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Euro 7 Impact Assessment Study

CLOVE

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Abstract

This report provides the cost-benefit of different policy options with regard to the potential regulation of the next step in vehicle emission standards (Euro 7). It first provides the policy, market and legal context in which the new standard is expected to be linked to. Second, it outlines what are the remaining problems with the current emission standards and how these are expected to evolve in the future. Then, it presents the available policy options for Euro 7 and formulates them into six structured scenarios that can be used to model the associated impacts and costs. The scenarios examine different possibilities with Euro 7 regulation ranging from small to moderate interventions but also looking at more aspirational targets. Then the report estimates the impacts of the six scenarios, that is their environmental impacts, cost implications, and impacts to the economy and the society, including competitiveness of the EU automotive sector, the functioning of the internal market, employment, training systems and skills, social inclusion, affordability, and consumer trust, coherence and proportionality. It also includes a modelled cost-benefit analysis of the different policy options. Finally, the report compares the different policy options along different criteria in order to assist selecting the most suitable one.

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Executive Summary

Background and Study Objectives

The European Green Deal (COM(2019) 640 final) is a new growth strategy for the EU, which has introduced a zero pollution ambition. Recognising the contribution of transport to air pollution, the European Green Deal has the ambition that transport becomes drastically less polluting, especially in cities. As part of this, the European Commission (EC) aims at introducing a new emission standard for cars, vans, lorries and buses, the so-called Euro 7. In parallel, the EC proposed the end of the internal combustion engines on new light duty vehicles by 2035 in their presentation for Fit-for-55 in July 2021.

Within this policy environment, the current study was commissioned after successful evaluation of the relevant CLOVE proposal in the call for tenders No 803/pp/GRO/IMA/19/1131/1075, entitled "*Study on post-Euro 6/VI emission standards in Europe (Part B)*". This call for tenders was issued within the "*Framework contract for studies and technical assistance in the field of emissions*", No. 688/PP/2018/FC. The CLOVE consortium, comprising LAT/AUTh, EMISIA, FEV, Ricardo, TNO, TU Graz, and VTT was formed within this framework contract with the aim to support the EC in their technical assessment of the new emission standard. As part of this work, CLOVE has issued a number of preceding reports that provided technical input to the current study:

- *Post Euro 6/VI Part B study: Euro 6/VI standards evaluation*", henceforth the **Evaluation report**[1]**.** It contains the analysis and the findings of the study for the retrospective assessment of Euro 6/VI vehicle emission standards.
- "*Post Euro 6/VI study: Combined report of Part A & Part B*", henceforth the **Combined report**[2]. It combines the outcomes from Tasks 2.1, 2.2 and 2.3 of Part A, and Task 1 of Part B to present the emission limits, the vehicle technology and the testing requirements that can be improved moving to Euro 7.
- "*Post Euro 6/VI Part B study: Potentials for Simplification of Vehicle Emission Standards*", henceforth the **Simplification report**[3], presents the Euro 6/VI emission standard components that can be improved to simplify the type approval procedures of Euro 7.
- "*Post Euro 6/VI Part A study: Review of international automotive emissions regulations*", henceforth the **Review on Int'l regulations**[4]. It focuses on reviewing current and forthcoming vehicle emission legislative developments in leading automotive markets around the world and makes key comparisons with the Euro 6/VI vehicle emission regulatory framework.

This report, entitled "Euro 7 impact assessment study" has been solely compiled by EMISIA and LAT/AUTh using technical input from that preceding CLOVE work and additional information collected within the AGVES group and from external sources. The objectives of the current study have been the following:

- To formulate a baseline scenario of projected emissions without a legislative change and to design – based on EC policy targets – a range of options for narrow revision, wider revision and profound revision of vehicle emission standards;
- To develop a methodology to assess the costs and benefits of each option;
- To compare the options, based on the assessment of the various impacts and their distribution across affected stakeholders' groups.

[1] CLOVE, 2021. "Post Euro 6/VI Part B study: Euro 6/VI evaluation study"
[2] CLOVE, 2021. "Post Euro 6/VI study: Combined report of Part A & Part B"
[3] CLOVE, 2021. "Post Euro 6/VI Part B study: Potentials for Simplification of Vehicle Emission Standards"
[4] CLOVE, 2020. "Post Euro 6/VI Part A study: Review of international automotive emissions regulations"

Methodology

Baseline emissions modelling

A baseline activity and emissions projection has been developed in order to evaluate the necessity for a new vehicle emission standard. This baseline is consistent with the policy objectives of the recently presented EU Fit-for-55 package, in terms total road transport activity projection and future technology mix. The emission factors used for the latest Euro 6d/VI E technologies were designed to reflect the impact of ❶ hot and cold-start operation, both distinguished within RDE/ISC conditions and outside of these conditions, ❷ degradation due to normal ageing and malfunctions, and ❸ the impact of tampering of the emission control systems. Moreover, fuel evaporation and break wear emission factors were developed on the basis of experimental evidence and modelling.

Description of policy options

Four policy options for the introduction of Euro 7 emission standards were investigated:

1. **Policy Option 0** (PO0) is assumed not to bring any changes over the current emission standards. Therefore, the emission limits remain at the levels today applicable for Euro 6/VI. Emissions follow the baseline development in this case.
2. **Policy Option 1** (PO1) is based on fuel-neutral limits at the lower value of current Euro 6/VI, regulatory simplification for type approval including an enhanced OBD, and a mildly reworked set of normal boundary conditions for type approval testing. Emissions outside of these normal boundary conditions are capped by a factor of 4 for LDVs and 3 for HDVs over the emission limit. For PN, the size threshold is assumed to decrease to 10 nm.
3. **Policy Option 2** (PO2) goes beyond PO1 and assumes decreased emission limits over Euro 6/VI combined with a widened set of driving conditions that are suitable for vehicle testing. It also considers the inclusion of additional pollutant definitions in the type approval (N_2O, HCHO, NMOG), and sets an emission cap by a factor of 3 for LDVs and 2 for HDVs in extended conditions. In addition, PO2 sets ☐a new diurnal limit for evaporation losses. As a sensitivity analysis, different levels of emission limits have been considered in different scenarios. As part of PO2, two options for brake wear control were also studied (POx acronym used). However, their assessment has been done independently of the exhaust emission control scenarios and their potential implementation can therefore be combined with any of the exhaust control scenarios.
4. **Policy Option 3** (PO3) incorporates the concept of a continuous monitoring of vehicle emission performance using on-board emission monitoring (OBM) sensors and over-the-air transmission of emission information, in addition to the provisions of PO2. Moreover, fuel system leak detection is assumed to be introduced as part of the improved OBD system.

Emission benefits, cost and cost-benefit analysis modelling

For all policy options and their associated scenarios, we estimated the total emission benefits over the baseline evolution and the incremental implementation costs over Euro 6d/VI E.

The avoidance of pollution from the introduction of Euro 7, i.e. the emission savings, creates a benefit when expressed in monetised terms. The monetised benefit (in €) is calculated by multiplying the emission savings with the external damage costs per unit of pollutant, that differs per pollutant, as reported by van Essen et al.[5] in the “Handbook on the external costs of transport” and some adjustment to introduce the contribution of NMVOC to secondary aerosol formation. Most of the benefits originate from decreased **health impacts** due to lower emissions of NO_x, NMVOC, $PM_{2.5}$ and NH_3. Additionally, benefits originate from decreased **environmental impacts** due to control of CH_4 and N_2O gases. A final monetary benefit originates from **fuel savings**, through enhanced fuel evaporation control.

For calculation of implementation costs, the cost model calculates the total societal cost as incremental costs differences over the baseline incurred for the implementation of each new regulatory component. The cost categories considered are **compliance costs** (hardware / R&D, engineering & calibration / initial investment in facilities or equipment), **costs associated with implementation activities** (testing / witnessing / fees) and **administrative costs** (associated with reporting & other information obligations).

The Cost-Benefit Analysis (CBA) model that was specifically developed to perform the retrospective assessment of the Euro 6/VI vehicle emission standards (*Evaluation report*) was also used for the impact assessment of the Euro 7 policy options examined in the current study. The cost-benefit results show whether the societal investment associated with the environmental policy provides at least similar quantity of benefits, when both are expressed in monetary terms.

Environmental impacts

All policy options result to significant environmental benefits, depending on the scenario considered in each policy option, especially when a conservative evolution of Euro 6/VI emission factors is to be anticipated. The expected percentage reductions in emissions of pollutants for the different exhaust control scenarios are calculated as cumulative differences in the complete time frame 2025-2050. Reductions are significant, especially for HDVs. A slight increase of CH_4 appears as a side-effect of stringent control of cold-start emissions but is of no environmental relevance, as total CH_4+N_2O from HDVs decrease significantly when N_2O reductions are also taken into account.

Cost-benefit analysis

The following observations can be done for the different policy options and scenarios, on the basis of the results of the cost-benefit analysis:

- PO1 results to a visible net benefit to the society which mostly comes from a reduction in the emission levels of HDVs, especially if emission levels are expected to evolve according to a conservative Euro 6/VI projection. For HDVs, there are benefits introduced by decreasing costs of the type-approval and by introducing an enhanced OBD and simplified procedures that can enable a more stringent IsC and MaS framework. An enhanced lifetime checking framework guarantees that future emission levels will remain where they are today by keeping constant the designed emission target of vehicles. For LDVs, additional benefits materialise due to the widening of boundary conditions and the streamlining of emission limits between CI and PI vehicles. Therefore, main benefits come from CI LDVs. One potentially interesting feature of PO1 is that even under our extreme estimate of high implementation cost and no worsening of the Euro 6/VI emission levels in the future, it results to very little overall net damage. This means that PO1 is a very safe option but – at best – delivers little, compared to other options, net benefits.

[5] van Essen et al., 2019. “Handbook on the external costs of transport”, DG MOVE.

- PO2 produces significant net benefits which, again, mostly originate from HDVs and secondarily from CI cars & vans. PO2 in general exhibits low benefit and high cost for PI LDVs. The central values for those appear negative (B/C is equal to 0.74, 0.67 and 0.35 for scenarios Sc1, Sc2 and Sc3, respectively) but considering the high net benefits from CI cars, this PO results to appreciable net positive benefits for cars and vans. More than 2/3 of the high benefits from lorries and buses come from NO_x reductions which are significant over Euro VI. However, PO2 also achieves reductions for PM which come from a better control of semi-volatile PM during cold start, decrease of the particle number limit and inclusion of the regeneration in emissions control. Approximately 8% and 4% of the benefit comes from exhaust PM control for buses and lorries CI, respectively, while these percentages become higher when considering PI ones, i.e. 21% and 18% for buses and lorries, respectively. However, a significant benefit (approximately 28% of the total for lorries CI and 25% of the total for buses CI) comes from the better control of N_2O – this is an environmental benefit due to the reduction of the total radiative forcing activity of N_2O and not due to health benefits. Some smaller-scale benefits come from the other pollutants. PO2.Sc3 also exhibits net benefits for lorries and buses but its benefits for LDVs become marginal (B/C=1.11) and, especially for PI cars and vans, the B/C ratio becomes less than 0.5. This is due to the significant additional costs this entails, compared to the improvement this offers. PO2.Sc3 provides an almost equal probability that it will be a net benefit or a net cost to the society for cars and vans. Especially if future PI registrations are higher than what the projection used in this study predicts, this may even result to significant overall net costs to the society from cars and vans.

- PO3 also leads to significant net benefits, despite its higher cost, originating (in addition to PO2) from the better control of degradation and malfunctions due to OBM. Actually, PO3 results to the overall highest net benefits both for LDV and HDV, even more so than PO2.Sc3 that has been formulated with the lowest emission limits but no OBM implementation. This suggests that OBM can bring real-world benefits due to the decrease of tampering and making sure that the emission control system operates within specifications that supersede its implementation costs.

- POx.ScB1 scenario introduces net benefits due to the decrease of PM which are at the same scale with net benefits of the exhaust control options for LDVs. This shows how important and beneficial the control of brake wear can be. POx.ScB2 results to overall net damages though, due to the high costs of implementation. As technology costs for brake wear decrease fast with time due to the immaturity of some of the relevant technologies, exact limits of brake wear may need to be reassessed when a specific time frame for regulatory intervention has been decided.

Economic and social impacts

Competitiveness on EU automotive sector

Competitiveness in the automotive sector can be expressed as the synthesis of cost savings, innovation capacity and global market access. PO1 encompasses a narrow revision of the current Euro 6/VI standards by reducing their complexity, whilst keeping a focus on real-world testing. This entails a cost increase which is due to a larger size of existing components and no new technology development, hence this investment will not lead to any particular innovation. As a result, PO1, can offer a low overall disadvantage to the competitiveness of the overall supply chain of the automotive industry.

In contrast, new technology and significant R&D investment are required to achieve the emission reductions in PO2. The development and implementation of advanced technologies aims to bring emission levels ahead of other major regions such as China and USA in terms of emission reductions, but also in terms of the associated innovation needed to achieve the low emission levels required. Such a development will enable the EU automotive industry and its supply chain to strengthen their global position in terms of competitiveness and potentially achieve comparative advantages by concentrating research and development on resource-efficient and less polluting technology.

PO3 would require the enhancement and further optimization of existing sensors, which will be benchmarked over the extended testing conditions prescribed already from PO2, which, by itself, promotes competition by increasing innovation. Overall, PO3 is based on innovative technology and concepts that are much needed for and by the automotive industry, therefore it is considered to have the highest (positive) impact on improving the long-term competitiveness of the EU automotive industry.

Functioning of the internal market

One emerging barrier at EU level, in which emission standards may have an indirect impact, is the introduction of complete bans of certain vehicle technologies by city authorities when designing their air quality policies. PO1, despite introducing fuel neutral limits, might not be able to fully prevent all upcoming market distortions, such as these specific bans of ICE in certain urban areas, as the emissions limits remained unchanged over Euro 6/VI. PO2 will introduce admittedly considerably more stringent requirements than PO1, thus will potentially have a higher impact on providing the necessary assurance to certain EU cities to reconsider such bans. Furthermore, PO3 provisions, can enable monitoring of real-world emissions and enhanced emission control over the lifetime of future vehicles. We expect that such possibilities my assist in lifting some of the market bans associated with national environmental policies in different member states.

Employment

Employment is considered to scale proportionally to competitiveness, when it comes to the production of vehicles powered with ICEs. A highly competitive industry with access to global markets produces a large number of vehicles and employs a large number of staff. For OEMs, none of the policies are expected to lead to any significant difference in the levels of employment, at least for conventional manufacturing of vehicles. PO3 may have significantly positive effects if new business opportunities arise (e.g. due to big-data produced by on-board sensors). For suppliers and testing equipment manufacturers, more components in PO2 and, additionally, sensors in PO3 are also assumed to have a proportionally positive impact on employment. Finally, simplification measures may have a negative impact on the workload of type-approval services and hence to employment in the sector but increased effort towards in-service conformity and market surveillance is expected to counterbalance for a large share of any loss.

Training systems and skills

PO1 introduces the lowest requirements in terms of new technology, hence, no significant impact is expected on re-training/upskilling employees in the automotive industry supply chain. Any new job positions are projected to require mostly the same level of education/skills as required today. On the other hand, PO2 is expected to be more research-intensive and will introduce advanced drivetrains, as well as exhaust aftertreatment technologies, to cope with more stringent emission limits and testing conditions. Although the further development of new existing innovative technologies will require upskilling/additional training on a portion of the workforce, existing requirements for new medium skilled personnel would still remain. As such, it is expected that a higher level of skillset and education will be required, but this demand will likely spread to the different sectors of the automotive industry supply chain, hence the overall impact on, EU level, should be considered low. PO3 is characterized by the introduction of ICT in vehicle emission control monitoring. This will increase the participation of on-board electronics and software to the automotive product, which will consequently require skills that have not, so far, been requested as among the core competences of automotive engineering. Therefore, additional technical skills will be required to develop, deploy, operate and maintain new digital technologies and sensing devices.

Social inclusion, affordability and consumer trust

As was the case with the Euro 6/VI standards, no tangible evidence exists to suggest that the impact of the incremental regulatory costs associated with Euro 7 standards (for all PO) are not affordable for consumers. Indicatively, PO2 leads to a marginal increase of vehicle costs that do not represent more than 2.7% for cars/vans and 5.5% for lorries/busses respectively, of estimated average vehicle prices (even the most stringent PO2.Sc3). A new emission standard may also change the perception for certain vehicle categories as being environmentally hostile and may remove public pressure from enforcing specific bans on those vehicle categories. In addition to the provisions of PO2, PO3 introduces mechanisms can guarantee lifetime compliance with any emission limit, therefore providing measured evidence and added verification to the consumers/public that vehicles continue to be clean during their full useful life.

Coherence

The Euro 7 proposals generally improve the internal coherence of regulation by introducing fuel/technology neutral limits, merging the main regulations of cars/vans and lorries/buses into a single regulatory piece, define a new border between LDV and HDV emissions legislation and introduce a single date of Euro 7 introduction per vehicle category. Moreover, Euro 7 proposals are consistent with other key EU policies/ interventions, including the European Green Deal, the vehicle roadworthiness legislation, the vehicle CO_2 standards – in particular with regard to vehicle mass definitions. Moreover, Euro 7 proposals go into the direction of the Revision of the Ambient Air Quality Directives, in particular towards serving the introduction of lower air quality standards proposed in the relevant inception impact assessment. The Euro 7 proposals generally improve internal coherence of regulation by streamlining emission limits, lifting technology discrimination, and providing clearer vehicle category discrimination, in line with CO_2 classification criteria.

Proportionality

All POs foresee the implementation and enforcement of harmonised measures/regulatory provisions for all EU-27 Member states, without exceptions. In that sense, all PO are expected to continue to provide added value and maintain a high degree of harmonisation at an EU level. In parallel, this harmonized approach provided clarity and a ‘steady’ environment for the EU automotive industry, in order to develop, manufacture and sell its products in a uniform fashion for all EU Member states.

1. Introduction: Political, Legal and Market Context

1.1. Contribution of road transport to air pollution

Road transport is a major contributor to air pollution, particularly in urban environments. Exhaust emissions of vehicles have been a significant source primarily of nitrogen oxides (NO_x) and ultrafine particles (UFP) in urban areas around the world. In the EU, road transport is the single most important source of NO_x, producing 39% of total manmade NO_x emissions in 2019[6]. In terms of particulate matter with a diameter of 10 μm or less (PM_{10}), road transport contribution is 10% when both exhaust with approximately two thirds of this originating from non-exhaust wear sources[1]. When looking at smaller particles, road transport appears responsible for 32-97% of total UFP in urban areas[7].

That significant contribution should be seen with reference to the fact that more than 30% of EU citizens are exposed to ozone concentrations that are above EU air quality standards. In fact, if the World Health Organization air quality guidelines are considered, practically the whole of EU population (98.6% in 2018) are exposed to ozone concentrations above acceptable levels[8]. Although ozone is a secondary pollutant formed in daylight by atmospheric processes, it is well known to depend on the emissions and corresponding ambient concentrations of NO_x and volatile organic compounds (VOC). Further to NO_x, VOCs are also produced by vehicle exhausts and fuel evaporation, although other sources (solvents, residential heating, etc.) may also be contributing at a measurable degree in an urban environment. In any case, ozone and air quality standards are mostly exceeded in traffic-influenced stations. In 2017 – the latest year for which data are reported by the European Environment Agency – 86% of ambient NO_2 exceedances were detected at roadside monitoring locations[9].

PM_{10} air quality standards exceedances are also observed in the EU, although exceedances in traffic impacted stations are in fact lower than in background monitoring stations. Most of background exceedances occur in Eastern EU, largely impacted by transboundary pollution and outdated industrial installations. In several Western EU countries, the exceedances are only observed in traffic impacted stations[4]. The fewer exceedances of acceptable PM_{10} concentrations than NO_2 and ozone should not be undervalued. Overall, in the EU, poor air quality is considered responsible for close to half a million (premature) deaths in 2018, the latest year for which EEA has made relevant calculations[10]. Particulate matter with diameter of 2.5 μm or less ($PM_{2.5}$) is responsible for three quarters of these calculated deaths, despite the lower occurrence of $PM_{2.5}$ exceedances than for ozone. This is because of the higher health risks that $PM_{2.5}$ exposure is associated with compared to ozone. This indicates that all efforts need to be done to further decrease PM emissions, including measures directed to traffic. For road vehicles, this would have impacts to both exhaust and non-exhaust (tyre, brake, and road wear) emissions.

1.2. Political Context

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6 EEA, 2021. "European Union emission inventory report 1990-2019".
7 Kumar P., et al., 2014. "Ultrafine particles in cities" *Environ Intl,* vol. 66, pp. 1-10.
8 EEA, 2020. "Exceedance of air quality limits".
9 EEA, 2019. "Exceedances of air quality limit values due to traffic".
10 EEA, 2020. "Air Quality in Europe 2020".

Addressing air pollution caused by transport in general, and road transport specifically, is a well-established priority of high-level EU policy. The European Green Deal (COM(2019) 640 final) is a new growth strategy for the EU, which has introduced a zero pollution ambition for Europe. Recognising the contribution of transport to air pollution, the European Green Deal sets the target that transport becomes drastically less polluting, especially in cities. A number of interventions and initiatives are foreseen in this direction. In particular for road transport, these range from establishing more stringent emission standards for new vehicles leading to better environmental performance, to interventions targeting traffic congestion and measures to promote and increase the efficiency of public transport.

Equally importantly, the European Green Deal places priority in reducing CO_2 emissions from vehicles towards fulfilling a zero-emission vision for future transport in the EU. Although in the policy context, the reduction of greenhouse gases (GHG) is a distinct target to the reduction of urban air pollution, there are significant interlinkages when deploying those two policy priorities in the field. Reduction of GHG is primarily based on the introduction of new vehicle technologies, such as battery-electric and fuel-cell ones, and new alternative and sustainable fuels. Other measures may involve traffic calming, intermodal shifts and optimisation of logistics for freight transport. All these and similar options have immediate impacts on the total quantity of air pollutants produced by road transport. Moreover, the choices made to decrease GHG may also affect air pollutant emissions from the existing stock and the available technological options for emissions control of new vehicles. Air pollutant and GHG political framework therefore creates a new era for future vehicle technologies and any assessment of new emission standards needs to be made in this new environment.

Such GHG reduction options and a pathway to a more sustainable transport to 2030 and beyond are in detail outlined in European Commission (EC) Communication [COM(2020) 562 final] and the associated impact assessment [SWD(2020) 176 final] on a 2030 Climate Target. This policy initiative puts EU in an accelerated pathway towards meeting its overall 2050 carbon-neutral economy. The new initiative aims at 55% reduction of GHG in 2030 over 1990 levels, in view of the 90% reduction targeted in 2050, with increased contributions from all activity sectors. Moreover, in the July 2021 presentation of the EU Fit-for-55 package [COM(2021) 550 final and COM(2021) 556 final], the European Commission proposed the end of the internal combustion engines from light duty vehicles by 2035. For road transport, this corresponds to significant vehicle technology and operational implications that one needs to take stock of when assessing the contribution of road transport to air pollution in the future. New powertrains and vehicle technologies (such battery electric and hydrogen fuelled vehicles) are emerging in place of the traditional internal 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 internal combustion engine to ensure protection of human health in urban areas and to prevent the internal market from fragmenting due to individual national initiatives (e.g. diesel or petrol bans)[11].

The European Commission's New Industrial Strategy[12] aims to empower Europe's industry to lead the twin transitions towards climate neutrality and digital leadership, while maintaining its global competitiveness and innovation level. One of the key signals of this new strategy is that there is significant potential for low-emission technologies and

[11] European Commission, 2020. Inception impact assessment "European vehicle emissions standards – Euro 7 for cars, vans, lorries & buses".

[12] European Commission, 2020. "Making Europe's businesses future-ready: A new Industrial Strategy for a globally competitive, green and digital Europe".

sustainable products, processes and services throughout the whole value chain from raw materials to energy-intensive industries, manufacturing and the industrial services sector. Hence, future incentives and investments aim at stimulating research and development (R&D), to support this industrial transition.

In the same direction, vehicles to be sold in the future will also need to take advantage of the new opportunities offered by enhanced digitalisation and automation supported, inter alia, by new communication infrastructure. Such opportunities are promoted by the EU Strategy for a Sustainable and Smart Mobility[13] that aims at increasing the sustainability, resilience and accessibility to the transport system. The opportunities set forward will further assist the decrease of road transport related pollution. Shifts from private to public and shared transportation, congestion avoidance, remote monitoring of vehicle performance, are all tools that can and will also contribute to air pollution reduction. Future vehicles will be equipped with several of the forthcoming technology options which will allow them to receive full benefit of the enhanced opportunities.

Decreasing the carbon content and increasing the contribution of renewable energy of liquid and gaseous fuels used in road transport will be also contributing towards meeting EU's GHG commitments. These may include hydrogen and other synthetic fuels produced by renewable energy. These priorities are currently pursued by the Evaluation of the Directive on the Deployment of Alternative Fuels Infrastructure[14]. Deploying new infrastructure for distribution of such alternative fuels is a prerequisite for their wider uptake. Similarly to the other measures primarily targeting GHG, use of new and alternative fuels may have implications to air pollutants of both new vehicles and the existing stock. Monitoring the effects of these new fuels should not be limited to those pollutants currently regulated but should also include new species that may become relevant because of the alternative fuel formulation.

1.3. Legal Context

In order to control pollutant emissions from road transport, all vehicles need to comply with emission standards, depending on the date of their first placement to the market. Emission standard regulations determine the pollutants that need to be monitored and the corresponding limit values that vehicles have to respect, specify the tests that have to be executed and outline calculation, measurement and instrument calibration methods which are required to demonstrate vehicle compliance. The latest applicable standard is the so-called Euro 6 for cars and vans, first introduced in 2014 by Regulation (EU) No 715/2007, and Euro VI for lorries and buses, first introduced in 2012 by Regulation (EU) No 595/2009. A number of implementing acts were put in place to clarify and revise the technical provisions for both regulations. It has to be clarified that emission standards do not limit emissions that primarily depend on fuel specifications, such as heavy metals, SO_x and benzene. These pollutants are the focus of fuel-specification relevant regulations[15].

The adoption of the Euro 6 standards and the implementing legislation brought changes to a number of aspects of the applicable legal framework (compared to Euro 5). These included:

- Stricter tailpipe emission limits for certain pollutants;

[13] European Commission, 2020. "Sustainable and Smart Mobility Strategy – putting European transport on track for the Future", (SWD(2020) 331 final).
[14] Directive (EU) 2014/94 of the European Parliament and of the Council.
[15] Directive 2009/30/EC of the European Parliament and of the Council.

- introduction of new testing procedures;
- changes concerning evaporative emissions; and
- new on-board diagnostics (OBD) requirements.

In particular for cars and vans, Implementing Regulation (EU) No 2017/1151 introduced the latest step in emissions limits, the so-called Euro 6d step and the Real Drive Emissions (RDE) procedure with which vehicle emissions are examined under on-road driving. The new testing environment admittedly created a much more robust and comprehensive framework for the control of vehicle emissions over actual operation conditions. The RDE framework became a global success and authorities in all major automotive markets in the world (except US) were fast in adopting it also within their national regulatory frameworks.

Similarly, for lorries and buses comprising the category of heavy-duty vehicles (HDVs), implementing Regulation (EU) 2016/1718 introduced the obligation to measure emissions of actual vehicles on the road using Portable Emission Measurement Systems (PEMS) for in-service conformity (ISC) checking. Emissions level checking under realistic on-road operation conditions has therefore become the cornerstone of emissions compliance in the HDV segment as well.

While emissions standards apply during type-approval, vehicle roadworthiness requirements aim at making sure that all vehicles in circulation perform as they are designed and do not produce high emission levels due to any technical defects or emission control system tampering. The relevant pieces of legislation include Directive 2014/45/EU, on periodical technical inspections (PTI), and Directive 2014/47/EU, on technical roadside inspections of commercial vehicles. The roadworthiness legislation and the emission standards have complementary objectives of ensuring that the emission standards are complied with during the different stages of the life of the vehicle, ensuring that emission levels are kept in control.

The European Commission has also adopted Regulation (EU) 2019/631 for LDV and Regulation (EU) 2019/1242 for HDV, setting fleet-wide CO_2 emission targets for 2025 and 2030. Both regulations contain provisions requiring the Commission to monitor the real-world representativeness of the CO_2 emissions determined during the TA (type-approval) or certification tests. To this end, the Commission, shall collect real-world fuel and/or energy consumption data from vehicles using On-Board Fuel and/or energy Consumption Monitoring (OBFCM) devices. Such devices have been introduced in the TA legislation through Regulation (EU) 2018/1832 (the so-called “WLTP 2nd act”), amending Regulation (EU) 2017/1151.

Vehicle emission standards in the EU contribute towards the attainment of air quality standards. Ambient air quality standards in the EU are currently mandated through Directive 2008/50/EC (parent directive) which aims at controlling concentrations of sulphur dioxide, nitrogen dioxide, particulate matter, lead, benzene, carbon monoxide and ozone. Additionally, Directive 2004/107/EC (fourth daughter directive) establishes target values for the ambient concentrations of heavy metals (arsenic, cadmium, nickel) and benzo(a)pyrene (BaP), the latter as a representative species for the family of polyaromatic hydrocarbons (PAH). Road transport directly contributes to the emission of most of these species, primarily via combustion processes but also due to brake and tyre wear and fuel evaporation.

The path to satisfactory air quality requires the gradual and continuous reduction of manmade pollutants liberated to the atmosphere. EU member states and the EU as a whole are parties to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) of 1979 and have signed the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone of

1999, which was revised in 2012 (the 'revised Gothenburg Protocol'). This revised protocol sets out new emission reduction commitments for each party for the year 2020 and beyond, taking 2005 as the base year. The protocol refers to sulphur dioxide, NO_x, non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and $PM_{2.5}$. The new National Emissions Ceilings Directive (NECD – 2016/2284/EU) sets the reduction targets for each of the member states in consistency with the revised Gothenburg Protocol. Target reductions are foreseen in two steps, the first aiming the period 2020-2029 and the second aiming beyond 2030. Foreseen reductions over 2005 are significant and range from above 60% for NO_x to about 50% for $PM_{2.5}$ for each member state and the EU as a whole. A significant share of these reductions is born by road transport emissions[16].

1.4. Market Context

The EU added value in the automotive market is evident by the creation of common emission standards for all member states that have been largely accepted also at an international scale. This delivers benefits both to the customers that can choose from a wide variety of types and models originating from different countries and to the manufacturers that can develop products for a wide customer basis.

Private and commercial customers in the EU can today select from a variety of vehicle powertrain technologies that serve their needs and usage patterns. Selections can be informed by vehicle labelling in terms of fuel efficiency and CO_2 emissions. The current fleet-wide CO_2 targets for new cars and vans (Regulation (EU) 2019/631) and lorries and buses (Regulation (EU) 2019/1242) have largely determined the powertrain technologies that OEMs are placing on the market. The 2030 Climate Plan[17] presented by the Commission in September 2020 aims to climate-neutral EU by 2050 and to an intermediate target of at least 55% net reduction in GHG emissions by 2030. This is anticipated to accelerate the placement on the market of low and zero CO_2 emission vehicles, such as plug-in hybrid, fuel cell and battery electric vehicles and, to a large extent, guide consumer choices.

Finally, consumer choice is greatly affected by financial and other incentives within member states directed to support the introduction of advanced vehicle technologies. Such incentives range from the reduction of purchase and/or ownership fees and taxes to accessibility benefits for specific regions and parking places. Evidence[18] from a number of member states suggests that such incentives have been largely successful and have managed to a significant steer of consumer choices towards cleaner vehicle options.

1.5. Scope of the study

Scope of the study is to provide the technical information and evidence required for an impact assessment on introducing stricter air pollutant emission standards for new vehicles. The study focuses on EU27 and concerns the following two vehicle categories:

[16] Borken – Kleefeld J., and Ntziachristos L., 2012. "The potential for further controls of emissions from mobile sources in Europe", IIASA.
[17] European Commission, 2020. "Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people," COM(2020) 562 final.
[18] Samos Z., et al., 2019. "The impact of vehicle taxations system on vehicle emissions", EIONET.

- Light duty vehicles (LDV) - comprise passenger cars and light commercial vehicles (vans). According to the Regulation 715/2007, vehicle categories M1, M2, N1 and N2 (as defined in Annex II to Directive 70/156/EEC) with a reference mass not exceeding 2,610 kg.
- Heavy duty vehicles - comprise buses and lorries, according to current regulation 595/2009 that applies to motor vehicles of categories M1, M2, N1 and N2 with a reference mass exceeding 2,610 kg and to all motor vehicles of categories M3 and N3.

Technical information has been largely collected from previous studies of the study team, primarily in the round of evaluating Euro 6/VI standards (*Evaluation report*). Figure 1-1 shows the structure of activities leading to providing evidence for this impact assessment of Euro 7.

Part A of the study focussed on the technical effectiveness of Euro 6/VI and to this aim collected a database with results of emission tests of a large number of latest technology vehicles. Part A also assessed the current Euro emission standards structure in comparison to what is being enforced in other parts of the world. Moreover, this part of the study focussed on identifying inefficiencies in the current regulatory framework in terms of pollutants covered and testing requirements. Finally, an overall assessment of the technical effectiveness of Euro 6/VI was conducted and those areas were identified that could be improved within a Euro 7 framework.

The evidence collected in Part A fed the subsequent analysis that was performed in Part B. Part B first assessed what vehicle technologies can be feasibly implemented to achieve lower emission levels from future Euro 7 vehicles and examined an extended list of pollutants that could be covered. Moreover, it identified those elements of the emission standards structure that could be improved with the aim of simplifying the type-approval process.

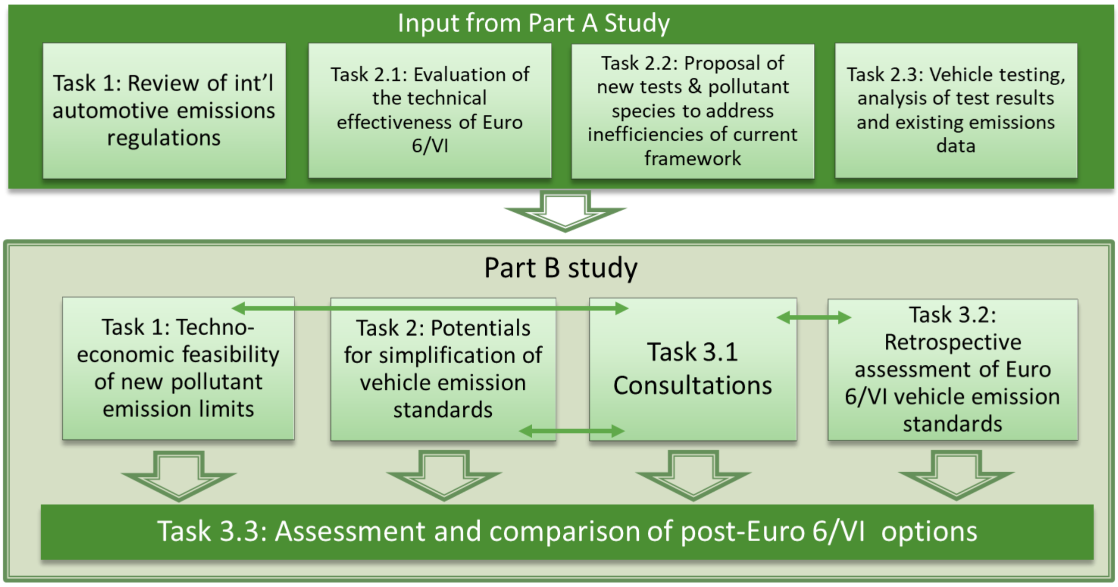

Figure 1-1: The ecosystem of studies of CLOVE consortium related to the impact assessment of Euro 7.

Part B was also responsible for conducting the consultation with stakeholders during the process of collecting information on the development of the new emission standard. The consultation comprised the following activities:

- A Public Consultation that lasted for 18 weeks, starting on 6 July 2020 and remaining open for contributions until 9 November 2020. This activity was conducted by the European Commission but its results and conclusions were also integrated in this study.
- Two 14-week-long targeted consultations, performed by the CLOVE consortium focussing more on technical aspects:
    - **1st Targeted Consultation**: Collecting input regarding the evaluation of Euro 6/VI (4 March to 8 June 2020).
    - **2nd Targeted Consultation**: Collecting input for the impact assessment of Euro 7 vehicle emissions standards (3 August to 9 November 2020)

As part of the stakeholder consultations conducted by the European Commission, the Euro 7 initiative was also discussed with stakeholders during a first stakeholder conference in October 2018. Subsequently, the Advisory Group on Vehicle Emission Standards (AGVES) was set up by merging relevant expert groups from industry, NGOs, academia, Member States etc. working on vehicle emission legislation, with eight meetings from May 2019 to April 2021.

The technical activities conducted by the consortium and the information collected led to the evaluation of the Euro 6/VI standard, which was one of the two final activities in part B. The second final activity was the provision of technical input to the impact assessment of the Euro 7 standard, which is presented in the current report. The results of all previous activities have been presented in a series of reports issued by the CLOVE consortium which contain with more detail the technical information used in the present report:

- "*Post Euro 6/VI Part B study: Euro 6/VI standards evaluation*", henceforth the **Evaluation report**[19]**.** It contains the analysis and the findings of the study for the retrospective assessment of Euro 6/VI vehicle emission standards.
- "*Post Euro 6/VI study: Combined report of Part A & Part B*", henceforth the **Combined report**[20]. It combines the outcomes from Tasks 2.1, 2.2 and 2.3 of Part A, and Task 1 of Part B to present the emission limits, the vehicle technology and the testing requirements that can be improved moving to Euro 7.
- "*Post Euro 6/VI Part B study: Potentials for Simplification of Vehicle Emission Standards*", henceforth the **Simplification report**[21]. Presents the Euro 6/VI emission standard components that can be improved to simplify the type approval procedures of Euro 7.
- "*Post Euro 6/VI Part A study: Review of international automotive emissions regulations*", henceforth the **Review on Int'l regulations**[22]. It focuses on reviewing current and forthcoming vehicle emission legislative developments in leading automotive markets around the world and makes key comparisons with the Euro 6/VI vehicle emission regulatory framework.

[19] CLOVE, 2021. "Post Euro 6/VI Part B study: Euro 6/VI standards evaluation", CLOVE Consortium.
[20] CLOVE, 2021. "Post Euro 6/VI study: Combined report of Part A & Part B," CLOVE Consortium.
[21] CLOVE, 2021. "Post Euro 6/VI Part B study: Potentials for Simplification of Vehicle Emission Standards", CLOVE Consortium.
[22] CLOVE, 2020. "Post Euro 6/VI Part A study: Review of international automotive emissions regulations", CLOVE Consortium.

We make extensive reference to these previous reports throughout the current study, as these provide the detailed evidence that underpins the technical information we need in this report to make the cost-benefit assessment of Euro 7.

2. Problem Definition – Baseline

2.1. What is/are the problem(s)?

2.1.1. Key simplification and consistency challenges in increasingly complex environment of vehicle emission standards

Vehicle emissions legislation in the EU is structured around a list of regulatory pieces derived from co-legislation and implementing (Commission) legislation, distinguishing between cars and vans (light duty vehicle - LDV) and lorries and buses (heavy duty vehicles - HDV). The emission limit values rely on both laboratory and on-road emissions testing for verification. Standard enforcement is materialised via a multitude of relevant mechanisms, applicable to different stages of the vehicle lifetime and with the responsibility potentially lying to different authorities. Such mechanisms include initial type-approval, conformity of production checking, in-service conformity demonstration, market surveillance, periodical technical inspections and road-side inspections. The various components of the legislation are not described in a single regulatory piece, but to a multitude of documents with numerous references to international standards (e.g. UNECE) and earlier pieces of regulation. This evolutionary approach, without fundamental changes to the structure of the legal framework, has resulted in the EU emissions legislation ecosystem to become bulky, complex and difficult to trace with the potential of misinterpretation. Based on the *simplification report*, notable examples of inconsistencies are highlighted as:

- Different limits and pollutants coverage depending on fuel (gasoline/diesel) and combustion technology (e.g. PFI/GDI)[23,24,25]. This creates competition between technologies while serving no real environmental target. It may also create confusion as to what limits apply for new, innovative technologies that cannot be clearly classified to any of the traditional categories included in the legislation.

- Different implementation dates for new emission steps for cars and categories of vans regarding new types and all models. This complicates type approval and in-service conformity monitoring as to whether specific vehicle families comply or not within each emission step and may create competition in introducing different van categories.

- A grey area in size distinction between vans and lorries. The Euro 6 standards apply to cars and vans, with a reference mass not exceeding 2610 kg (under certain conditions this limit can be extended to 2840 kg). This is not in line with existing UN vehicle classifications based on technical permissible maximum laden mass (TPMLM)

- A type-approval procedure comprising a non-optimised range of tests which may lead to overlap of conformity checking in some areas and omission of compliance checking in some other areas.

[23] In the context of this study, it is estimated that 70% of new PI registrations in 2020 were GDI ones.
[24] Green Car Congress, 2019. "Gasoline direct injection was the most widely adopted emerging fuel saving technology in 2018: 51%".
[25] Diaz S., et al., 2020. "European Vehicle Market Statistics, Pocketbook 2020/21".

2.1.2. Untapped limits for regulated pollutants and lacking limits for new unregulated pollutants

Air pollution, especially in urban areas, poses a significant risk factor to human health. The EU policy framework for air quality includes three cornerstones: Green Deal/Clean Air for All (COM(2018) 330), Air Quality (AQ) Directives, and the National Emissions Ceiling Directive (NECD). The Clean Air for All states that "*Air pollution continues to be the number one environmental cause of early death in the EU, with estimates of more than 400,000 premature deaths per year*". As of February 2021, 56 infringement procedures against 20 MS remained pending due to exceedances and non-compliance[26].Currently in the EU, the Euro 6/VI standards cover nitrogen oxides (NO_x), carbon monoxide (CO), total hydrocarbons (THC), non-methane hydrocarbons (NMHC), particulate matter (PM), and solid particulate number above 23 nanometres ($sPN_{>23nm}$) emissions. Ammonia (NH_3) and methane (CH_4) emissions are regulated directly for Euro VI engines only, and indirectly for Euro 6 engines, as difference between THC and NMHC. Certain pollutants are regulated indirectly through the Fuel Quality directive[27] (e.g. SO_2, Pb, benzene and fuel-originating PAHs).

Based on the findings of the *Combined report*, there are a number of factors that can contribute in achieving much better air pollution control from available vehicle technologies:

- Emission performance of several passenger cars on the road today outperform the Euro 6/VI limit values by a large margin. Hybrid and plug-in hybrid technologies, despite equipped with internal combustion engines, have been shown to emit by more than one order of magnitude lower emissions than what emission standards call for. Taking advantage of best available technologies vis-à-vis their related costs is required to maximize the potential benefit to the society.
- The current range of air pollutants contained in the emission standards definition does not cover all relevant species. As new vehicle technologies, exhaust aftertreatment technologies, fuels and additives are expected to be introduced in the future, the focus should also move into covering these species as well. A notable example are brake wear particle emissions, which are even emitted by battery electric vehicles (BEV) and which are not today covered by emission standards.
- In the Combined report, the analysis of the tests database collated in this study[28] (referred as CLOVE database) showed that the Euro 6d and 6d-temp vehicles perform well and comply with the respective limits when tested under the current RDE test conditions, i.e. under the test conditions that they were designed for and type-approved in. However, a clear increase of emissions is observed in many vehicles when these are tested under a wider range of driving conditions. This trend is observed for both the regulated and the (currently) non-regulated pollutants in real-world driving conditions such as: Cold start/short urban trips, low ambient temperatures, harsh accelerations, high vehicle payload, particle filter regeneration events. Although one may readily reckon that the frequency of some of these conditions is low in everyday driving, providing no limit under such events

[26] European Commission at work (Accessed 02.2021).
[27] Directive 2009/30/EC
[28] The database includes measurement data from CLOVE partners (both from testing activity within the current framework contract and from own data) as well as from JRC

can still result to disproportional contribution to air pollution despite these correspond to infrequent operation.

