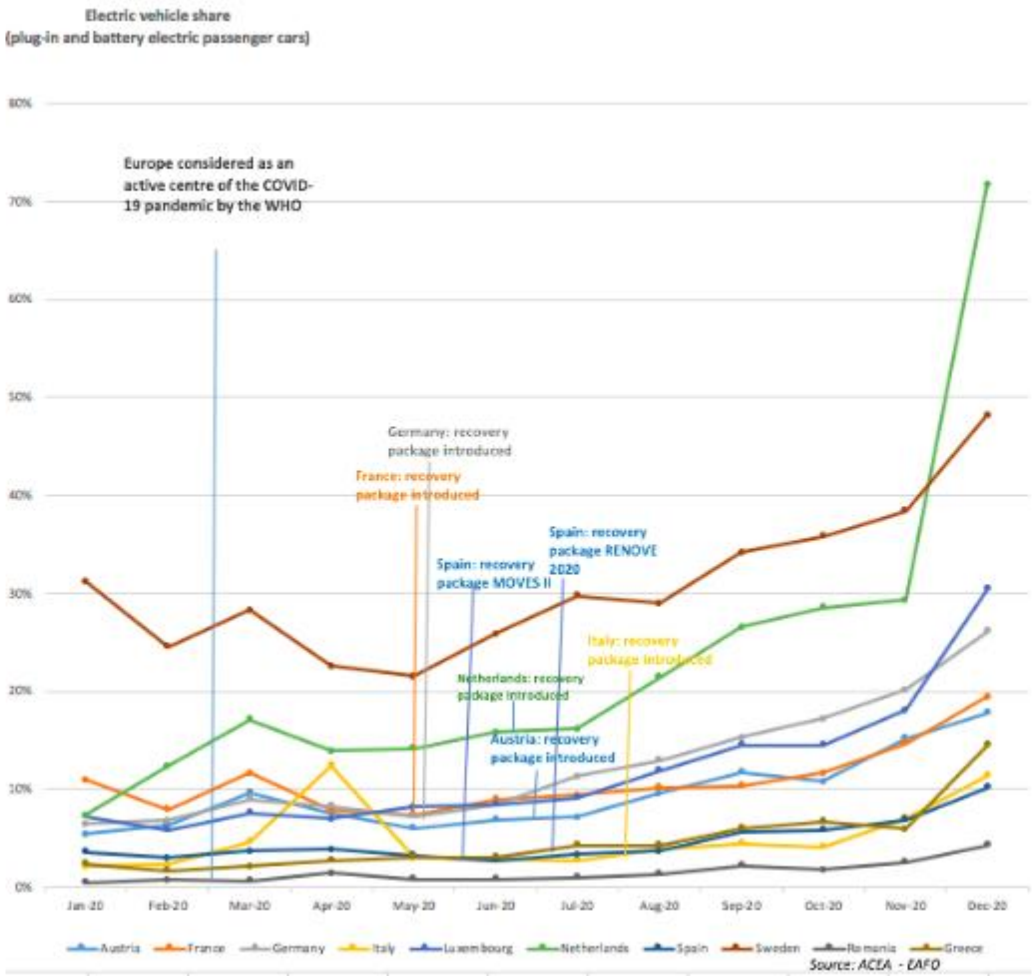
Lessons have been learned from the 2008-2009 crisis in this respect[414]: electric vehicle targeted measures have been designed in countries such as Austria, France, Germany, Greece, Italy, Romania and in the Netherlands whereas other measures already in place and targeting also clean vehicles (e.g. *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])

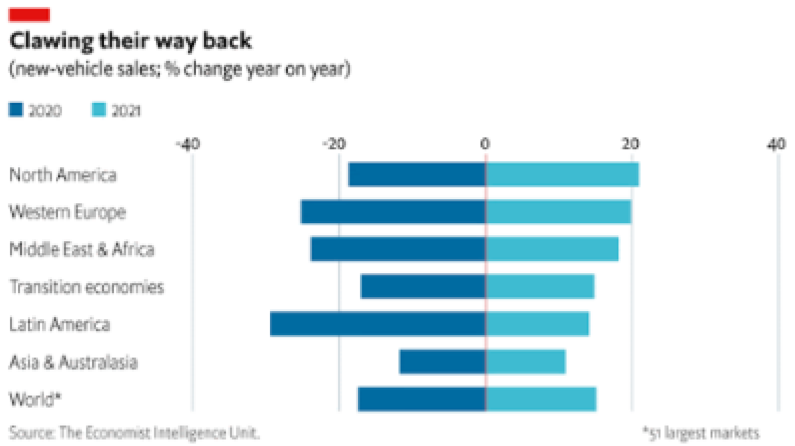


Outlook and perspectives

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]

[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



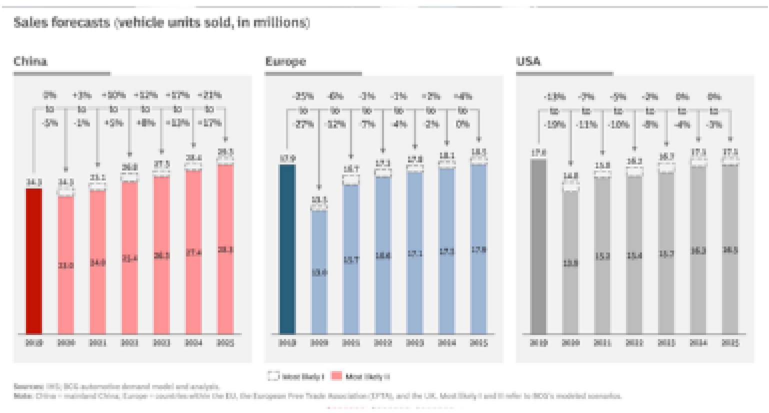
As regards new vehicle sales, a recovery of demand in the EU at the same level as 2019 is foreseen by 2023 only[420]. It is anticipated that the unprecedented shift away from fossil fuel vehicles, in favour of low- emission or electric vehicles will continue and that Europe's share of global Electric 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.

[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 #]	6.55×10^{25}	1.92×10^{24}	**1.29×10^{24} (-33%)**	1.06×10^{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} [#]	3.70×10^{25}	7.49×10^{23}	**5.17×10^{23} (-31%)**	4.06×10^{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.