2.1.3. Misleading conclusions on vehicle's real-world emissions throughout its entire lifetime on EU roads

The current durability requirements have not been thoroughly assessed with regard to their effectiveness in providing lifetime emissions compliance for both cars/vans and lorries/buses. As a result, vehicles may be disproportionally contributing to air pollution as they grow older during their actual life time. In addition to that, advancements in emission control technologies pose new challenges for current regulatory provisions. The new systems developed to reduce emissions are more complex and the functionality of the whole emission control system is becoming increasingly intertwined with engine operation and the accompanied calibrations. This increases the need for a more complete demonstration of their durability. Moreover, the *Evaluation report* indicated that on-board diagnostic (OBD) requirements may not be robust enough to ensure detection of degradation or failure of emission control systems under all circumstances and driving conditions.

2.2. What are the problem drivers?

A complex regulatory framework

Admittedly, the current legal framework is particularly complex, characterised by a very large legal text with references to a large number of supporting legislation (including UNECE Regulations). It has been the result of a gradual evolutionary process with multiple additions and revisions introduced without changes to its overall structure. Besides the implications to the costs of compliance, this complexity makes challenging both compliance with and enforcement of the legal framework. It also provides room for different interpretations of type approval requirements that can limit the effectiveness of related measures. Moreover, it severely impedes transparency and citizen's understanding of the regulations.

Separate, not technology-neutral emission standards

Despite its increased complexity, the Euro 6/VI emission standard including the latest revisions is considered, to a large extent, internally coherent according to the *Simplification report*. However, some inconsistencies still remain, notably the fact that the standards are not technology and fuel-neutral (i.e. that limits are different depending on the vehicle technology) and the differences in implementation dates for cars and vans.

Irregular implementation periods

A particular point of confusion is the multitude of dates in the enforcement of the different standards. This approach has been also the case in the past but it has been significantly amplified in the Euro 6/VI introduction period. Different steps within the same standard may involve different testing settings, compliance limits, coverage of emissions processes, etc. Although such a complex system may offer flexibility to OEMs to introduce technologies in a gradual manner, at the same time it creates an administrative burden to authorities, complicates the type-approval procedure and may create competition between van categories. Furthermore, such a process undermines the effectiveness of ISC and MaS efforts by impeding the identification of suitable similar vehicles to achieve statistical significance of testing and to allocate the right testing procedure (version of RDE, conformity factor to be included, evaporation method to be applied, etc.) to each of them. Complicating these procedures may entail less vehicles tested and less effectiveness overall.

Complicated type approval process

The complexity is particularly obvious when one looks at emission limits and pollutants covered. There are different limit values for vehicle powertrain types, different pollutants covered depending on vehicle combustion concept, various test procedures foreseen depending on fuel use, different classification of similar vehicles to heavy duty or light duty categories, different type-approval families regarding the emission control item considered. As a result, the type-approval procedure becomes an art of synthesis of new experimental tests, prior evidence collected from similar vehicles within the same family, technical explanations given by the OEM, etc. This makes extremely difficult to transparently prove that a type-approval certificate serves its purpose, i.e. confirming that the type-approved vehicle maintains acceptable emission levels over its useful life. Despite complications, current vehicles tested by independent laboratories (evidence in the *Combined report*) seem to perform well over RDE compliant tests. However, there is extremely little evidence from independent compliance checking on vehicles with high mileage, or regarding low temperature testing, or fuel evaporation compliance, etc. This gives room to on-road emission levels that are higher than what standards call for.

Excessive type approval tests

The testing protocols for obtaining type approval are extensive and aim at controlling a range of emission processes, operation, and environmental conditions. Tests for exhaust emissions are to be executed on the chassis dynamometer, on the road, in the SHED, on the engine bench for crankcase emissions and for durability demonstration, on specialised test rigs for fuel permeation, etc. In fact, the number of tests for a single vehicle type-approval is so large that it is questionable whether a single vehicle model has ever gone through the complete range of tests to obtain it. Instead, this long list leads to building the type-approval as a puzzle collecting information with the methods outlined in the previous section, thus putting the overall efficiency of the process in question. Moreover, the tests need to be assessed for their complementarity or overlapping, to remove unnecessary administrative bottlenecks and costs which are not translated to more effective type-approval procedure.

High administrative costs

Controlling vehicle emissions performance and warranting that vehicles comply with emissions standards should not result to disproportionate costs for the industry and the authorities. The introduction of Euro 6/VI has been calculated to lead to a net increase of enforcement and administrative costs over Euro 5/V in the order of €1.65 billion in the period 2013-2020 which translates to about €6.0 billion if this is extended to 2050, without including enforcement test costs. Enforcement costs are a nuisance to the industry, are transferred to the customer through vehicle price increase and have a direct negative effect to the market operation and growth potential.

Limited use of technological potential for emissions reductions

Based on the findings of the *Evaluation report*, the Euro 6/VI standards and new testing requirements have been a significant driver to foster the development and, even more so, the market uptake of advanced emission control technologies, such as hybrids, plug-in hybrids and alternative fuels. The research and development efforts invested for fuel efficiency lead to new breakthroughs and designs that may also benefit air pollutants control, at minimal additional cost. It has been demonstrated in the *Combined report*, that the potential of such technological innovations is not fully taken advantage with today's emissions standards.

Limited testing representativeness

Despite the wide range of tests, there are still concerns of whether the complete range of on-road representative operation conditions is satisfactorily covered during type approval. For cars and vans, the analysis in the *Combined report* for testing outside of the RDE boundaries showed that some degree of emissions under real-world conditions remains unaccounted for during type-approval testing. For instance, minimum RDE test boundaries only include trips above 16 km, while stop-and-go driving, high mileage vehicles (>160 thousand km), long idling events and low or high ambient temperatures (<-7ºC or >35ºC) are not included in today's regulations. Moreover, certain discreet operation events such as periodical regenerations of aftertreatment devices are not fully taken into consideration by today's regulations. Such operation conditions cannot be considered extreme and potentially large proportions of the overall emissions produced by vehicles are under such conditions which are not adequately covered.

Lack of control over certain emission modes

Outside of RDE boundaries, limited control of exhaust emissions is currently mandated. In fact, current regulations allow manufacturers to use auxiliary emission strategies (AES) to protect the engine and emission control devices from extreme events. Typical RDE driving is not expected to lead to any such extreme event, hence AES is more critical in the area outside the RDE boundaries. Although one needs to recognise that AES is a necessary procedure when the vehicle undergoes extreme operation stress, it should also be recognised that operation with AES condition should still be capped by a certain maximum so as not to result to emission levels that are disproportionate to the actual intervention required to protect the powertrain components. In other words, the emission performance outside of RDE boundaries can be a source of unnecessary high emissions.

Unsuitable tests for heavy vehicle types

Similarly, the current emission testing procedures for heavy-duty vehicles are intended to reflect the average driving conditions of both lorries and buses. However the engine cycles (World Harmonized Transient Cycle (WHTC) and World Harmonized Stationary Cycle (WHSC)) coverage remains insufficient and the potential for optimisation of a vehicle's engine to the test remains. Similarly, the *Evaluation report* indicated that data exclusion flexibilities from on-road PEMS testing (e.g. elimination of the "moving average window" levels at less than 10% of rated power) can exclude significant real-world emissions generating conditions. In reality, current tests mostly reflect operation of long-haul lorries or delivery trucks operating in mixed urban and non-urban conditions. Tests at low power and long idling, reflecting operation of urban busses, special utility vehicles such a refuse trucks, or auxiliary power unit operation w/o driving are excluded. Evidence suggests that there is still high probability that emissions levels under such conditions are not on par with corresponding emission limits. This is another example where current testing conditions fail to provide a holistic control of emissions on the road.

Emissions control tampering

The substantial effort invested during type-approval to verify vehicle compliance may become obsolete for a variety of reasons when vehicles are placed on the road. Tampering may take place either by users of private vehicles to personalise and improve performance (e.g. DPF removal or software files "tunes") or by users of commercial vehicles to obtain a decrease of operational costs (e.g. disabling SCR operation). Emissions control tampering typically by-passes (parts of) the on-board diagnostics (OBD) system thus compromising the vehicle's ability to detect malfunctions. Such practices destroy the whole structure of emissions improvement by introducing more stringent emissions standards. Periodical technical inspections may be insensitive in detecting tampering and ISC testing organised by specific OEM fleets may not result in exposing the extent of the problem. Methods to improve monitoring of emissions performance integrated in emissions standards, together with advanced antitampering techniques can have a significant impact in improving air pollutants emissions rates on the road.

Inadequate durability provisions

Other reasons for disproportionally increasing emissions levels over emission limits in real world conditions include emission control system ageing. The current useful life for which vehicles need to demonstrate emissions compliance is considered to under-represent real-world lifetime. For example, the *Evaluation report* estimated that Euro VI standards currently cover around 60% of today's average lifetime of heavy-duty vehicles (in terms of age and mileage). Also, the procedures used to demonstrate emissions control systems durability concern primarily thermal ageing and no poisoning mechanisms. Assisted by the fact that emission control devices are not part of the vehicle warranty and that OEMs have no responsibility to report emissions-related warranty and repair claims, the current regulatory requirements seem not offering adequate check of emissions control systems ageing effects.

Limited OBD effectiveness

A third reason for on road emission levels to be distinctly different than the ones foreseen by emissions standards may relate to malfunctions encountered in emissions control systems. The OBD system is designed to detect malfunctions and inform the vehicle user to bring the vehicle for maintenance. However, OBD does not actually monitor emission levels, it is designed to infer emissions performance degradation above certain thresholds over the in-laboratory regulated cycle by identifying malfunctioning components. However, thresholds may be exceeded when different malfunctions are superimposed or when malfunctions and system degradation are combined. Only monitoring of actual emissions levels can lead to beyond doubt control of real-world emissions.

Pollutants coverage

Vehicle exhausts contain a number of species which are known to be toxic or carcinogenic to humans and adversely affect air quality but are not directly included in the vehicle emission standards. Such species include non-methane organic gases (NMOG), ammonia (NH3), particles under 23nm (SPN<23nm), and non-exhaust emissions such as brake and tyre wear emissions. Regarding non-CO_2 GHG species with an air pollution potential, CH_4 (for cars and vans) and N_2O are also not covered by current emission standards. Based on the findings of the Combined report, the highest priority in the preliminary recommendations on the coverage of new additional species are for non-methane organic gases (NMOG), CH_4, N_2O, NH_3, HCHO and solid particles below 23 nm, as well as brake and tyre wear particle emissions.

2.3. What are the consequences?

Insufficient contribution towards zero pollution target

Today, a number of member states exceed their total emissions allowances and citizens are exposed to atmospheric pollutant levels which exceed safe levels. Substantial short to medium term improvements are required to bring air quality to within safe levels. Significant efforts in such reductions will have to be shared by road transport, due to its contribution to urban air pollution. Although latest vehicle standards in the EU seem to introduce significant improvements, more will have to be done to serve the zero-pollution ambition in the EU.

Market fragmentation

Authorities in several member states that fail to meet their air quality targets plan to introduce or have already introduced local, regional or national measures and restrictions to address the problem. These may include ban of specific vehicle powertrains and vehicle categories from environmentally sensitive zones (often named as low emissions zones). Furthermore, the *Evaluation report* indicated that Member States' taxation policies on vehicle purchase/registration or vehicle ownership/circulation, affect the incentives that consumers face when deciding on what type of vehicles to purchase (i.e. move towards alternative fuelled vehicles). The uniform market rules are put in risk by such practices by the member states. This, in turn fragments the market and directs customers away of certain vehicle options. This goes against free market competition rules and puts industrial sectors at risk, depending which member states they mostly target at.

Loss of consumer trust

Such problems are magnified by the general loss of consumer trust to vehicles and their environmental performance, owed in part to the recent 'Dieselgate' emissions scandal. This loss of trust has a number of repercussions, including fragmented decision-making at local or regional level often due to overreaction or induced by unreliable non-scientific information sources. Further to such practices creating market distortions and obstacles to the placement of the market of all available powertrain concepts, they are often questionable with regard to their contribution towards environmental improvement.

Outdated limits risk EU loosing technological leadership

Overall, the current Euro 6/VI limits, which were introduced in 2007 for cars/vans and 2009 for lorries/buses[29], no longer seem to be on par with the progress made in engine and emission control technology. A broad range of cutting-edge technologies for reducing air pollutants from vehicles is already offered in the market, while evidence provided in the *Combined report* suggests that several models exhibit on-road performance that is already much better than what Euro 6/VI limits call for. This means that the full technological potential is not exploited towards achieving the maximum environmental benefits. Not taking advantage of the technology potential, risks that the entire automotive value chain in the EU may be loosing its technological leadership. EU industry faces increasing global competitive pressures, major markets such as the US and China have in recent years implemented more stringent emission standards in order to reduce vehicle emissions and to stimulate innovation. The fact that the current EU emission standards may no longer be in the forefront in the global stage, in terms of the environmental protection they offer, can potentially result in new technological breakthroughs implemented in other regions of the world, which are not fully utilised in the EU.

2.4. How will the problems evolve?

2.4.1. Policy Option 0: status quo/baseline

The introduction of Euro 6 for cars and vans has brought sizable reductions to total NO_x emissions. Figure 2-1 shows the projected evolution of NO_x emissions from cars and vans (collectively Light Duty Vehicles – LDVs) starting from the introduction of Euro 6 standards in 2014 all the way to 2050. Moreover,

Table 2-1 summarises key performance quantities over the complete time horizon of analysis (2014-2050). Emission savings data for LDVs show that, in the absence of Euro 6 (Euro 5 baseline), an additional 0.45 Mt of NO_x would have been emitted in 2020 only,

[29] Regulation (EC) 715/2007 and Regulation (EC) 595/2009

and 1.68 Mt in total between 2014 and 2020. The reduction achieved in 2020 (33.2%) is actually higher than the 24% reduction that was expected as a result of Euro 6 according to the IA staff working document supporting the adoption of the Euro 5 and 6 standards[30]. However, we note that the IA staff working document examined a scenario with a lower limit of 75 mg/km in comparison to the 80 g/km eventually adopted.

This is to a large extent because Euro 5 emission levels were proven to be significantly higher than what expected by the legislator provisions, even if one corrects for the impact of dieselgate on emission levels. The reduction has therefore been achieved even if the actual on-road emission levels of Euro 6 diesel vehicles before the introduction of RDE requirements is today known to have been in excess of 200 mg NO_x/km while some earlier models were in excess of 400 mg NO_x/km compared to the regulated limit of 80 mg NO_x/km[31]. The performance of Euro 6 petrol vehicles has overall been within expected emission limits levels.

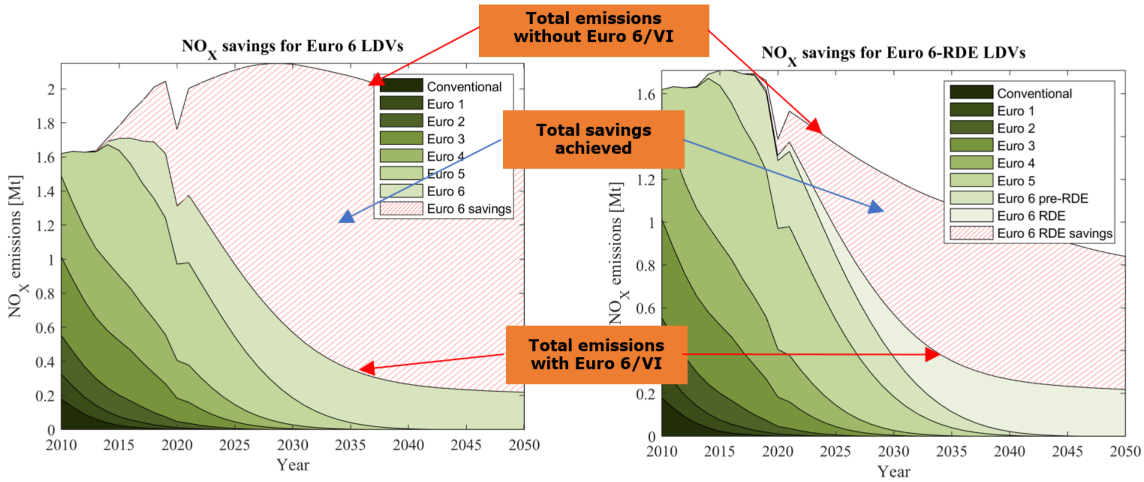

Figure 2-1: NOx evolution in EU-28 for Euro 6 LDVs (cars and vans). Left: Total Euro 6 benefits, Right: Benefits distinguished to Euro 6 pre-RDE and post RDE. Source: Evaluation report.

Despite Euro 6 pre RDE managed to somehow correct for the very high Euro 5 emissions levels, the RDE introduced substantial additional reductions over the already decreased Euro 6a/b/c levels. The comparison with the pre-RDE levels suggests that 9% of the total impact on NO_x emissions over the 2014- 2020 period is the result of the RDE introduction, and over 23% in Year 2020 only, despite RDE-compliant vehicles only started to be introduced in 9.2017. With the introduction of Euro 6d, a total of 44.2 Mt NO_x is estimated to be saved until 2050, mainly driven by savings from CI cars & vans (Table 2-2). The total emission reduction for NO_x achieved in 2020 was calculated to be 0.45 kt while the support study to the Euro 6 impact assessment targeted this to be 0.172 kt. The almost three-fold reduction estimated here was not so much an expression of the effectiveness of Euro 6 but rather a representation of the ineffectiveness of Euro 5 that led to much higher levels than what had earlier been considered. Moreover, Euro 6 introduced further reductions to PM, again low in absolute level but three-fold over the earlier projected ones. This was mostly due to the introduction of the PN limit and 20% of the achieved reduction (0.61 kt) was delivered by PI vehicles.

[30] European Commission, 2005. Commission staff working document - Annex to the Proposal on type approval of motor vehicles with respect to emissions and on access to vehicle repair information, amending Directive 72/306/EEC, (COM(2005) 683 final).

[31] Matzer C., et al., 2019. “Update of emission factors for HBEFA Version 4.1 - Final Report,” Technical University Graz.

Table 2-1: Net reductions of Euro 6 from LDVs (cars and vans) in EU-28 in comparison to the baseline (Euro 5). Comparison to IA staff working document estimates for 2020.

Pollutant	Euro 6 RDE over Euro 6 pre-RDE			Euro 6 (total) over Euro 5			IA staff working document impact in 2020[32]
	2014-2020	In 2020	2021-2050	2014-2020	In 2020	2021-2050	
NO_x (Mt)	0.12	0.08	17.94	1.68	0.45	44.19	0.172
% change	1.8	7.7	56.6	19.5	33.2	76.3	
$PM_{10,exh}$ (kt)	0.47	0.27	49.88	12.51	3.19	249.82	1
% change	0.2	0.7	2.9	4.7	7.4	12.8	(1)
CO (Mt)	0.27	0.15	14.70	2.78	0.82	60.81	
% change	3.0	11.3	36.6	24.2	40.9	70.5	n.a.
THC (Mt)	0.03	0.02	2.46	0.06	0.03	2.58	1
% change	3.7	11.9	34.0	6.3	15.1	35.1	

Table 2-2: Summary of Euro 6 net emissions reductions separately for CI and PI light duty vehicles (cars and vans).

[32] European Commission, 2005. Commission staff working document {COM(2005) 683 final} Impact Assessment Annex to the Regulation of the European Parliament and of the Council on type approval of motor vehicles with respect to emissions and on access to vehicle repair information.

Pollutant	Euro 6 RDE to Euro 6 pre-RDE			Euro 6 (total) to Euro 5		
	2014-2020	In 2020	2021-2050	2014-2020	In 2020	2021-2050
	Compression Ignition LDVs					
NO_x (Mt)	0.12	0.07	17.50	1.65	0.44	43.30
% change	1.7	7.6	57.4	19.6	33.4	76.9
$PM_{10, exh}$ (kt)	0.17	0.10	25.4	10.5	2.58	199.6
% change	0.1	0.4	2.2	5.6	8.8	15.0
THC (Mt)	0.00	0.00	0.16	0.02	0.00	0.14
% change	0.0	0.0	15.2	13.2	20.4	13.7
CO (Mt)	0.00	0.00	0.43	0.07	0.02	0.54
% change	0.0	0.0	11.5	11.3	17.6	14.1
	Positive Ignition LDVs					
NO_x (Mt)	0.01	0.00	0.44	0.03	0.01	0.90
% change	3.4	11.6	37.0	14.1	26.6	54.6
$PM_{10, exh}$ (kt)	0.30	0.17	24.52	2.00	0.61	50.2
% change	0.4	1.3	4.2	2.5	4.5	8.1
THC (Mt)	0.03	0.02	2.30	0.04	0.02	2.44
% change	4.4	13.5	37.2	5.0	14.3	38.6
CO (Mt)	0.27	0.15	14.27	2.71	0.80	60.3
% change	3.2	11.9	39.2	24.8	41.9	73.1
NMHC (Mt)	0.03	0.02	1.92	0.03	0.02	2.04
% change	4.2	12.9	34.4	4.7	13.5	36.7

In particular for PM_{10}, emissions improvements are mostly due to the introduction of gasoline particle filters (GPFs) for petrol vehicles and due to overall system optimisation for diesel vehicles. The GPFs have a significant impact in decreasing particle numbers but less so in decreasing the mass of PM. In any case, PM levels of both PFI and GDI petrol cars of Euro 5 and later were complying with the established PM limit with some margin, even without the use of the GPF. Hence, further reductions brought by GPFs are still visible but rather marginal.

Reductions for other pollutants than NO_x are more marginal and - in the period - considered these are mostly accrued as positive side-effects of emission control measures adopted to decrease NO_x emissions. However, engine recalibration and better aftertreatment to meet limits over RDE may have also helped in reducing emissions.

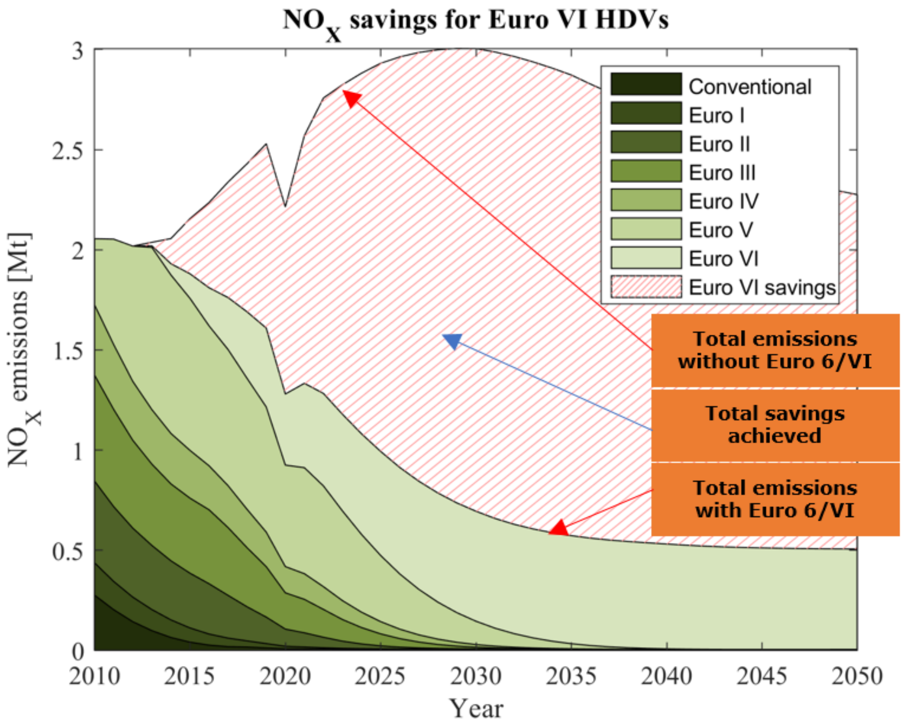

Figure 2-2: NO_x savings in EU-28 for Euro VI HDVs (lorries and buses).

For HDVs, the analysis indicates expected savings of NO_x emissions of 60.46 Mt for the whole period up to 2050 as illustrated in Figure 2-2. In 2020, the expected savings are estimated at around 0.93Mt of NO_x. This represents a 52% change from the baseline, a significantly higher reduction than the level estimated in the Euro VI IA staff working document for the year 2020[33].

In the case of PM emissions, one will have to make a distinction between the levels achieved with and without the consideration of non-exhaust emissions (Figure 2-3). When only exhaust emissions are concerned, the mandatory introduction of a DPF in order to achieve exhaust PM limits showed brought a significant reduction in emissions which reach in total 52.5% in the post 2020 period, compared to 22% expected through the IA staff working document estimate. If one takes non-exhaust PM into consideration, then the overall reductions become much less pronounced, in the order of 28%, in the post 2020 period. Most importantly, total PM emissions from HDV seem to not satisfactorily decrease in the future. The mild reduction is despite a combination of a decrease in the PM exhaust introduced by Euro VI vehicles over Euro 5 as well as a decrease in non-exhaust PM assumed. The latter is expected to originate from the assumption that future EV buses and trucks may be equipped with lighter powertrains, i.e. assuming they can be charged while operating, e.g. through induction loops (buses) or pantographs (trucks) and regenerative braking. Practically, $PM_{2.5}$ emissions even in 2050 do not seem to be significantly different than in 2015, a strong indication that non-exhaust PM sources, in particular for HDVs, will have to be addressed. This will be particularly true if our assumption of lighter constructions in the future does not materialise. If future HDVs are larger and heavier than current ones because they need to carry a heavy battery load and

[33] European Commission, 2007. "Commission staff working document - Annex to the Proposal for a Regulation of the European Parliament and of the Council on the approximation of the laws of the Member States with respect to emissions from on-road heavy duty vehicles and on access to vehicle repair information - Impact assessment", (COM(2007) 851 final).

if regenerative braking cannot be efficiently put in practice, non-exhaust PM emissions may even increase compared to today's levels.

The previous analysis shows that both light duty and heavy-duty vehicle categories seem to deliver the expected reductions foreseen in the corresponding impact assessment studies for the introduction of each vehicle technology. It is also important to look at how the calculated revised emissions reductions compare to the foreseen reductions in the impact assessment of the NECD (SWD(2013) 531). In order to estimate the values, we revisited data from the calculations that went to the original TSAP reports #4 and #11 that fed the NECD impact assessment. As the study team participated in the consortium preparing those reports, we had access to the basic data that went in preparing the information. We therefore recalculated NECD reductions targets for road transport by only keeping cars, vans lorries and buses, thus removing the contribution of mopeds and motorcycles from the published values. The comparison between newly estimated values and the reduction targets foreseen are shown in Table 2-4.

Table 2-3 provides a summary of the impact of Euro VI on main pollutant emissions, in different time periods over the complete time frame studied. Euro VI vehicles were taken up fast in the fleet of main markets in the EU. This led to faster reductions up to 2020 than originally foreseen and for NO_x these seem to have introduced the expected change by 2030 already in 2020. Further reductions are expected to be materialised in the more distant horizon as older vehicles continue to be replaced by Euro VI.

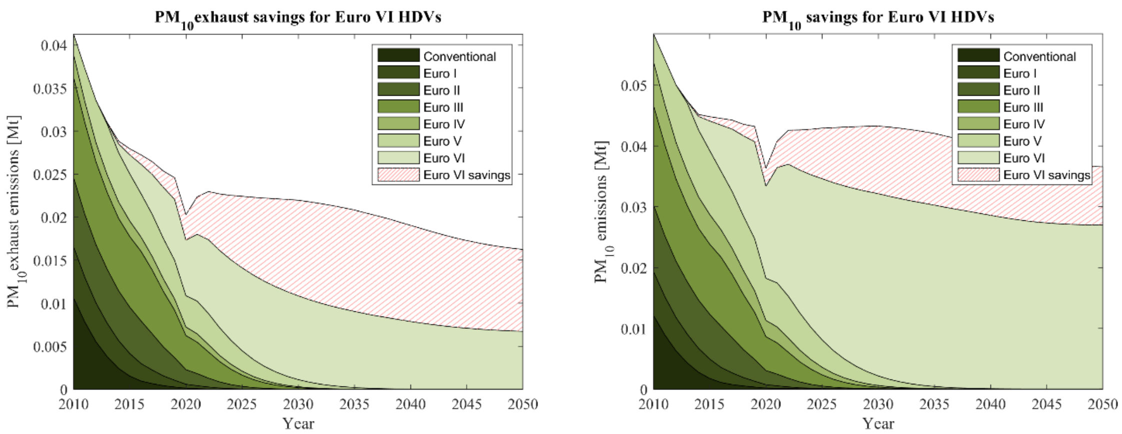

Figure 2-3: PM savings in EU-28 for Euro VI HDVs (lorries and buses).
Left: Exhaust emissions, Right: Exhaust and non-exhaust emissions.

The previous analysis shows that both light duty and heavy-duty vehicle categories seem to deliver the expected reductions foreseen in the corresponding impact assessment studies for the introduction of each vehicle technology. It is also important to look at how the calculated revised emissions reductions compare to the foreseen reductions in the impact assessment of the NECD (SWD(2013) 531). In order to estimate the values, we revisited data from the calculations that went to the original TSAP reports #4[34] and #11[35]

[34] Borken – Kleefeld J., and Ntziachristos L., 2012. "The potential for further controls of emissions from mobile sources in Europe" IIASA.
[35] Amann M., 2014. "The Final Policy Scenarios of the EU Clean Air Policy Package, TSAP Report#11 Version 1.1a", IIASA.

that fed the NECD impact assessment. As the study team participated in the consortium preparing those reports, we had access to the basic data that went in preparing the information. We therefore recalculated NECD reductions targets for road transport by only keeping cars, vans lorries and buses, thus removing the contribution of mopeds and motorcycles from the published values. The comparison between newly estimated values and the reduction targets foreseen are shown in Table 2-4.

Table 2-3: Summary of Euro VI net reductions on total level of emissions from HDVs (lorries and buses) in EU-28 - Comparison to the IA staff working document estimates.

Euro VI over Euro V Calculated				Difference over baseline*
Pollutant	Up to 2020	In 2020	2021-2050	Expected change in 2020*
NO_x (Mt)	4.01	0.93	60.46	0.22
% change	35.7	52.0	76.4	37
$PM_{10,exh}$ (kt)	11.0	2.95	300	3.3
% change	13.5	22.6	52.5	22
CO (Mt)	1.48	0.34	21.7	-
% change	43.1	61.9	90.0	-
NH_3 (kt)	-4.78	-1.15	-88.9	-
% change	-30.4	-45.7	-81.4	-
THC (kt)	10.7	2.84	270	52 (NMVOC)
% change	14.0	23.4	50.5	43

*Values obtained from scenarios A/G1 produced in the so-called 'LAT Study' referenced in the IA staff working document of the Euro VI regulation (SEC(2007) 1718) and retrieved from the original publication[36].

Table 2-4 shows that both in NO_x and exhaust $PM_{2.5}$, the absolute emission levels we estimate to be achieved in 2030 are higher than the ones planned for in the revised NECD impact assessment study (SWD(2013) 531)**.** The majority of this exceedance originates from the remaining Euro 5 cars and vans emissions which, even in 2030, correspond to 40% of total NO_x emissions of total from cars and vans. Also, a significant part of NO_x exceedance comes from lorries and trucks. The current emission estimate suggests that the cold-start for heavy duty vehicles is more important than earlier considered and Euro VI steps have not managed to effectively control this part of emissions (for details one can consult the *Combined report*). Moreover, emissions control tampering has been seen to be significant for Euro VI lorries and even more contributes to increasing the average level of exhaust emissions (section 9.4.2.12). This has also impacts on exhaust PM with currently expected reductions appearing lower than what was scheduled during the NECD revision.

[36] Zierock K., et al., 2007. "Further improvement and application of the transport and environment TREMOVE model LOT2 - Scenario Runs Final Report", LAT.

Table 2-4: Emissions and emissions reduction targets foreseen for cars, vans, trucks, lorries and buses in the baseline development of the NECD impact assessment vis-à-vis revised emissions reductions estimated in the current study. CLE: Current Legislation Scenario that in case of NOx from road transport was identical to the MTFR one.

Pollutant	2005	2010		2030		ΔEmissions (2030-2010)	
	NECD CLE	NECD CLE	Current Study	NECD CLE	Current Study	NECD CLE	Current Study
NO_x (kt)	4880	3732	3667.7	861.7	1250.6	-2871	-2417.1
%change over 2005	*0%*	*-23.5%*		*-82%*		-	-
$PM_{2.5\ exhaust}$ (kt)	198	141	134.3	9.0	14.6	-132	-119.7
%change over 2005	*0%*	*-28.6%*		*-82%*		-	-
$PM_{2.5\ Total:\ Exh\ +\ NonExh}$ (kt)	237	187.6	174.6	70.9	57.0	-116.7	-117.6
%change over 2005	*0%*	*-20.9%*		*-95%*		-	-
NH_3 (kt)	128	88.0	74.9	46	28.9	-42	-46.0
%change over 2005	*0%*	*-31.2%*		*-70%*		-	-
VOC (kt)	1647	803.5	790.7	64.8	227.0	-738.7	-563.8
%change over 2005	*0%*	*-51.1%*		*-34.5%*		-	-

The evidence earlier presented shows that Euro 6/VI achievements are large in terms of decreasing air pollution from road transport but still fail to meet the NECD targets. Current industry estimates on fleet and activity evolutions[37] are that by 2030 more than 99% of air quality monitoring stations will be in compliance with $PM_{2.5}$ and NO_2 air quality limit values. This corroborates earlier findings[34] that delivery of the actual reductions scheduled for Euro 6/VI will decrease the number of zones where NO_2 air quality limits are not met to 0.2% (unlikely) to 3.0% (uncertain). Based on the impact assessment of revised NECD, this suggests that only 2% up to 8% of the EU citizens (Table A5.8 of SWD(2013) 531) will continue to leave in areas where compliance with NO_2 air quality limit values is unlikely (2%) or uncertain (8%). However, if we fail to meet NECD targets as earlier demonstrated, there will continue to be higher exceedances than those earlier mentioned and an ozone-related air quality issue will remain. TSAP #11 report estimated that even when NECD MTFR scenario targets are materialised, there will continue to be more than 14,000 thousand premature deaths in the EU due to ozone alone. Evidently, decrease in ozone exceedances cannot come from road transport alone but will have to be assisted by reductions in other sectors[37].

Despite the substantial reductions, the introduction of Euro 6/VI does not seem enough to address all air quality policy related issues. In particular, Euro 6/VI seems to be failing in the following areas:

Remaining air quality exceedances

There will continue to be a small but sizable share of the population (at least 8%) that will continue to leave in non-exceedance zones of NO_2, O_3 or PM_{10} air quality limits. This goes against the promulgated objectives of the European Green Deal of zero-pollution ambition to protect all European citizens. Other sectors will also need to improve, in

[37] White L., 2020. "Final presentation of findings of Urban AQ project for ACEA", AGVES meeting 27.11.2020.

particular to zero-out exceedances of PM and O_3, but road transport will continue to be dominant in terms of contribution to NO concentrations.

Other species

Total hydrocarbon emissions are currently regulated but this does not sufficiently cover oxygenated and heavy volatile organic species. Instead, the non-methane organic gases (NMOG) definition comprises an extended range of toxicity-relevant species. In particular, according to the *combined report*, transport is a source of ambient concentrations (directly and through photochemical reactions) of formaldehyde (HCHO). Due to lack of available data, the latter is not addressed in the current study.

Nanoparticle emissions (i.e. volatile, semi-volatile, and solid particles smaller than 23 nm) have detrimental health effects, not only through direct exposure, but also because of their role in the formation of secondary aerosols. Sub 23 nm solid particles have been detected in exhaust from both CI and PI engines. In recent tests with new equipment developed in EU funded projects, two and more additional orders of magnitude of particles below 23nm have been shown in the exhaust of some types of engines (gasoline PFI, natural gas) for which at the moment there is no requirement to assess PN emissions. Therefore, the PMP group has come up with a recommendation to extend the measurement down to 10 nm. Studies do not always decouple exhaust gases from exhaust particles, or solid nanoparticles from volatile and semi-volatile ones and animal studies may not accurately replicate human health responses, or what happens when particles enter the human body. Specific effects of nanoparticles (transition metals, nanocarbon, nucleation mode) from vehicle sources have hardly been studied from modern emissions control technologies. However, there is recognisable agreement in the scientific community that there is further scope for action in decreasing nanoparticle concentrations in the atmosphere.

Non-exhaust particles and, in particular brake wear particles, have been recognized as the leading source of non-exhaust particles, contributing up to 21% of all particles emissions related to traffic[38]. Technologies to decrease emissions of such particles exist and can be taken advantage of.

Secondary contributions to PM

In terms of exhaust PM, it is clear that Euro 6 and – in particular Euro VI – have brought significant reductions. However, several exhaust components contribute to the formation of PM in the atmosphere through secondary process, such as NH_3. NH_3 is produced from the urea-based SCR systems for NOx control from diesel engines, and from TWC equipped cars. Recent remote sensing data[39] show that NH_3 emissions are not well controlled for petrol cars while some increasing trends are shown for SCR-equipped buses as well. The little evidence suggests that our estimates of reductions in Table 2-4 may be linked to high uncertainty. Better monitoring of ammonia will be required to assess the environmental implications of latest vehicle technologies.

[38] Grigoratos T., and Martini G., 2015. "Brake wear particle emissions: A review". Environmental Science and Pollution Research, p. 2491–2504.
[39] Ricardo, 2020. "Are ammonia emissions from road vehicles important?".

Transport externalities

Even when air quality limits are met, ambient concentration of pollutants continue to harm the health of people and the ecosystem[40]. This is because in reality, there is not safe limit of air pollution and this is why WHO proposes target ambient pollution concentration levels as guidelines and not as strict limits. For example, the newly published WHO Guidelines[41] recommend an annual mean of 10 μg/m^3 compared to the current level of 40 μg/m^3 for NO_2 as a better guideline to protect human health. Evidently, there is a sweet-spot of how much emission reduction can be achieved by technology measures. The cost for the society may eventually disproportionally increase if investments to achieve the emission reductions exceed the benefits. However, the impact assessment studies for both Euro 6 and Euro VI, as well as the *evaluation report* showed that benefits clearly outperformed investments costs. This meant that Euro 6/VI did not take advantage of all margin provided to decrease costs to the society when externalities are also included.

Market Fragmentation, loss of consumer trust and implications to the industry

As the *Evaluation report* outlined, city authorities and citizens around EU[42,43] remain concerned with regard to the road transport technology potential to bring sizable reductions in air pollutant concentrations. There are current worries that even vehicle technologies up to Euro 6d-temp do not perform as they were expected to. Measurement campaigns designed and executed by cities[42,44] using remote sensing produce data that show that even latest vehicle technologies do not deliver their targets under several driving conditions in the real world. Other data from environmentally-sensitive organisations[45,46] show that specific vehicle types or testing conditions result to emission level that exceed designed targets. One will have to stand critical to some of these conclusions on failures, since recent evidence from the CLOVE *Combined report* shows that latest Euro 6d and Euro VI vehicles perform within targets over RDE and normal road operation conditions. Therefore, some of the conclusions reached by such third-party studies may need to be reviewed with proper scientific scrutiny.

Still, such evidence and opinions made public especially in the wake of the 'Dieselgate', have made city authorities concerned, at the same time when several city cases have been referred to the European Court of Justice on exceedance of air quality targets (latest evidence, case of Thessaloniki, Greece, press release EC 3.12.2020[47]). Therefore, in designing their air quality plans, city authorities often go all the way of introducing complete bans of vehicle technologies, a practice especially true for diesel vehicles[43]. There is a proliferation of such low emission zones in the EU[48] including permanent measures that ban older vehicle technologies and emergency measures that ban all traffic with combustion engines (for example, Vienna when PM_{10} exceeds 50 μg/m^3). Again, such measures may be criticised on their effectiveness. Allowing electric vehicles and not latest diesel vehicles when PM_{10} limits are exceeded may make no sense at all, as it is non exhaust emissions that mainly contribute to PM_{10}; in such cases it could be that larger

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[40] de Bruyn S., et al., 2018. "Environmental prices handbook - EU28 Version.
[41] WHO, 2021. Ambient (outdoor) air pollution
[42] Vaneerdeweg R., and Barrera G., 2020. "How Euro 7 can live up to its promise to improve air quality and restore trust", AGVES Meeting 26.11.2020.
[43] v. d. Gaag J., and Barrera G., 2020. "Enabling European cities & Regions to improve air quality by reducing vehicle emissions" AGVES Meeting 27.10.2020.
[44] Dallmann T., et al., 2019. "Remote sensing of motor vehicle emissions in Paris", TRUE Initiative.
[45] ICCT, 2020. "Findings from recent ICCT research on vehicle emission standards," ICCT - AGVES Meeting 26.11.2020.
[46] Krajinska A., and Mueller J., 2020. "Looking beyond today's limits: Evidence from T&E's work", AGVES Meeting 27.10.2020.
[47] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2151
[48] Sadler Consultants Ltd, 2020. "Urban Access Regulations in Europe" (Accessed 12.2020).

and heavier EVs produce more PM_{10} than well operating Euro 6 diesels. In another example, Paris has announced to phase out diesel vehicles by 2024. However, latest evidence from CLOVE *Combined report* shows current Euro 6d diesel vehicles to be at the same level of NO_x with petrol cars under normal city operation conditions. Therefore, the ban on diesel vehicles, including latest technologies, does not seem to bring an appreciable impact on air quality, and is not based on scientific evidence. Still, such measures show the lack of trust on what technology can deliver and announcements on the future phasing out of combustion engines continue to increase[49]. The evaluation report showed that Euro 6/VI seems to fail to restore this lack of trust to combustion engines.

The long-term implications of such practices are evident. The market share of diesel vehicles has dropped from an all-time high of approximately 55% in 2007[50] to 28% in 2020[51] with yet further reductions foreseen for the future. The diesel car has in particular been in the scrutiny of consumer organisations[52]. Therefore, the effectiveness of significant investments made by the industry and introduction of advanced exhaust aftertreatment is now compromised. Second, it is clear that both the new and second-hand diesel vehicle markets do not operate as they should, with a significant stock of both new and second-hand diesel vehicles remaining unsold. The value of unsold ICE cars in Germany alone reached €15bn by July 2020[53]; the SARS-CoV-2 pandemic is obviously the main reason of this but announcement to phase out combustion vehicles by 2030 have definitely contributed to this direction. In Belgium alone, the value of unsold second-hand vehicles reached €0.85bn in 2019 with the majority of this being diesel vehicles[54]. Third, the continuous drop in the sales of diesel cars has contributed to the continuous increase of mean CO_2 from new vehicles in the EU for a third year in 2019 since 2017[55].

International competitiveness

The net trade surplus of the EU automotive industry amounted to €73.9bn in 2019 with US and China representing 44.5% of total exports value[56]. In the US, California regulatory authorities are designing the next standard in NO_x emissions from HD trucks, aiming at an overall reduction of 90% over current levels by 2027, including improved testing, engine power coverage conditions and monitoring procedures. China have adopted the RDE procedure for passenger cars under China 6 standards, but with a NO_x limit of 35 mg/km in the China 6b step to be enforced from 2023 on, representing a 56% lower limit value for NO_x than Euro 6d diesel limits, as shown in the CLOVE report on the *review of Int'l regulations*.

Such developments show that key exporting markets for the EU industry move ahead with much more stringent targets than current ones in the EU and sizeable investments will be required by the EU automotive industry to retain its competitiveness in these markets. Evidently, such investments may only be financially sustainable if these are also required in the EU, which is the main market of automotive manufacturers. Based on the previous short analysis, Euro 6/VI does not seem to be sufficient in this direction.

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49 Wapperlhorst S., 2020, "The end of the road? An overview of combustion-engine car phase-out announcements across Europe".
50 EMISIA, 2020 "European road transport & emissions trends report (ERTE2020)".
51 ACEA, 2020 Fuel types of new passenger cars in the EU (Accessed 02.2021).
52 BEUC, 2018. "What do local bans of diesel cars in cities mean for consumer policy?".
53 Financial Times, 2020. "German car industry slams Berlin stimulus package" (Accessed 12.2020).
54 ADESA, 2019. "Diesel fear the cause of unsold stock in cars worth 805.2 million euros" (Accessed 12.2020).
55 EEA, 2020, "Average CO2 emissions from new cars and new vans increased again in 2019"
56 ACEA,2020, "The automobile industry pocket guide - 2020/2021," ACEA.

3. Objectives

3.1. General objectives

Improving the health and welfare of the population within the EU and achieving long-term environmental sustainability are significant objectives for the EU policymakers. The challenge is particularly acute in relation to the road transport sector, which emits significant quantities of air pollutants harmful to the environment and human health.

The **general objective** of the post Euro6/VI initiative is, in line with the objectives set by current Euro 6/VI standards, to further improve the current Euro 6/VI standards on air pollutant emissions from cars, vans, lorries and buses. In particular, this is necessary in order to:

- Ensure a high level of environmental and health protection in the European Union by reducing air pollutant emissions from transport.
- Ensure the proper functioning of the internal market by setting harmonised rules for road transport vehicles.

Addressing these objectives will help in correcting the problems identified in section **Error! Reference source not found.** regarding the remaining air quality problems caused by road transport as well as the current market operation points, including lack of consumer trust, market fragmentation and risks for the competitiveness of the EU automotive industry.

3.2. Specific objectives

Improvement in the current automotive standards should primarily be seen with reference to achieving a number of **specific objectives.** In particular, the general objectives can be better served, only if the following specific objectives are met:

- Reduce complexity, inconsistencies and compliance costs related to the current Euro 6/VI standards. Provide appropriate and up-to-date limits for all relevant air pollutants.
- Ensure that air pollutants are kept under control over the entire lifetime of the vehicles and under all conditions of use.

4. Policy Options for Euro 7

4.1. Baseline development without introduction of a new emission standard

In order to assess the need for introducing a new emission standard for vehicles, we first had to calculate the expected evolution of emissions respecting only what has been already proposed at an EU level. This is the so-called **baseline** emission projection.

In July 2021, the European Commission presented the “EU fit-for-55” package which set forward an ambitious plan, investing in a climate-neutral future for the benefit of the people. This plan reconfirms the commitment towards meeting the target of achieving a 90% reduction in overall transport emissions by 2050 compared to 1990 levels. This is considered as one of the main objectives of the Sustainable and Smart Mobility Strategy towards achieving climate neutrality, as proposed in December 2020 [COM(2020) 789 final]. The revised plan targets a 55% emission reduction by 2030 compared to 1990, as adopted with the *European Climate Law* [Regulation (EU) 2021/1119].

In order for our baseline development to be consistent with the policy objectives of Fit for 55, we started with the total road transport activity projection being consistent with the DG CLIMA baseline that has gone into the assessment in the revised 2020 climate and energy legislative framework (SWD(2021) 613). Further to introduction of new vehicle technologies, the baseline considers measures that improve the efficiency of the transport system, promote public means of transport over private vehicles, and enhance modal shifts from road transport to other transport means.

Figure 4-1 shows the relative evolution of total activity (vehicle-km) projected in this baseline for cars & vans, and lorries & buses, respectively. Total activity for both vehicle categories is expected to grow in the future, following increases in the GDP and the needs of mobility of a larger population of people. The drop of activity in 2020 and less so in 2021 is due to COVID-19 pandemic and comes as a consequence of the lock-downs and curfews in several member states (more on this in section 4.2).

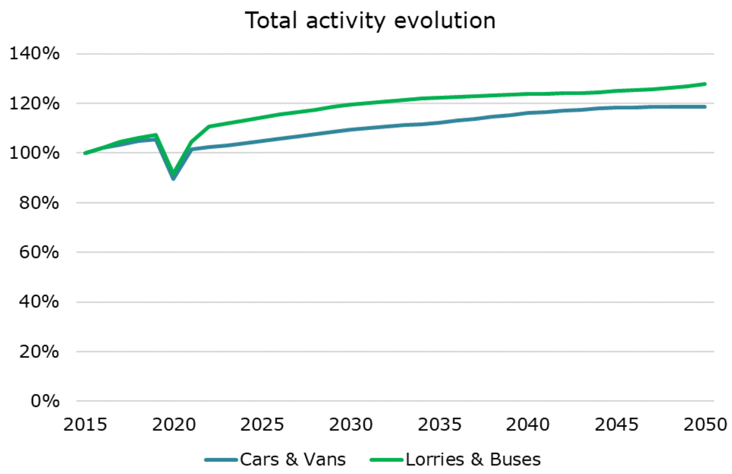

Figure 4-1: Relative activity evolution for cars & vans and lorries & buses in the baseline (2015=100).

This baseline that has been used for comparison of the policy options throughout this report assumes that the last emission standards introduced for vehicles are the Euro 6d for cars & vans (Regulation (EU) 715/2017) and Euro VI E for lorries & buses (Regulation (EU) 595/2009) and that no further legislative initiative is specifically taken towards decreasing air pollutant emissions of transport in the future.

The renewed targets of mid-term CO_2 reductions announced by the fit-for-55 package call for an accelerated pace of zero and low tailpipe CO_2 emission vehicles entering the market and an accelerated shift of mobility to public transport, among other measures. Most importantly, the new target for a 55% emission reduction by 2030 compared to 1990 is associated with the phasing out of internal combustion engines by 2035. The impact of introducing zero tailpipe emission vehicles at an accelerated pace into the baseline development will have to be quantified.

Figure 4-2 illustrates the projected technology/fuel mix until 2050, regarding new registrations of cars & vans and lorries & buses in the EU27 considered in our baseline development. For all vehicle categories, we have used the latest information on registration statistics up to 2020, on the basis of data published by ACEA[57]. For cars & vans, the future technology mix is consistent with EU fit-for-55 MIX Scenario 2021 as in SWD(2021) 613 final. Already in 2030, more than 40% of new registrations are projected to be of zero tailpipe emission (battery electric or fuel cell H_2). For the remaining vehicles with internal combustion engines, the majority comprises of hybrid and plug-in hybrid vehicles. In fact, the 'conventional' vehicle technology may still include some form of advanced electrified components but not to a degree that would appreciably impact the specifications of the emission control system compared to vehicles that would not use such electrified components.

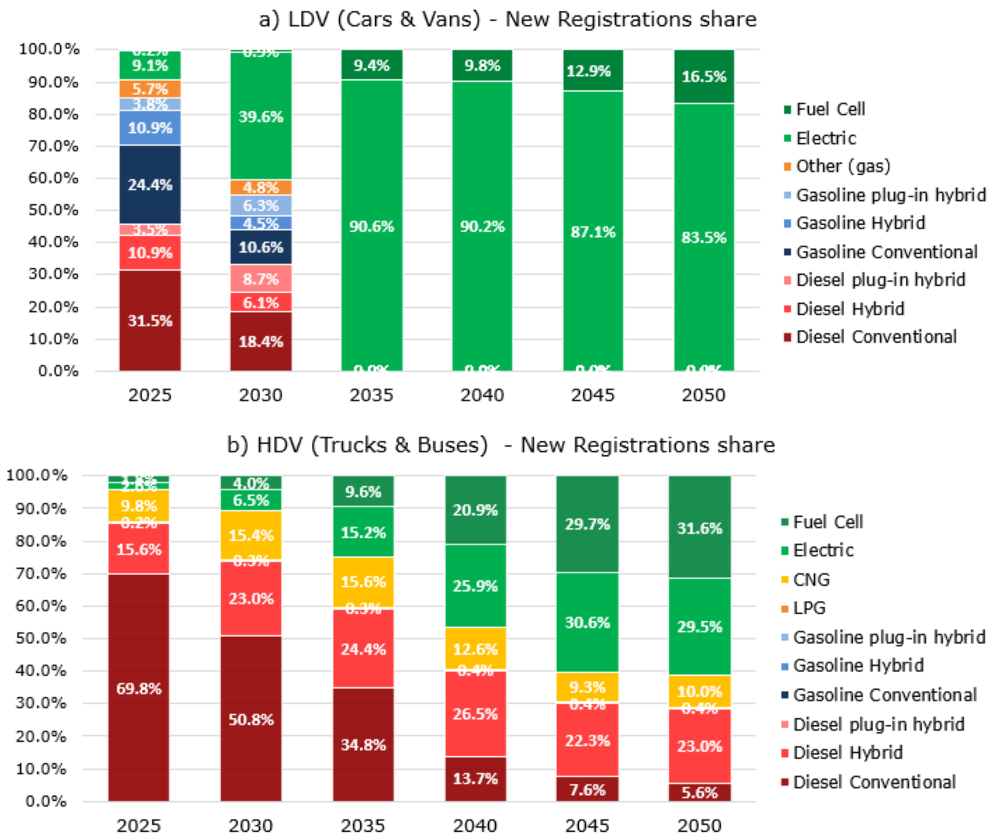

Figure 4-2: Technology mix for registration of (a) cars & vans, (b) trucks & buses considered over the years of the modelling time-horizon for the baseline.

For lorries & buses, again the total fleet development is based on the EU fit-for-55 MIX Scenario 2021 consistent with to SWD(2020) 176 final. However, we have further

[57] ACEA, accessed Feb 2020: https://www.acea.be/press-releases/article/fuel-types-of-new-cars-electric-10.5-hybrid-11.9-petrol-47.5-market-share-f

elaborated the technology mix by including industry expectations[58] for different vehicle categories (trucks, buses) and declared initiatives at city level especially for urban buses[59], as well as own (CLOVE) engineering judgment. We argue that the technology mix used is consistent with overall policy targets and realistic in terms of an engineering assessment of technology potential. Battery electric vehicles and fuel cells ones are almost equally split in the future. The mix of technologies is further distinguished if one looks at the individual vehicles categories, e.g. urban buses vs long-haul trucks.

Based on the total activity statistics, and the technology mix for future new registrations, we implemented the COPERT/SIBYL framework (details in Annex I) to model the evolution of emissions. SIBYL projected the fleet and activity turnover per vehicle technology and COPERT assigned appropriate emission factors (emission rates expressed in g/km or #/km) based on operational and environmental conditions (i.e., speed, trip distribution, mean ambient temperature, etc.) in each member state.

In particular for Euro 6 cars & vans and Euro VI lorries & buses, we introduced revised emission factors that were based on latest measurements conducted by the CLOVE consortium. The relevant analysis is presented in detail in the CLOVE *Combined report*. Based on this analysis, two sets of emission factors were produced (see section 9.4.2 of the current report). One is referred to as the 'normal Euro 6/VI' dataset which is based on experimental information on emission performance of latest Euro 6d and modelling of the Euro VI E emission performance, as in detail described in the *Combined report*. The estimation of Euro VI E emission performance was conducted by introducing relevant engineering considerations on the collected experimental information of Euro VI D, as we had no access to experimental information on Euro VI E technology performance at the time of preparing this report. The second dataset, referred to as 'conservative' Euro 6/VI reflects a gradual worsening of the emission levels of new vehicles in the future, as a probable result of several factors:

- The fact that the current experimental database collected by CLOVE mostly contains results from vehicles of the higher market segments, that can afford expensive emission control systems. We have seen in the past that vehicles in lower market segments are generally not equipped with such sophisticated systems thus exhibiting higher emissions over certain operation conditions than their more expensive counterparts.
- The trade-offs between CO_2 and air pollutants (primarily NO_x) which may further push OEMs to relax NO_x control within limit allowances to accommodate intermediate CO_2 targets in the period from 2025 and 2030.
- The gaining of experience by the OEMs in calibration and optimisation of the emission control system together with improvements in the measuring techniques. These can enable a decrease of the margin of safety over the limit value or, vice-versa, an increase in the emission level set as an engineering target. This may be pushed by the need of an overall cost reduction for emission control.

All these reasons may lead to an increase in the real-world mean emission levels of new registrations with time. Such a trend is not uncommon and has been observed in the past; for example, the first set of emission factors for Euro 6a/b vehicles developed by the ERMES group was based on vehicles of higher market segments. This was at a lower level than subsequent revisions of emission factors that also used data from lower

[58] ERTRAC, 2017. European roadmap electrification of road transport.

[59] DG Transport, European Clean Bus deployment Initiative.

segments[60]. All details of activity projection, technology mix and emissions calculations and projections are given in the Annex of this report while the input data for the analysis are presented in the *Combined report*.

Based on the process shortly presented above, Figure 4-3 shows the evolution of NO_x and $PM_{2.5}$ emissions over the time horizon of the analysis. The left panel exhibits NO_x evolution with the two sets of emission factors up to 2050. Total emissions drop significantly even without the introduction of a new emission standard over Euro 6/VI due to the increased rate of penetration of zero emission vehicles to the fleet. The right-hand panel shows the corresponding reductions of $PM_{2.5}$, split between exhaust and non-exhaust (brake, tyre wear) sources. Although exhaust $PM_{2.5}$ experiences a significant drop over time due to the introduction of zero emission technologies, non-exhaust $PM_{2.}$5 remains significant.

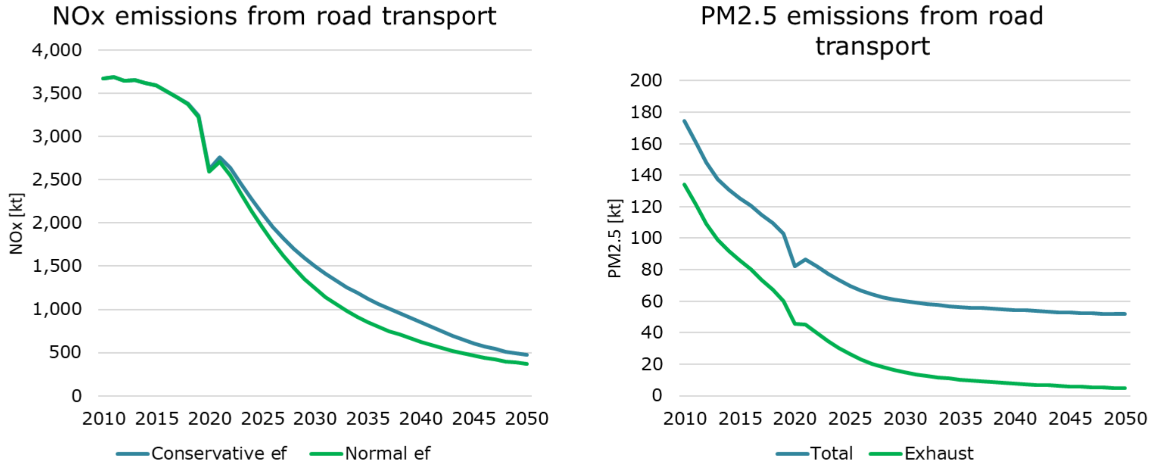

Figure 4-3: Evolution of (a) NOx and (b) PM2.5 emissions from road transport in the baseline for normal and conservative emission development. PM2.5 total includes both exhaust emissions and the contributions from tyre and brake wear in this particle size range.

The numerical values of emission reductions achieved in the baseline are summarised in Table 4-1 and

Table 4-2 for the main vehicle categories and pollutants over the reference year, for the normal and conservative emission performance evolution respectively. Based on combined cars, vans, lorries and buses emission reductions, total road transport NO_x emissions appear to be 87% (conservative) to 90% (normal) lower in 2050 than in 2015. Reductions for $PM_{2.5}$ and, in particular PM_{10}, are lower due to the increasing relative contribution of non-exhaust sources (primarily tyre and brake wear) for which no measures have been introduced up to Euro 6/VI. This means that even if zero-tailpipe emission technologies are placed in the market on large numbers (as is the hypothesis of the baseline - Figure 4-2), $PM_{2.5}$ is not satisfactorily decreased. In order to achieve this, one will have to introduce specific measures targeting non-exhaust emissions.

For CO and THC emissions, the impacts of Euro 6/VI were found to be lower than NO_x and $PM_{2.5}$ in this baseline, the main reason being that older technologies often complied with emission limits, already with a margin. The second reason has been that the reductions brought with Euro 6/VI in limit values for CO and HC were generally not as high as for NO_x and PM_{exh}. For example, Euro 6 introduced a reduction of 55% in NO_x for

[60] Keller, M. 2013. HBEFA Status Report ERMES Meeting Sept. 2013.

CI cars and 0% for CO over Euro 5. Similarly, Euro VI introduced 80% and 50% reduction in NO_x and PM_{exh}, respectively, compared again to 0% for CO over Euro V.

For lorries and buses some increases in NH_3 emissions (negative values on the table) are due to the widespread use of SCR systems and the slight possibility of urea slip. The use of SCR was much less extensive at Euro V. However, despite relative increases, the absolute level of emissions remains low compared to cars & vans in which NH_3 emissions are dominated by aged catalysts of PI vehicles. Therefore, the increase introduced with Euro VI is of limited environmental impact while measured Euro VI lorries and buses were generally found to be well within NH_3 limits (*Combined report*).

Table 4-1: Summary of emission reductions (kT and in %) in the baseline for main pollutants and vehicle categories compared to the reference year (2015) for the normal evolution of Euro 6/VI emission performance.

Pollutant		2015	2020	2025	2030	2035	2040	2045	2050
Cars & Vans									
NO_x	kt	0	399	758	1,175	1,434	1,579	1,655	1,692
	%	0.0	23.4	44.3	68.8	83.9	92.4	96.9	99.0
$PM_{2.5}$	kt	0	33.3	44.9	51.8	53.4	52.9	52.5	52.5
	%	0.0	37.3	50.3	58.0	59.8	59.2	58.8	58.8
PM_{10}	kt	0	36.1	43.3	48.9	49.6	48.1	47.0	46.9
	%	0.0	30.7	36.8	41.5	42.1	40.8	39.9	39.8
PN	#	0.0E+00	4.3E+25	6.8E+25	8.1E+25	8.4E+25	8.5E+25	8.6E+25	8.6E+25
	%	0.0	50.6	79.6	94.4	98.3	99.2	99.7	99.9
CO	kt	0	1,192	1,728	2,286	2,665	2,935	3,112	3,200
	%	0.0	36.8	53.4	70.6	82.3	90.7	96.2	98.9
THC	kt	0	138	190	257	323	380	421	449
	%	0.0	29.5	40.6	54.8	68.8	81.0	89.8	95.8
NH_3	kt	0	19.4	23.4	26.4	30.8	37.0	42.8	45.9
	%	0.0	41.1	49.5	55.8	65.1	78.3	90.5	97.2
Lorries and Buses									
NO_x	kt	0	600	887	1,187	1,318	1,394	1,475	1,526
	%	0.0	31.9	47.2	63.1	70.1	74.2	78.4	81.1
$PM_{2.5}$	kt	0	10.3	11.1	14.1	16.2	18.4	20.4	21.3
	%	0.0	28.2	30.6	38.9	44.4	50.5	56.2	58.7
PM_{10}	kt	0	10.7	9.7	12.3	14.3	16.6	18.9	19.6
	%	0.0	24.3	21.9	27.9	32.3	37.7	42.8	44.5
PN	#	0.0E+00	3.1E+25	4.6E+25	5.1E+25	5.3E+25	5.3E+25	5.3E+25	5.3E+25
	%	0.0	58.8	85.3	96.4	98.6	98.9	99.0	99.1
CO	kt	0	169	259	338	363	369	381	391
	%	0.0	35.5	54.5	71.2	76.5	77.7	80.4	82.5
THC	kt	0	21.5	26.8	27.0	25.1	24.7	27.8	29.7
	%	0.0	41.7	51.8	52.2	48.6	47.9	53.8	57.5
NH_3	kt	0	0.2	-1.9	-3.1	-3.7	-3.3	-1.8	-0.7
	%	0.0	2.9	-32.2	-53.1	-63.2	-55.2	-30.1	-12.1

Table 4-2: Summary of emission reductions (kT and in %) in the baseline for main pollutants and vehicle categories compared to the reference year (2015) for the conservative evolution of Euro 6/VI emission performance.

Pollutant		2015	2020	2025	2030	2035	2040	2045	2050
Cars & Vans									
NO_x	kt	0	383	677	1,052	1,320	1,503	1,618	1,680
	%	0.0	22.4	39.6	61.6	77.2	87.9	94.7	98.3
$PM_{2.5}$	kt	0	33.3	44.7	51.5	53.1	52.7	52.4	52.5
	%	0.0	37.2	50.0	57.7	59.5	59.1	58.7	58.8
PM_{10}	kt	0	36.1	43.1	48.6	49.4	47.9	46.9	46.9
	%	0.0	30.6	36.6	41.3	41.9	40.7	39.8	39.8
PN	#	0.0E+00	4.3E+25	6.8E+25	8.1E+25	8.4E+25	8.5E+25	8.6E+25	8.6E+25
	%	0.0	50.5	79.2	93.8	97.8	98.9	99.6	99.9
CO	kt	0	1,188	1,718	2,273	2,653	2,927	3,109	3,199
	%	0.0	36.7	53.1	70.2	81.9	90.4	96.0	98.8
THC	kt	0	138	190	257	323	380	421	449
	%	0.0	29.5	40.6	54.8	68.8	81.0	89.8	95.8
NH_3	kt	0	19.4	21.7	21.0	23.4	31.2	40.2	45.2
	%	0.0	41.1	45.9	44.4	49.5	66.1	85.0	95.5
Lorries and Buses									
NO_x	kt	0	591	821	1,070	1,175	1,260	1,371	1,440
	%	0.0	31.4	43.7	56.9	62.5	67.0	72.9	76.6
$PM_{2.5}$	kt	0	10.3	11.1	14.1	16.2	18.4	20.4	21.3
	%	0.0	28.2	30.6	38.9	44.4	50.5	56.2	58.7
PM_{10}	kt	0	10.7	9.7	12.3	14.3	16.6	18.9	19.6
	%	0.0	24.3	21.9	27.9	32.3	37.7	42.8	44.5
PN	#	0.0E+00	3.1E+25	4.6E+25	5.1E+25	5.3E+25	5.3E+25	5.3E+25	5.3E+25
	%	0.0	58.8	85.3	96.4	98.6	98.9	99.0	99.1
CO	kt	0	169	259	338	363	369	381	391
	%	0.0	35.5	54.5	71.2	76.5	77.7	80.4	82.5
THC	kt	0	21.5	26.8	27.0	25.1	24.7	27.8	29.7
	%	0.0	41.7	51.8	52.2	48.6	47.9	53.8	57.5
NH_3	kt	0	0.2	-1.9	-3.1	-3.7	-3.3	-1.8	-0.7
	%	0.0	2.9	-32.2	-53.1	-63.2	-55.2	-30.1	-12.1

4.2. The impact of COVID-19 on the baseline development

The baseline that we have introduced in the analysis considers the impact of the COVID-19 pandemic on emission relevant parameters. These parameters include – most prominently – total transport activity and its related energy consumption as well as the impact on sales of new vehicles.

An approach to model the COVID-19 impact on transport has already been adopted by the European Commission in their SWD(2020) 176 final document, using the available data at the end of 2020. The approach adopted estimated that the projected decrease in total energy consumption of road transport in 2020 was about 17% over 2019.

At the time of preparing the current report, there are still no official statistics on how much transport activity has been hit by COVID-19 in 2020 while there are no solid projections on how much 2021 and later years will be affected. Evidence from various sources indicate that the interventions brought forward to limit the infection propagation of COVID-19 resulted in extensive mobility restrictions with a pronounced impact on most transport modes.

The latest proposal for amending Regulation (EU) 2019/631[61] as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition, provided some interesting information regarding the impact of COVID-19 on transport sector. It is indicated that the COVID-19 epidemic has had a significant influence on the global automobile industry, creating unprecedented problems for the whole industry. New registrations of passenger cars and light commercial vehicles fell by 23.7% and 18.9% percent in the EU-27, respectively, compared to 2019. In light of the vaccination campaigns and the expected gradual relaxation of containment measures, it is anticipated that the Western and Central European automotive demand for 2021 achieves 15.3 million units for 2021, with a 11% growth compared to 2020. Finally, there is evidence already that the current crisis will not slow down the current transition to electrification. On the contrary, industry and technological innovation experts expect the crisis to become a catalyst for the transformation.

JRC estimated that from February 2020 until April 2020, the total activity decline was from 60% to 90% for passenger cars and 15% for freight transport[62]. For the same period Aloi et al. (2020)[63] recorded drops in passenger activity of the order of 85-90% in hard-hit areas in Southern Europe. Although such high numbers reflect the first lockdowns of Spring 2020 and some recovery has taken place since, their impact in total annual-average activity is significant.

Data from Eurostat[64] also showed that for most EU27 Member states there has been an average 5% decline in freight transport activity, in terms of million tonne-kilometres (TKM). A number of market intelligence reports have also aimed at quantifying the impact of COVID-19 on road freight market contraction, estimating average impacts of the order of 6.2%[65], ranging from 4.8%-17%[66].

Following the impacts of COVID-19 on EU GDP in SWD(2020) 176 final and the evidence collected from other sources mentioned, the short-term estimate points to a sharp activity drop of 15% in 2020 followed by significant recovery in 2021. in the same setting, the crisis is projected to result to a permanent loss of total activity of 7% by 2030, compared to the pre-COVID projections. Figure 4-4 presents this comparison of the pre-COVID and, corrected, post-COVID estimated projections of activity introduced in our current baseline.

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[61] COM(2021) 556 final, (2021), https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf

[62] JRC, 2020. "Future of Transport: Update on the economic impacts of COVID-19"

[63] Aloi. et al. (2020) Effects of the COVID-19 Lockdown on Urban Mobility: Empirical Evidence from the City of Santander (Spain). Sustainability 2020, 12, 3870; doi:10.3390/su12093870.

[64] Eurostat (accessed March 2021), Summary of quarterly road freight transport by type of operation and type of transport

[65] Post Covid-19 Forecasts: European Road Freight Transport Growth 2020-2024 - Transport Intelligence (ti-insight.com)

[66] European Road Freight Transport - Transport Intelligence (ti-insight.com)

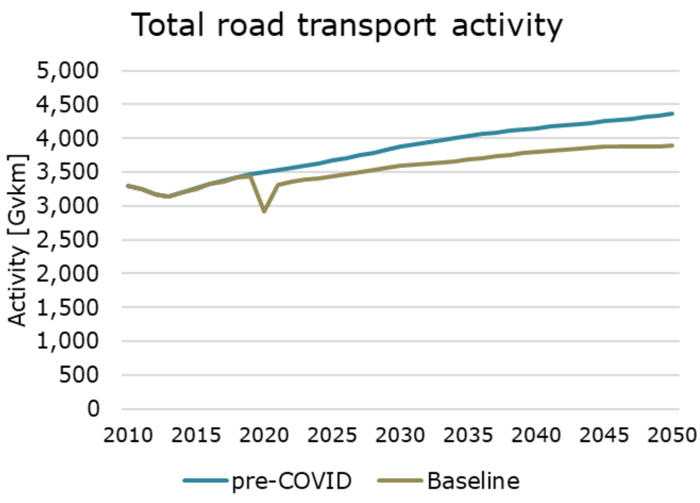

Figure 4-4: Evolution of total road transport activity in EU27 considered in the baseline of this report.

With regard to new vehicle sales, according to ACEA statistics[67] for 2020, the total EU passenger car sales declined by 23.7% compared to 2019, as a direct result of the COVID-19 pandemic. This was due to containment measures and other restrictions throughout the year (e.g., full-scale lockdowns) as well as uncertainty about the future which had an unprecedented impact on car sales across the EU. In fact, 2020 saw the biggest drop on a yearly basis in car demand since ACEA records began, with new-car registrations falling by 3 million units compared to 2019. All EU27 markets recorded double-digit declines throughout 2020. Concerning freight transport stock, new registrations of lorries above 3.5 tonnes recorded a decline of about 26% compared to 2019 levels[68]. All these effects were taken into account in the baseline development for the present IA, with details given in Annex I section 9.4.

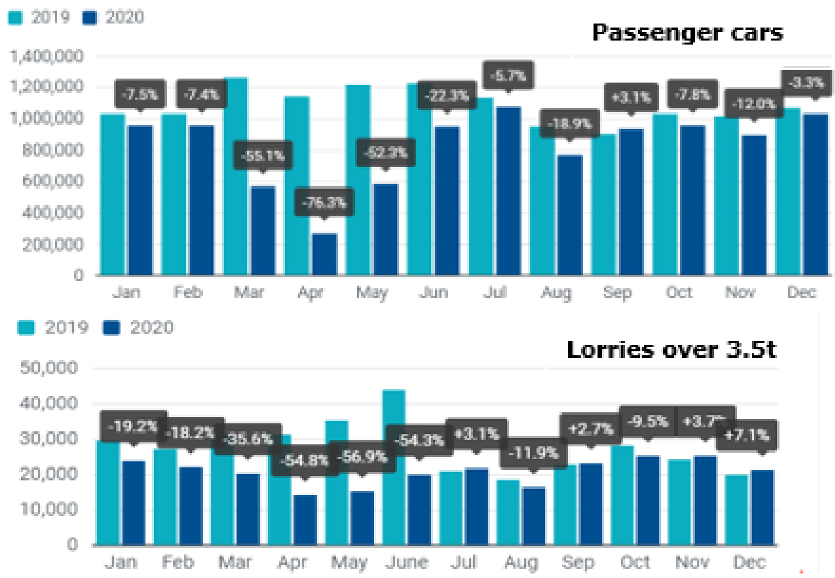

Figure 4-5: Registration of new passenger car and lorries (over 3.5t) in the EU in 2020 compared to 2019 (Source: ACEA)

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[67] ACEA 2021. https://www.acea.be/press-releases/article/passenger-car-registrations-23.7-in-2020-3.3-in-december. Accessed on February 21

[68] ACEA, 2021. https://www.acea.be/press-releases/article/commercial-vehicle-registrations-18.9-in-2020-4.2-in-december. Accessed on February 21

4.3. Description of the policy options

4.3.1. Policy Option 0: No change over current standards

The first policy option is to introduce no new emission requirements over what is currently already regulated, specifically:

- Regulation (EC) No 715/2007 and its implementing Regulation (EU) 2017/1151 for cars & vans.
- Regulation (EC) No 595/2009 and its implementing Regulation (EU) No 582/2011 for lorries & buses.

This also includes any amendments of these four Regulations.

In this context, pollutant emissions are considered to develop identically to the baseline in this policy option and emission limits remain at the levels today applicable for Euro 6/VI. Such a policy option obviously introduces no incremental costs over the baseline. A summary of emission limit values are shown in Table 4-3 both for light duty and heavy duty vehicles. In addition to exhaust emissions, PO0 considers evaporation emissions control with a limit of 2 g/test.

Table 4-3: Exhaust emission limits considered in Policy Option 0. Limits are identical to the current ones at Euro 6/VI.

Pollutant	Concept	CO	THC	NMHC	NO_x	THC+NO_x	PM	$PN_{>23nm}$	NH_3	CH_4
Category		**(mg/km)**						**(km^{-1})**		
Euro 6 Cars & Vans with RM≤1305 kg	PI	1000	100	68	60	–	4.5 (DI)	6×10^{11} (DI)	–	–
	CI	500	–	–	80	170	4.5	6×10^{11}		
Euro 6 Vans with 1305<RM ≤1760 kg	PI	1810	130	90	75	–	4.5 (DI)	6×10^{11} (DI)		
	CI	630	–	–	105	195	4.5	6×10^{11}		
Euro 6 Vans with RM>1760 kg	PI	2270	160	108	82	–	4.5 (DI)	6×10^{11} (DI)		
	CI	740	–	–	125	215	4.5	6×10^{11}		
		(mg/kWh)						**(km^{-1})**	**(ppm)**	**(mg/kWh)**
Lorries & Buses	CI @WHSC	1500	130	–	400	–	10	8×10^{11}	10	–
	CI @WHTC	4000	160	–	460	–	10	6×10^{11}	10	–
	PI @WHTC	4000	–	160	460	–	10	6×10^{11}	10	500

In terms of testing conditions, PO0 requires compliance both over laboratory and on-road conditions. For LDVs, laboratory compliance will have to be demonstrated over WLTP and on-road compliance needs to be demonstrated in RDE testing, as specified in Regulation (EU) 2017/1151. For HDVs, emissions compliance of engines is demonstrated in WHSC and WHTC testing in the laboratory while on-road compliance is demonstrated by means of ISC tests, as specified in Regulation (EU) 582/2011. The main testing boundaries and specifications for RDE and ISC conditions are shown in Table 4-4 for cars & vans and

Table 4-5 for lorries & buses.

Table 4-4: Testing conditions for on-road emissions compliance demonstration for cars & vans in PO0.

Parameter	Normal conditions	Extended conditions
Ambient temperature [°C]	Moderate: 0 – 30°C	Extended: -7 – 0°C or 30 – 35°C
Average Speed [km/h]	Urban: 15-40 km/h + Limitations for trip distance and duration, and speed range coverage	
Max speed	145 km/h (160 km/h <3% of motorway)	
Auxiliaries	No limitation	
Trip characteristics	90-120 min, 34% urban, 33% rural, 33% highway	
Engine loading	Speed based limits of $v \times a[95^{th}]$ [W/kg]	
Max. altitude [m]	700	1300
Positive elevation gain [m/100km]	Total: <1200 [m/100km] | Urban: <1200 [m/100km]	
Age of Vehicle for ISC [$\times 10^3$ km]	15 – 100	
Useful life [$\times 10^3$ km]	160	

Table 4-5: Testing conditions for on-road emissions compliance demonstration for trucks & buses in PO0.

Parameter	Boundary conditions
Ambient temperature [°C]	-7°C to 35°C
Auxiliaries	No limitation
Min Trip duration | Trip characteristics	4× WHTC work | U, R. H shares according to category
Engine loading	Only work windows > 10% P_{max} valid
Max. altitude [m]	1600 m
Payload (%)	10 – 100
Age of Vehicle [$\times 10^3$ km]	N2, N3 < 16t, M3 < 7.5t: 25-300 | N3 > 16t, M3 > 7.5t: 25 – 700

4.3.2. Policy Option 1: Refined architecture of vehicle emission standards

Policy Option 1 implies a narrow revision of Euro 6/VI which addresses key simplification and consistency aspects of current regulations in order to establish more comprehensive control and at the same time decrease enforcements costs. This policy option does not aim at introducing more stringent limits but only to make the current ones consistent for different technologies. It would also involve simplifying the existing emission tests while keeping a focus on real-world testing. The options available have been presented in detail in Chapter 5 of the *Simplification report*.

In terms of emission limits and in an effort to deliver fuel-neutral standards so as to further simplify the relevant regulation, Table 4-6 presents the proposed emission limits in this policy option. Numerical values are in general at the same level with Euro 6/VI but fuel-related specificities have been removed and the lower applicable value has been retained. One distinct change is the decrease of the solid particle number size threshold from 23 nm to 10 nm. The PMP group has already come up with a proposal on how this can be introduced in the regulations and what sampling and measurement implications this will have[69]. Due to the maturity of the proposal, we believe that the introduction of the lower particle threshold may even occur before the introduction of Euro 7, therefore we have considered this threshold in all policy options further to PO0. The second distinct change is the introduction of an NH_3 limit at 20 mg/km. This is not a particularly stringent limit but is introduced as an equivalent to the one for HDVs, to avoid ill-calibrated SCR systems (CI) and malfunctioning TWC (PI).

Simplification in the regulation is further promoted by a number of measures considered in this policy option, including the following (More details and objectives of proposals can be found in the *Simplification report*):

1. Merge regulations 715/2207 and 595/2008 in a combined new emissions regulation text.
2. Replace the reference mass by TPMLM and define new border between LD and HD.
3. Introduce a single date of Euro 7 introduction per category.
4. Align the CoP, ISC, and MaS frameworks.
5. Introduce improved on-board diagnostics (OBD) as a support element to enable testing for ISC/MaS.

Table 4-6: Proposed limit values for exhaust emissions of cars & vans and lorries & buses under PO1

Pollutant	CO	THC	NMHC	NO_x	PM	$PN_{>10nm}$	NH_3	Evaporative emissions
Category	(mg/km)					(km^{-1})	(mg/km)	g/test (for gasoline only)
Euro 6 Cars & Vans RM≤1305 kg	500	100	68	60	4.5	6×10^{11}	20	2
Euro 6 Vans 1305<RM≤1760 kg	630	130	90	75	4.5	6×10^{11}	20	2
Euro 6 Vans RM>1760 kg	740	160	108	82	4.5	6×10^{11}	20	2
	(mg/kWh)					(kWh^{-1})	(ppm)	
Lorries & Buses	4000	660	160	460	10	6×10^{11}	10	-

A number of changes are also introduced with regards to the type approvals tests and testing conditions for which the cars & vans limits are applicable:

1. Repeal of conformity factors for RDE.
2. Repeal of idle, opacity, off-cycle emissions and crankcase tests.
3. Repeal ATCT testing.
4. Further streamlining the boundary conditions for testing between all vehicle categories, as presented in

[69] Informal documents GRPE-81-10 and GRPE-81-11 of UN29. Available at 81st session | UNECE.

5. **Parameter**	Conditions

6. Table 4-7 for cars and vans. In principle, this approach now introduces the former

Max speed (km/h)	145
Auxiliaries	No limitation
Trip characteristics	Any trip longer than 16 km
Engine loading	As in current Euro 6 RDE
Towing, aerodynamic modifications	Not allowed
Max. altitude [m]	1300
Positive elevation gain [m/100km]	No limitation
Age of Vehicle at ISC [×103 km]	10 – 160
Useful life [×103 km]	160

'RDE extended' conditions within normal boundaries.

Parameter	Conditions
Ambient temperature [°C]	-7 – 35°C
Max speed (km/h)	145
Auxiliaries	No limitation
Trip characteristics	Any trip longer than 16 km
Engine loading	As in current Euro 6 RDE
Towing, aerodynamic modifications	Not allowed
Max. altitude [m]	1300
Positive elevation gain [m/100km]	No limitation
Age of Vehicle at ISC [$\times 10^3$ km]	10 – 160
Useful life [$\times 10^3$ km]	160

Table 4-7: Normal driving conditions for cars & vans in Policy Option 1

Driving beyond normal driving conditions corresponds to a rather small portion of total mileage and section 9.4.1 makes an overall assessment of mileage distribution within and beyond normal conditions. Emission levels beyond normal driving need to respect limits with an **emissions cap at 4× of the emission limit over RDE** per pollutant for light duty vehicles and **3× the emission limit for heavy duty vehicles**.

For lorries and buses, the boundary conditions of

Table 4-5 still hold but the minimum distance for compliance is decreased from 25,000 km to 10,000 km. Moreover, the following elements are introduced in legislation, in order to assist in regulatory simplification:

1. On-road testing becomes the basis of regulation. Emission limits (per kWh) refer to on-road testing.

2. The type-approval testing may be replaced be OEM declarations for the following components: OBD, durability, crankcase emissions, NO_x control operation, reagent freeze protection.
3. OBD provisions for malfunction detection are kept by OBD OTLs and IUPR provisions are repealed. Exceedances of applicable limits is verified through enhanced OBD operation.
4. Off cycle emissions testing is repealed.

Policy Option 1 does not require significant development times as it is largely built on a mild refinement of the requirements for existing emission control. Simplifications introduced in the removal of IUPR calibration are considered to cancel out investments needed for the introduction of improved OBD. Because of the limited development needs, PO1 is not expected to be challenging for implementation within a short time frame. Table 4-8 shows the proposed implementation framework. The same table also suggests a minimum time for further revisions of the regulations and the advance notice given for the industry to be suitably prepared.

Table 4-8: Dates and conditions of Euro 7 implementation in PO1

Introduction date of Euro 7	1.1.2025
Types of registrations affected	All new registrations (no 'new type approvals' defined)

4.3.3. Policy Option 2: Improved air pollutant limits and advanced tests for cars, vans, lorries and buses in addition to policy option 1

In Policy Option 2, one in principle builds on the same elements of PO1 regarding simplification of the regulations and streamlining of testing conditions, and all relevant elements of PO1 are expected to be introduced in PO2 as well. The main differences are related to emission limits, coverage of pollutants and testing boundary conditions considered. In detail, the new elements introduced in PO2 are as follows:

1. Coverage of an extended list of pollutants, as presented in Table 4-9.
2. Introduction of more stringent limits than PO1, as shown in Table 4-10. Different pollutant limit values combinations need to be explored as individual scenarios, to assess optimum cost-benefit ratios.
3. Boundary conditions of higher stringency can also be defined, as presented in Table 4-11. For normal conditions, the emission limit is applicable, whereas for extended conditions, **an emissions cap at 3× of the emission limit values is applicable for LDV and 2× the emission limit values for HDV**.
4. New diurnal limit and other requirements for evaporation losses as shown in Table 4-12.
5. Consideration of test results even when emission control system regeneration events occur during testing. Such events cannot result to an emissions test considered as void.
6. Control of brake wear emissions by means of improved brake technology, as presented in
7. Table 4-14.

Table 4-9: Extended list of pollutants covered in PO2 for both LDV and HDV and their relevance

Pollutant	Process	Relevance		
		Health	**Air quality**	**Climate**
Nitrous Oxide (N_2O)	Emission control devices			×
Formaldehyde (CH_2O)	Combustion	×	×	
Non-methane organic gases (NMOG)	Oxygenated fuels, e.g. alcohols	×		
Brake wear emissions	Non-exhaust: brake	×		
Tyre and road wear emissions*	Non-exhaust: tyre and road wear	×		

*Currently it is not yet technologically feasible to develop a test and limit for tyre and road wear emissions. Therefore, this action is introduced in PO2 but it justifies further review on limits and test conditions.

In particular for NO_2, PO2 considers that no separate limit to NO_x has to be introduced. This is because emission limits proposed are low enough to offer adequate protection from both NO and NO_2, regardless of the relative proportion these are emitted within the NO_x group.

Table 4-10: Proposed limit values for exhaust emissions of cars & vans and lorries & buses under PO2

Pollutant	CO	NMOG	NO_x	PM	PN_{10}	NH_3	CH_4	N_2O	HCHO[§]
Category	(mg/km)				(km^{-1})	(mg/km)			
Scenarios 1 & 2 Cars and Vans									
Cars & Vans with TPMLM≤2500 kg	400	45	30	2	1×10^{11}	10	20	20	5
Vans with TPMLM>2500 kg & PWR<35 kW/t	600	45	45	2	1×10^{11}	10	20	30	10
Scenario 3 Cars and Vans									
Cars & Vans with TPMLM≤2500 kg	400	25	20	2	1×10^{11}	10	10	10	5
Vans with TPMLM>2500 kg & PWR<35 kW/t	600	25	30	2	1×10^{11}	10	10	15	10
	(mg/kWh)				(km^{-1})	(mg/kWh)			
Scenarios 1 & 2 Lorries and Buses									
Cold emissions (100th Percentile)	7500	200	350	12	5×10^{11}	70	500	300	80
Hot emissions (90th Percentile)	300	50	90	8	1×10^{11}	70	350	60	20
Scenario 3 Lorries and Buses									
Cold emissions (100th Percentile)	3000	75	175	12	5×10^{11}	70	500	300	30
Hot emissions (90th Percentile)	300	50	90	8	1×10^{11}	70	350	60	20

[§] HCHO limits have not been included in the current assessment due to the lack of appropriate emission factors for current and future vehicles.

Table 4-11 presents the testing conditions for normal conditions for which limits of Table 4-10 are applicable. For all other conditions, an emissions cap of 3× the limits of Table 4-10 is to be applied if one of the conditions is violated, except for the trip characteristics for which a budget approach (Combined report) is applicable.

Table 4-11: Normal driving conditions for cars & vans in Policy Option 2

Parameter	Scenario 1	Scenarios 2 & 3
Ambient temperature [°C]	-7 – 35	
Max speed (km/h)	145	160
Auxiliaries	No limitation	
Trip characteristics	Any trip ≥ 10 km | Trips <10 km emissions limited within a budget[§]	
Engine loading	As in current Euro 6 RDE	Any condition
Towing, aerodynamic modifications	Not allowed	
Max. altitude [m]	1600	
Positive elevation gain	No limitation	
Age of Vehicle at ISC [$\times10^3$ km]	10 – 200	3 - 240
Useful life	200	240

[§] The details of the budget approach are defined in the *Combined report* and the emission budget allowance is specific to power and the boundary conditions applicable.

Table 4-12 shows the emission limit provisions for evaporation. In order to achieve fuel neutrality for evaporation limit specifications, we define a range of fuel volatilities for which evaporation limits are applicable. By doing so, no specificity for PI or CI combustion concepts is required as fuel evaporation is not combustion principle specific. Moreover, evaporation control specifications include new technology for limiting vapour losses during refuelling and new test provisions (arbitrary testing temperature).

Table 4-12: Proposed evaporation testing conditions and limits for LDVs under PO2

Category	Passenger cars, Vans < 2.5t TPMLM (N1 classes I-II)		Vans > 2.5t TPMLM (N1 class III)	
Scenario	Scenario 1 & 2	Scenario 3	Scenario 1 & 2	Scenario 3
Emissions limit at diurnal test (g/day)	0.5	0.3	0.7	0.5
Refuelling test	0.05 g/L fuel dispensed			
Testing conditions	• 48-h diurnal test remains, but emission limit applies to the worst result of the two days • Reduced pre-conditioning drive • Soak and drive temperatures not prescribed; any value between 25 and 38°C			
RVP of fuels for which regulation is applicable	In this report, the limit is considered to be at 40 kPa			

For HDVs, emission limit values have been presented in Table 4-10. Table 4-13 shows normal driving conditions. **For conditions beyond normal driving, an emissions cap 2× of the emission limit is applicable.**

PO2 also considers that reductions are technologically possible and need to be introduced with regard to brake wear emissions. The PMP Group has significantly progressed in developing a measurement method and protocol[70] while technological options to decrease wear are already in the market or close to becoming commercial. For PO2, we have introduced two scenarios regarding control of brake wear emissions (

Table 4-14). In principle, Scenario 1 assumes the use of better pad material only, while Scenario 2 also assumes collection of wear particles produced (details on Annex I Section 9.5). For vans, we have assumed that the proposed limit scales with the TPMLM category to provide margin due to larger brakes used and more thermal energy dissipated. No inclusion of brake wear control has been included for lorries and buses.

PO2 will require some more effort to introduce new technology and fulfil the lower emission limits set. However, we have considered that the conditions of Table 4-8 for the implementation dates for PO1 can also be met in PO2.

[70] PMP, 2021. Minutes of workshop towards a regulation on brake wear emissions.

Table 4-13: Normal driving conditions for lorries & buses in Policy Option 2

Parameter	Scenario 1	Scenarios 2 & 3	
Ambient temperature [°C]	-7°C to 35°C		
Auxiliaries	No limitation		
Min trip duration | Trip characteristics	3× WHTC work and budget limits for shorter trips | Any trip		
Engine loading	All		
Max. altitude [m]	1600		
Payload (%)	10 - 100	0 -100	
	Scenario 1	**Scenario 2**	**Scenario 3**
Age of Vehicle [×10^3 km] per TPMLM class	5 - 300 for <16t 10 - 700 for ≥ 16t	3 - 300 for <16t 6 - 700 for ≥ 16t	3 - 450 for <16t 6 - 1050 for ≥ 16t
Useful life [×10^3 km] per TPMLM class	300 for <16t 700 for ≥ 16t		450 for <16t 1050 for ≥ 16t

Table 4-14: Proposed scenarios for brake wear control

Scenario	Passenger cars, Vans < 2.5t TPMLM (N1 classes I-II)* (mg/km)
Scenario B1	7
Scenario B2	5

*Class N1-III vehicles may eventually require a different limit value, depending on the test load applied

4.3.4. Policy Option 3: Advanced measures and lifetime compliance of cars, vans, lorries and buses in addition to Policy Option 2

Policy Option 3 introduces the concept of a continuous monitoring of vehicle emission performance by means of on-board emission monitoring (OBM) sensors. In addition to the provisions of PO2, this policy option introduces the following emission control related components:

1. Introduction of OBM as a mandatory component of vehicle emissions compliance requirements.
2. Monitoring emissions compliance throughout the useful life with OBM.
3. Introduction of OBD for leak detection of evaporation losses.

4. Introduction of limp mode for over-emitters based on relevant enhanced OBD information.
5. Geofencing capability to allow zero emission mode for PHEV (although this is not assessed in the current study).
6. Targeted periodic technical inspections, in-service compliance tests and market surveillance campaigns based on enhanced OBD information.

PO3 is expected to be based on existing sensors that are already commercially available as new exhaust sensor development is not expected to be commercially viable with the phase out of ICEs by 2035. presents the technical specifications of OBM implementation.

In PO3, we have assumed the same emission limits with PO2.Sc1/2. The decreased emission limits of PO2.Sc3 have not been introduced because it is uncertain whether the very low levels of PO2.Sc3, in particular for NO_x, can be reliably measured using on-board sensors throughout the lifetime of the vehicle.

Operating conditions over which OBM functionalities need to be applicable are again specified according to those of PO2 (Table 4-11 and Table 4-13). The more relaxed boundary conditions have been used in PO3.Sc1 and the more demanding ones in PO3.Sc2. Similarly, the more relaxed evaporation control requirements of *Table 4-12* are assumed for PO3.Sc1 and the more demanding ones for PO3.Sc2. Finally, any of the brake wear control scenarios of

Table 4-14 can be introduced in PO3 as well. PO3 is based on existing exhaust sensors and the communication infrastructure considered for OBFCM. Therefore, it can be implemented within the time frame of PO1 and PO2, as specified in Table 4-8.

Table 4-15: Technical specifications of OBM for scenarios considered in Policy Option 3

Parameter	Specifications
Scenario Characteristics	Introduction of OBM functionalities infrastructure in the short-term using the OBFCM communication and using exhaust sensors which are available today
Communications platform	Based on OBFCM protocol, intermittent signal transmission
Pollutants OBM	**NO_x and NH_3**: Monitoring of emission performance and identification of malfunctions in combination with OBD. **PM**: Only health condition of DPF (no actual PM measurement)
Functionalities	1. Limits exceedance reporting via MIL/enhanced OBD 2. Enhanced malfunction detection over OBD 3. Information for ISC/MaS candidate testing 4. Feedback to adjust emission control system performance (real-time calibration) 5. Geofencing for PHEV 6. Enabling limp model for emissions exceedance 7. Tampering detection
Emission compliance demonstration	Demonstrate compliance over normal operation conditions for the pollutants measured

5. Assessment of Policy Options

This section presents an assessment of the different policy options (POs) in terms of their environmental, economic and social impacts, and presents the results of the cost-benefit analysis conducted. Details on the input information that went into the modelling of technology assessment, emissions and costs for each policy option are given in the *Simplification report* and in the *Combined report*. A summary of the information in a consistent manner is provided in

Annexes

Annex I: Analytical methods used part of the current report. We have followed the following steps in estimating the impacts of each PO:

1. Each of the policy options presented in Chapter 0 was translated into a set of requirements regarding vehicle technology, R&D, calibration, and type-approval costs. The details of the method used and the corresponding input data are presented in section 9.5.
2. The technology requirements also led to an estimation of the emission levels of such future vehicles under different operating conditions. The derivation of emission factors was conducted applying a detailed simulation approach on the technological potential, presented in the *Combined report*. A summary of the emission factors used is presented in section 9.4.
3. The Euro 7 compliant vehicles per vehicle category are introduced in the fleet replacing Euro 6/VI ones in the baseline with the introduction date being defined in each of the POs. The fleet, activity, and emission evolution in each PO are then modelled using the SIBYL/COPERT models, as described in section 9.2.
4. The difference in emissions over the baseline is then quantified and the health benefit this emissions difference leads to is calculated in monetised terms, as described in section 9.6. This produces the cost/benefit and the cost-effectiveness ratios for each PO.
5. Finally, the different social and economic impacts of each policy option are assessed by means of a number of criteria, using results from the open literature and viewpoints submitted during the stakeholder consultations, as described in section 9.7.

The following sections in this chapter present the results of this analysis for each of the PO. First, we present environmental impacts in terms of emission reductions over the baseline. This is considered as the most probable fleet evolution, assuming that renewed CO_2 targets will be announced for vehicles later in 2021. Then each scenario within each PO, is separately discussed in terms of its environmental impacts, economic impacts and cost-benefit. Finally. social impacts are generally discussed per policy option ad are only distinguished per scenario when this is required.

5.1. Policy Option 1

5.1.1. Environmental impacts

Figure 5-1 and Figure 5-2 show the NO_x evolution and Figure 5-3 and Figure 5-4 show the $PM_{2.5}$ evolution in PO1.Sc1 over the baseline with two sets of Euro 6/VI emission factors. Table 5-1 summarizes this information in a tabular form with percentage values corresponding to relative reductions in the period between the introduction date of Euro 7 and 2050. In general, environmental impacts are limited for PO1.Sc1, especially if future development for Euro 6/VI emissions follow the normal development. This is because PO1.Sc1 does not lead to more strict control of emissions for PI cars & vans over Euro 6d and for lorries & trucks over Euro VI E, with the exception of the emissions cap on operation beyond normal RDE.

For CI cars & vans, decreasing the NO_x emission limit to the level of PI vehicles (60 mg/km) may have some benefit only if the conservative emission factors are assumed. This is because current Euro 6d CI cars & vans have been seen to already comply with the Euro 6d PI limits (for details see Combined report and this report section 9.4.2).

Experimental information presented in the *Combined report* suggests that, especially, NO_x emissions from CI vehicles over operation conditions that exceed the current RDE boundaries in terms of max speed, speed variation or elevation gain can result to levels which are several times higher than what observed in RDE conditions. As a result, controlling emissions under such events has a beneficial overall effect on total emissions from road transport, despite such operation conditions are not assumed to appear in more than 19% of total mileage. Hence, environmental benefits are seen for introducing a cap in beyond normal RDE conditions.

Benefits are also observed for NH_3 emissions from PI cars and, secondarily, vans. This is because PI engines may be shifted to rich fuel operation outside of RDE conditions both to optimise performance and drivability but also to protect emission control components against very high exhaust temperatures. Such fuel-rich conditions are known to produce high CO emissions in the engine and high NH_3 concentrations in the three-way catalyst[71]. Benefits in this case appear both over the normal and the conservative evolution of Euro 6/VI emission factors. Our experimental evidence (Section 9.4.2) shows that CO emissions do increase in conditions beyond RDE but not to an extent that PI vehicles are shown to consistently exceed the 4× Euro 6d emission limit considered as a relaxed limit beyond RDE in this scenario.

Introducing PO1.Sc1 is expected to introduce additional benefits over a potential conservative development of emissions from Euro 6/VI for additional reasons:

- By introducing a lower NO_x limit for CI cars & vans. Although current Euro 6d CI cars & vans already seem to comply with the PI limit, it is not certain that this will also hold in the future when lower CO_2 targets pose a more demanding challenge on the NO_x/CO_2 trade-off. Decreasing the limit protects against an undesirable increase in the average Euro 6 emission levels despite these continue to comply with the limits.
- By introducing enhanced OBD, thus enabling more effective ISC and MaS frameworks over the useful life of the vehicles. This requires retaining a low enough engineering target for the emission levels of vehicles because these may be checked for compliance over their complete useful life.
- On top of enhanced OBD, by simplifying the type-approval procedure, one may make more resources available for increasing the frequency of ISC and MaS testing. This is important to make sure that the on-road performance remains within expected ranges. Increasing the frequency of on-road testing is expected to retain emission factors at their 'normal' levels and avoid a conservative development. This is because we have assumed that OEMs will retain the current engineering margin over the limit to avoid cases where normal degradation leads to emission levels too close to the emission limit during ISC testing with a risk of being proven incompliant. This is particularly significant for lorries and trucks where initial type-approval is only done for a single vehicle of a potentially large family. Increasing the amount of ISC and MaS testing may therefore revert such an undesirable development.

Finally, emission benefits for lorries and buses only appear for NO_x due to their better control through enhanced ISC and MaS testing. No other benefits are shown for remaining pollutants, as no new emission-related requirements have been introduced with this scenario.

[71] Heeb et al. 2005. Three-way catalyst-induced formation of NH3—velocity- and acceleration-dependent emission factors

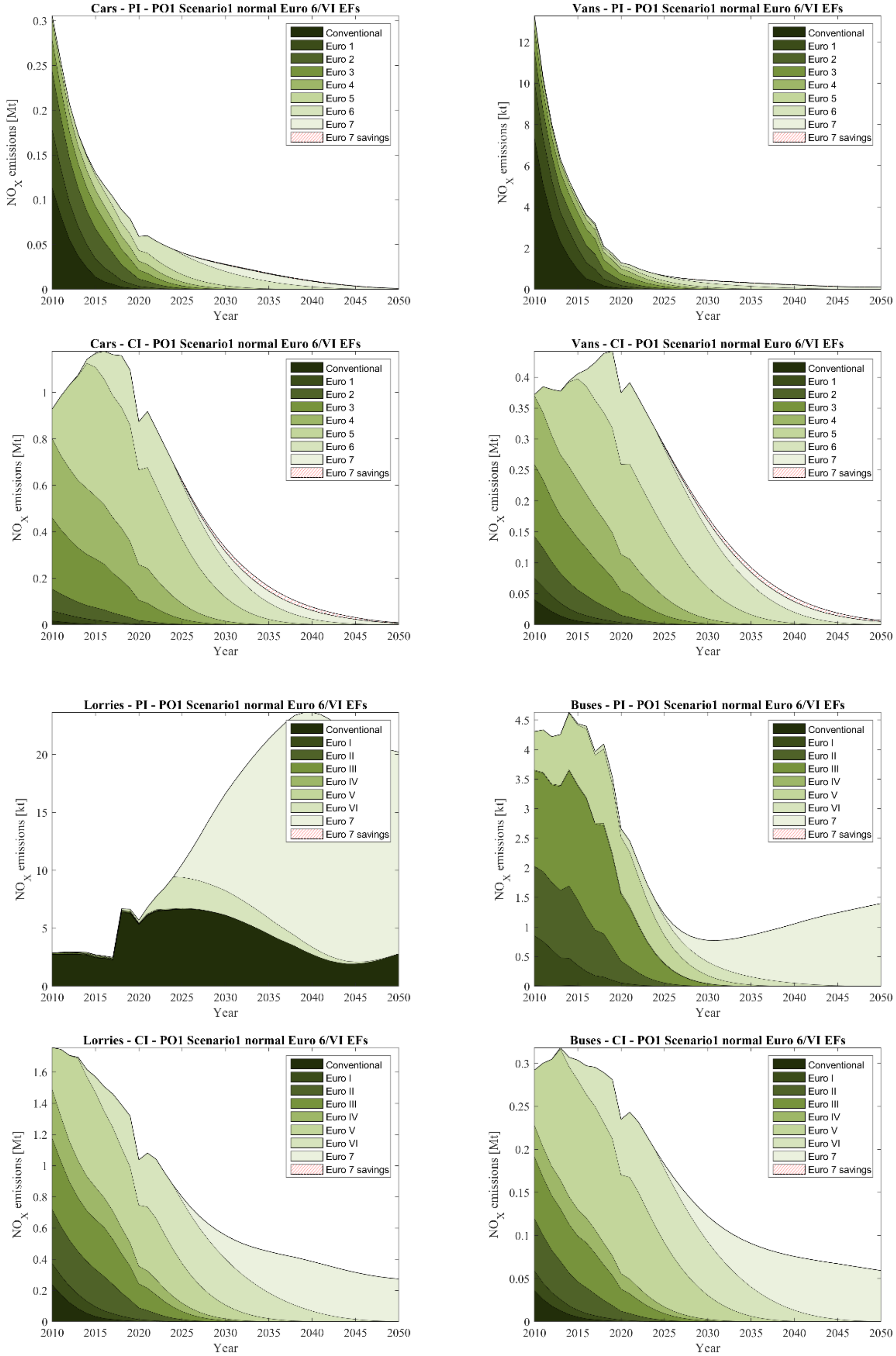

Figure 5-1: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO1.Sc1 over the baseline and normal evolution of Euro 6/VI emission factors.

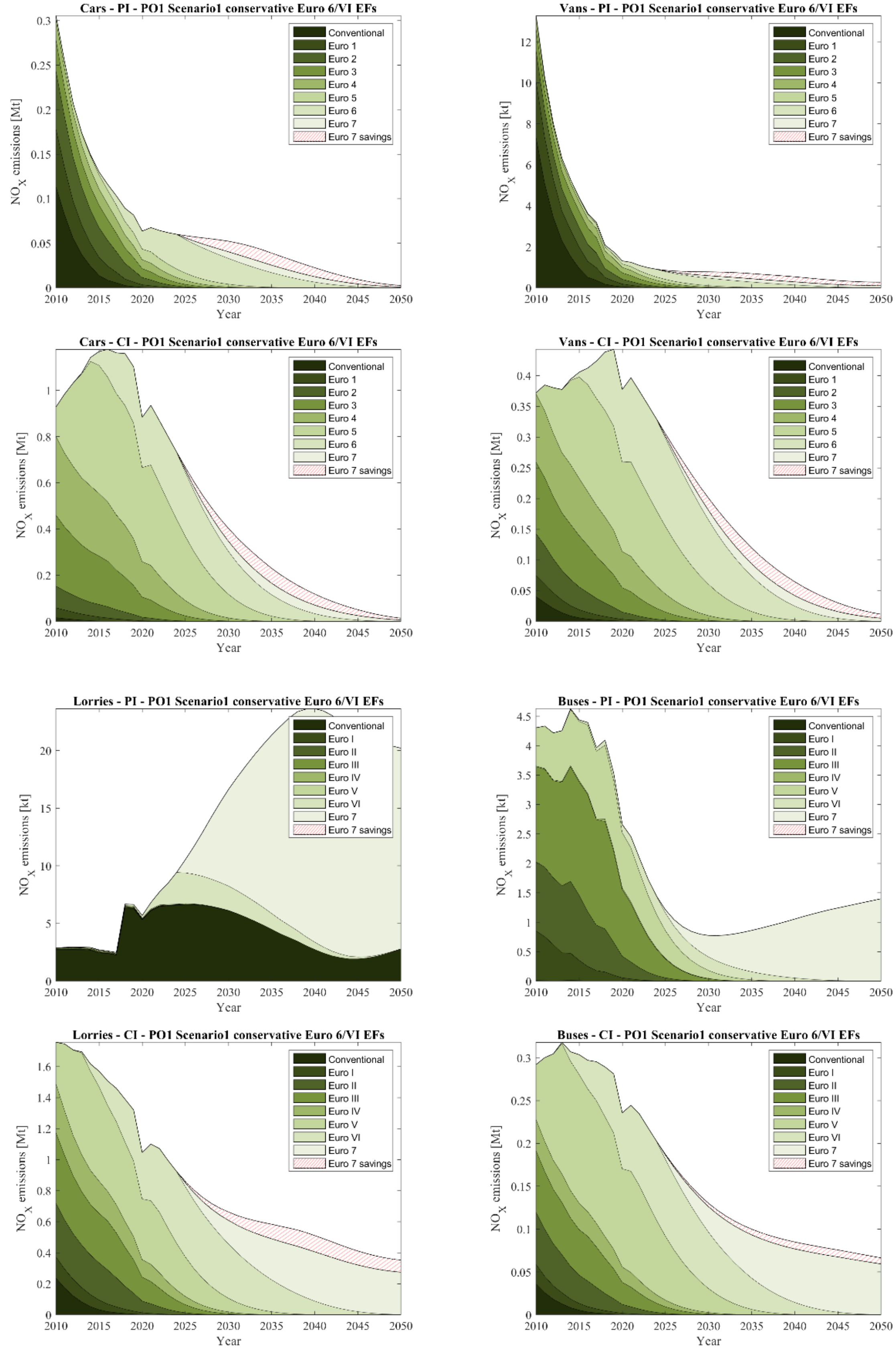

Figure 5-2: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO1.Sc1 over the baseline and conservative evolution of Euro 6/VI emission factors.

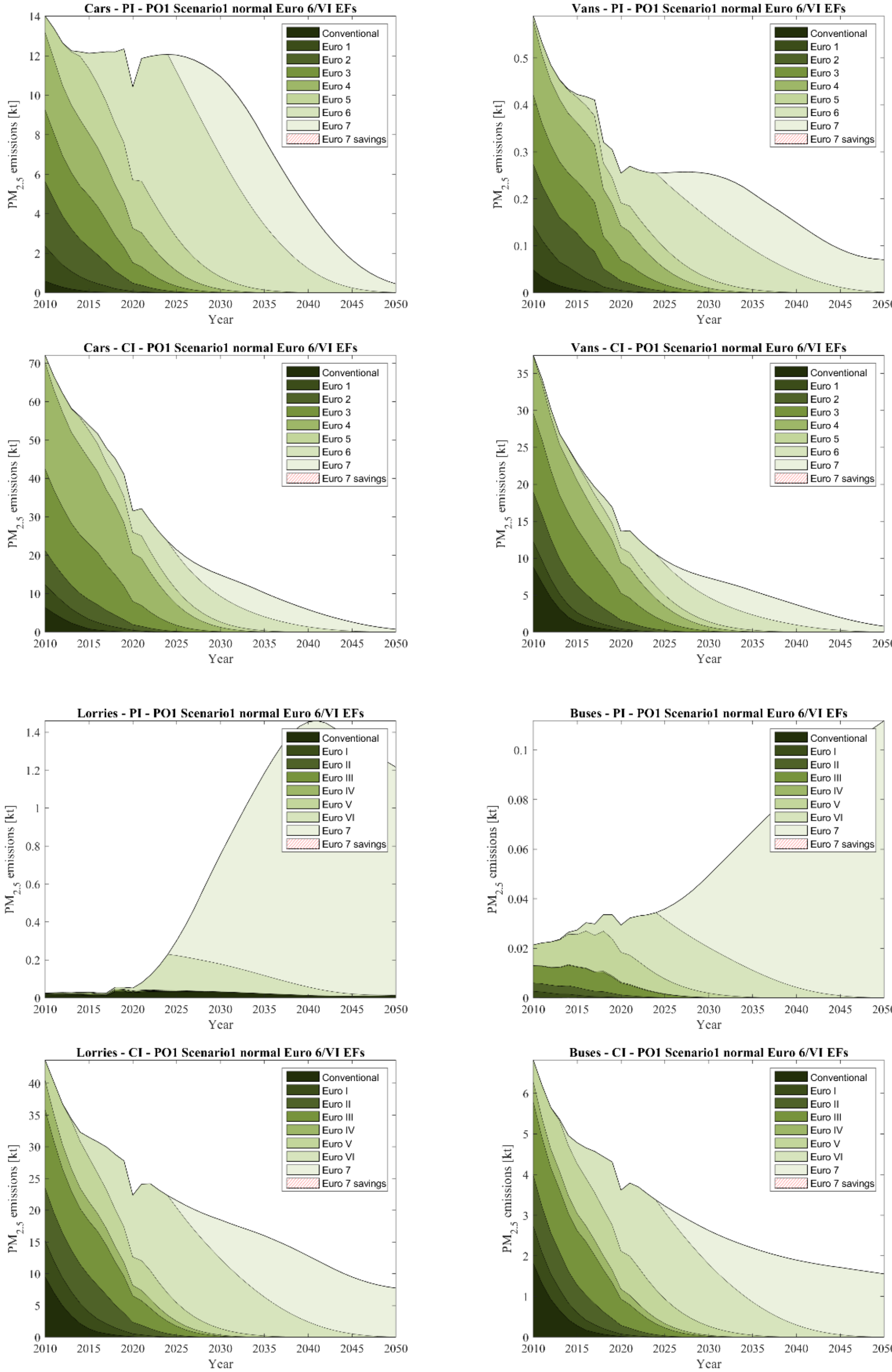

Figure 5-3: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO1.Sc1 over the baseline and normal evolution of Euro 6/VI emission factors.

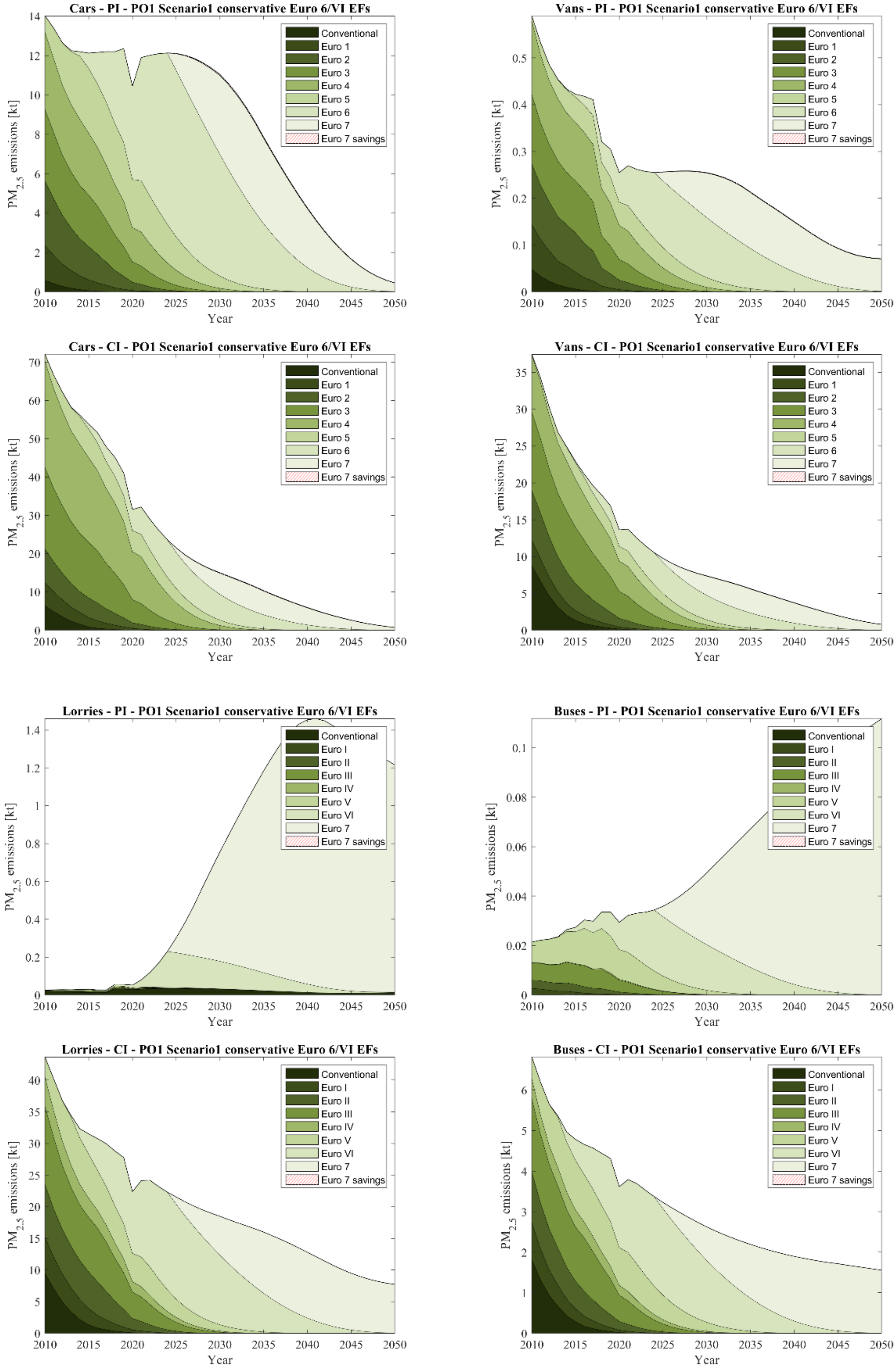

Figure 5-4: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO1.Sc1 over the baseline and conservative evolution of Euro 6/VI emission factors.

Table 5-1: Summary of emission reductions (kT/# and in % 2025-2050) in PO1.Sc1 for main pollutants and vehicle categories over the baseline and normal evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries - CI	Lorries - PI
CO	kt	20	386	9	10	0	0	0	0
	%	1.5	3.2	1.4	4.2	0.0	0.0	0.0	0.0
NO_x	kt	318	10	137	0	0	0	0	0
	%	6.68	2.4	5.50	2.9	0.0	0.0	0.0	0.0
VOC - TOTAL	kt	4.0	3.6	1.4	0.1	0	0	0	0
	%	1.1	0.1	1.0	0.2	0.0	0.0	0.0	0.0
VOC-EXH	kt	4.0	3.6	1.4	0.1	0.0	0.0	0.0	0.0
	%	1.1	0.6	1.0	0.7	0.0	0.0	0.0	0.0
$PM_{2.5}$-TOTAL	kt	0.3	0.1	0.1	0.003	0.0	0.0	0.0	0.0
	%	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
$PM_{2.5}$-EXH	kt	0.3	0.1	0.1	0.003	0.0	0.0	0.0	0.0
	%	0.8	1.6	0.6	1.8	0.0	0.0	0.0	0.0
PM_{10}-TOTAL	kt	0.3	0.1	0.1	0.003	0	0	0	0
	%	0.06	0.05	0.04	0.03	0.0	0.0	0.0	0.0
PM_{10}-EXH	kt	0.3	0.1	0.1	0.003	0	0	0	0
	%	0.8	1.6	0.6	1.8	0.0	0.0	0.0	0.0
SPN_{10}	#	9.8E+19	3.7E+20	3.3E+19	7.8E+18	0	0	0	0
	%	0.2	1.6	0.2	1.8	0.0	0.0	0.0	0.0
CH_4+N_2O	kt	881	49	369	1	0	0	0	0
	%	1.2	0.8	1.2	0.8	0.0	0.0	0.0	0.0
NMVOC	kt	0.5	2.8	0.2	0.1	0	0	0	0
	%	0.9	0.1	0.7	0.1	0.0	0.0	0.0	0.0
NH_3	kt	0.1	19.6	0.03	0.55	0	0	0	0
	%	0.3	6.67	0.3	9.09	0.0	0.0	0.0	0.0
CH_4	kt	3.5	0.8	1.2	0.01	0	0	0	0
	%	1.1	0.6	1.1	0.7	0.0	0.0	0.0	0.0
N_2O	kt	2.8	0.1	1.2	0.003	0	0	0	0
	%	1.2	0.9	1.2	1.0	0.0	0.0	0.0	0.0
VOC-EVAP	kt	0	0	0	0	0	0	0	0
	%	-	0.0	-	0.0	-	0.0	-	0.0

The health benefits arising from the reduction of pollutants are later analysed, when social impacts are described in section 0. However, there are two potential sources of environmental benefits that are not directly associated with health benefits:

- Reduction of emissions of CH_4 and N_2O;
- Any fuel savings due to the better control of evaporation emissions.

In PO1, there have been no additional provisions over Euro 6/VI neither in terms of GHG nor in terms of evaporation control. Hence, Table 5-3 for cars & vans and in Table 5-4 for lorries and buses show zero emission monetised benefits. We have retained these tables in this section for completeness, as reductions indeed appear in the following policy options and we want to demonstrate zero benefits in this PO for the avoidance of doubt.

Table 5-2: Summary of emission reductions (kT/# and in % 2025-2050) in PO1.Sc1 for main pollutants and vehicle categories over the baseline and conservative evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries - CI	Lorries - PI
CO	kt	113	386	48.3	10	0	0	0	0
	%	7.53	3.2	7.05	4.2	0.0	0.0	0.0	0.0
NOx	kt	1,051	220	452	5.07	159	0	1,990	0
	%	17.7	27.5	15.2	33.6	5.91	0.0	13.9	0.0
VOC - TOTAL	kt	4	4	1	0.1	0	0	0	0
	%	1.1	0.1	1.0	0.2	0.0	0.0	0.0	0.0
VOC-EXH	kt	4	4	1	0.1	0	0	0	0
	%	1.1	0.6	1.0	0.7	0.0	0.0	0.0	0.0
$PM_{2.5}$-TOTAL	kt	1.67	0.90	0.565	0.019	0	0	0	0
	%	0.716	0.552	0.455	0.416	0.0	0.0	0.0	0.0
$PM_{2.5}$-EXH	kt	1.67	0.90	0.565	0.019	0	0	0	0
	%	4.45	8.74	3.53	10.0	0.0	0.0	0.0	0.0
PM_{10}-TOTAL	kt	1.67	0.90	0.565	0.019	0	0	0	0
	%	0.403	0.296	0.249	0.218	0.0	0.0	0.0	0.0
PM_{10}-EXH	kt	1.67	0.90	0.565	0.019	0	0	0	0
	%	4.45	8.74	3.53	10.0	0.0	0.0	0.0	0.0
SPN_{10}	#	6.1E+20	3.8E+21	2.1E+20	8.1E+19	0	0	0	0
	%	1.46	12.7	1.35	14.8	0.0	0.0	0.0	0.0
CH_4+N_2O	kt	1980	49	902	1	0	0	0	0
	%	1.3	0.8	1.4	0.8	0.0	0.0	0.0	0.0
NMVOC	kt	0.5	3	0.2	0.1	0	0	0	0
	%	0.9	0.1	0.7	0.1	0.0	0.0	0.0	0.0
NH_3	kt	0.1	78	0.03	2.24	0	0	0	0
	%	0.3	19.2	0.3	25.5	0.0	0.0	0.0	0.0
CH_4	kt	3	1	1	0	0	0	0	0
	%	1.1	0.6	1.1	0.7	0.0	0.0	0.0	0.0
N_2O	kt	7	0.1	3	0	0	0	0	0
	%	1.3	0.9	1.4	1.0	0.0	0.0	0.0	0.0
VOC-EVAP	kt	0	0	0	0	0	0	0	0
	%	-	0.0	-	0.0	-	0.0	-	0.0

Table 5-3: Environmental impacts from cars & vans in monetised terms for PO1.Sc1.

Environmental impacts in monetised terms for PO1 for LDVs (billion EUR)			
Scenario	**Euro 6/VI EF**	**CH_4+N_2O**	**Fuel savings EVAP**
PO1.Sc1	Normal	0.20	0.00
	Conservative	0.46	0.00

Table 5-4: Environmental impacts from lorries & buses in monetised terms for PO1.Sc1.

Environmental impacts in monetised terms for PO1 for HDVs (billion EUR)			
Scenario	**Euro 6/VI EF**	**CH_4+N_2O**	**Fuel savings EVAP**
PO1.Sc1	Normal	0.00	0.00
	Conservative	0.00	0.00

5.1.2. Economic impacts

Regulatory costs

The regulatory simplification provisions introduced in PO1.Sc1 intend to reduce complexity, remove inconsistencies and improve the efficiency of the legislation. Hence, it is expected to result to a decrease in compliance costs and administrative burden, due to the streamlining/simplification of testing procedures for the automotive industry. Details on the cost elements introduced in PO1.Sc1 are given in Annex I, section 9.5. In short, due to the streamlining of regulations between cars & vans and lorries & buses, clarification of the compliance dates, better alignment of the CoP, ISC and MaS frameworks, and simplification of the testing requirements, we expect a reduction both on the number of type approvals granted, as well as to the costs per type approval (details provided in section 9.5.6). This leads to an overall reduction of regulatory costs over current Euro 6/VI.

In terms of technology for operation within normal RDE boundaries, we assume that in PO1.Sc1 no new hardware is required. With regard to PI vehicles, no new requirements over what is applicable today at Euro 6/VI are proposed for normal driving operation so today's Euro 6d vehicles would already be compliant with Euro 7 within the normal RDE boundaries. Our assessment is that this assumption also includes GPF operation, despite decreasing the particle size threshold to 10 nm from 23 nm in this policy option. In case that some adjustments will be needed for some vehicle types to achieve the limit over the new threshold, we expect these to be covered by normal technology evolution at the time new models will have to be introduced to the market. This requirement is hence assumed to lead to no appreciable additional cost per vehicle. Only R&D costs are foreseen (section 9.5.4) to better design the PM emission control system to guarantee compliance even with the lower PN threshold both for cars & vans and lorries & buses.

In terms of CI LDVs, we have already identified that today's Euro 6d vehicles would be compliant with a 60 mg NO_x/km limit over RDE. The current emission level of CI Euro 6d passenger cars at 160 000 km over RDE is considered to be at 49 mg NO_x/km, as derived from the experimental data and the necessary processing (section 9.4.2), which is below the 60 mg NO_x/km Euro 6 PI limit, already with a safe margin. Also in this case, no additional hardware costs would be considered necessary for operation within normal driving conditions, except of additional R&D costs to better setup the whole deNO_x emission control system.

However, the emissions control by a cap for beyond normal driving conditions will have technology repercussions. In order to be able to control emissions over these extended operation conditions, new hardware will be required, including a larger TWC and an improved GPF (Table 5-5) for PI while it is assumed that 50% of the CI cars & vans will need larger components for exhaust emission control (Table 5-6). In addition, new R&D and calibration effort compared to Euro 6d will be needed. These two tables show incremental sizes and costs over Euro 6d. For CI cars and vans, costs are further split depending on whether MHEV or PHEV vehicles are considered. These incremental costs are applied to 50% of the net registrations since the remaining 50% is expected to comply with the requirements of PO1.Sc1 already at Euro 6d. Finally, all values in these tables correspond to the 'average' vehicle and are further distinguished in our modelling depending on the size of the vehicle.

For lorries and buses, no new hardware has been considered. In terms of limits and approach, nothing is changed over Euro VI. In reality, the only cost elements in this case are rather minor R&D which will be required to introduce enhanced OBD functionality on the vehicles. But this entails no additional hardware costs.

Table 5-5: Hardware cost breakdown for the average PI car/van (not discounted values expressed in €$_{2021}$) in PO1.Sc1 (incremental over Euro 6d).

Technology (car/van)	PO1.Sc1 (cars / vans)				
	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	EU6d → EU7	€/l	€
TWC	1.8 / 1.6	2.7 / 2.4	0.9 / 0.8	80.0	72.2 / 63.7
	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	EU6d → EU7	€/unit	€
Optimised coated GPF (no size increase)	0	1	1	15.0	15.0

Note: PI vans are on average smaller than PI cars and hence entail lower hardware costs

Table 5-6: Hardware cost breakdown for the average CI car/van (not discounted values expressed in €$_{2021}$) in PO1.Sc1 (incremental over Euro 6d). These values have been applied to 50% of new registrations while the rest is assumed to already comply with the emission requirements of PO1.Sc1.

Technology (car/van)	PO1. Sc1 (cars / vans)				
	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	EU6d → EU7	€/l	€
DOC	1.5 / 1.8	2.2 / 2.7	0.7 / 0.9	42	30.9 / 38.1
SCR	3.7 / 4.5	5.5 / 6.8	1.8 / 2.3	30	55.2 / 68.0
SCRF	2.8 / 3.4	4.1 / 5.1	1.4 / 1.7	55	75.9 / 93.6
ASC (NH_3 slip catalyst)	0.9 / 1.1	1.4 / 1.7	0.5 / 0.6	23	10.6 / 13.0

Note: CI vans are on average larger than PI cars and hence entail higher hardware costs

Table 5-8 shows how the costs (benefits if appearing negative) develop over the complete period of Euro 7 modelling. In general for all categories, annual benefits decrease with time because the number of type approvals of ICE equipped vehicles also decreases with time, therefore any benefits from regulatory simplification subside. Moreover, R&D costs occur at the beginning and are amortised over a period of a model year (5 years) so total regulatory costs decrease significantly beyond this time frame since first introduction. Costs are most important for cars due to their larger sales/production volume and are followed by CI lorries for which R&D costs are also significant, even of their production volumes are relatively smaller.

In general, net costs to the industry take place, initially because of R&D costs for all vehicle categories. Gradually, for several vehicle categories, costs become negative because there are limited hardware costs and benefits appear mostly because of a decrease of type approvals and the mean cost per type approval.

Table 5-9 presents the same regulatory costs in 5-year intervals over the period of implementation of Euro 7 for the different vehicle categories considered.

Costs for light duty vehicles are very low in the post 2035 time-frame due to the phase-out of ICEs. However, a very small number of PHEV is projected to remain in the heavier van categories. This causes some very low but non-zero costs in this category in the future.

Table 5-7 presents the split of the regulatory costs in PO1.Sc1. As explained, additional hardware is required to cap the emissions outside of the RDE operation range as previously discussed and this creates a net cost per vehicle and a net cost to the industry, despite the simplification of the type- approval procedure. Some clarifications are required for the values obtained:

- Hardware costs are introduced for both PI and CI cars and vans to control emissions in the are beyond the current RDE.
- Further to additional hardware cost, higher R&D investment is also required for all vehicle types, although this is significantly higher for cars & vans. For lorries & buses, R&D costs are mostly required for attaining the PN limits even when decreasing the threshold to 10 nm.
- R&D and implementation costs per vehicle appear much higher for HDVs due to the much smaller production volumes of such vehicles compared to cars & vans.
- In general, benefits per PI heavy duty engine family appear much larger than CI. This is because we have assumed much less families required for PI compared to CI, due to the simpler emission control system. As a result of the much less type-approvals required, benefits for PI lorries and buses are higher on a per vehicle level than CI ones.

Table 5-8 shows how the costs (benefits if appearing negative) develop over the complete period of Euro 7 modelling. In general for all categories, annual benefits decrease with time because the number of type approvals of ICE equipped vehicles also decreases with time, therefore any benefits from regulatory simplification subside. Moreover, R&D costs occur at the beginning and are amortised over a period of a model year (5 years) so total regulatory costs decrease significantly beyond this time frame since first introduction. Costs are most important for cars due to their larger sales/production volume and are followed by CI lorries for which R&D costs are also significant, even of their production volumes are relatively smaller.

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Table 5-9 presents the same regulatory costs in 5-year intervals over the period of implementation of Euro 7 for the different vehicle categories considered.

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Table 5-7: Regulatory costs (discounted – NPV2025) for PO1.Sc1 (increments over baseline – negative means overall benefit)

Euro 7 regulatory costs compared to Euro 6/VI						
	LDVs PI	LDVs CI	LDVs Total	HDVs PI	HDVs CI	HDVs Total
Equipment costs						
1) Hardware costs						
Additional cost per vehicle (€)	33.26	104.10	71.09	0.00	0.00	0.00
Total additional cost (billion €)	1.31	4.70	6.01	0.00	0.00	0.00
2) R&D and related calibration costs including facilities and tooling costs						
Additional cost per vehicle (€)	27.55	32.17	30.02	102.86	102.86	102.86
Total additional cost (billion €)	1.08	1.45	2.54	0.13	0.52	0.65
Implementation costs						
1) Testing costs						
Additional cost per model / engine family (thousand €)	-2,345	-9,386	-3,871	-7,439	-3,121	-3,897
Additional cost per vehicle (€)	-22.31	-21.55	-21.90	-70.83	-32.90	-40.30
Total additional cost (million €)	-878.49	-972.25	-1,851	-87.34	-167.34	-254.68
2) Witnessing costs						
Additional cost per model / engine family (thousand €)	-156.66	-626.90	-258.54	-263.47	-110.54	-138.01
Additional cost per vehicle (€)	-1.49	-1.44	-1.46	-2.51	-1.17	-1.43
Total additional cost (million €)	-58.68	-64.94	-123.62	-3.09	-5.93	-9.02
3) Type approval fees						
Additional cost per type-approval (thousand €)	-1.83	-2.37	-2.08	-0.52	-0.51	-0.51
Additional cost per vehicle (€)	-0.34	-0.33	-0.33	-0.52	-0.24	-0.30
Total additional cost (million €)	-13.32	-14.74	-28.05	-0.64	-1.23	-1.87
4) Administrative costs related to the implementation process						
Additional cost per type-approval (thousand €)	-97.40	-126.32	-110.72	-31.08	-30.35	-30.59
Additional cost per vehicle (€)	-18.03	-17.42	-17.71	-31.12	-14.46	-17.71
Total additional cost (million €)	-710.18	-785.98	-1,496	-38.38	-73.53	-111.91
Total additional regulatory costs						
Total additional regulatory cost per vehicle until 2050 (€)	18.64	95.53	59.70	-2.12	54.09	43.12
Total additional regulatory cost until 2050 (billion €)	0.73	4.31	5.04	0.00	0.28	0.27

Table 5-8: Total annual regulatory costs (discounted – NPV2025) for PO1.Sc1 (increments over baseline – negative values express total benefits)

Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	638.92	978.12	7.73	377.43	67.46	283.26	3.94	29.86	2,002.20	384.52
2026	201.62	501.35	2.41	238.10	17.54	92.07	1.01	8.46	943.48	119.08
2027	44.26	323.69	0.56	180.05	-1.33	23.66	-0.02	0.86	548.57	23.17
2028	-11.92	254.60	-0.10	151.78	-2.60	-0.44	-0.41	-1.53	394.36	-4.98
2029	-31.78	225.00	-0.32	134.64	-4.67	-8.46	-0.53	-2.40	327.55	-16.05
2030	-38.56	209.80	-0.37	121.93	-5.40	-10.90	-0.55	-2.40	292.80	-19.26
2031	-31.55	160.01	-0.34	93.76	-5.60	-11.31	-0.55	-2.40	221.88	-19.85
2032	-23.08	115.59	-0.29	67.83	-5.46	-10.73	-0.53	-2.34	160.05	-19.06
2033	-15.42	73.78	-0.28	43.53	-5.46	-10.42	-0.52	-2.29	101.61	-18.69
2034	-7.37	35.59	-0.04	21.00	-5.14	-9.41	-0.50	-2.18	49.18	-17.22
2035	0.00	0.01	0.00	0.00	-4.93	-8.35	-0.68	-1.89	0.01	-15.85
2036	0.00	0.01	0.00	0.04	-4.64	-7.46	-0.66	-1.82	0.04	-14.57
2037	0.00	0.01	0.00	0.07	-4.45	-6.63	-0.63	-1.73	0.07	-13.43
2038	0.00	0.00	0.00	0.10	-4.18	-5.85	-0.61	-1.66	0.10	-12.29
2039	0.00	0.00	0.00	0.13	-3.72	-5.22	-0.58	-1.42	0.13	-10.94
2040	0.00	0.00	0.00	0.15	-3.19	-4.55	-0.58	-1.37	0.15	-9.68
2041	0.00	0.00	0.00	0.20	-2.78	-4.00	-0.56	-1.30	0.20	-8.63
2042	0.00	0.00	0.00	0.24	-2.33	-3.49	-0.54	-1.25	0.24	-7.60
2043	0.00	0.00	0.00	0.28	-1.97	-3.01	-0.52	-1.20	0.28	-6.69
2044	0.00	0.00	0.00	0.32	-1.90	-2.89	-0.50	-0.99	0.32	-6.28
2045	0.00	0.00	0.00	0.27	-1.90	-2.78	-0.48	-0.95	0.27	-6.11
2046	0.00	0.00	0.00	0.27	-1.83	-2.67	-0.46	-0.92	0.27	-5.88
2047	0.00	0.00	0.00	0.28	-1.83	-2.57	-0.44	-0.88	0.28	-5.72
2048	0.00	0.00	0.00	0.28	-1.76	-2.41	-0.42	-0.71	0.28	-5.30
2049	0.00	0.00	0.00	0.29	-1.76	-2.31	-0.41	-0.68	0.29	-5.16
2050	0.00	0.00	0.00	0.29	-1.69	-2.22	-0.39	-0.66	0.29	-4.97

Table 5-9: Cumulative regulatory costs in 5-year periods (discounted – NPV2025) for PO1.Sc1 (increments over baseline – negative values express total benefits)

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	638.92	978.12	7.73	377.43	67.46	283.26	3.94	29.86	2,002	384.52
2026-2030	163.62	1,514	2.17	826.51	3.54	95.93	-0.50	2.99	2,507	101.96
2031-2035	-77.42	384.98	-0.94	226.13	-26.58	-50.22	-2.78	-11.10	532.74	-90.67
2036-2040	0.00	0.02	0.00	0.48	-20.17	-29.70	-3.06	-7.99	0.50	-60.92
2041-2045	0.00	0.00	0.00	1.31	-10.88	-16.18	-2.58	-5.68	1.31	-35.32
2046-2050	0.00	0.00	0.00	1.42	-8.88	-12.18	-2.12	-3.85	1.42	-27.03

Competitiveness of the EU automotive industry

PO1.Sc1 introduces a somewhat narrow revision of emissions control over Euro 6/VI. For PI cars & vans and all lorries and buses there are practically no changes in emission limits considered over Euro 6/VI. An NH_3 limit is introduced for PI cars but at a level that does not assume any significant investment in new technology from the automotive industry. This limit mostly introduces a check for excess (uncontrolled) NH_3 emissions. Only for CI cars and vans there is a marginal reduction of NO_x emission limit but, again, this has been seen to be already respected by latest vehicle technologies in the market today. PO1.Sc1 also addresses operation outside of the current RDE operation conditions to a certain extent and additional hardware will be required, as presented in

Table 5-8 shows how the costs (benefits if appearing negative) develop over the complete period of Euro 7 modelling. In general for all categories, annual benefits decrease with time because the number of type approvals of ICE equipped vehicles also decreases with time, therefore any benefits from regulatory simplification subside. Moreover, R&D costs occur at the beginning and are amortised over a period of a model year (5 years) so total regulatory costs decrease significantly beyond this time frame since first introduction. Costs are most important for cars due to their larger sales/production volume and are followed by CI lorries for which R&D costs are also significant, even of their production volumes are relatively smaller.

In general, net costs to the industry take place, initially because of R&D costs for all vehicle categories. Gradually, for several vehicle categories, costs become negative because there are limited hardware costs and benefits appear mostly because of a decrease of type approvals and the mean cost per type approval.

Table 5-9 presents the same regulatory costs in 5-year intervals over the period of implementation of Euro 7 for the different vehicle categories considered.

Costs for light duty vehicles are very low in the post 2035 time-frame due to the phase-out of ICEs. However, a very small number of PHEV is projected to remain in the heavier van categories. This causes some very low but non-zero costs in this category in the future.

Table 5-7, the incremental equipment costs (hardware and R&D) are in the range of 60-140€/vehicle for cars/vans, while for lorries/buses this remains at 103€/vehicle (only R&D). This mostly refers to larger sizes of emission control devices than what used today and no entirely new emission control concepts.

As a result of the minor incremental costs per vehicle, the impact of this policy option to the overall competitiveness of the automotive industry is considered negligible. The total investment costs are in the order of M€ 5 (

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Table 5-7) for the complete modelling period. However, in an industry that already invests ~€61 billion annually for R&D[72], the maximum additional costs correspond to 0.3% additional investment expenditure. This is rather insignificant to cause any significant competitive disadvantage in the long run.

The second criterion to assess impacts on competitiveness is the contribution of PO1 towards accessibility of the EU automotive sector to the international market. PO1.Sc1 is expected to have a limited effect of aligning the EU with policy developments on emissions standards around the world and especially the US/California and China, as it does not seem advanced enough to bring emission rates to the level of most stringent standards around the world. In that sense, this does not seem to offer any competitive advantage to the EU industry in terms of technological solutions for emissions control to access the different markets.

Emission standards lead to the development of new technology, thus indirectly contributing to improvement of competitiveness through innovation. PO1 introduces no major breakthrough in technology and no significant investment in R&D. As a result, PO1 will have a very limited effect in improving the relative global ranking of the EU automotive industry. This introduces risks with time, that the entire automotive value chain in the EU weakens its technological leadership on a global stage. That said, PO1.Sc1 partly addresses vehicle operation outside of current RDE, which will further improve the EU's position as a global leader when it comes to on-road testing and emission compliance, however, even this is not an overall significant advantage, only perhaps for some instrument and testing systems suppliers.

Table 5-10 provides a summary and a qualitative score for the three criteria contributing to the assessment of the impact of each policy option to the competitiveness oof the EU automotive industry. Although some minor impacts were identified in the previous paragraphs of this section, our overall assessment is that PO1 will overall have a negligible effect on competitiveness and we have scored all relevant criteria with 0 – no impact.

Table 5-10: Qualitative assessment of PO1 impact on competitiveness

[72] ACEA, 2021. The automobile industry pocket guide

Policy Option 1 - Competitiveness		
Key Impacts	**Scale of impact**	**Comments**
Cost savings	0	Marginal cost benefits due to simplification but not at a scale that can lead to significant competitiveness advancement, while they are counterbalanced by additional costs for new H/W and R&D.
International market access (parity with other advanced emission standards)	0	PO1 does not decrease emission limits to those applicable or forthcoming in other advanced markets around the world
Innovation capacity (R&D investment, new technologies)	0	Limited investment in new R&D, no new concepts/breakthroughs or innovative emission control techniques required

Functioning of the internal market

Based on the findings of the *Evaluation report*, Euro 6/VI standards led to a level of harmonisation which would not have been possible for separate limits at the member state level, hence positively influencing the functioning of the European internal market. However, the *Evaluation report* also reported that measures and restrictions which have been imposed locally and regionally by relevant administrations (e.g. discrete tax incentives, ULEZ, ZEZ, etc)[73] produce artificial bottlenecks for placement to the market of some vehicle technologies, primary diesel ones, that have received negative publicity because of the higher NO_x limit than their petrol counterparts[74].

Such national incentives indirectly affect the market operation and create market distortions. When major European cities ban specific vehicle technologies, the cost of introducing these specific powertrains at national level can become unbearable for local dealers due to the low volume sales. For example, in Greece, 70% of sales of passenger cars are in Athens alone and another 5% in Thessaloniki, the two largest cities in the country [75]. If a powertrain technology becomes banned in Athens due to pollution impacts, it then becomes non-profitable for the dealers to maintain its sales for the rest of the country. In Greece, no passenger cars were available to the market prior to 2010 because of such diesel bans only in Athens and Thessaloniki.

Such local measures result in the fragmentation of the EU internal market and impose unnecessary barriers to intra-EU trade activity, in contrast to the policy objective of the Euro standards of ensuring intra-EU harmonisation. If this fragmenting effect continues, it may have a negative impact on the effectiveness of the current emission limits (Euro 6/VI) and can also lead to increased costs of compliance and enforcement for stakeholders, according to the *Evaluation report*. Moreover, it may create obstacles for users of specific vehicles that may find difficulties in the maintenance of their vehicles, if specific vehicle powertrains cease to be imported and supported at a national level.

With this context in mind, introducing same numerical limits in PO1 for all vehicle types regardless of fuel use is expected to lift negative publicity from diesel vehicles alone, provided of course that diesel vehicles continue to respect applicable limits. PO1 further improves over Euro 6/VI in this respect by introducing enhanced OBD. This can be used both to early detect emission violators but also as a tool to enable more efficient ISC and

[73] Sadler Consultants Ltd, "Urban Access Regulations in Europe," Accessed in 12.2020
[74] Numerous press articles, e.g. EU relaxation of diesel emission limits was illegal, court rules. Accessed March 2021
[75] SEAA, 2021. Vehicle classifications in Greece, Accessed March 2021.

MaS implementation, thus improving the methods to demonstrate compliance. Obviously, just equalizing the limits proposed in PO1 will not correct all potential and upcoming market distortions; in particular those created by ULEZ and ZEZ that, in some cases, even aim at a complete ban of vehicles with tailpipes. Still, this is a step in a direction that may lift some market disruptions, at least in the short run.

SMEs

In general, the European automotive vehicle manufacturing mostly comprises large manufacturers active in engine development, vehicle assembly and automotive parts production. There are also several SMEs active in various areas of the supply and service chain. SMEs are much more common at the lower tiers of the automotive sector supply chain[76]. Lower-tier vendors may face challenges when it comes to access to human capital, finance, expertise and capabilities to fulfil basic cost requirements, product quality and distribution criteria. This makes it particularly challenging for SMEs in developing EU countries in lower tiers of the supply chain because they may lack proper access to the latest technology and funding. New technologies, new customer preferences and new market entrants have the potential to reduce the current importance of economies of scale and create opportunities for SMEs to increase their profitably in the future[77]. For these reasons, a special analysis is required on the potential impacts of new emission standards in the vulnerable sector of SMEs.

Table 5-11 presents an overview of the structure of the automotive manufacture, supply, sales and aftermarket sectors based on the relevant Eurostat NACE codes and processing of the relevant Eurostat information. Moreover, in the same table, we have introduced an estimate of the number of technical services for type approval notified according to article 74 of Regulation (EU) 2018/858[79] and Article 41 of Directive 2007/46/EC[80], which are not separate in Eurostat classification although these are important actors in placing vehicles on the market. Not all of these technical services shown in Table 5-11 are active in whole vehicle type-approval. Moreover, the number of SMEs in this business sector is an estimate only based on understanding of the market structure – no such data are provided by Eurostat. Several of the SMEs can just be subsidiaries or branches of larger technical services operating internationally. Based on this table, the SMEs active in the automotive sector, can be distinguished into three general groups:

- **SME Manufacturers**: SMEs directly involved in the direct manufacturing and assembly of, mostly specialised, vehicles.
- **SME R&D and Suppliers**: Active typically as component and subsystem suppliers, and in the sales, repair and aftermarket segments.
- **SME Testing**: SMEs involved in the in the realm of vehicle testing/type approval (e.g. technical services), vehicle testing equipment and sensors, etc.

It is clear that in all aspects of the vehicle manufacturing and supply chain, SMEs are present and possess a significant share of activities. However, we need to distinguish the activities of those SMEs who are potentially affected by the introduction of new emission standards. We can argue that the majority of SMEs appearing in the manufacture of motor vehicles in Table 5-11 are actually active as body builders based on existing

[76] European Commission, 2014. “Amending Regulations (EC) No 715/2007 and (EC) No 595/2009 as regards the reduction of pollutant emissions from road vehicles”, {COM(2014) 28 final}

[77] ILO, 2021. “The future of work in the automotive industry: The need to invest in people’s capabilities and decent and sustainable work”

powertrain and chassis designs produced by larger manufacturers. The many SMEs shown in Table 5-11 as OEMs are mostly vehicle body builders and not powertrain manufacturers. We base this argument on an analysis of the small volume manufacturers according to the definition of Regulation (EU) 443/2009. In total, 76 OEMs are counted in the list of small volume manufacturers (14 being ESCA members), out of which, 47 are located in the EU27. We have looked on available information for these companies and we identified 35 SMEs on vehicle assembly and manufacturing. Some of them are active only on the production of EVs so this is an absolute maximum number of SMEs potentially using internal combustion engines in their vehicles. We also looked at the lorries and trucks sector by looking at the survey stakeholders in the framework of the study on the technical support for the development of the HDV CO_2 certification[78]. We could identify no SME active in the manufacturing of powertrains in this sector. From further analysis of public records for these 35 SMEs and our knowledge of the market, our understanding is that these are mostly small companies (i.e. less than 50 people) building specialised vehicles on the basis of powertrains produced by larger manufacturers. Examples of such companies are Pagani in Italy using Mercedes engines, Praga in Czech Republic using Suzuki engines, De Tomaso in Italy using Ford engines, etc. Of course, additional calibration is required to make the vehicles fulfil emission standards with the specific powertrains and this is mostly executed by these small SMEs, often in collaboration with larger automotive R&D suppliers in the EU.

Even with regard to these 35 SMEs PO1 is not considered to significantly affect their operations. PO1 actually leads to a decrease of vehicle costs and hence provides room for more R&D investment together with margin for increase of sales due to potential decrease of vehicle prices. PO1.Sc1 introduces additional calibration needs and considers that mild hybridisation introduced for CO_2 control will suffice meeting the emission limits outside of the RDE conditions. For specialised powertrains, this may in addition need larger aftertreatment devices and more delicate calibration to balance emissions compliance with high performance beyond RDE. However, such modifications are incremental changes that can be well addressed by the engineering teams of such SMEs with the help of R&D suppliers.

For SMEs in the R&D and suppliers group, we see only a marginal positive effect in the sense that any new H/W or R&D activities should have a positive impact on them. However, this is not considered that can substantially boost their activities over current levels. Our overall assessment is that PO1 may have a moderate positive impact in the short run and a negligible impact for the operation of such SMEs in the medium to long run.

Table 5-11: Enterprises structure in the automotive manufacturing and type approval logistics chain (Sources: Eurostat, Data Codes: SBS_SC_IND_R2 and SCS_NA_SCA_R2)

[78] LAT, TU Graz, Ricardo, TNO, Second interim report on technical support for the development of the HDV CO2 certification.

Category	NACE	Description	Employees	Number of companies	No of Large Companies (>250 staff)
OEMs	29.1	Manufacture of motor vehicles	1 120 455	1 800	113
Suppliers	29.2 29.3	Manufacture of bodies, trailers and semi-trailers Manufacture of parts and accessories	159 259 1 296 480	6 247 9 060	82 799
Sales, Repair & Aftermarket	45	Wholesale and retail trade and repair of motor vehicles and motorcycles	2 823 932	818 660	850
Technical services for type approval	Included in 71.20	Technical testing and analysis (in accordance with Article 74 of Regulation (EU) 2018/858)[79] and Article 41 of Regulation 2007/46/EC[80]	n/a	215	~20

One particular SME business segment that can be negatively affected is the one comprising technical services for type-approval. Decreasing the need for testing and the number of type approvals required obviously affects the turnover of such SMEs and increases competition. More precisely, compared to the full introduction of Euro-6/VI, the recommendations for simplification included in PO1 are projected to reduce the number of type approvals by an estimated 43% for petrol cars and lorries/buses and 62% for diesel cars and vans. This is largely because simplification is based on shifting attention from demonstration tests at the TA stage to checking of the emissions compliance of the in-service vehicle during its complete (or at least for the largest part of its) lifetime. At the same time, we expect that Market Surveillance according to Regulation 2018/858 will counterbalance the revenues for these companies. Indeed, already 28 companies (March 2021) have been notified according to article 74 of Regulation 2018/858. Therefore, simplification efforts in PO1 will have a negative impact on total revenues which are expected to be balanced by increase MaS requirements in the same time frame that Euro 7 is expected to be introduced. Hence, the overall activities of SMEs are expected to be marginally affected.

Economic affordability for SME users

Regarding economic affordability of SME users, as presented in

[79] Technical Services list according to 2018/858 (Accessed Mar 2021)
[80] Technical Services list according to 2007/46/EC (Accessed Mar 2021)

Table 5-8 shows how the costs (benefits if appearing negative) develop over the complete period of Euro 7 modelling. In general for all categories, annual benefits decrease with time because the number of type approvals of ICE equipped vehicles also decreases with time, therefore any benefits from regulatory simplification subside. Moreover, R&D costs occur at the beginning and are amortised over a period of a model year (5 years) so total regulatory costs decrease significantly beyond this time frame since first introduction. Costs are most important for cars due to their larger sales/production volume and are followed by CI lorries for which R&D costs are also significant, even of their production volumes are relatively smaller.

In general, net costs to the industry take place, initially because of R&D costs for all vehicle categories. Gradually, for several vehicle categories, costs become negative because there are limited hardware costs and benefits appear mostly because of a decrease of type approvals and the mean cost per type approval.

Table 5-9 presents the same regulatory costs in 5-year intervals over the period of implementation of Euro 7 for the different vehicle categories considered.

Costs for light duty vehicles are very low in the post 2035 time-frame due to the phase-out of ICEs. However, a very small number of PHEV is projected to remain in the heavier van categories. This causes some very low but non-zero costs in this category in the future.

Table 5-7, for PO1.Sc1, the incremental equipment costs (hardware and R&D) are low and do not exceed some tens of Euros per vehicle, for any of the technologies considered. Assuming these costs are passed-on directly to vehicle prices, this range is low in terms of today's total vehicle pricing, in order to poses as a significant factor in the affordability of new vehicles by SME users. In fact, as presented in Section 0, subsection *Social inclusion and affordability*, the cost range does not surpass the 0.5% of the estimated average vehicle prices (cars and vans), which is a marginal increase.

5.1.3. Cost-benefit analysis

Table 5-12 presents the results of the cost-benefit analysis for PO1.Sc1. The values in the table are average benefits occurring per year either due to simplification of the type-approval procedure or due to environmental impacts converted into monetised terms. All values correspond to average annual benefits over the implementation period (up to 2050) expressed in NPV terms (discounted values). The compliance cost reductions contain monetary benefits originating from less testing requirements, lower witnessing costs and fees due to the lower number of type approvals as well as reduced administrative costs.

The costs for the implementation of each scenario are then presented in Table 5-13. Our approach for constructing the values in these table are the following:

- Administrations bear no costs or benefits, this has been a central assumption also in the *Evaluation study*. This is because all such costs or benefits are transferred to the OEMs through the fees.
- All implementation costs from the manufacturers are eventually transferred to the customers through an increase in the vehicle price that will eventually occur through the lifetime of each vehicle model/type.
- All costs allocated to consumers appear as recurrent annual costs calculated on the basis of the average number of vehicles sold each year. Although on a single consumer this cost may occur as one-off when purchasing the vehicle, in the body of consumers, these appear as annual costs because vehicle sales occur every year. Hence no one-off costs appear for consumers.
- One-off costs for manufacturers only include R&D investment (including new facilities) which appears once in the production cycle of vehicles under a new emission standard.
- Recurrent costs for the manufacturers include hardware, calibration and type-approval costs which are obviously recurring costs for as long as vehicles are produced in the period of the calculations.
- All values are discounted over the period of implementation (up to 2050) and all recurrent costs appear as average annual values in NPV terms – except of R&D costs that appear as one-off in this period.

Table 5-12 shows that most of the benefits in PO1.Sc1 come from the decrease of emissions, especially in case Euro 6/VI emission levels develop according to the conservative scenario. For normal development of the emission factors, annual environmental benefits in monetised terms are marginal. Other benefits come from the reduction of costs for type-approvals, as earlier explained. These are recurrent annual benefits and the table shows average values over the complete enforcement period.

Table 5-12: Overview of benefits (billion EUR / year) considered in PO1.Sc1 over the baseline. Ranges shown are for the normal or conservative evolution of Euro 6/VI emission factors.

	Overview of Benefits (total for all provisions) – PO1 Scenario1		
	Description	**Amount**	**Comments**
billion EUR / year	**Direct benefits**		
LDVs-PI	Compliance cost reductions (recurrent)	0.064	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.0149 - 0.144	Main recipient of the benefit: Citizens
LDVs-CI	Compliance cost reductions (recurrent)	0.071	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.218 - 0.716	Main recipient of the benefit: Citizens
LDVs	Compliance cost reductions (recurrent)	0.135	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.233 - 0.86	Main recipient of the benefit: Citizens
HDVs-PI (CNG)	Compliance cost reductions (recurrent)	0.005	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0 - 0	Main recipient of the benefit: Citizens
HDVs-CI	Compliance cost reductions (recurrent)	0.010	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0 - 0.813	Main recipient of the benefit: Citizens
HDVs	Compliance cost reductions (recurrent)	0.015	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0 - 0.813	Main recipient of the benefit: Citizens

Table 5-13 presents an overview of costs incurring for implementation of PO1.Sc1 and their distribution to consumers, business and administrations. All costs directly incurring to the business are eventually passed on to consumers through indirect costs, by means of an increase of vehicle prices, assuming OEM profitability does not change in the long run. As earlier said, administrations are not considered to bear any net costs because these are always paid by OEMs (business) when applying for each type-approval.

Table 5-13: Overview of Costs (billion EUR) considered in PO1.Sc1 over the baseline

Overview of Costs – PO1 Scenario1							
billion EUR		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs-PI	Direct costs	0.000	0.000	1.085	-0.013	0.000	0.000
	Indirect costs	0.000	0.028	0.000	0.000	0.000	0.000
LDVs-CI	Direct costs	0.000	0.000	1.452	0.110	0.000	0.000
	Indirect costs	0.000	0.166	0.000	0.000	0.000	0.000
Total LDVs	Direct costs	0.000	0.000	2.537	0.096	0.000	0.000
	Indirect costs	0.000	0.194	0.000	0.000	0.000	0.000
HDVs-PI (CNG)	Direct costs	0.000	0.000	0.127	-0.005	0.000	0.000
	Indirect costs	0.000	0.000	0.000	0.000	0.000	0.000
HDVs-CI	Direct costs	0.000	0.000	0.523	-0.010	0.000	0.000
	Indirect costs	0.000	0.011	0.000	0.000	0.000	0.000
Total HDVs	Direct costs	0.000	0.000	0.650	-0.015	0.000	0.000
	Indirect costs	0.000	0.010	0.000	0.000	0.000	0.000

5.1.4. Social impacts

The following sections describe the expected social benefits of PO1. These are distinguished into:

- Health benefits
- Impacts on employment
- Impacts on training systems/skills
- Impacts on social inclusion/affordability
- Impacts on consumer trust

Health benefits

Table 5-14 and

Health impacts in monetised terms for PO1 for LDVs (billion EUR)						
Scenario	Euro 6/VI EF	NOx	PMexh	PMnonexh	NH3	NMHC
PO1.Sc1	Normal	5.54	0.05	0.00	0.24	0.01
	Conservative	20.63	0.33	0.00	0.94	0.01

Table 5-15 show the health benefits provided by two different scenarios in PO1 over the two different sets of emission factors considered in our analysis. The health impacts are distinguished per pollutant. It should be clarified that the health impacts are lower than the total benefits shown in the tables of the cost-benefit analysis because the total benefits include the contribution of N_2O and CH_4 that do not directly contribute to health.

For PO1, the majority of health benefits originate from the reduction of NO_x, both from LDVs and HDVs. Some additional benefit originates from NH_3 control of PI vehicles, especially in the conservative development of emission factors. For HDVs, health benefits may be materialised only if the conservative development of Euro VI emission factors is materialised and Euro 7 managed to revert this. For normal evolution of emission factors, NO_x improvements are very low.

Table 5-14: Health impacts in monetised terms from PO1 in LDVs.

Health impacts in monetised terms for PO1 for LDVs (billion EUR)						
Scenario	**Euro 6/VI EF**	**NO_x**	**PM_{exh}**	**PM_{nonexh}**	**NH_3**	**NMHC**
PO1.Sc1	Normal	5.54	0.05	0.00	0.24	0.01
	Conservative	20.63	0.33	0.00	0.94	0.01

Table 5-15: Health impacts in monetised terms from PO1 in HDVs.

Health impacts in monetised terms for PO1 for HDVs (billion EUR)						
Scenario	**Euro 6/VI EF**	**NO_x**	**PM_{exh}**	**PM_{nonexh}**	**NH_3**	**NMHC**
PO1.Sc1	Normal	0.00	0.00	0.00	0.00	0.00
	Conservative	21.14	0.00	0.00	0.00	0.00

Employment

Impacts on employment are seen as one of the most important of social impacts that any new regulatory initiative may bring along. In general, accelerating the transition towards cleaner vehicles in terms of air pollutants, would mean an increase of activity in R&D and production of advanced technologies and components that will enable vehicles to emit low levels of air pollutants in real-world driving conditions.

In particular for PO1, no significant impacts on the employment are expected, at least ones that can be directly linked to the new Euro 7 standards. This is mainly due to the relatively low extent of new technology that PO1 requires in order to be materialised. To the extent that manufacturers make use of the simplification measures to either invest on R&D or decrease vehicle prices, either of these should in fact lead to increased employment levels. However, as earlier explained, type approval services and related businesses may be slightly negatively impacted due to more streamlined/simplified regulatory testing requirements and compliance procedures. Again, the requirements for MaS brought along with Regulation (EU) 2018/858 is estimated to increase the volume PO1 estimated to have a limited positive impact on new employment due to increased R&D activities. Table 5-16 provides an overview of expected PO1 impacts on employment.

Training systems/skills

Investment in human resources by professional growth and training is important in order to sustain a manufacturing base in Europe. Availability of professional workforce is an important factor in the growth and productivity of the automobile industry. PO1 does not require major technological breakthroughs on emission control and engine technology but it is rather based on already developed systems, hence no significant reskilling should be expected.

Table 5-17 provides an overview of expected PO1 impacts on training and skills.

Table 5-16: Qualitative assessment of PO1 impact on employment.

Policy Option 1 - Employment			
Key Factors	**Category**	**Scale of impact[81]**	**Comments**
Impact on overall employment levels	**Vehicle OEMs**	0 - 1	Despite a decrease of costs per vehicle due to a decrease of type approval effort, PO1.Sc1 is associated with a net cost to the industry but will also introduce higher manufacturing needs. Overall, these effects are of small scale so no appreciable difference is expected.
	Automotive component suppliers (i.e.Tier 1 suppliers[82])	0	As PO1 has the lowest requirements in terms of technology and advanced systems, the impact will be relatively low
	Testing equipment and R&D services (incl. SMEs)	0	Less testing equipment may be required for type approval centres but testing for the OEMs that are the large consumers of equipment will not change.
	Type approval services (e.g. TS)	-1	Simplification intends to reduce complexity and improve efficiency of the legislation. This will entail a decrease in the number of type approvals, which may negatively impact employment levels of type approval services. However, the effect would be low due to the expected activity rise of other (lifetime) compliance testing (ISC,MaS) during Euro 7.

Table 5-17: Qualitative assessment of PO1 impact on training/skills

Policy Option 1 – Training/Skills			
Key Factors	**Category**	**Scale of impact[83]**	**Comments**
Impact on required education/ skill level of personnel	**Vehicle OEMs**	0	PO1 has the lowest requirements in terms of technology, hence, no measurable impact is expected on re-training or upskilling personnel. New job positions will require mostly the same level of education/skills as today. For testing equipment, inclusion of PN10 and measurements outside of normal operation conditions can bring some further training of personnel.
	Automotive component suppliers (i.e. Tier 1 suppliers)	0	
	Testing equipment and R&D services (incl. SMEs)	1	
	Homologation services (e.g. TS)	0	

Social inclusion and affordability

In order to assess the impact on consumer affordability, vehicle prices are compared with the estimated net increase in cost per vehicle, to establish what share of a vehicle price

[81] For the legend/custom scale interpretation of impacts see Paragraph 9.7.2
[82] Tier 1 suppliers are typically larger companies that supply parts or systems directly to OEMs
[83] For the legend/custom scale interpretation of impacts see Paragraph 9.7.2

they represent. PO1 is expected to be beneficial both to the environment but also to the economics of vehicle ownership costs thus have no negative impacts on affordability. Marginal price increases are observed which reach 0.5% of vehicle price for small CI vehicles. We do not consider this to be of any concern to potential customers.

Table 5-18: Analysis of relative regulatory costs of PO1 Sc1 over the baseline: economic affordability of consumers

Economic Affordability of Consumers: Policy Option 1					
	Engine	Vehicle segment	Regulatory cost per vehicle (in euro)	Average vehicle price (in euro)**	Share of vehicle price
			Scenario 1		Scenario 1
Cars	PI	Small	18.64	15,275	0.12%
		Medium	18.64	28,344	0.07%
		Large	18.64	60,430	0.03%
	CI	Small	80.95	15,153	0.53%
		Medium	80.95	28,118	0.29%
		Large	80.95	59,948	0.14%
Cars	PI-CI*	Small	48.39	15,217	0.32%
		Medium	48.39	28,236	0.17%
		Large	48.39	60,200	0.08%
Lorries	PI-CI*	Small	48.00	70,169	0.07%
		Medium	48.00	91,219	0.05%
		Large	48.00	140,337	0.03%
Buses	PI-CI*	Small	4.92 (savings)	134,522	0.00% (savings)
		Medium	4.92 (savings)	168,152	0.00% (savings)
		Large	4.92 (savings)	201,782	0.00% (savings)

* Weighted average of costs over new registrations.
** Weighted to the number of sales per year and discounted over the time horizon of 2050.

Consumer trust

Based on the results of the 2nd stakeholder consultation, most stakeholders apart from vehicle OEMs (i.e. components suppliers, member states/national authorities and civil society) believe that the new emission standards will improve consumer trust in the entire automotive industry supply chain (28 out of 47). That said, since PO1 introduces marginal changes to the existing requirements and emission limits, the impact is expected to be low. Marginally, the non-discriminatory character of emission limits to combustion technology introduced with fuel-neutral limits at Euro 7 PO 1 can overall increase consumer trust.

Table 5-19: Qualitative assessment of PO1 impact on consumer trust

Policy Option 1 – Consumer Trust		
Key Factors	**Scale of impact**	**Comments**
Impact on consumer trust in the EU (automotive supply chain)	1	**2nd Targ. Consultation**: Apart from vehicle OEMs, most stakeholders supported that the new standards will improve consumer trust in the automotive industry. For PO1 this effect is estimated as low, as it brings the lowest level of stringency.

5.2. Policy Option 2

5.2.1. Environmental impacts

PO2 introduces more stringent limits for all vehicle categories and coverage of an extended list of pollutants compared to Euro 6/VI. In PO2.Sc1, reductions proposed are significant for NO_x, PN, and CO over Euro 6/VI. NMHC are replaced with NMOG and more stringent limits are proposed for NMOG over Euro 6/VI NMHC. Also, normal driving conditions definition becomes more inclusive than current RDE, including what was considered as 'extended conditions' under Euro 6, among other changes. In PO2.Sc3, boundary conditions for RDE become even more ambitious and cover operation that goes beyond what was earlier considered as 'extended' conditions under Euro 6.

Emission limits are also introduced for the first time for N_2O and HCHO, although the latter is not assessed in the current study. Finally, emission limits for NH_3 are streamlined in stringency between the different vehicle categories. PO2 also introduces an enhanced control of evaporation emissions with more comprehensive testing as well as control of brake wear emissions.

This PO introduces significant changes to emission limits over the Euro 6/VI. Based on the 2nd targeted consultation, suppliers (17 out of 28), national authorities/TS (10 out of 16) and all civil society stakeholders (6 out 6) considered the decrease of limits to be of medium-to-high significance, while 13 out of 19 Vehicle OEMs (including their associations) considered that the decrease of air pollutant emissions limits is of a low significance or not relevant when designing the new Euro 7 standard (13 out of 16). Therefore, based on stakeholders' majority opinion, decreasing the limits is overall considered of significance when designing the new emission standard.

The more stringent limits lead to significantly lower emissions than the baseline. These are shown for PO2.Sc1 in Figure 5-5 and Figure 5-6 for NO_x and in Figure 5-7 and Figure 5-8 for $PM_{2.5}$. Table 5-20 and We do not present emission evolution pictures for PO2.Sc2 due to the similarity with PO2.Sc1. However, it is interesting to compare findings in Table 5-20 and **Error! Not a valid bookmark self-reference.** with Table 5-22 and Table 5-23, in order to understand the impact of extending the 'normal driving' conditions definition to total emission reductions. As one can tell, the differences are limited to LDVs because the changes in boundary conditions for HDVs are basically limited to operation above 2000 m in extended conditions and a marginal increase in the initial mileage above which ISC testing is possible (Table 4-13). **We need to make a note for this last extension of mileage:** In our impact assessment, we did not have evidence to quantify whether this initial mileage lowering can have positive effects to the environmental performance of HDVs. For HDVs, often driven in excess of 1Mkm, extending the lower mileage of ISC testing by a couple of thousand of kilometres does not really mean much, unless there are specific technical reasons that may specifically result to higher emissions for new vehicles. For example, this may be the case for particle filters on CNG buses that may require an initial distance to achieve high efficiency ratios. But, on the other hand, ash emissions from CNG buses are very low so a denser filter may have to be used from the beginning of operation as ash might be too difficult to accumulate. Therefore, in our analysis, we could not identify specific environmental benefits but one may not exclude that such benefits may be encountered in reality.

However, our impact assessment study could quantify the emission benefits of extending the definition of normal conditions of driving for passenger cars. In this case, the driving frequency in conditions outside of 'normal' driving are reduced and this has benefits for practically all regulated pollutants, both from CI and PI concepts. The additional reductions are visible, even if not extremely large, and scale with implementation costs discussed next.

Table 5-21 also show the evolution of the emission reductions over the baseline for the two sets of possible evolution of Euro 6/VI emission levels in PO2.Sc1.

Reductions of NO_x are highest for lorries, CI buses, then CI cars and vans, and least so for PI vehicles. The significant reductions in lorries come from the fact that in our fleet evolution, a significant number of these vehicles remain to be powered by ICE. Therefore, decreasing emission limits has a significant impact on total emissions. On the contrary, new registrations of cars become totally electrified practically by year 2035. So, impacts of emission limit reductions of PO2.Sc1 for cars & vans over the baseline are less pronounced than for lorries.

In terms of CO, there are significant reductions in the emissions of PI vehicles due to the decrease of the limit and control of emissions under the complete operation map. For other technologies, decrease is more mild and even some mild overall increases appear for CI vans and lorries. These are a side-effect of the higher engine demand at start up to fast warm up the emission control system required to achieve the NO_x reductions required. Despite these emissions increases, vehicles continue to be well within emission limits. In reality the increase is of no environmental concern because it represents only a 6.5% increase over the period of a very small initial contribution from CI lorries and vans, to begin with. Interestingly, we do not see the same negative effect for buses. This is mostly due to the expected performance of urban buses: the Euro 7 hot emission level at urban conditions is expected to be much lower than the Euro VI one (due to the efficient operation of the emission control devices) and this overtakes the increase caused by cold-start.

In terms of exhaust PM, there are significant reductions on a relative scale achieved in particular for PI and CI HDVs. This is for different reasons in each case. For CI lorries and buses, better control is achieved mostly by the reduction of semi-volatile PM during fast light-up of closed-coupled oxidation emission control devices. Moreover, improved DPFs to decrease particle number emissions also have a role to play in this reduction but of much smaller scale compared to the reduction of semi-volatiles at cold-start. This is why the relative decrease of PM is much higher than PN in this case.

On the contrary, for PI lorries and buses, it is mostly the control of PN emissions, due to the decrease of the PN limit, that also has an impact on PM emissions. In this scenario, all PI lorries and buses are considered to require a particle filter in order to meet the emission limit and this has a larger impact on PN than PM emissions because such filters preferentially collect small solid particles that represent only a fraction of total PM mass.

Significant emission reductions are also achieved for cars and vans, in particular of CI ones. This is due to the significant decrease of the corresponding emission limit, that corresponds to a much better control of emissions during cold start. The reduction achieved is particularly important when one assumes the conservative development of Euro 6 emission factors. As will be later described, this more stringent control will require advanced emission control, both for PI and CI cars & vans.

With regard to PM and PN from cars and vans, emission reductions are achieved due to the decrease of the emission limit, the size threshold and the more thorough inclusion of DPF regeneration control in the regulations. For PI vehicles, PN emissions reductions are overall more significant because of their higher emission level at Euro 6d than their CI counterparts. However, relative reductions for PM are more significant for CI cars because of better control of PM emissions during active regenerations; active regenerations are not relevant for GPFs in PI cars.

Significant reductions are also achieved for pollutants which are not regulated for cars and vans at Euro 6. In particular, setting a relevant emission limit for NH_3 and an increased durability distance for PI cars and vans leads to NH_3 reductions that range from 30-36% compared to Euro 6d levels of cars and even more so for PI vans. We do not expect reductions for CI cars and vans as these have not been shown (see *Combined report*) to exceed the level of 10 mg/km set at PO2 at Euro 6d. On the contrary, some reductions are expected from CI lorries by setting a limit expressed per unit of energy produced rather than in content units (ppm) as in Euro VI.

Setting a realistic limit for N_2O contributes to a reduction of CH_4+N_2O of up to 42% for CI lorries and buses. This appears despite a projected increase of CH_4. At this stage, it is not entirely clear why methane emissions seem to increase at Euro 7 HDV CI but this is what evidence with advanced emission control systems (see Combined report). What has to be stressed is that such an increase of CH_4, to the extent this is verified in practice, is of no environment value, it corresponds to approximately 0.0001% of total road freight equivalent CO_2 emissions in the modelling period. For cars and vans, reductions are shown to be achieved mostly by setting a direct limit for CH_4 emissions rather than because of N_2O.

Finally, VOC emissions from PI cars and vans seem to be further decreased over Euro 6d levels. The decreases are almost similar in size between exhaust and evaporation control measures. For other vehicle categories, emission levels already at Euro 6/VI seem to be already within or close to the limits proposed at Euro 6 with the policy option so reductions are more marginal in size. Often, these are delivered not so much because of a direct impact of the emission standard but as a (positive) side-effect of introducing emission control for other pollutants (primarily PM).

In general, similar observations made with the normal evolution of Euro 6/VI emission factors can also be done for the evolution of emissions in case Euro 6/VI emission factors develop according to our conservative Euro 6/VI emission reduction estimates. The difference, as seen from We do not present emission evolution pictures for PO2.Sc2 due to the similarity with PO2.Sc1. However, it is interesting to compare findings in Table 5-20 and **Error! Not a valid bookmark self-reference.** with Table 5-22 and Table 5-23, in order to understand the impact of extending the 'normal driving' conditions definition to total emission reductions. As one can tell, the differences are limited to LDVs because the changes in boundary conditions for HDVs are basically limited to operation above 2000 m in extended conditions and a marginal increase in the initial mileage above which ISC testing is possible (Table 4-13). **We need to make a note for this last extension of mileage:** In our impact assessment, we did not have evidence to quantify whether this initial mileage lowering can have positive effects to the environmental performance of HDVs. For HDVs, often driven in excess of 1Mkm, extending the lower mileage of ISC testing by a couple of thousand of kilometres does not really mean much, unless there are specific technical reasons that may specifically result to higher emissions for new vehicles. For example, this may be the case for particle filters on CNG buses that may require an initial distance to achieve high efficiency ratios. But, on the other hand, ash emissions from CNG buses are very low so a denser filter may have to be used from the beginning of operation as ash might be too difficult to accumulate. Therefore, in our analysis, we could not identify specific environmental benefits but one may not exclude that such benefits may be encountered in reality.

However, our impact assessment study could quantify the emission benefits of extending the definition of normal conditions of driving for passenger cars. In this case, the driving frequency in conditions outside of 'normal' driving are reduced and this has benefits for practically all regulated pollutants, both from CI and PI concepts. The additional reductions are visible, even if not extremely large, and scale with implementation costs discussed next.

Table 5-21, is that the absolute benefit with the introduction of PO2.Sc1 becomes even higher over the baseline in this case. Otherwise, the explanation of the trends is similar as in the case of normal evolution of emission factors.

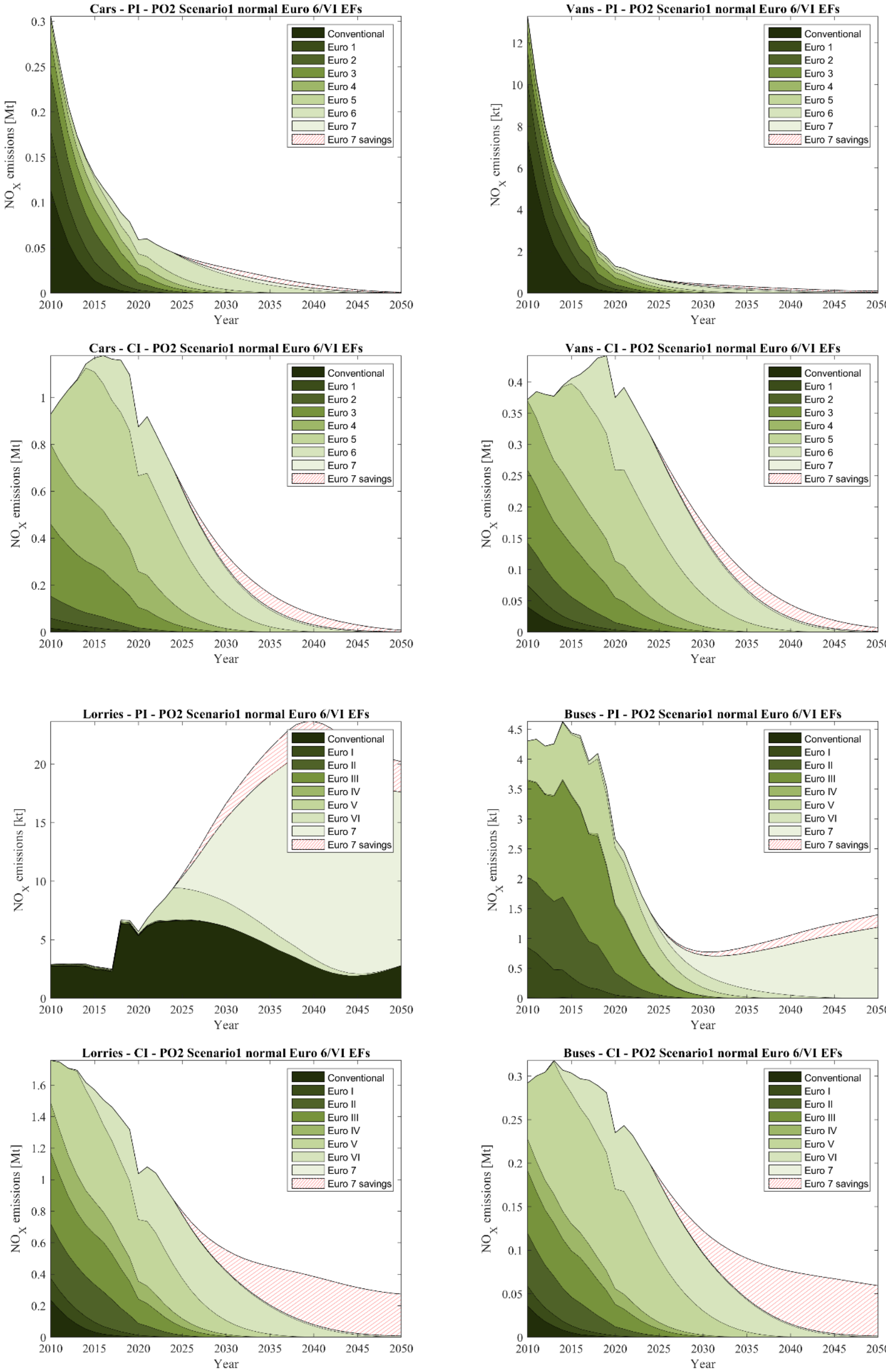

Figure 5-5: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO2.Sc1 over the baseline and normal evolution of Euro 6/VI emission factors.

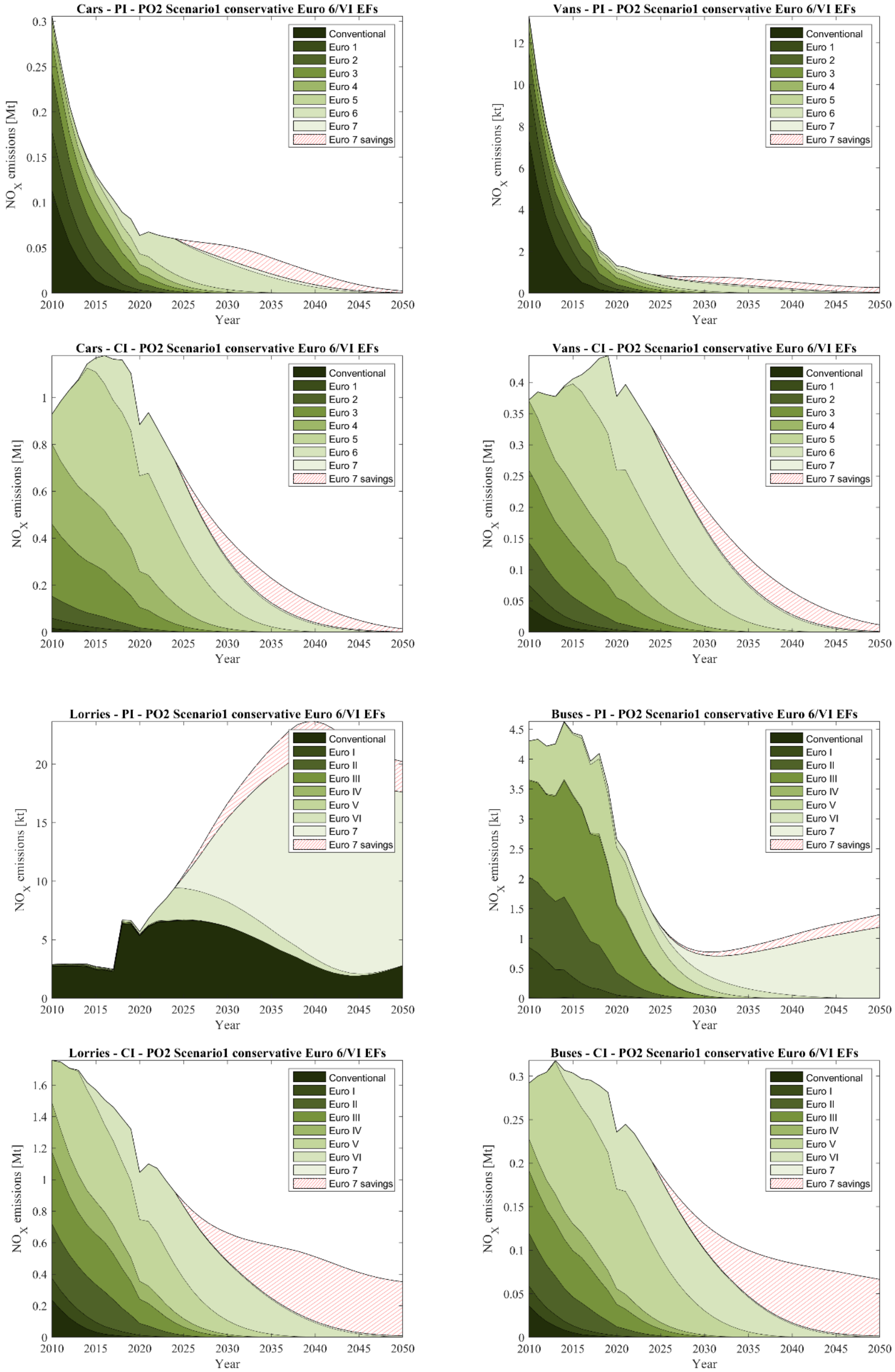

Figure 5-6: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO2.Sc1 over the baseline and conservative evolution of Euro 6/VI emission factors.

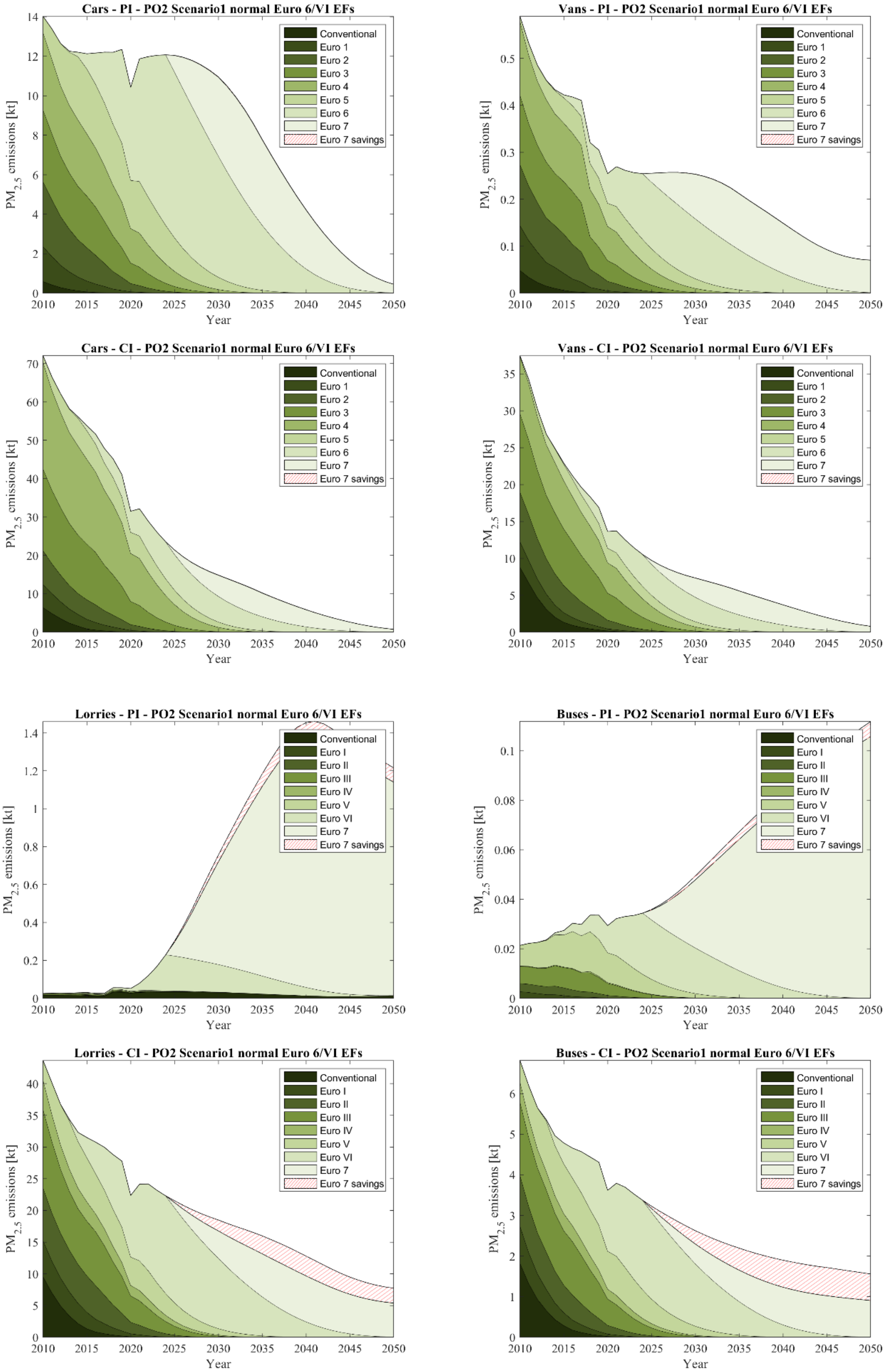

Figure 5-7: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO2.Sc1 over the baseline and normal evolution of Euro 6/VI emission factors.

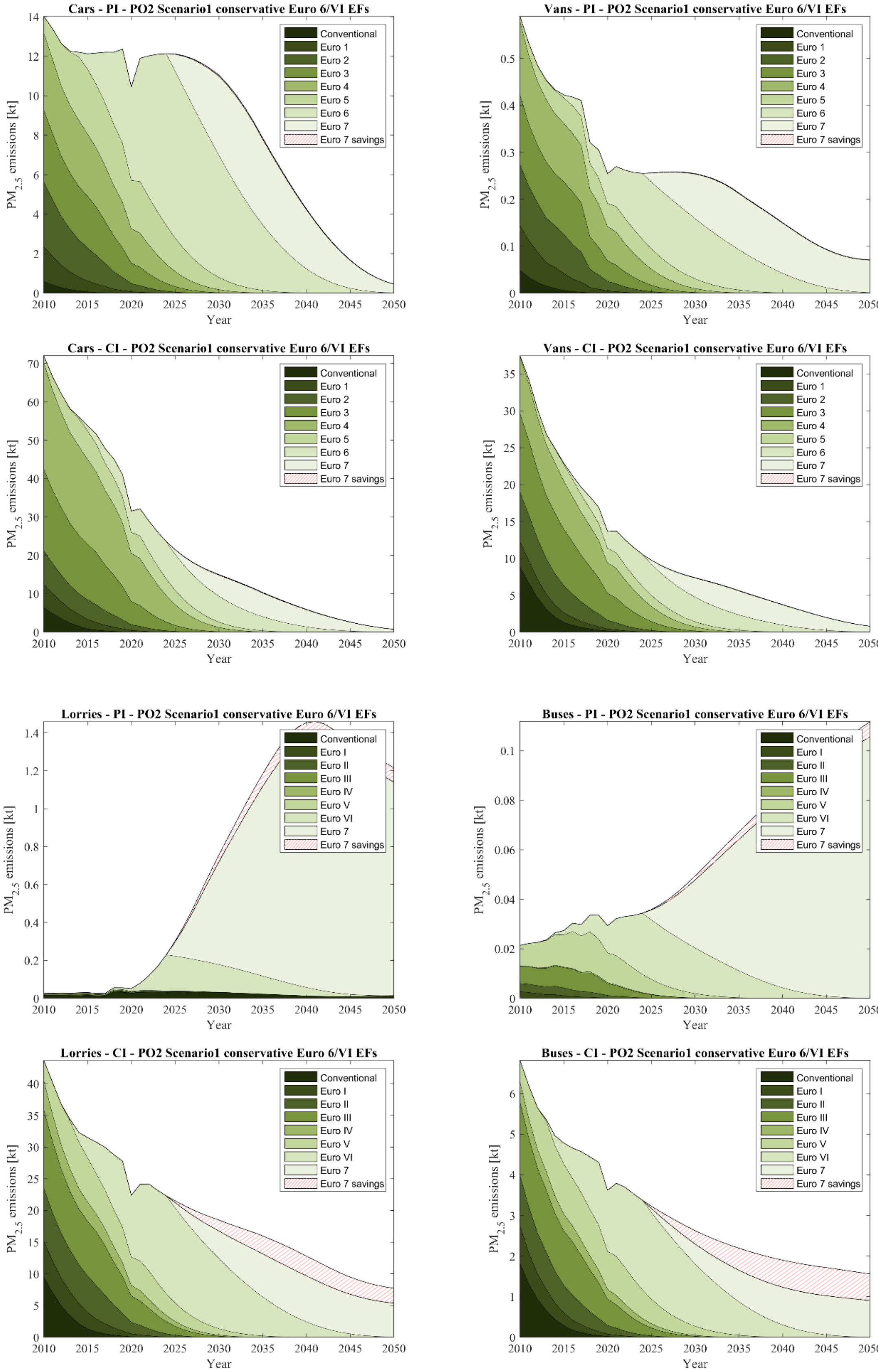

Figure 5-8: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO2.Sc1 over the baseline and conservative evolution of Euro 6/VI emission factors.

Table 5-20: Summary of emission reductions (kT and in %) in PO2.Sc1 for main pollutants and vehicle categories over the baseline and normal evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	2.7	2,466	-12.1	64.5	20.0	20.7	-81.2	373
	%	0.21	20.7	-1.97	27.0	7.23	26.0	-6.20	26.3
NO_x	kt	986	84	424	1.96	1,174	3.13	5,769	56.5
	%	20.7	20.3	17.1	25.3	47.4	11.6	49.7	11.06
VOC	kt	86	421	28.5	8.4	14.3	0	63.4	0
	%	22.8	15.1	21.3	18.4	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	91	28.5	1.85	14.3	0	63.4	0
	%	22.8	15.8	21.3	17.5	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	0.474	0.201	0.125	0.0035	13.4	0.09	60.5	1.62
	%	0.205	0.125	0.101	0.077	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	0.474	0.201	0.125	0.0035	13.4	0.09	60.5	1.62
	%	1.35	2.28	0.82	2.13	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	0.474	0.201	0.125	0.0035	13.4	0.09	60.5	1.62
	%	0.115	0.067	0.055	0.040	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	0.474	0.201	0.125	0.0035	13.4	0.090	60.5	1.62
	%	1.35	2.28	0.82	2.13	37.3	25.7	34.8	27.8
SPN_{10}	#	7.35E+20	8.60E+21	2.44E+20	1.82E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	1.78	36.4	1.61	42.5	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	-1,005	54.8	-1,634	0.437	40,005	0	203,404	0
	%	-1.33	0.853	-5.30	0.363	41.5	0.0	38.2	0.0
NMVOC	kt	3.65	419	0.79	8.4	14.7	0	67.8	0
	%	6.7	15.7	3.05	19.2	44.7	0.0	39.2	0.0
NH_3	kt	-0.2	75	-0.2	2.04	10.4	0.125	57.2	0
	%	-0.9	25.6	-2.1	33.4	43.0	2.56	42.7	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	-9	0.1	-8	0.001	138	0	702	0
	%	-4.0	0.7	-7.7	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	330	0	6.58	0	0	0	0
	%	-	14.9	-	18.7	-	0.0	-	0.0

We do not present emission evolution pictures for PO2.Sc2 due to the similarity with PO2.Sc1. However, it is interesting to compare findings in Table 5-20 and **Error! Not a valid bookmark self-reference.** with Table 5-22 and Table 5-23, in order to understand the impact of extending the 'normal driving' conditions definition to total emission reductions. As one can tell, the differences are limited to LDVs because the changes in boundary conditions for HDVs are basically limited to operation above 2000 m in extended conditions and a marginal increase in the initial mileage above which ISC testing is possible (Table 4-13). **We need to make a note for this last extension of mileage:** In our impact assessment, we did not have evidence to quantify whether this initial mileage lowering can have positive effects to the environmental performance of HDVs. For HDVs, often driven in excess of 1Mkm, extending the lower mileage of ISC testing by a couple of thousand of kilometres does not really mean much, unless there are specific technical reasons that may specifically result to higher emissions for new vehicles. For example, this may be the case for particle filters on CNG buses that may require an initial distance to achieve high efficiency ratios. But, on the other hand, ash emissions from CNG buses are very low so a denser filter may have to be used from the beginning of operation as ash might be too difficult to accumulate. Therefore, in our analysis, we could not identify specific environmental benefits but one may not exclude that such benefits may be encountered in reality.

However, our impact assessment study could quantify the emission benefits of extending the definition of normal conditions of driving for passenger cars. In this case, the driving frequency in conditions outside of 'normal' driving are reduced and this has benefits for practically all regulated pollutants, both from CI and PI concepts. The additional reductions are visible, even if not extremely large, and scale with implementation costs discussed next.

Table 5-21: Summary of emission reductions (kT and in %) in PO2.Sc1 for main pollutants and vehicle categories over the baseline and conservative evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	91	2,466	26.2	64.5	20.0	20.7	-81.2	373
	%	6.1	20.7	3.82	27.0	7.23	26.0	-6.20	26.3
NO_x	kt	1,710	288	736	6.72	1,328	3.13	7,693	56.5
	%	28.8	36.1	24.7	44.4	49.4	11.6	53.6	11.06
VOC	kt	86	421	28.5	8.4	14.3	0	63.4	0
	%	22.8	15.1	21.3	18.4	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	91	28.5	1.85	14.3	0	63.4	0
	%	22.8	15.8	21.3	17.5	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	0.805	0.592	0.483	0.429	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	5.01	9.4	3.75	10.3	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	0.453	0.317	0.265	0.225	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	5.01	9.4	3.75	10.3	37.3	25.7	34.8	27.8
SPN_{10}	#	1.25E+21	1.20E+22	4.19E+20	2.55E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	2.98	40.0	2.72	47.1	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	41,391	54.8	20,111	0.437	40,005	0	203,404	0
	%	27.4	0.853	30.4	0.363	41.5	0.0	38.2	0.0
NMVOC	kt	3.65	419	0.79	8.4	14.7	0	67.8	0
	%	6.7	15.7	3.05	19.2	44.7	0.0	39.2	0.0
NH_3	kt	-0.2	121	-0.2	3.55	10.4	0.125	57.2	0
	%	-0.9	29.8	-2.1	40.3	43.0	2.56	42.7	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	137	0.1	67.3	0.001	138	0	702	0
	%	27.5	0.7	30.6	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	330	0	6.58	0	0	0	0
	%	-	14.9	-	18.7	-	0.0	-	0.0

The impacts of PO2.Sc3 in the emission evolution are shown in Figure 5-9 and Figure 5-10 for NOx and Figure 5-11 and Figure 5-12 for $PM_{2.5}$ over the baseline for the normal and conservative evolution of emission factors, respectively. PO2.Sc3 leads to visible but not impressive reductions compared to PO2.Sc2 with which they share the same boundary conditions but different limits and durability distance. This is for a variety of reasons. First, the need to have an engineering safety factor over the limit means that also the 30 mg/km limit (PO2.Sc2) leads to very low absolute emission levels that during the hot part of the RDE go below 5 mg/km for the average CI or PI car. So, under hot conditions, the additional benefit by further decreasing the limit becomes only marginal. Second, the decreased limit in PO2.Sc3 is mostly reflected to a decrease of emissions over cold start than hot operation, for reasons that are in detailed analysed in the *Combined report*. In short though, decreasing the limit decreases the available margin of emissions during cold-start. Hot stabilised emissions are practically at the same very low levels regardless of whether NO_x is limited at 30 mg/km (PO2.Sc2) or 20 mg/km (PO2.Sc3). This results into a marginal reduction of the overall NO_x emission factor when hot and cold-start contributions are weighted over their real impact in actual vehicle use. In terms of PM, most of the difference comes from the extension of the useful life distance, as emission limits are identical. PO2.Sc3 also brings benefits to CO for CI lorries and vans due to the durability distance increase over PO2.Sc1/2.

When it comes to lorries and buses, there are again marginal differences between PO2.Sc3 over PO2.Sc2. The satisfactory control of cold-start already at PO2.Sc2 due to the decrease of the reference energy (3xWHTC) over which the limit is applicable as well as the removal of any additional margins for extended conditions already at PO2.Sc2 (coverage of all conditions of use) are projected to significantly decrease the actual emission factor over Euro VI already at PO2.Sc1. Therefore, the additional reduction offered by decreasing the NO_x limit from 150 mg/kWh to 100 mg/kWh offers a lower magnitude of reduction. Finally, there is little difference in the exhaust emissions of $PM_{2.5}$ between PO2.Sc2 and PO2.Sc3 for lorries and trucks, only as a result of extension of the vehicle useful life. The same conclusions in terms of NO_x and $PM_{2.5}$ are drawn regardless of whether the baseline if formulated with the normal or conservative evolution of Euro VI, although actual values change between the two cases.

Marginal additional reductions of PO2.Sc3 over PO2.Sc2 are established for all other pollutants. This is to be expected as the main impacts of PO2 (stringent limits for all relevant pollutants under all testing conditions) are already materialised with PO2.Sc2 and the additional reductions by further tightening up the limits are of less importance. The same practically applies for further tightening evaporation control in PO2.Sc3, compared to PO2.Sc2. The additional NMVOC reduction offered by a lower diurnal evaporation limit (0.3 g/day compared to 0.5 g/day) is 7% of what already achieved in PO2.Sc2.

Table 5-22: Summary of emission reductions (kT and in %) in PO2.Sc2 for main pollutants and vehicle categories over the baseline and normal evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	12.5	2,509	-7.6	65.7	20.0	20.7	-81.2	373
	%	0.95	21.0	-1.24	27.5	7.23	26.0	-6.20	26.3
NO_x	kt	999	91	430	2.11	1,174	3.13	5,769	56.5
	%	21.0	21.9	17.3	27.2	47.4	11.6	49.7	11.06
VOC	kt	86	423	28.5	8.5	14.3	0	63.4	0
	%	22.9	15.2	21.4	18.5	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	94	28.5	1.91	14.3	0	63.4	0
	%	22.9	16.3	21.4	18.0	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	0.722	0.342	0.211	0.0065	13.4	0.09	60.5	1.62
	%	0.313	0.213	0.171	0.144	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	0.722	0.342	0.211	0.0065	13.4	0.09	60.5	1.62
	%	2.05	3.87	1.38	3.97	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	0.722	0.342	0.211	0.0065	13.4	0.09	60.5	1.62
	%	0.175	0.113	0.093	0.075	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	0.722	0.342	0.211	0.0065	13.4	0.090	60.5	1.62
	%	2.05	3.87	1.38	3.97	37.3	25.7	34.8	27.8
SPN_{10}	#	7.95E+20	8.62E+21	2.65E+20	1.83E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	1.93	36.5	1.75	42.6	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	-1,005	54.8	-1,634	0.436	40,005	0	203,404	0
	%	-1.33	0.853	-5.30	0.362	41.5	0.0	38.2	0.0
NMVOC	kt	3.88	422	0.87	8.5	14.7	0	67.8	0
	%	7.2	15.8	3.36	19.4	44.7	0.0	39.2	0.0
NH_3	kt	-0.2	75	-0.2	2.04	10.4	0.125	57.2	0
	%	-0.9	25.7	-2.1	33.5	43.0	2.56	42.7	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	-9	0.1	-8	0.001	138	0	702	0
	%	-4.0	0.7	-7.7	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	330	0	6.58	0	0	0	0
	%	-	14.9	-	18.7	-	0.0	-	0.0

Table 5-23: Summary of emission reductions (kT and in %) in PO2.Sc2 for main pollutants and vehicle categories over the baseline and conservative evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	101	2,509	30.7	65.7	20.0	20.7	-81.2	373
	%	6.7	21.0	4.48	27.5	7.23	26.0	-6.20	26.3
NO_x	kt	1,723	295	742	6.87	1,328	3.13	7,693	56.5
	%	29.0	37.0	24.9	45.4	49.4	11.6	53.6	11.06
VOC	kt	86	423	28.5	8.5	14.3	0	63.4	0
	%	22.9	15.2	21.4	18.5	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	94	28.5	1.91	14.3	0	63.4	0
	%	22.9	16.3	21.4	18.0	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	0.911	0.678	0.552	0.496	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	5.67	10.7	4.29	11.9	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	0.513	0.363	0.303	0.260	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	5.67	10.7	4.29	11.9	37.3	25.7	34.8	27.8
SPN_{10}	#	1.31E+21	1.21E+22	4.40E+20	2.56E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	3.12	40.1	2.85	47.1	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	41,391	54.8	20,111	0.436	40,005	0	203,404	0
	%	27.4	0.853	30.4	0.362	41.5	0.0	38.2	0.0
NMVOC	kt	3.88	422	0.87	8.5	14.7	0	67.8	0
	%	7.2	15.8	3.36	19.4	44.7	0.0	39.2	0.0
NH_3	kt	-0.2	121	-0.2	3.55	10.4	0.125	57.2	0
	%	-0.9	29.9	-2.1	40.3	43.0	2.56	42.7	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	137	0.1	67.3	0.001	138	0	702	0
	%	27.5	0.7	30.6	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	330	0	6.58	0	0	0	0
	%	-	14.9	-	18.7	-	0.0	-	0.0

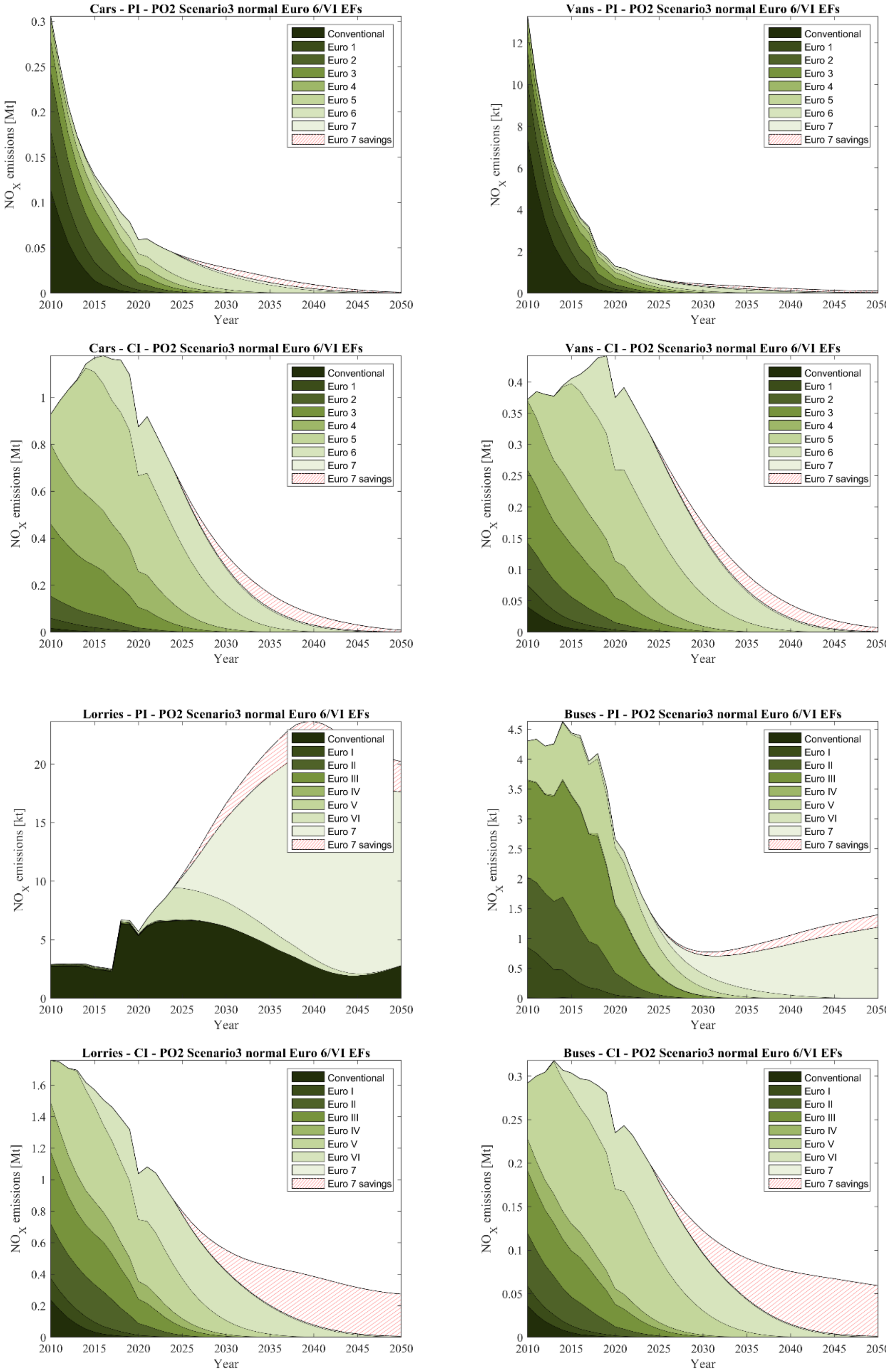

Figure 5-9: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO2.Sc3 over the baseline and normal evolution of Euro 6/VI emission factors.

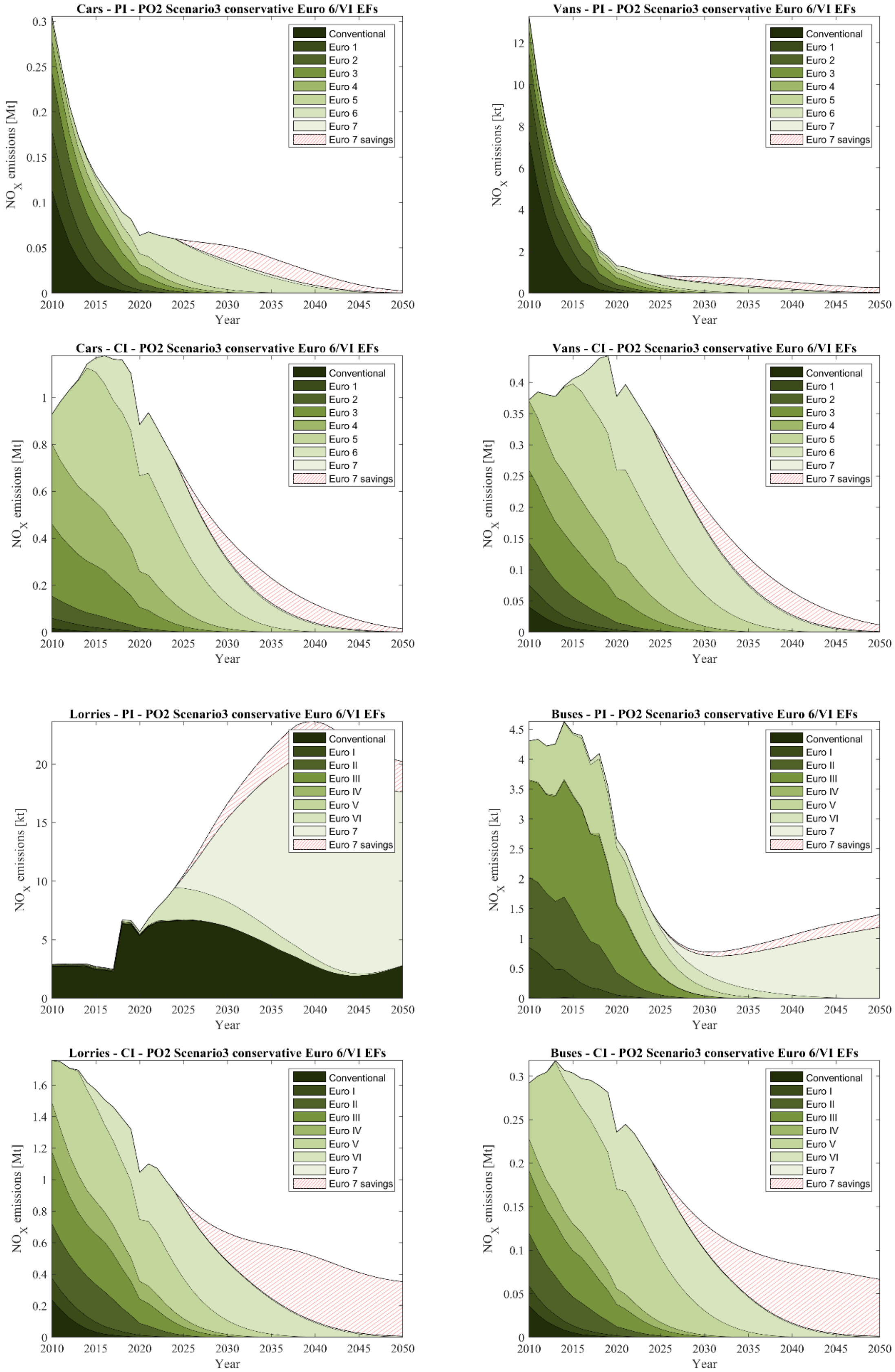

Figure 5-10: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO2.Sc3 over the baseline and conservative evolution of Euro 6/VI emission factors.

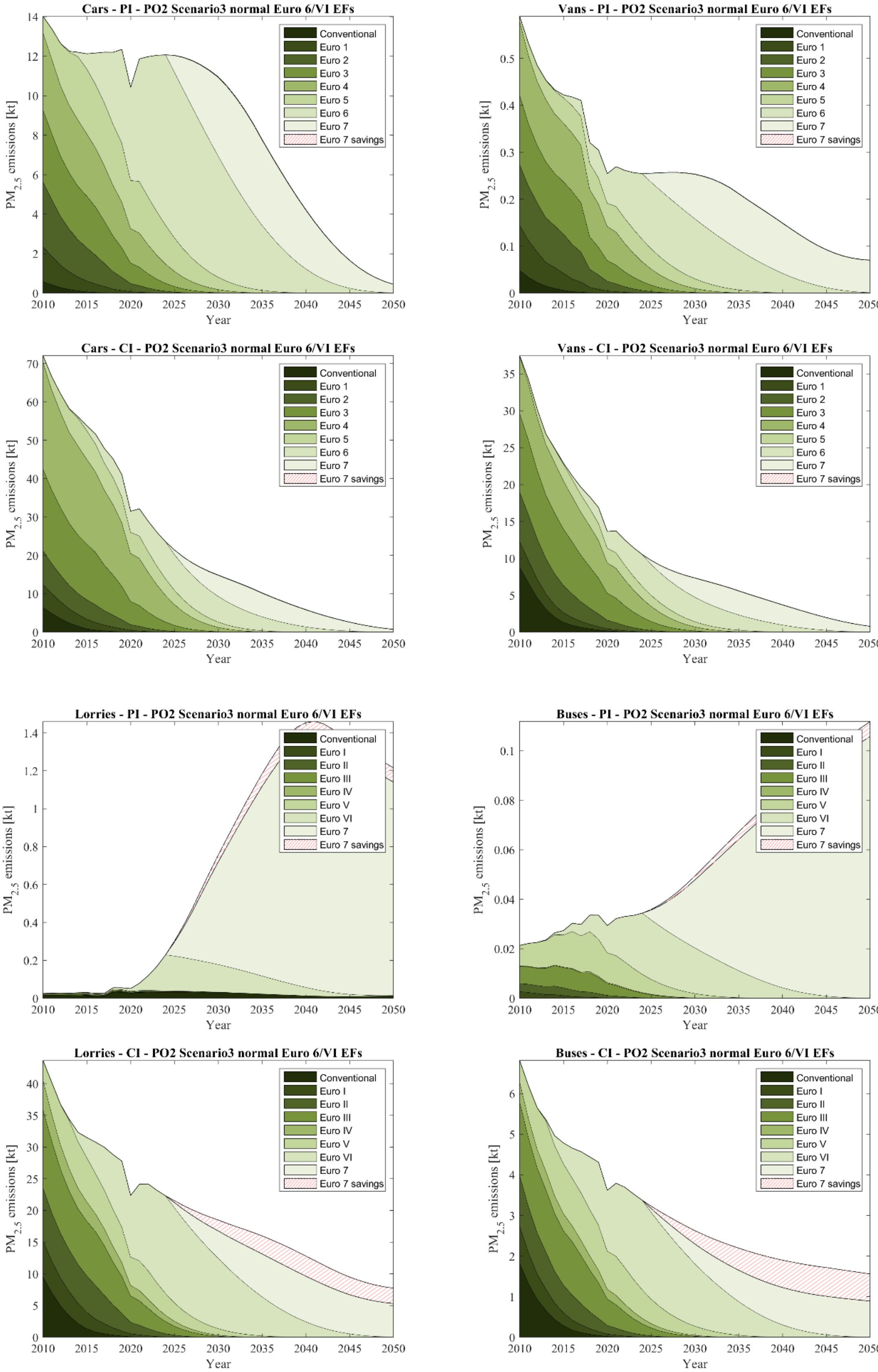

Figure 5-11: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO2.Sc3 over the baseline and normal evolution of Euro 6/VI emission factors.

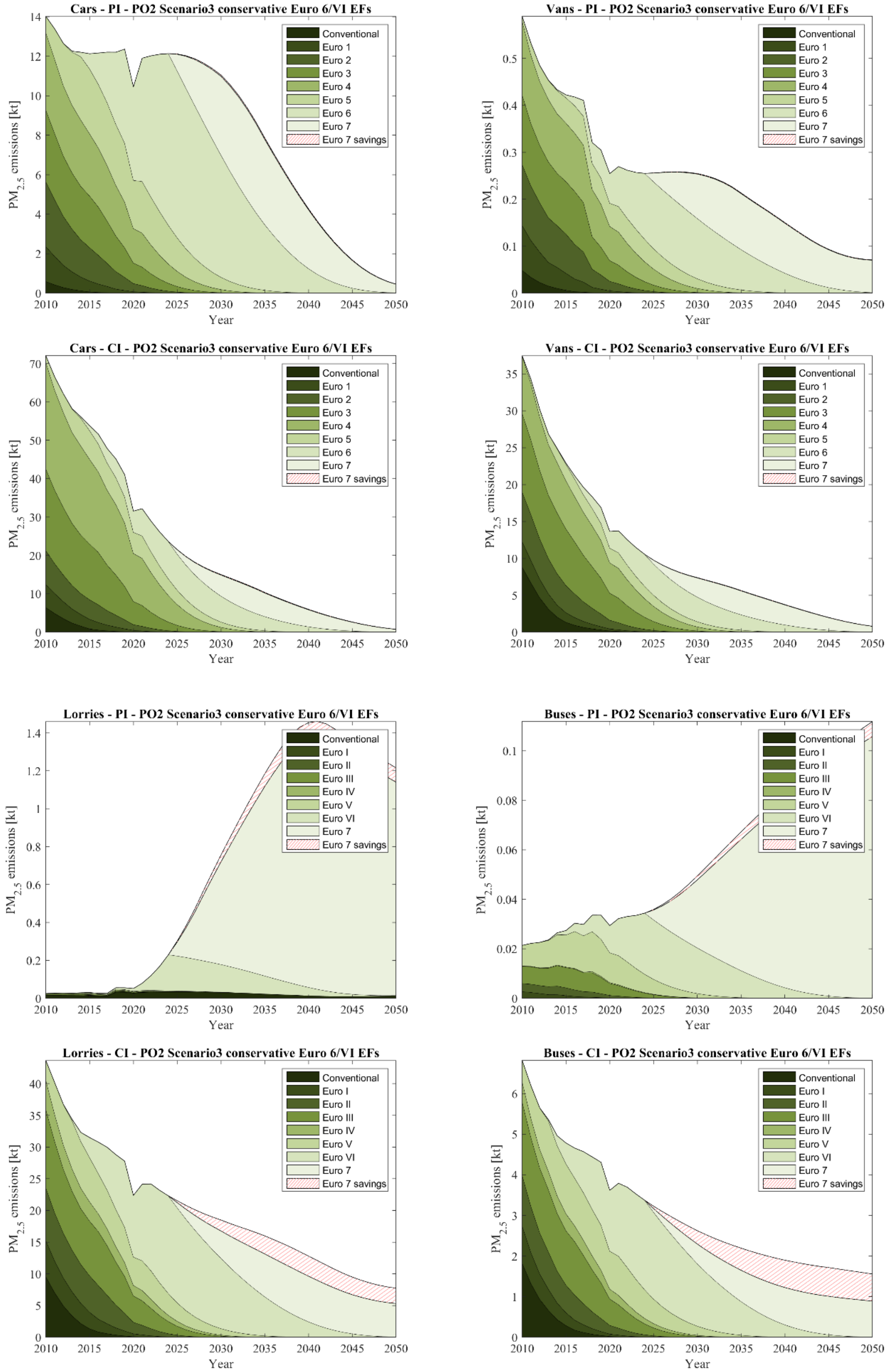

Figure 5-12: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO2.Sc3 over the baseline and conservative evolution of Euro 6/VI emission factors.

Table 5-24: Summary of emission reductions (kT and in % 2025-2050) in PO2.Sc3 for main pollutants and vehicle categories over the baseline and normal evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	65.7	2,612	26.7	68.6	38.1	20.7	105	373
	%	4.96	21.9	4.36	28.8	13.8	26.0	8.01	26.3
NO_x	kt	1,009	99	435	2.29	1,180	3.13	5,816	56.5
	%	21.2	23.8	17.5	29.6	47.6	11.6	50.1	11.06
VOC	kt	97	465	34.1	9.3	14.4	0	68.6	0
	%	25.7	16.7	25.6	20.4	42.6	0.0	38.5	0.0
VOC-EXH	kt	97	115	34.1	2.37	14.4	0	68.6	0
	%	25.7	19.9	25.6	22.5	42.6	0.0	38.5	0.0
$PM_{2.5}$-TOTAL	kt	0.856	0.356	0.290	0.0075	13.6	0.090	61.4	1.62
	%	0.371	0.221	0.235	0.166	24.1	4.63	16.6	5.68
$PM_{2.5}$-EXH	kt	0.856	0.356	0.290	0.0075	13.6	0.090	61.4	1.62
	%	2.43	4.03	1.90	4.58	37.7	25.7	35.4	27.8
PM_{10}-TOTAL	kt	0.856	0.356	0.290	0.0075	13.6	0.090	61.4	1.62
	%	0.208	0.118	0.128	0.087	17.6	2.44	11.5	3.33
PM_{10}-EXH	kt	0.856	0.356	0.290	0.0075	13.6	0.090	61.4	1.62
	%	2.43	4.03	1.90	4.58	37.7	25.7	35.4	27.8
SPN_{10}	#	8.08E+20	8.63E+21	2.73E+20	1.83E+20	4.14E+20	3.09E+20	1.89E+21	5.56E+21
	%	1.96	36.5	1.80	42.6	8.34	74.0	6.94	78.8
CH_4+N_2O	kt	19,730	72.6	8,250	1.630	40,839	0	208,983	0
	%	26.1	1.130	26.7	1.355	42.4	0.0	39.3	0.0
NMVOC	kt	5.69	464	1.90	9.3	14.8	0	72.3	0
	%	10.5	17.4	7.30	21.3	44.8	0.0	41.8	0.0
NH_3	kt	0.07	76	0.03	2.09	10.6	0.125	58.6	0
	%	0.3	25.9	0.3	34.2	43.8	2.56	43.7	0.0
CH_4	kt	91	1.87	32.2	0.043	-0.335	0	-3.67	0
	%	28.2	1.55	30.0	2.06	-36.1	0.0	-70.2	0.0
N_2O	kt	61.5	0.1	26.1	0.003	141	0	721	0
	%	25.9	0.9	26.5	1.0	42.4	0.0	39.3	0.0
VOC-EVAP	kt	0	351	0	6.97	0	0	0	0
	%	-	15.9	-	19.8	-	0.0	-	0.0

Table 5-25: Summary of emission reductions (kT and in % 2025-2050) in PO2.Sc3 for main pollutants and vehicle categories over the baseline and conservative evolution of Euro 6/VI emission factors.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	154	2,612	65.1	68.6	38.1	20.7	105	373
	%	10.3	21.9	9.48	28.8	13.8	26.0	8.01	26.3
NO_x	kt	1,732	303	747	7.05	1,334	3.13	7,741	56.5
	%	29.2	38.0	25.0	46.6	49.6	11.6	53.9	11.06
VOC	kt	97	465	34.1	9.3	14.4	0	68.6	0
	%	25.7	16.7	25.6	20.4	42.6	0.0	38.5	0.0
VOC-EXH	kt	97	115	34.1	2.37	14.4	0	68.6	0
	%	25.7	19.9	25.6	22.5	42.6	0.0	38.5	0.0
$PM_{2.5}$-TOTAL	kt	2.26	1.11	0.764	0.0235	13.6	0.090	61.4	1.62
	%	0.969	0.687	0.62	0.518	24.1	4.63	16.6	5.68
$PM_{2.5}$-EXH	kt	2.26	1.11	0.764	0.0235	13.6	0.090	61.4	1.62
	%	6.03	10.9	4.78	12.4	37.7	25.7	35.4	27.8
PM_{10}-TOTAL	kt	2.26	1.11	0.764	0.0235	13.6	0.090	61.4	1.62
	%	0.545	0.368	0.337	0.272	17.6	2.44	11.5	3.33
PM_{10}-EXH	kt	2.26	1.11	0.764	0.0235	13.6	0.090	61.4	1.62
	%	6.03	10.9	4.78	12.4	37.7	25.7	35.4	27.8
SPN_{10}	#	1.32E+21	1.21E+22	4.48E+20	2.56E+20	4.14E+20	3.09E+20	1.89E+21	5.56E+21
	%	3.15	40.1	2.90	47.2	8.34	74.0	6.94	78.8
CH_4+N_2O	kt	62,126	72.6	29,995	1.630	40,839	0	208,983	0
	%	41.1	1.130	45.4	1.355	42.4	0.0	39.3	0.0
NMVOC	kt	5.69	464	1.90	9.3	14.8	0	72.3	0
	%	10.5	17.4	7.30	21.3	44.8	0.0	41.8	0.0
NH_3	kt	0.07	122	0.03	3.59	10.6	0.125	58.6	0
	%	0.3	30.0	0.3	40.9	43.8	2.56	43.7	0.0
CH_4	kt	91	1.87	32.2	0.043	-0.335	0	-3.67	0
	%	28.2	1.55	30.0	2.06	-36.1	0.0	-70.2	0.0
N_2O	kt	208	0.1	101	0.003	141	0	721	0
	%	41.7	0.9	45.9	1.0	42.4	0.0	39.3	0.0
VOC-EVAP	kt	0	351	0	6.97	0	0	0	0
	%	-	15.9	-	19.8	-	0.0	-	0.0

Table 5-26 and

Environmental impacts in monetised terms for PO2 and for POx (brake wear) for LDVs (billion EUR)

Scenario	Euro 6/VI EF	CH4+N2O	Fuel savings EVAP
PO2.Sc1	Normal	-0.28	0.02
	Conservative	9.77	0.02
PO2.Sc2	Normal	-0.28	0.02
	Conservative	9.77	0.02
PO2.Sc3	Normal	4.41	0.02
	Conservative	14.46	0.02

Table 5-27 show the environmental benefits in monetised terms of CH_4+N_2O and any fuel savings due to better control of fuel evaporation emissions. For cars & vans, benefits improve with the scenario and the reference considered, due to the additional regulatory provisions considered, over Euro 6. There are no differences between PO2.Sc1 and PO2.Sc2 for two reasons: First, there is no difference in the evaporation control requirements between the two scenarios (Table 4-12). Second, despite PO2.Sc2 marginally covers a wider range of driving conditions under 'normal', our emission factors for CH_4+N_2O do not differ between normal and extended conditions, first because we have very little experimental information and, second, because these pollutants are currently not controlled so there is no regulatory pressure to decrease their emissions within normal driving. In PO2.Sc3, benefits originate from a decrease in emission limits both to exhaust (CH_4, N_2O - Table 4-10) and fuel evaporation (Table 4-12) but the latter is marginal. For lorries and buses, no fuel savings are calculated (zero penetration of gasoline-powered lorries and busses assumed) while the emission limits proposed for CH_4+N_2O are identical between the two scenarios.

Table 5-26: Environmental impacts from cars & vans in monetised terms for PO2.

Environmental impacts in monetised terms for PO2 and for POx (brake wear) for LDVs (billion EUR)			
Scenario	**Euro 6/VI EF**	**CH_4+N_2O**	**Fuel savings EVAP**
PO2.Sc1	Normal	-0.28	0.02
	Conservative	9.77	0.02
PO2.Sc2	Normal	-0.28	0.02
	Conservative	9.77	0.02
PO2.Sc3	Normal	4.41	0.02
	Conservative	14.46	0.02

Table 5-27: Environmental impacts from lorries & buses in monetised terms for PO2.

Environmental impacts in monetised terms for PO2 for HDVs (billion EUR)			
Scenario	**Euro 6/VI EF**	**CH_4+N_2O**	**Fuel savings EVAP**
PO2.Sc1	Normal	36.63	0.00
	Conservative	36.63	0.00
PO2.Sc2	Normal	36.63	0.00
	Conservative	36.63	0.00
PO2.Sc3	Normal	37.49	0.00
	Conservative	37.49	0.00

Further to introducing control measures for exhaust emissions, this policy option also introduces control requirements for brake wear emissions. In fact, there are two steps proposed for reductions, one based only on improved brake pads (Scenario B1) and the second additionally including brake wear particles collection (Scenario B2). Figure 5-13 shows the evolution of total $PM_{2.5}$ (exhaust and non-exhaust, i.e. brake and tyres) for cars & vans and lorries & buses for Scenario B1 where only pad-based control of wear emissions is introduced. The first observation relates to the fact that, if no control measures are introduced, $PM_{2.5}$ emissions are shown to increase in time for both vehicle categories. This is because non-exhaust emissions are produced from vehicles with and without ICEs, that is including EVs. Reduction of the total mass of $PM_{2.5}$ will be made possible already by introducing better pads on the vehicles. For lorries & buses, there have been no control measures considered so emissions continue to increase in the future as transport activity is also considered to increase. When it comes to PM_{10}, the relative reduction of total PM_{10} emissions offered by better brake pads is higher, because of the reduced contribution of exhaust emissions in this wider size range.

Figure 5-14 shows the emission evolution of total $PM_{2.5}$ (exhaust and non-exhaust) for cars & vans where both better pads and particle collection mechanisms on-board the vehicle are installed (Scenario B). Additional reductions are achieved over Scenario A that decrease total $PM_{2.5}$ to less than 50% of its original value in 2050. Again, the reductions in PM_{10} are more prominent because of the decreased contribution of exhaust emissions in this size range relative to non-exhaust sources.

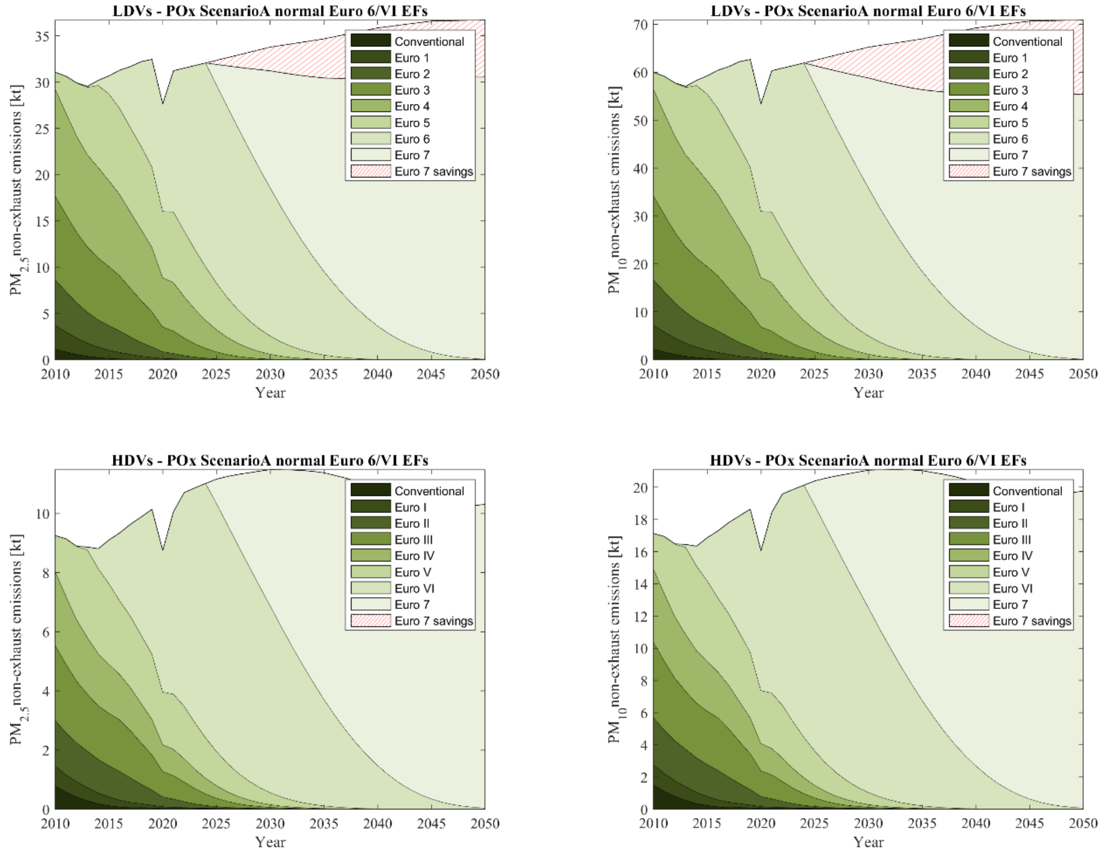

Figure 5-13: Decrease in the evolution of $PM_{2.5}$ and PM_{10} for LDVs and HDVs for the brake wear scenario B1 over the baseline.

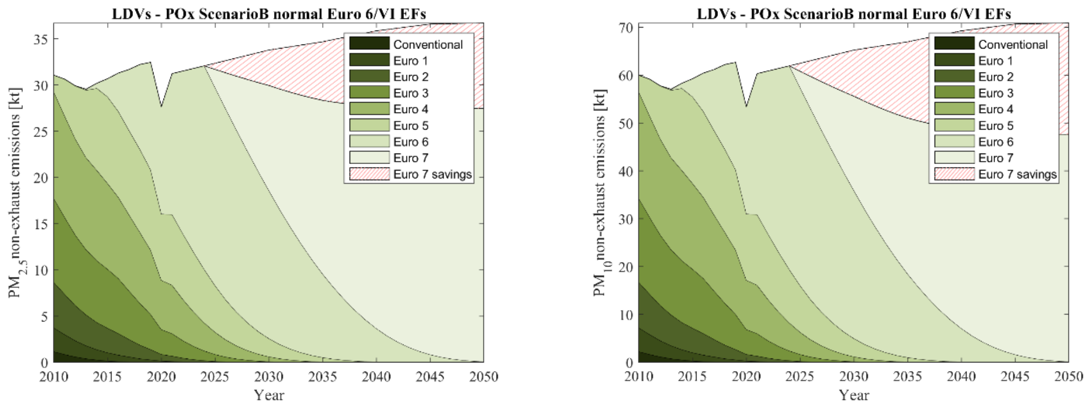

Figure 5-14: Decrease in the evolution of $PM_{2.5}$ and PM_{10} for LDVs for the brake wear scenario B2 over the baseline

Table 5-28: Summary of emission reductions of $PM_{2.5}$ and PM_{10} (kT and in %) over the baseline for introduction of brake wear control measures for LDVs (no emission reductions for HDVs).

	Pollutant		Cars	Vans
POx.ScB1	PM10 non-EXH	kt	220	60.4
		%	15.9%	16.0%
	PM2.5 non-EXH	kt	87.6	24.0
		%	12.2%	12.4%
POx.ScB2	PM10 non-EXH	kt	330	90.6
		%	23.9%	23.9%
	PM2.5 non-EXH	kt	131	36.1
		%	18.3%	18.5%

5.2.2. Economic impacts

Regulatory costs

Further to simplification introduced with PO1, PO2 introduces several new components with regard to Euro 6/VI including, most importantly, decreased pollutant limits, coverage of new pollutants, control over all conditions of driving, enhanced evaporation emissions testing and control of brake wear emissions. PO2 is a comprehensive new emission step involving changes in the design, hardware and type-approval of vehicles. For these reasons, this also introduces significant cost impacts, as in detail presented in Annex I, section in 9.5.

Particularly for emissions control technologies, Table 5-29 and

Table 5-30 present the cost breakdown for PI and CI cars/vans, respectively. In the case of PI, both gasoline and CNG vehicles are considered, while the technologies related to evaporative emissions control are integrated only for gasoline vehicles. Similarly, Table 5-31 and Table 5-32 present the technology cost breakdown for PI (natural gas) and CI lorries/buses, respectively. For both vehicle types, additional cost is considered for the more demanding durability requirements, depending on the scenario. This cost refers to the total volume of the component, assumed to equal to 10% of its total cost for PO2.Sc3. Particularly for lorries/buses, and due to heavily increased durability requirements, it is assumed that 30% of the fleet will have to replace aftertreatment components during its lifetime in PO2.Sc3. This is proportionally decreased (5% cost increase and 15% replacement rate) for PO2.Sc2 due to less stringent durability requirements.

Table 5-33 to Table 5-35 present the regulatory costs for the scenarios modelled in PO2. Most of the regulatory costs appear for CI vehicles, mostly LDVs but also HDVs. Costs are generally lower over the baseline because costs are dominated by hardware hence the less ICE vehicles placed on the market, the less the total regulatory costs sum up to. Moreover, costs are generally higher in PO2.Sc3 due to the more demanding emission control that requires software of advanced specifications.

Table 5-29: Hardware cost breakdown for the average PI car/van (not discounted values expressed in €$_{2021}$) in PO2 (incremental over Euro 6d).

The column 'Unit cost' indicate the cost per liter or the cost per unit for volume increase or for item unit increase, respectively, where applicable. The column 'Cost' presents the total incremental cost for each technology.

Technology	PO2.Sc1					PO2.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/l	€	Euro 6d	Euro 7	Δ	€/l	€
TWC	1.8/1.6	2.7/2.4	0.9/0.8	80	72.2/64	1.8/1.6	2.7/2.4	0.9/0.8	80	72/64
TWC durability for 200k km	0	2.7/2.4	2.7/2.4	4	10.8/9.6	0	2.7/2.4	2.7/2.4	4	10.8/9.6

Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/unit	€	Euro 6d	Euro 7	Δ	€/unit	€
Optimised coated GPF for gasoline (no size increase)	0	1	1	5	5	0	1	1	15	15
ORVR canister	0	1	1	10	10	0	1	1	10	10
Anti-spitback/vapour valve	0	1	1	2	2	0	1	1	2	2
High flow purge valve	0	1	1	2	2	0	1	1	2	2

Technology	PO2.Sc3				
	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/l	€
TWC	1.8/1.6	2.7/2.4	0.9/0.8	80	72/64
TWC durability for 240k km	0	2.7/2.4	2.7/2.4	8	21.6/19.1
GPF (for CNG)	0	1.5/1.6	1.5/1.6	57	86.4/90.7
CUC (NH_3 slip catalyst)	0	0.9/0.8	0.9/0.8	23	20.8/18.3
CUC durability for 240k km	0	0.9/0.8	0.9/0.8	2.3	2.1/1.8

Technology	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/unit	€
Optimised coated GPF for gasoline (no size increase)	0	1	1	15	15
e-cat (EHC)	0	1	1	125	125
SAI	0	1	1	78	78
ORVR canister	0	1	1	10	10
Anti spitback/ vapour valve	0	1	1	2	2
High flow purge valve	0	1	1	2	2
Larger canister	0	1	1	4	4
Low permeability tank, hoses	0	1	1	20	20

Table 5-30: Hardware cost breakdown for the average CI car/van (not discounted values expressed in €$_{2021}$) in PO2 (incremental over Euro 6d).

The column 'Unit cost' indicate the cost per liter or the cost per unit for volume increase or for item unit increase, respectively, where applicable. The column 'Cost' presents the total incremental cost for each technology.

Technology	PO2.Sc1					PO2.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/l	€	Euro 6d	Euro 7	Δ	€/l	€
MHEV and PHEV										
DOC	1.5/1.8	2.2/2.7	0.7/0.9	42	29.4/37.8	1.5/1.8	2.2/2.7	0.7/0.9	42	29.4/37.8
DOC durability for 200k km	0	2.2/2.7	2.2/2.7	2.1	4.6/5.7	0	2.2/2.7	2.2/2.7	2.1	4.6/5.7
SCR	3.7/4.5	5.5/6.8	1.8 2.3	30	54.0/69.0	3.7/4.5	5.5/6.8	1.8/2.3	30	54.0/69
SCR durability for 200k km	0	5.5/6.8	5.5/6.8	1.5	8.3/10.2	0	5.5/6.8	5.5/6.8	1.5	8.3/10.2
SCRF	2.7/3.4	4.1/5.1	1.4/1.7	55	77.0/93.6	2.7/3.4	4.1/5.1	1.4/1.7	55	77/93.6
ASC (NH_3 slip catalyst)	0.9/1.1	1.4/1.7	0.5/0.6	23	11.5/13.8	0.9/1.1	1.4/1.7	0.5/0.6	23	11.5/13.8
ASC durability for 200k km	0	1.4/1.7	1.4/1.7	1.2	1.6/2.0	0	1.4/1.7	1.4/1.7	1.2	1.6/2.0
Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/unit	€	Euro 6d	Euro 7	Δ	€/unit	€
MHEV										
e-cat (EHC)	0	1	1	125	125	0	1	1	125	125
PHEV										
e-cat (EHC)	0	2	2	125	250	0	2	2	125	250
Turbine bypass	0	1	1	15	15	0	1	1	15	15

Technology	PO2.Sc3				
	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/l	€
MHEV and PHEV					
DOC	1.5 / 1.8	2.2 / 2.7	0.7 / 0.9	42	29.4/38.1
DOC durability for 240k km	0	2.2 / 2.7	2.2 / 2.7	4.2	9.2/11.4
SCR	3.7 / 4.5	5.5 / 6.8	1.8 / 2.3	30	54.0/69.0
SCR durability for 240k km	0	5.5 / 6.8	5.5 / 6.8	3	16.5/20.4
SCRF	2.7 / 3.4	4.1 / 5.1	1.4 / 1.7	55	77.0/93.5
ASC (NH_3 slip catalyst)	0.9 / 1.1	1.4 / 1.7	0.5 / 0.6	23	11.5/13.8
ASC durability for 240k km	0	1.4 / 1.7	1.4 / 1.7	2.3	3.2/3.9
Technology	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/unit	€
MHEV					
SAI	0	1	1	78	78
e-cat (EHC)	0	1	1	125	125
PHEV					
e-cat (EHC)	0	2	2	125	250
Turbine bypass	0	1	1	15	15

Table 5-31: Hardware cost breakdown for the average PI lorry/bus (not discounted values expressed in €$_{2021}$) in PO2 (incremental over Euro VI E).

The column 'Unit cost' indicate the cost per liter or the cost per unit for volume increase or for item unit increase, respectively, where applicable. The column 'Cost' presents the total incremental cost for each technology.

Technology	PO2.Sc1					PO2.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/l	€	Euro VI	Euro 7	Δ	€/l	€
TWC (for CNG λ=1)	10	15	5	80	400	10	15	5	80	400
Improved TWC durability	0	15	15	4	60	0	15	15	4	60
15% fleet TWC replacement	0	15	15	80	180	0	15	15	80	180
PF for CNG	0	12.8	128	57.2	732.7	0	12.8	128	57.2	732.7
Oxidation Catalyst (OC)	11.4	14	2.6	43.9	114.2	11.4	14	2.6	43.9	114.2
Improved OC durability	0	14	14	2.2	30.8	0	14	14	2.2	30.8
15% fleet OC replacement	0	14	14	43.9	92.2	0	14	14	43.9	92.2
SCR	21.3	37.5	16.2	20.4	330.5	21.3	37.5	16.2	20.4	330.5
Improved SCR durability	0	37.5	37.5	1	37.5	0	37.5	37.5	1	37.5
15% fleet SCR replacement	0	37.5	37.5	20.4	114.8	0	37.5	37.5	20.4	114.8
ASC	7.1	12.5	5.4	16	86.4	7.1	12.5	5.4	16	86.4
Improved ASC durability	0	12.5	12.5	0.8	10	0	12.5	12.5	0.8	10
Technology	**Quantity (units)**			**Unit cost**	**Cost**	**Quantity (units)**			**Unit cost**	**Cost**
	Euro VI	**Euro 7**	**Δ**	**€/unit**	**€**	**Euro VI**	**Euro 7**	**Δ**	**€/unit**	**€**
Optimised PF for LNG	0	1	1	60	60	0	1	1	60	60
Engine-out box	0	1	1	500	500	0	1	1	500	500
2nd urea injector	1	2	1	100	100	1	2	1	100	100

Technology	PO2.Sc3				
	Volume [l]			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/l	€
TWC (for CNG λ=1)	10	15	5	80	400
Improved TWC durability	0	15	15	8	120
30% fleet TWC replacement	0	15	15	80	360
PF for CNG	0	12.8	128	57.2	732.7
Oxidation Catalyst (OC)	11.4	14	2.6	43.9	114.2
Improved OC durability	0	14	14	4.4	61.6
30% fleet OC replacement	0	14	14	43.9	184.5
SCR	21.3	37.5	16.2	20.4	330.5
Improved SCR durability	0	37.5	37.5	2	75
30% fleet SCR replacement	0	37.5	37.5	20.4	229.5
ASC	7.1	12.5	5.4	16	86.4
Improved ASC durability	0	12.5	12.5	1.6	20
Technology	**Quantity (units)**			**Unit cost**	**Cost**
	Euro VI	**Euro 7**	**Δ**	**€/unit**	**€**
Optimised PF for LNG	0	1	1	60	60
Engine-out box	0	1	1	500	500
2nd urea injector	1	2	1	100	100
48V EHC peripherals	0	1	1	800	800
48V EHC battery w/ preheat	0	1	1	1500	1500
e-cat (EHC)	0	4	4	250	1000

Table 5-32: Hardware cost breakdown for the average CI lorry/bus (not discounted values expressed in €$_{2021}$) in PO2 (incremental over Euro VI).

The column 'Unit cost' indicate the cost per liter or the cost per unit for volume increase or for item unit increase, respectively, where applicable. The column 'Cost' presents the total incremental cost for each technology.

Technology	PO2.Sc1					PO2.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/l	€	Euro VI	Euro 7	Δ	€/l	€
DOC	11.4	14	2.6	43.9	114.2	11.4	14	2.6	43.9	114.2
Improved DOC durability	0	14	14	2.2	30.8	0	14	14	2.2	30.8
15% fleet DOC replacement	0	14	14	43.9	92.2	0	14	14	43.9	92.2
SCR	21.3	37.5	16.2	20.4	330.5	21.3	37.5	16.2	20.4	330.5
Improved SCR durability	0	37.5	37.5	1	37.5	0	37.5	37.5	1	37.5
15% fleet SCR replacement	0	37.5	37.5	20.4	114.8	0	37.5	37.5	20.4	114.8
ASC	7.1	12.5	5.4	16	86.4	7.1	12.5	5.4	16	86.4
Improved ASC durability	0	12.5	12.5	0.8	10	0	12.5	12.5	0.8	10
Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/unit	€	Euro VI	Euro 7	Δ	€/unit	€
Optimised coated DPF	0	1	1	60	60	0	1	1	60	60
Engine-out box	0	1	1	500	500	0	1	1	500	500
2nd urea injector	1	2	1	100	100	1	2	1	100	100
48V EHC peripherals	0	1	1	800	800	0	1	1	800	800
e-cat (EHC)	0	1	1	250	250	0	1	1	250	250

Technology	PO2.Sc3				
	Volume [l]			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/l	€
DOC	11.4	14	2.6	43.9	114.2
Improved DOC durability	0	14	14	4.4	61.6
30% fleet DOC replacement	0	14	14	43.9	184.5
SCR	21.3	37.5	16.2	20.4	330.5
Improved SCR durability	0	37.5	37.5	2	75
30% fleet SCR replacement	0	37.5	37.5	20.4	229.5
ASC (NH3 slip catalyst)	7.1	12.5	5.4	16	86.4
Improved ASC durability	0	12.5	12.5	1.6	20
Technology	Quantity (units)			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/unit	€
Optimised coated DPF	0	1	1	60	60
Engine-out box	0	1	1	500	500
2nd urea injector	1	2	1	100	100
48V EHC peripherals	0	1	1	800	800
48V EHC battery w/ preheat	0	1	1	1500	1500
e-cat (EHC)	0	4	4	250	1000
SAI	0	1	1	100	100
Burner	0	1	1	1500	1500

Table 5-33: Cumulative regulatory costs over 2025-2050 (discounted – NPV2025) for PO2.Sc1 (increments over baseline)

Euro 7 regulatory costs compared to Euro 6/VI						
	LDVs PI	**LDVs CI**	**LDVs Total**	**HDVs PI**	**HDVs CI**	**HDVs Total**
Equipment costs						
1) Hardware costs						
Additional cost per vehicle (€)	81.07	328.35	**213.11**	1,138	1,481	**1,414**
Total additional cost (billion €)	3.19	14.82	**18.01**	1.40	7.53	**8.94**
2) R&D and related calibration costs including facilities and tooling costs						
Additional cost per vehicle (€)	103.52	111.74	**107.91**	1,245	1,248	**1,248**
Total additional cost (billion €)	4.08	5.04	**9.12**	1.54	6.35	**7.88**
Implementation costs						
1) Testing costs						
Additional cost per model / engine family (thousand €)	-2,228	-9,386	**-3,779**	-7,439	-3,121	**-3,897**
Additional cost per vehicle (€)	-21.20	-21.55	**-21.38**	-70.83	-32.90	**-40.30**
Total additional cost (million €)	-834.70	-972.25	**-1,807**	-87.34	-167.34	**-254.68**
2) Witnessing costs						
Additional cost per model / engine family (thousand €)	-156.66	-626.90	**-258.54**	-263.47	-110.54	**-138.01**
Additional cost per vehicle (€)	-1.49	-1.44	**-1.46**	-2.51	-1.17	**-1.43**
Total additional cost (million €)	-58.68	-64.94	**-123.62**	-3.09	-5.93	**-9.02**
3) Type approval fees						
Additional cost per type-approval (thousand €)	-1.83	-2.37	**-2.08**	-0.52	-0.51	**-0.51**
Additional cost per vehicle (€)	-0.34	-0.33	**-0.33**	-0.52	-0.24	**-0.30**
Total additional cost (million €)	-13.32	-14.74	**-28.05**	-0.64	-1.23	**-1.87**
4) Administrative costs related to the implementation process						
Additional cost per type-approval (thousand €)	-97.40	-126.32	**-110.72**	-31.08	-30.35	**-30.59**
Additional cost per vehicle (€)	-18.03	-17.42	**-17.71**	-31.12	-14.46	**-17.71**
Total additional cost (million €)	-710.18	-785.98	**-1,496**	-38.38	-73.53	**-111.91**
Total additional regulatory costs						
Total additional regulatory cost per vehicle until 2050 (€)	143.54	399.36	**280.14**	2,278	2,680	**2,602**
Total additional regulatory cost until 2050 (billion €)	5.65	18.02	**23.67**	2.81	13.63	**16.44**

Table 5-34: Cumulative regulatory costs over 2025-2050 (discounted – NPV2025) for PO2.Sc2 (increments over baseline)

Euro 7 regulatory costs compared to Euro 6/VI						
	LDVs PI	LDVs CI	LDVs Total	HDVs PI	HDVs CI	HDVs Total
Equipment costs						
1) Hardware costs						
Additional cost per vehicle (€)	88.44	328.35	**216.55**	1,138	1,481	**1,414**
Total additional cost (billion €)	3.48	14.82	**18.30**	1.40	7.53	**8.94**
2) R&D and related calibration costs including facilities and tooling costs						
Additional cost per vehicle (€)	115.21	116.26	**115.77**	1,250	1,255	**1,254**
Total additional cost (billion €)	4.54	5.25	**9.78**	1.54	6.38	**7.93**
Implementation costs						
1) Testing costs						
Additional cost per model / engine family (thousand €)	-2,228	-9,386	**-3,779**	-7,439	-3,121	**-3,897**
Additional cost per vehicle (€)	-21.20	-21.55	**-21.38**	-70.83	-32.90	**-40.30**
Total additional cost (million €)	-834.70	-972.25	**-1,807**	-87.34	-167.34	**-254.68**
2) Witnessing costs						
Additional cost per model / engine family (thousand €)	-156.66	-626.90	**-258.54**	-263.47	-110.54	**-138.01**
Additional cost per vehicle (€)	-1.49	-1.44	**-1.46**	-2.51	-1.17	**-1.43**
Total additional cost (million €)	-58.68	-64.94	**-123.62**	-3.09	-5.93	**-9.02**
3) Type approval fees						
Additional cost per type-approval (thousand €)	-1.83	-2.37	**-2.08**	-0.52	-0.51	**-0.51**
Additional cost per vehicle (€)	-0.34	-0.33	**-0.33**	-0.52	-0.24	**-0.30**
Total additional cost (million €)	-13.32	-14.74	**-28.05**	-0.64	-1.23	**-1.87**
4) Administrative costs related to the implementation process						
Additional cost per type-approval (thousand €)	-97.40	-126.32	**-110.72**	-31.08	-30.35	**-30.59**
Additional cost per vehicle (€)	-18.03	-17.42	**-17.71**	-31.12	-14.46	**-17.71**
Total additional cost (million €)	-710.18	-785.98	**-1,496**	-38.38	-73.53	**-111.91**
Total additional regulatory costs						
Total additional regulatory cost per vehicle until 2050 (€)	162.59	403.87	**291.43**	2,282	2,687	**2,608**
Total additional regulatory cost until 2050 (billion €)	6.40	18.22	**24.63**	2.81	13.67	**16.48**

Table 5-35: Cumulative regulatory costs over 2025-2050 (discounted – NPV2025) for PO2.Sc3 (increments over baseline)

Euro 7 regulatory costs compared to Euro 6/VI						
	LDVs PI	**LDVs CI**	**LDVs Total**	**HDVs PI**	**HDVs CI**	**HDVs Total**
Equipment costs						
1) Hardware costs						
Additional cost per vehicle (€)	252.74	387.24	**324.56**	2,004	3,074	**2,865**
Total additional cost (billion €)	9.95	17.47	**27.43**	2.47	15.64	**18.11**
2) R&D and related calibration costs including facilities and tooling costs						
Additional cost per vehicle (€)	115.21	116.26	**115.77**	1,250	1,255	**1,254**
Total additional cost (billion €)	4.54	5.25	**9.78**	1.54	6.38	**7.93**
Implementation costs						
1) Testing costs						
Additional cost per model / engine family (thousand €)	-2,228	-9,386	**-3,779**	-7,439	-3,121	**-3,897**
Additional cost per vehicle (€)	-21.20	-21.55	**-21.38**	-70.83	-32.90	**-40.30**
Total additional cost (million €)	-834.70	-972.25	**-1,807**	-87.34	-167.34	**-254.68**
2) Witnessing costs						
Additional cost per model / engine family (thousand €)	-156.66	-626.90	**-258.54**	-263.47	-110.54	**-138.01**
Additional cost per vehicle (€)	-1.49	-1.44	**-1.46**	-2.51	-1.17	**-1.43**
Total additional cost (million €)	-58.68	-64.94	**-123.62**	-3.09	-5.93	**-9.02**
3) Type approval fees						
Additional cost per type-approval (thousand €)	-1.83	-2.37	**-2.08**	-0.52	-0.51	**-0.51**
Additional cost per vehicle (€)	-0.34	-0.33	**-0.33**	-0.52	-0.24	**-0.30**
Total additional cost (million €)	-13.32	-14.74	**-28.05**	-0.64	-1.23	**-1.87**
4) Administrative costs related to the implementation process						
Additional cost per type-approval (thousand €)	-97.40	-126.32	**-110.72**	-31.08	-30.35	**-30.59**
Additional cost per vehicle (€)	-18.03	-17.42	**-17.71**	-31.12	-14.46	**-17.71**
Total additional cost (million €)	-710.18	-785.98	**-1,496**	-38.38	-73.53	**-111.91**
Total additional regulatory costs						
Total additional regulatory cost per vehicle until 2050 (€)	326.88	462.76	**399.44**	3,149	4,280	**4,060**
Total additional regulatory cost until 2050 (billion €)	12.87	20.88	**33.75**	3.88	21.77	**25.65**

Table 5-36: Total annual regulatory costs (discounted – NPV2025) for PO2.Sc1 (increments over baseline) – negative values express total benefits

Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	2,812	3,955	48.00	1,290	975.11	4,229	57.90	462.63	8,106	5,724
2026	1,179	2,287	19.21	813.45	390.69	1,860	22.40	197.24	4,299	2,470
2027	589.17	1,618	8.90	607.46	184.23	988.80	9.72	99.58	2,824	1,282
2028	343.82	1,316	4.80	501.74	119.54	654.79	5.19	62.31	2,167	841.83
2029	225.98	1,152	3.00	434.15	90.17	516.25	3.64	46.58	1,815	656.64
2030	156.62	1,040	2.05	382.23	78.39	448.67	3.11	39.09	1,581	569.25
2031	111.46	794.54	1.41	293.32	72.81	406.37	2.85	35.11	1,201	517.14
2032	77.29	572.78	0.93	211.93	70.11	376.52	2.75	32.40	862.93	481.78
2033	46.15	365.54	0.46	135.75	67.02	346.76	2.64	29.68	547.90	446.10
2034	21.53	175.91	0.31	65.43	63.66	311.80	2.60	27.63	263.18	405.68
2035	0.00	0.03	0.00	0.00	60.36	279.12	2.35	25.88	0.03	367.70
2036	0.00	0.02	0.00	0.07	57.37	248.58	2.32	24.06	0.10	332.32
2037	0.00	0.02	0.00	0.14	54.42	219.96	2.28	22.36	0.16	299.03
2038	0.00	0.01	0.00	0.20	51.71	193.15	2.25	20.74	0.21	267.86
2039	0.00	0.01	0.00	0.26	45.37	172.25	2.22	19.40	0.26	239.24
2040	0.00	0.00	0.00	0.31	39.51	152.75	2.21	18.12	0.31	212.60
2041	0.00	0.00	0.00	0.40	33.96	134.40	2.16	16.78	0.40	187.30
2042	0.00	0.00	0.00	0.49	28.84	117.21	2.12	15.50	0.49	163.67
2043	0.00	0.00	0.00	0.57	23.99	101.14	2.07	14.30	0.57	141.50
2044	0.00	0.00	0.00	0.64	23.61	96.69	2.02	13.33	0.65	135.66
2045	0.00	0.00	0.00	0.63	23.16	92.43	1.98	12.27	0.63	129.84
2046	0.00	0.00	0.00	0.64	22.78	88.36	1.94	11.27	0.64	124.35
2047	0.00	0.00	0.00	0.64	22.32	84.47	1.89	10.34	0.65	119.02
2048	0.00	0.00	0.00	0.65	21.93	80.80	1.85	9.60	0.65	114.19
2049	0.00	0.00	0.00	0.66	21.48	77.23	1.82	8.78	0.66	109.30
2050	0.00	0.00	0.00	0.66	20.67	74.30	1.78	8.01	0.66	104.76

Table 5-37: Total annual regulatory costs (discounted – NPV2025) for PO2.Sc2 (increments over baseline)

Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	3,063	3,992	51.14	1,301	977.11	4,245	57.99	464.27	8,407	5,745
2026	1,306	2,320	20.81	822.59	391.23	1,863	22.43	197.61	4,469	2,475
2027	691.22	1,645	10.20	614.76	184.77	991.88	9.74	99.88	2,961	1,286
2028	424.77	1,337	5.84	507.44	120.05	657.33	5.21	62.55	2,275	845.14
2029	288.74	1,168	3.81	438.49	90.60	518.29	3.66	46.77	1,899	659.32
2030	203.68	1,052	2.66	385.43	78.74	450.26	3.12	39.23	1,644	571.36
2031	144.20	802.13	1.84	295.30	73.08	407.57	2.86	35.22	1,243	518.73
2032	98.38	576.90	1.21	213.00	70.31	377.36	2.76	32.48	889.50	482.90
2033	58.06	367.31	0.62	136.21	67.15	347.28	2.65	29.73	562.19	446.81
2034	26.47	176.33	0.38	65.54	63.73	312.03	2.60	27.65	268.72	406.01
2035	0.00	0.03	0.00	0.00	60.36	279.12	2.35	25.88	0.03	367.70
2036	0.00	0.02	0.00	0.07	57.37	248.58	2.32	24.06	0.10	332.32
2037	0.00	0.02	0.00	0.14	54.42	219.96	2.28	22.36	0.16	299.03
2038	0.00	0.01	0.00	0.20	51.71	193.15	2.25	20.74	0.21	267.86
2039	0.00	0.01	0.00	0.26	45.37	172.25	2.22	19.40	0.26	239.24
2040	0.00	0.00	0.00	0.31	39.51	152.75	2.21	18.12	0.31	212.60
2041	0.00	0.00	0.00	0.40	33.96	134.40	2.16	16.78	0.40	187.30
2042	0.00	0.00	0.00	0.49	28.84	117.21	2.12	15.50	0.49	163.67
2043	0.00	0.00	0.00	0.57	23.99	101.14	2.07	14.30	0.57	141.50
2044	0.00	0.00	0.00	0.64	23.61	96.69	2.02	13.33	0.65	135.66
2045	0.00	0.00	0.00	0.63	23.16	92.43	1.98	12.27	0.63	129.84
2046	0.00	0.00	0.00	0.64	22.78	88.36	1.94	11.27	0.64	124.35
2047	0.00	0.00	0.00	0.64	22.32	84.47	1.89	10.34	0.65	119.02
2048	0.00	0.00	0.00	0.65	21.93	80.80	1.85	9.60	0.65	114.19
2049	0.00	0.00	0.00	0.66	21.48	77.23	1.82	8.78	0.66	109.30
2050	0.00	0.00	0.00	0.66	20.67	74.30	1.78	8.01	0.66	104.76

Table 5-38: Total annual regulatory costs (discounted – NPV2025) for PO2.Sc3 (increments over baseline) – negative values express total benefits

Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	4,261	4,374	65.65	1,412	1,022	4,890	60.14	526.83	10,113	6,499
2026	2,365	2,659	33.59	921.84	442.51	2,469	24.68	255.62	5,979	3,192
2027	1,621	1,943	21.36	702.21	241.83	1,561	12.08	153.58	4,287	1,969
2028	1,234	1,598	15.49	583.85	182.43	1,191	7.64	112.16	3,431	1,494
2029	986.59	1,394	12.04	504.57	151.58	1,020	6.16	92.46	2,897	1,270
2030	796.88	1,245	9.58	441.86	138.34	921.04	5.66	81.25	2,493	1,146
2031	602.02	950.64	7.18	338.92	131.14	847.67	5.35	74.57	1,899	1,059
2032	429.64	684.36	5.09	244.61	126.86	788.44	5.21	69.24	1,364	989.75
2033	271.10	436.42	3.12	156.57	122.23	730.92	5.04	64.06	867.20	922.25
2034	129.23	209.67	1.59	75.38	116.05	657.27	4.95	59.69	415.86	837.96
2035	0.01	0.03	0.00	0.00	110.06	588.32	4.65	55.74	0.04	758.77
2036	0.00	0.02	0.00	0.08	104.57	523.98	4.58	51.89	0.10	685.01
2037	0.00	0.02	0.00	0.14	99.24	463.68	4.50	48.27	0.16	615.69
2038	0.00	0.01	0.00	0.21	94.26	407.19	4.43	44.84	0.22	550.72
2039	0.00	0.01	0.00	0.26	82.73	363.15	4.36	41.78	0.27	492.02
2040	0.00	0.00	0.00	0.32	72.02	321.95	4.34	39.09	0.32	437.39
2041	0.00	0.00	0.00	0.41	61.93	283.26	4.24	36.22	0.42	385.64
2042	0.00	0.00	0.00	0.50	52.57	247.04	4.14	33.51	0.51	337.25
2043	0.00	0.00	0.00	0.58	43.76	213.17	4.04	30.97	0.59	291.93
2044	0.00	0.00	0.01	0.66	43.04	203.81	3.94	28.73	0.67	279.52
2045	0.00	0.00	0.01	0.65	42.24	194.85	3.85	26.49	0.66	267.43
2046	0.00	0.00	0.01	0.66	41.51	186.28	3.76	24.38	0.67	255.93
2047	0.00	0.00	0.01	0.66	40.70	178.08	3.67	22.41	0.67	244.86
2048	0.00	0.00	0.01	0.67	39.97	170.29	3.59	20.70	0.68	234.55
2049	0.00	0.00	0.01	0.68	39.17	162.78	3.51	18.97	0.69	224.42
2050	0.00	0.00	0.01	0.68	37.69	156.61	3.43	17.33	0.69	215.06

Table 5-39: Total annual regulatory costs (discounted – NPV2025) for the brake wear scenario POx.ScB1 (increments over baseline)

Regulatory costs discounted over NPV (million EUR)	Cars	Vans	LDVs
2025	457.73	58.81	516.54
2026	425.41	54.83	480.24
2027	394.90	51.06	445.96
2028	366.48	47.50	413.98
2029	340.28	44.14	384.43
2030	315.48	40.97	356.45
2031	290.63	37.57	328.19
2032	267.13	34.35	301.48
2033	244.93	31.30	276.23
2034	223.96	28.42	252.38
2035	204.17	25.70	229.87
2036	196.87	24.83	221.70
2037	189.83	23.98	213.82
2038	183.05	23.17	206.22
2039	176.50	22.38	198.88
2040	170.19	21.62	191.81
2041	164.13	20.89	185.02
2042	158.28	20.18	178.46
2043	152.64	19.49	172.13
2044	147.21	18.82	166.03
2045	141.96	18.18	160.14
2046	136.66	17.56	154.22
2047	131.56	16.96	148.52
2048	126.64	16.38	143.03
2049	121.91	15.82	137.74
2050	117.36	15.28	132.65

Table 5-40: Total annual regulatory costs (discounted – NPV2025) for the brake wear scenario POx.ScB2 (increments over baseline)

Regulatory costs discounted over NPV (million EUR)	Cars	Vans	LDVs
2025	2,555	322.62	2,878
2026	2,241	283.17	2,524
2027	1,947	246.27	2,193
2028	1,674	211.77	1,886
2029	1,421	179.56	1,601
2030	1,184	149.50	1,334
2031	1,129	142.42	1,271
2032	1,076	135.66	1,211
2033	1,025	129.18	1,154
2034	976.47	122.99	1,099
2035	930.10	117.06	1,047
2036	896.86	113.09	1,010
2037	864.80	109.26	974.06
2038	833.88	105.55	939.43
2039	804.06	101.96	906.03
2040	775.30	98.50	873.80
2041	747.70	95.15	842.85
2042	721.07	91.91	812.98
2043	695.38	88.78	784.16
2044	670.60	85.76	756.36
2045	646.70	82.83	729.53
2046	622.56	80.01	702.56
2047	599.31	77.28	676.59
2048	576.93	74.64	651.57
2049	555.39	72.09	627.48
2050	534.65	69.62	604.28

Table 5-41: Cumulative regulatory costs (discounted – NPV2025) for PO2.Sc1 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	2,812	3,955	48.00	1,290	975.11	4,229	57.90	462.63	8,106	5,724
2026-2030	2,495	7,413	37.97	2,739	863.02	4,468	44.06	444.80	12,685	5,820
2031-2035	256.43	1,909	3.11	706.43	333.97	1,721	13.19	150.69	2,875	2,218
2036-2040	0.00	0.06	0.00	0.98	248.39	986.69	11.29	104.68	1.04	1,351
2041-2045	0.00	0.01	0.00	2.73	133.57	541.87	10.35	72.18	2.74	757.98
2046-2050	0.00	0.01	0.00	3.25	109.17	405.16	9.28	48.01	3.26	571.62

Table 5-42: Cumulative regulatory costs (discounted – NPV2025) for PO2.Sc2 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	3,063	3,992	51.14	1,301	977.11	4,245	57.99	464.27	8,407	5,745
2026-2030	2,914	7,523	43.32	2,769	865.38	4,481	44.15	446.05	13,249	5,837
2031-2035	327.11	1,923	4.05	710.06	334.63	1,723	13.22	150.95	2,964	2,222
2036-2040	0.00	0.06	0.00	0.98	248.39	986.69	11.29	104.68	1.04	1,351
2041-2045	0.00	0.01	0.00	2.73	133.57	541.87	10.35	72.18	2.74	757.98
2046-2050	0.00	0.01	0.00	3.25	109.17	405.16	9.28	48.01	3.26	571.62

Table 5-43: Cumulative regulatory costs (discounted – NPV2025) for PO2.Sc3 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	4,261	4,374	65.65	1,412	1,022	4,890	60.14	526.83	10,113	6,499
2026-2030	7,004	8,837	92.06	3,154	1,157	7,163	56.22	695.07	19,088	9,071
2031-2035	1,432	2,281	16.97	815.48	606.34	3,613	25.21	323.30	4,546	4,567
2036-2040	0.01	0.06	0.01	1.00	452.82	2,080	22.21	225.87	1.08	2,781
2041-2045	0.01	0.01	0.02	2.81	243.53	1,142	20.20	155.92	2.85	1,562
2046-2050	0.01	0.01	0.03	3.35	199.04	854.04	17.96	103.78	3.39	1,175

Table 5-44: Cumulative regulatory costs (discounted – NPV2025) for the brake wear scenario POx.ScB1 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars	Vans	LDVs
2025	457.73	58.81	516.54
2026-2030	1,843	238.51	2,081
2031-2035	1,231	157.33	1,388
2036-2040	916.45	115.98	1,032
2041-2045	764.22	97.56	861.78
2046-2050	634.14	82.02	716.15

Table 5-45: Cumulative regulatory costs (discounted – NPV2025) for the brake wear scenario POx.ScB2 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars	Vans	LDVs
2025	2,555	322.62	2,878
2026-2030	8,467	1,070	9,537
2031-2035	5,136	647.32	5,783
2036-2040	4,175	528.36	4,703
2041-2045	3,481	444.43	3,926
2046-2050	2,889	373.64	3,262

It is important to assess what will be the impacts of these cost ranges in the structure and sales of the automotive industry. To put these costs into perspective, one needs to put them in the context of current trends in the automotive industry and also compare them to previous emission standards. Structural changes in the automotive industry occur mainly as a result of current and future CO_2 targets. Such climate targets are the main driver behind the uptake of zero-emission vehicles (i.e. BEV, FCEV), which is expected to increasingly intensify over the next decade, as well as the hybridisation of 'conventional' vehicle powertrains. These add significant burden to vehicle price (Table 5-46). However, global advances in the cost of zero-emission technology, such as in batteries, would have an impact on the prices of the automotive industry products. At the same time, expenditure in conventional internal combustion would be decreasing. This path ahead includes value pools shifting to new business models[84].

In the study of FTI Consulting[85] focusing on cars, an analysis was made on costs imposed by new regulations, regarding vehicle emissions. Such costs have been estimated by the Commission in previous impact assessment studies, consultants, research institutions and other entities. Table 5-46 presents the results of the literature review results, focusing and comparing the costs related to the Euro 5 and 6 standards and the CO_2 target of 95 g/km for 2020.

[84] McKinsey, 2019. "RACE 2050 – A vision for the European Automotive Industry"
[85] FTI Consulting, 2015. "Regulation and Competitiveness of the EU Automotive Industry", June 2015

Table 5-46: Equipment[86] cost estimates, for cars/vans, based on open literature (Sources: FTI Consulting, 2015. "Regulation and Competitiveness of the EU Automotive Industry", Evaluation report)

Equipment costs (literature)				
Year	**Regulation/ projected target**	**Estimated cost (€)**	**Comments**	**Sources**
Euro standards				
2009	Euro 5	377-590	Diesel – reducing PM and NOx (sales-weighted average cost)	Impact Assessment - European Commission (2005)[87]
2009	Euro 5	51-105	Petrol – reducing HC and NOx (sales-weighted average cost)	Impact Assessment - European Commission (2005)
2009	Euro 5	900		Effect of regulations and standards on vehicle prices - AEA Technology (2011)
2014	Euro 6	213	Diesel – relative to Euro 5 – upper estimate	Impact Assessment - European Commission (2006)
2014	Euro 6	~300	Cost in 2020 to meet air quality standards	An Economic Assessment of Low Carbon Vehicles - AEA-Ricardo-Cambridge Economics (2013)
2020	Euro 6	PI: 402-465 CI: 751-1703	Hardware costs for Euro 6d vehicles (2014-2020)	Euro 6/VI Evaluation report (2021).
CO_2 targets				
2013	95g/km target (2020)	1000	Relative to 2010 baseline average cost of vehicle	An Economic Assessment of Low Carbon Vehicles - AEA-Ricardo-Cambridge Economics (2013)
2013	95g/km target (2020)	>1000	Relative to 2013 emission levels	Emission regulation: The industry's biggest challenge - Evercore ISI (2014)
2013	95g/km target (2020)	1.750-2.188	Based on 2020 cost curves, relative to 2009 level	Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars - TNO (2011)
2013	95g/km target (2020)	700-900	Volume OEMs, relative to 2013 emission level	CO_2 reduction 2021 and beyond - Roland Berger (2014)
2013	95g/km target (2020)	1.400-1.500	Premium OEMs, relative to 2013 emission level	CO_2 reduction 2021 and beyond - Roland Berger (2014)
2013	95g/km target (2020)	2000	Relative to 2010 baseline average cost of vehicle	CO_2 reduction potentials for passenger cars until 2020 - IKA, Institut fur Kraftfahrzeuge (2012)
2018	Post-2020 CO_2 targets (cars)	419-2.752	Projected cost in 2030	Assessing the impacts of selected options for regulating CO_2 emissions from new passenger cars and vans after 2020 – Ricardo (2018)
2018	Post-2020 CO_2 targets (vans)	426-2,439	Projected cost in 2030	Assessing the impacts of selected options for regulating CO_2 emissions from new passenger cars and vans after 2020 – Ricardo (2018)

[86] Equipment costs include the hardware cost and the necessary R&D and other activities to make this equipment operational on the vehicle.
[87] European Commission, 2005. "Impact Assessment of Euro 5 proposal" {COM(2005) 683 final}

Overall, the Euro 5 and Euro 6 standards each added a cost in the range of 300-900€ (depending on the Euro 6 step considered) to the average cost of passenger cars, although based on the *Evaluation report* this estimate is increased to ~1700 €/veh. for the last Euro 6d step of CI vehicles. On the other hand, the CO_2 standards/targets for 2020, added an incremental regulatory cost in the range of 900-2000€. This indicates an approximate difference of two between the two cost categories, highlighting the added cost burden for manufacturers to improve CO_2 performance of cars. In comparison, for cars/vans the range of additional equipment costs are (over the baseline):

- PO2.Sc1: 180-440€ per car/van (Table 5-33)
- PO2.Sc2: 200-445€ per car/van (Table 5-34)
- PO2.Sc.3: 360-500€ per car/van (Table 5-35)

Similarly, the same summarized table, based on available information, is produced for lorries/buses and presented in Table 5-47.

Table 5-47: Equipment[88] cost estimates for lorries/buses, based on open literature

Equipment costs (literature)				
Year	**Regulation/ projected target**	**Estimated cost (€)**	**Comments**	**Sources**
Euro standards				
2007	Euro VI	2,539 - 4,009	CI, sales weighted average cost per (2012 prices)	Impact Assessment - European Commission (2007)[89]
2016	Euro VI	2,272[90]	Modelling based on a 12L CI engine	Costs of emission reduction technologies for HDV- ICCT (2016)
2020	Euro VI	1,556-€3,635	Hardware costs (2013-2020)	Euro 6/VI Evaluation report (2021)
CO_2 targets				
2018	Post-2020 CO_2 targets	858-7,339	Base cost assumptions 2025	Impact Assessment - European Commission (2018)[91]
2018	Post-2020 CO_2 targets	4,657-33,185	Base cost assumptions 2030	Impact Assessment - European Commission (2018)

The relevant IA[91] for the CO_2 targets of lorries/busses assumes a range of additional costs of 858-7,339 €/vehicle, under base cost assumptions for 2025 and 4,657-33,185€/vehicle for 2030, while the present Euro 7 IA estimates the range of additional/incremental equipment cost, discounted over the 26-year horizon as:

- For PO2.Sc1: 2380-2730 €/lorry and bus (Table 5-33)

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[88] Equipment costs include the hardware cost and the necessary R&D and other activities to make this equipment operational on the vehicle.
[89] European Commission, 2007. "Impact Assessment- Proposal with respect to emissions from on-road heavy duty vehicles and on access to vehicle repair information", COM(2007)851 final
[90] Based on reported $2,280 (2015 value)
[91] European Commission, 2018. "Impact Assessment-Proposal for a Regulation setting CO_2 emission performance standards for new heavy duty vehicles"

- For PO2.Sc2: 2380-2730 €/lorry and bus (Table 5-34)
- For PO3.Sc3: 3250-4330€/lorry and busses (Table 5-35)

This indicates that the incremental costs of Euro 7 implementation over the CO_2 standards are significantly smaller, supporting the notion that CO_2 targets are a major driver concerning socio-economic impacts.

Competitiveness of the EU automotive industry

A specific economic activity is considered competitive if it is successful in penetrating new markets and gaining a comparative advantage in international trade[92]. In this context, the role of robust EU policy development is vital in maintaining a level playing field in terms of market access, allowing the EU automotive industry to maintain its competitive advantage globally. In assessing the contribution of PO2 in this direction, we first assess the current status of the EU industry competitiveness.

The entire EU automotive industry has a strong position in international trade and clearly benefits from the market opportunities on both developed and emerging markets. That said, it should be acknowledged that international competition intensifies on a global stage, with constant technology breakthroughs/advancements to fulfil new emission standards with increased stringency and scope both in terms of air pollutants and CO_2 targets. In terms of policy related to emissions standards, the EU can no longer boast that it is an absolute global leader[93]. Major markets and advanced economies/regions around the world, such as the US and China have, at least in certain areas, introduced more demanding emissions standards and requirements than the current EU framework in place[94,95]. For example, China has already announced a new set of emission limits, part of the forthcoming China 6b standard, to come into effect by 2023. For cars/vans, these limit values, which are fuel-neutral (as in the US) are 40-50% lower compared to current EU pollutant limits (NO_X, THC, NMHC)[94]. US also seems to be more advanced in terms of evaporative emissions control, according to the *Review on Int'l regulations report*.

Obviously, emission standards in different parts of the world are not set as a result of competition between environmental authorities, rather the establishment of standards serves to protect human health. Therefore, standards should be proportional to the environmental problems in the area they have been applicable to. However, emission standards indirectly lead to the development of new technology, promote research and innovation and the green economy. The new technology developed also creates opportunities in other parts of the world. For example, there are discussions currently in the US for further tightening the PM control on the occasion of LEV IV standard[96], which may lead to the introduction GPFs for petrol vehicles, first introduced with Euro 6. Obviously, EU OEMs would be in an advantageous position if this is to be decided.

Introducing the R&D activities and technology required for PO2, especially PO2.Sc3, is expected to boost EU OEMs competitiveness. This is actually required because, in terms of market activity, the sales of EU-manufactured cars relative to global

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[92] Vošta M., Kocourek, A., 2017. "Competitiveness of the European Automobile Industry in the Global Context". Politics in Central Europe, Vol. 13, No. 1

[93] European Commission, 2017. "GEAR 2030 Report", High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the EU

[94] Review on Int'l regulations,

[95] Evaluation report: "*While the introduction of RDE helped the competitiveness of the industry, the fact that the requirements are less stringent than in other regions like the USA, undermines the technological leadership of the EU industry.*"

[96] CARB,2020. Advanced Clean Cars II Meetings & Workshops. Accessed March 2021

sales have decreased since 2007[97]. Moreover, the position of the EU automotive industry has been gradually replaced to an extent by emerging, fast-growing markets, especially those in Asia, and as a consequence the European share in global car production is falling. The EU share on the global production of new motor vehicles shrank from 32% in 2000 to 20% in 2015[98]. More recently, in 2019, over 50% of the world motor vehicle production resides in Asia, while EU-27 has a share of approximately 19%[99] (Figure 5-15).

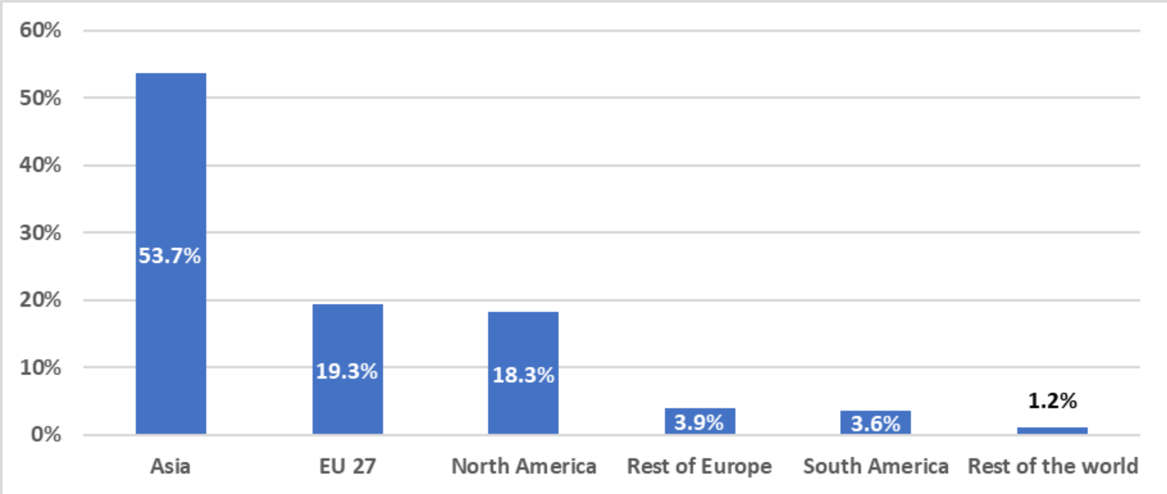

Figure 5-15: World Motor Vehicle Production in 2019 (Source: OICA[99])

Over the last few years, the net exports of the EU automotive industry, in terms of motor vehicles units, has been reduced, while imports have skyrocketed, recording almost a 60% rise in 2019 from 2014 levels. (Table 5-48).

Table 5-48: EU motor vehicles imports/exports in the EU during 2014-2019 (Source: ACEA)

EU motor vehicle trade							
Trade in volume (million units)	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**% change 2014/2019**
Imports	2.63	3.08	3.41	3.66	4.20	4.16	58.5%
Exports	6.05	6.23	6.25	5.88	6.02	5.61	-7.2%

This can act as an indication that the EU automotive industry needs to increase efforts on growing export volumes but also responding to evolving demands, which would entail a stronger emphasis on innovation in order to sustain competition and lead to the growth of global competitiveness. The European automotive industry is faced with the challenge of

[97] European Commission, 2017. “GEAR 2030 Report”, High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the EU
[98] Vošta M., Kocourek, A., 2017. “Competitiveness of the European Automobile Industry in the Global Context”. Politics in Central Europe, Vol. 13, No. 1
[99] OICA, 2021. “2019 *Production Statistics* [online]”. Organisation Internationale des Constructeurs d’Automobiles, assessed on 25.02.21

kickstarting a new growth momentum in Europe to maintain value generation in the region. In addition, Europe must cope with the increasing influence of other markets (i.e. Asia and the North America)[100]. Additionally, awareness of air pollution issues and related policy is increasing in developing countries, such as Brazil and India, which results in added measures to improve environmental performance of vehicles. By stimulating research and development on advanced emission control technologies, making vehicles cleaner, which other countries would inevitably need to implement, the EU will benefit from innovation, investment prospects and the trade export potential. **Overall, if EU standards and targets are more ambitious than those in other countries the technology readiness of European companies may be expected to stay ahead that of suppliers based in other countries.**

In the 2nd Targeted Consultation, focusing on the industrial stakeholders, half of component/equipment suppliers (14 out of 28) indicated that the new emissions standards will increase the competitiveness of the EU automotive industry and its entire supply chain on the global stage, while vehicle OEMs and their associations (13 out of 19) did not share the same view, mainly due to concerns due to potential technology bottlenecks, depending on the stringency level around limit values and testing conditions as well as the increasing competition from battery electric vehicles (BEV). Hence, in the view of components/equipment suppliers, PO2 which foresees increased stringency in terms of limits values and extended testing conditions, is seen as a step towards improving overall competitiveness, while the vehicle OEMs seem to have reservations on such a notion.

Admittedly, PO2 and particularly PO2.Sc3, proposes one of the most stringent set of requirements (if not the most stringent) worldwide, especially in terms of pollutant emission limit values and extended testing conditions under RDE/on-road testing. A potential adoption of PO2.Sc3 will in all indication bring the EU in the forefront globally, in terms of stringency of pollutant emission standards, overtaking the current policy developments in the US and China. **Such a development will enable the EU automotive industry and its supply chain to strengthen their position globally in terms of competitiveness and potentially achieve comparative advantages by concentrating research and development on resource-efficient and less polluting technology that other regions/countries will inevitably need to implement**[101]. Ultimately, an eventual stimulus in EU competitiveness of this kind, may positively impact the main EU production/trade indicators shown above, and potentially increase the market share of EU motor vehicles production globally and EU motor vehicle exports.

However, it should be highlighted that, driven by EU's European Green Deal and 2030 Climate Target Plan initiatives, the EU automotive industry is expected to undergo structural changes in its value chain due to the development of digital technologies and the so-called decarbonization of road transport[102], i.e. the shift towards low and zero-emission mobility[103]. In this context, the manufacturing and uptake of zero-emissions vehicles (BEV, FCEV) as well as digital technologies to support the integration of transport (e.g. connected and automated driving) have become today a major focus area and an integral part of the race of major markets towards maintaining competitiveness and decreasing the dependence on fossil fuels. Such developments may prove to be a

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[100] McKinsey, 2019. "RACE 2050 – A vision for the European Automotive Industry"

[101] European Commission, 2005. "Annex to Thematic Strategy on air pollution and The Directive on Ambient Air Quality and Cleaner Air for Europe", {COM(2005)446 final}{COM(2005)447 final}

[102] European Commission, 2017. "GEAR 2030 Report", High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the EU

[103] The new 2030 Climate Plan aims to accelerate even more the shift toward alternatively-powered and zero-emission mobility by 2030

stronger driver towards increasing EU automotive sector competitiveness, even than more stringent Euro emissions standards, as proposed in PO2. However, the jury is still out. **In particular for lorries & buses, it is not yet clear whether electrification will be able to replace ICEs even towards the long-term horizon of 2050. In this case, developing clean ICE technologies will definitely create competitive advantages over any alternative solutions.**

Table 5-49: Qualitative assessment of PO2 impact on competitiveness

Policy Option 2- Competitiveness		
Key Impacts	**Scale of impact**	**Comments**
Cost savings	-1	Net costs for all vehicle categories in order to introduce the required technology on the vehicles. The height of the costs is up to 2.3% of vehicle price for Sc1 and Sc2 and 2.7% for Sc3 for small vehicles. For larger vehicles, the relative increase is lower.
International market access (parity with other advanced emission standards)	2-3	The indication is that PO2 will bring EU in front of other major regions/markets such as China and USA/California in terms of vehicle emissions standards policy and in the related innovation and technology required to deliver these low emission levels. The scale of the impact depends on whether the most stringent Sc3 (3) will be adopted instead of Sc1 & Sc2 (2)
Innovation capacity (R&D investment, new technologies)	1-2	See subsection: '*Innovation, research and technological leadership*', which encompasses the impact on the capacity to innovate, in terms of competitiveness. A similar trend is expected, especially due to new R&D efforts required, further to emission control, to cope with the increased stringency of PO2. Again, the scale of the impact depends on whether the most stringent Sc3 (2) will be adopted instead of Sc1 & Sc2 (1)

Innovation, research and technological leadership

Implementation of PO2 requires advanced technologies to meet more stringent standards. This will be more essential in the case of PO2.Sc3, as in the case of PO2.Sc1 and PO2.Sc2 it is estimated that cutting edge technology available today or currently under development can play an important role in covering the technological requirements of this option. Overall, PO2 will provide the incentive for the entire automotive industry supply chain (e.g. vehicle manufacturers, emission control technology/components suppliers) to innovate and develop more efficient technologies, the exact scale of which will depend on the chosen scenario. Similar to PO1, PO2 is oriented toward technology neutrality, thus not dictating or singling out a single technology package. This allows a range of propulsion technologies, including advanced combustion engine and emissions aftertreatment technology, and electrified powertrains (e.g. hybrids and plug-in hybrids) to coincide in the market. Increased efforts for innovation would result in greater opportunities for technological advancements and growth and improved chances for the EU automotive industry and its supply chain to maintain their current competitive position on the global stage.

In the 2nd Targeted Consultation almost most stakeholders (48 out of 66) agreed that the new standards will stimulate innovation and R&D activity. However, over than half OEMs (and their associations) (11 out of 19) were particularly concerned for possible technological bottlenecks in case a Best Available Technology (BAT) approach is followed, especially regarding future limits and testing conditions, and that ‘traditional’ internal combustion engine (ICE) businesses and business models will be negatively affected. Overall, 20 out of 44 industrial stakeholders shared this view, while national authorities/TS and civil society (12 out 22) did not offer a clear opinion.**PO2 does not introduce the concept of BAT as the only viable solution but a balanced approach according to mix of technologies presented in section 9.5.3. This reflects an incremental technology improvement which promotes innovation without introducing technology bottlenecks.**

While the implementation of stricter regulatory requirements (in the form of new emissions standards) may require periodic investment and may add an upfront financial burden to the industry, in the long term this can create the proper environment for more incentives in fresh capital investment, helping the EU automotive sector to sustain its level of innovation, gain a leaner structure, adapt to the challenges of the future and better compete with its competitors on a global scale[104].

Table 5-50: Qualitative assessment of PO2 impact on innovation and R&D

Policy Option 2 – Innovation and R&D			
Key Factors	**Category**	**Scale of impact**	**Comments**
Impact on innovation and research	**Vehicle OEMs**	3	Overall, PO2 is expected to: -Stimulate innovation and R&D, for the entire automotive industry supply chain -Facilitate the introduction of new production methods, technologies and products - Create new business and research-related investment opportunities **2nd Targ. Consultation**: Most respondents agreed that the Euro 7 standards will stimulate R&D. Thus, the impact is scaled proportionally from PO1 to PO2, due to the increased requirements technology-wise
	Automotive component suppliers (i.e.Tier 1 suppliers)	3	
	Testing equipment and R&D services (incl. SMEs)	3	
	Type approval services (e.g. TS)	1	As type approval services do not have a direct role in manufacturing, any positive effect will be low.

Functioning of the internal market

Building on the relevant section regarding the impact of PO1 (i.e. Section 0), additional insights are provided here regarding the impact of PO2 on the functioning of the internal market.

During the 1st Targeted consultation, the majority of stakeholders appeared to agree with the fact that a single pan-EU Euro standard (such as the Euro6/VI standard) is more effective in terms of reducing pollution, than the option of MS to act freely on a national level. Overall, it is considered that centralized standardisation in terms of vehicle standards has been a driving factor in the creation of the competent EU single market. On the other hand, during the 2nd targeted consultation, about half of the industrial stakeholders (25 out of 44) expressed their concern that stringent limits (such as those prescribed in PO2) may be more easily met by higher price vehicles and this can potentially lead to market distortion. The main argument of the respondents is that more

[104] European Commission, 2017. “GEAR 2030 Report”, High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the EU

stringent limits could require more complex and costly emission control technology thus resulting in higher prices, which can limit or affect consumer choices (e.g. reluctance to change their old vehicles). On the side of the national/authorities 6 of 16 stakeholders shared the same concern, while over half of civil society respondents disagreed or remained neutral (4 out of 6).

As already mentioned, a number of European countries/cities have proposed sales bans on new fossil-fuel vehicles or are proposing incentive schemes specifically for zero-emission vehicles. Such kind of fragmented introduction of the proposed sales bans, would have a major impact in the EU Single Market, creating uncertainty and probably creating obstacles for people who want to buy and sell used cars within the EU. Therefore, all vehicle technology choices should be supported and available to continue having a positive influence on air quality while guaranteeing that affordable solutions exist for road transport, at least until zero tailpipe emission vehicles become the technology of choice for all EU citizens[105]. In this direction, the increased stringency of PO2, which aims to significantly improve the performance of new vehicles in terms of air pollutants (under all driving conditions), may contribute and provide the necessary assurance to certain EU countries/cities to reconsider/redesign such bans or vehicle access limitations policies.

SMEs

SME Group 1 (vehicle manufacturing)

PO2 introduces some significant new technology requirements for compliance with the decreased emission limits. SMEs specialising in sporty and lightweight vehicles are mostly interested in required developments around petrol engines. As earlier shown, petrol vehicles are assumed to require some larger components on a mild-hybrid basis that we expect will become mainstream even for specialised vehicles.

SME Group 2 (sales, repair, aftermarket)

Based on the findings of the *Evaluation report*, SMEs were mainly suppliers of equipment that, in their majority, were only indirectly affected by the Euro 6/VI emissions standards through the increased demand for improved emissions control and other equipment. In their majority they are not directly affected by the testing and other requirements of the Euro 6/VI standards, as companies that fall in the scope of type approval are, most often, large manufacturers of complete systems (Tier 1 suppliers). Hence, assuming proportionality, the same type of effect for supplier SMEs as in Euro 6/VI can be expected for the implementation of the Euro 7 standard. While some smaller component/systems suppliers in developing countries may be negatively affected due to the lack of latest technology and innovations, to cope with increasing demand for advanced/state-of-the art parts and technologies, the overall effect on SMEs is expected to be minor.

In the 2nd targeted consultation, in a question related to SMEs[106], almost all industrial stakeholders (38 out of 44 respondents) were either uncertain or pessimistic on the potential positive effect on SMEs, active in the development of components and systems. However, most stakeholders acknowledged that the Euro 7 standard will stimulate innovation and R&D in the automotive sector, which will positively impact SMEs as well, in the long run.

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[105] AECC, 2021. “Modern internal combustion engine vehicles are ready to be part of the solution for improved urban air quality”. Assessed on Mar. 2021

[106] “Do stricter Euro 7 standards enhances the role of SMEs in the development of components and systems”

SME Group 3 (type approval, testing and sensors)

For this group of SMEs, the adoption of PO2 is expected to be overall beneficial. Almost 50% of EU SMEs undertook some innovation activity over the period 2014-16, the last years for which such data are available. Some of these SMEs developed disruptive innovation or breakthrough innovation, while others have focused on more incremental innovation[107].

In particular the new standards, would have important spill-over effects, stimulating innovation and research activity by SMEs. Emission control systems/technology development, new testing requirements and the accompanied measurement/sensing technologies (e.g. on-board sensors) will result in new business opportunities and investments. Furthermore, the digitalisation, artificial intelligence, robotics, smart technologies are becoming increasingly important in the entire automotive supply chain, including SMEs. All the above will increase the volume of data on the environmental performance of vehicles, which would require meta-analysis and feed relevant studies/research projects.

As PO2 also includes the aspect of simplification, SMEs such as TS and homologation centres also may be affected negatively to a certain extent.

Stepping up Europe's 2030 climate ambition – Impact on SMEs

In the context of GHG targets related IA[108], although the modelling methods used for macro-economic analysis do not offer clear insights on specific impacts for SMEs, a favourable outlook was projected for such companies. This is because the EU economy is becoming increasingly capital and technology oriented and increasingly focused on the production of new technologies, goods and solutions, around cleaner road transport, which the new Euro 7 standards will also contribute.

Economic affordability for SME users

Regarding economic affordability of SME users, one may assume that these costs will passed onto vehicle pricing. As described in Section 0, (subsection *Social inclusion and affordability)*, the effect of PO2 in current vehicles prices does not exceed 2.7% of the vehicle price (even in the case of the most stringent Scenario3). This can be considered somewhat low, in order to have a measurable impact should be expected in the affordability of such vehicles by SME users.

5.2.3. Cost-benefit analysis

The tables in this section summarise the costs and associated benefits of the two scenarios in PO2. All assumptions that went into formulating the corresponding tables for PO1 (Section 5.1.3) also hold in case of PO2 as well. Ranges shown for any benefits correspond to the normal and conservative development of Euro 6/VI emission levels. Any costs shown only correspond to the central cost estimates within the uncertainty of the calculation.

In comparison to PO1, benefits in terms of cost reductions for compliance appear in Table 5-51 for PO2.Sc1 and in Table 5-53**Error! Reference source not found.** for PO2.Sc2,

[107] European Commission, 2019. "The annual report on European SMEs",
[108] European Commission, 2020. "Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people" COM(2020) 562 final.

together with monetised benefit from the reductions of air pollutants. In general, compliance cost reductions appear similar between PO1 and PO2 because these consider the reductions produced by simplifying the type-approval context. In that respect, there are no major differences between the two policy options as no differences are observed in the type-approval procedure for exhaust emissions. However, costs for evaporation control type approval have increased in this scenario, compared to PO1 and this somewhat decreases the benefit specifically from PI cars and vans. In terms of benefits from air pollution emission reductions, PO2 exhibits much higher overall monetised benefits for all vehicle types and in particular for CI lorries and buses.

Table 5-51: Overview of benefits considered in PO2.Sc1 over the baseline and normal or conservative evolution of Euro 6/VI emission factors.

	Overview of Benefits (total for all provisions) – PO2 Scenario1		
	Description	**Amount**	**Comments**
billion EUR / year	*Direct benefits*		
LDVs-PI	Compliance cost reductions (recurrent)	0.062	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.102 - 0.221	Main recipient of the benefit: Citizens
LDVs-CI	Compliance cost reductions (recurrent)	0.071	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.638 - 1.51	Main recipient of the benefit: Citizens
LDVs	Compliance cost reductions (recurrent)	0.133	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.74 - 1.73	Main recipient of the benefit: Citizens
HDVs-PI (CNG)	Compliance cost reductions (recurrent)	0.005	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.0263 - 0.0263	Main recipient of the benefit: Citizens
HDVs-CI	Compliance cost reductions (recurrent)	0.010	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.29 - 5.07	Main recipient of the benefit: Citizens
HDVs	Compliance cost reductions (recurrent)	0.015	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.32 - 5.1	Main recipient of the benefit: Citizens

The associated total costs for introducing the provisions in this Scenario are shown in **Error! Not a valid bookmark self-reference.** and

Table 5-54 and

Table 5-56 for PO2.Sc1, PO2.Sc2 and PO2.Sc3, respectively. In comparison to PO1, net costs appear for all vehicle categories, due to the significant new hardware required as well as the R&D investment and higher calibration costs that exceed any reductions delivered by the simplification of the type-approval procedure. Similar to PO1, all costs are primarily assigned to OEMs and these are indirectly passed on to the consumers through an increase in vehicle price. In this balance, no cost is assumed for administrations, as any costs are assumed to be passed on to the manufacturers through fees and charges of the type approval process.

Environmental benefits and associated costs are generally higher in PO2.Sc3 than in PO2.Sc1/2 on one hand due to the lower emission limit in this scenario and the more advanced technology required.

Table 5-52: Overview of Costs considered in PO2.Sc1 over the baseline.

Overview of Costs – PO2 Scenario1								
billion EUR		Citizens/Consumers		Businesses		Administrations		
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs-PI	Direct costs	0.000	0.000	3.617	0.078	0.000	0.000
	Indirect costs	0.000	0.217	0.000	0.000	0.000	0.000
LDVs-CI	Direct costs	0.000	0.000	4.838	0.507	0.000	0.000
	Indirect costs	0.000	0.693	0.000	0.000	0.000	0.000
LDVs	Direct costs	0.000	0.000	8.455	0.585	0.000	0.000
	Indirect costs	0.000	0.910	0.000	0.000	0.000	0.000
HDVs-PI (CNG)	Direct costs	0.000	0.000	1.531	0.049	0.000	0.000
	Indirect costs	0.000	0.108	0.000	0.000	0.000	0.000
HDVs-CI	Direct costs	0.000	0.000	6.314	0.282	0.000	0.000
	Indirect costs	0.000	0.524	0.000	0.000	0.000	0.000
HDVs	Direct costs	0.000	0.000	7.844	0.331	0.000	0.000
	Indirect costs	0.000	0.632	0.000	0.000	0.000	0.000

Table 5-53: Overview of Benefits considered in PO2.Sc2 over the baseline and normal or conservative evolution of Euro 6/VI emission factors.

	Overview of Benefits (total for all provisions) – PO2 Scenario2		
	Description	**Amount**	**Comments**
billion EUR / year	*Direct benefits*		
LDVs-PI	Compliance cost reductions (recurrent)	0.062	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.106 - 0.225	Main recipient of the benefit: Citizens
LDVs-CI	Compliance cost reductions (recurrent)	0.071	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.648 - 1.52	Main recipient of the benefit: Citizens
LDVs	Compliance cost reductions (recurrent)	0.133	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.754 - 1.74	Main recipient of the benefit: Citizens
HDVs-PI (CNG)	Compliance cost reductions (recurrent)	0.005	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.0263 - 0.0263	Main recipient of the benefit: Citizens
HDVs-CI	Compliance cost reductions (recurrent)	0.010	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.29 - 5.07	Main recipient of the benefit: Citizens
HDVs	Compliance cost reductions (recurrent)	0.015	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.32 - 5.1	Main recipient of the benefit: Citizens

Table 5-54: Overview of Costs considered in PO2.Sc2 over the baseline

Overview of Costs – PO2 Scenario2							
billion EUR		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs-PI	Direct costs	0.000	0.000	3.617	0.107	0.000	0.000
	Indirect costs	0.000	0.246	0.000	0.000	0.000	0.000
LDVs-CI	Direct costs	0.000	0.000	4.838	0.515	0.000	0.000
	Indirect costs	0.000	0.701	0.000	0.000	0.000	0.000
LDVs	Direct costs	0.000	0.000	8.455	0.622	0.000	0.000
	Indirect costs	0.000	0.947	0.000	0.000	0.000	0.000
HDVs-PI (CNG)	Direct costs	0.000	0.000	1.531	0.049	0.000	0.000
	Indirect costs	0.000	0.108	0.000	0.000	0.000	0.000
HDVs-CI	Direct costs	0.000	0.000	6.314	0.283	0.000	0.000
	Indirect costs	0.000	0.526	0.000	0.000	0.000	0.000
HDVs	Direct costs	0.000	0.000	7.844	0.332	0.000	0.000
	Indirect costs	0.000	0.634	0.000	0.000	0.000	0.000

Table 5-55: Overview of Benefits considered in PO2.Sc3 over the baseline and normal or conservative evolution of Euro 6/VI emission factors.

	Overview of Benefits (total for all provisions) – PO2 Scenario3		
	Description	**Amount**	**Comments**
billion EUR / year	*Direct benefits*		
LDVs-PI	Compliance cost reductions (recurrent)	0.062	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.113 - 0.232	Main recipient of the benefit: Citizens
LDVs-CI	Compliance cost reductions (recurrent)	0.071	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.836 - 1.7	Main recipient of the benefit: Citizens
LDVs	Compliance cost reductions (recurrent)	0.133	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.948 - 1.94	Main recipient of the benefit: Citizens
HDVs-PI (CNG)	Compliance cost reductions (recurrent)	0.005	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.0263 - 0.0263	Main recipient of the benefit: Citizens
HDVs-CI	Compliance cost reductions (recurrent)	0.010	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.35 - 5.13	Main recipient of the benefit: Citizens
HDVs	Compliance cost reductions (recurrent)	0.015	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.38 - 5.15	Main recipient of the benefit: Citizens

Table 5-56: Overview of Costs considered in PO2.Sc3 over the baseline

Overview of Costs – PO2 Scenario3							
billion EUR		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs-PI	Direct costs	0.000	0.000	3.617	0.356	0.000	0.000
	Indirect costs	0.000	0.495	0.000	0.000	0.000	0.000
LDVs-CI	Direct costs	0.000	0.000	4.838	0.617	0.000	0.000
	Indirect costs	0.000	0.803	0.000	0.000	0.000	0.000
LDVs	Direct costs	0.000	0.000	8.455	0.973	0.000	0.000
	Indirect costs	0.000	1.298	0.000	0.000	0.000	0.000
HDVs-PI (CNG)	Direct costs	0.000	0.000	1.531	0.090	0.000	0.000
	Indirect costs	0.000	0.149	0.000	0.000	0.000	0.000
HDVs-CI	Direct costs	0.000	0.000	6.314	0.595	0.000	0.000
	Indirect costs	0.000	0.837	0.000	0.000	0.000	0.000
HDVs	Direct costs	0.000	0.000	7.844	0.685	0.000	0.000
	Indirect costs	0.000	0.987	0.000	0.000	0.000	0.000

The Table 5-57 to **Error! Reference source not found.** present the benefits and costs for the brake wear scenarios Pox. ScB1 and ScB2.

Table 5-57: Overview of benefits considered for the brake wear scenario POx.ScB1 over the baseline

	Overview of Benefits (total for all provisions) – POx.ScB1		
	Description	Amount	Comments
billion EUR / year	*Direct benefits*		
LDVs	Compliance cost reductions (recurrent)	0	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.381	Main recipient of the benefit: Citizens

Table 5-58: Overview of costs considered for the brake wear scenario POx.ScB1 over the baseline

Overview of Costs – POx.ScB1							
billion EUR		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs	Direct costs	0.000	0.000	0.000	0.254	0.000	0.000
	Indirect costs	0.000	0.254	0.000	0.000	0.000	0.000

Table 5-59: Overview of benefits considered for the brake wear scenario POx.ScB2 over the baseline

	Overview of Benefits (total for all provisions) – POx.ScB2		
	Description	**Amount**	**Comments**
billion EUR / year	*Direct benefits*		
LDVs	Compliance cost reductions (recurrent)	0	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.571	Main recipient of the benefit: Citizens

Table 5-60: Overview of costs considered for the brake wear scenario POx.ScB2 over the baseline

Overview of Costs – POx.ScB2							
billion EUR		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs	Direct costs	0.000	0.000	0.000	1.157	0.000	0.000
	Indirect costs	0.000	1.157	0.000	0.000	0.000	0.000

5.2.4. Social impacts

Health benefits

Table 5-61 and

Table 5-62 show the health benefits in monetised terms of the three scenarios in PO2 together with the two scenarios of brake wear control. It is clear that most of the benefits come from the reduction of NO_x but PM_{exh} reductions are also significant, especially in the case of HDVs. Some significant reductions are also visible from the more efficient NH_3 and NMHC control introduced with this policy option. Heath benefits from brake-wear control are measurable due to the significant reductions in PM mass terms achieved in the two scenarios designed.

Table 5-61: Health impacts in monetised terms from PO2 and POx (brake wear) in LDVs.

Health impacts in monetised terms for PO2 and for POx (brake wear) for LDVs (billion EUR)						
Scenario	**Euro 6/VI EF**	**NO_x**	**PM_{exh}**	**PM_{nonexh}**	**NH_3**	**NMHC**
PO2.Sc1	Normal	17.84	0.09	0.00	0.94	0.63
	Conservative	32.67	0.37	0.00	1.45	0.63
PO2.Sc2	Normal	18.15	0.14	0.00	0.94	0.64
	Conservative	32.98	0.42	0.00	1.45	0.64
PO2.Sc3	Normal	18.41	0.16	0.00	0.95	0.70
	Conservative	33.24	0.44	0.00	1.46	0.70
POx.ScA	Normal	0.00	0.00	9.90	0.00	0.00
POx.ScB	Normal	0.00	0.00	14.85	0.00	0.00

Table 5-62: Health impacts in monetised terms from PO2 in HDVs.

Health impacts in monetised terms for PO2 for HDVs (billion EUR)						
Scenario	Euro 6/VI EF	NO_x	PM_{exh}	PM_{nonexh}	NH_3	NMHC
PO2.Sc1	Normal	68.58	6.22	0.00	0.79	0.10
	Conservative	88.80	6.22	0.00	0.79	0.10
PO2.Sc2	Normal	68.58	6.22	0.00	0.79	0.10
	Conservative	88.80	6.22	0.00	0.79	0.10
PO2.Sc3	Normal	69.09	6.29	0.00	0.80	0.11
	Conservative	89.32	6.29	0.00	0.80	0.11

Employment

Overall, PO2 and especially Scenario3, introduces significant new components in emissions control and decreased limits that have a measurable impact on vehicle production costs. With the advent of electrification in vehicle powertrain, additional costs in conventional powertrain development and production may have disproportional consequences if financial and R&D investment in a decaying technology is considered not profitable and viable. Currently, fast shifts towards electrification need to be carefully considered in terms of impacts to employment in the EU automotive sector. There are several concerns that a rapid shift to electromobility may pose tens to hundreds of thousands of jobs in risk[109,110], before new business models around EVs take up the space of the lost ‘traditional’ vehicle manufacturing job positions. It is therefore important to assess whether any policy option proposed under Euro 7 affects this sensitive balance that may threaten employment in the short term in the EU. The following Sections shortly present the current employment status in the automotive industry and the potential impacts that PO2 may have on this.

Current status of employment in the EU automotive sector

Historically, employment in the European automotive industry has exhibited resilience despite difficult circumstances. It has recovered from the most recent global financial and economic crisis and continues to make a significant contribution to GDP, trade and employment[111]. Overall, data for the period 2014-2018 (last year that relevant data are available in Eurostat - Table 5-63) indicate a rise in the total level of employment in the automotive sector including the supply chain, by about 14%. Employment regarding motor vehicles, bodywork and trailers relates to vehicle OEMs, while part/accessories and indirect manufacturing employment is related to component suppliers (i.e. Tier 1 suppliers) and related SMEs. If indirect manufacturing is taken into account, the largest employer is the sector of manufacturing parts and accessories with a 36.6% share of total employment (2018) in the automobile industry, which highlights its importance.

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[109] Autovista Group, Severe job cuts looming as Germany moved to EV production (Accessed March 2021)
[110] Mönnig, Anke; Schneemann, Christian; Weber, Enzo; Zika, Gerd; Helmrich, Robert, 2019 “Electromobility 2035: Economic and labour market effects through the electrification of powertrains in passenger cars”, IAB-Discussion Paper, No. 8/2019, Institut für Arbeitsmarkt- und Berufsforschung (IAB), Nürnberg
[111] ILO, 2021. “The future of work in the automotive industry: The need to invest in people’s capabilities and decent and sustainable work”

In parallel to an increase in employment in the automotive sector over the 2014-2018 time period, Table 5-63 shows that the registrations and production of new motor vehicles, that have both increased in EU 27. This confirms what one would expect that a rise in sales is linked to an increase in employment despite improvements in the production automation that also takes place in parallel in this period.

It must be acknowledged that COVID-19 had a negative impact on the European automotive industry. Evidence in Chapter 4 suggested that new vehicle registrations decreased by about 25% in 2020, compared to 2019 levels. This is directly related to the fact that several manufacturing units had to put their production on hold for certain periods in 2020, mainly due to lockdowns but also due to low consumer demand. Partially due to the lack of EU official data and the on-going developments, the precise implications of COVID-19 for 2020 and 2021, regarding automotive industry employment levels are still largely uncertain. However, IFO Institute[112] already report a prompt decline in the number of working hours within 2020 but do not report any drastic job cuts.

Table 5-63: Number of employees in the EU automotive supply chain per type of industry (Sources: Eurostat, Annual detailed enterprise statistics for industry [Data code: sbs_na_ind_r2]); Eurostat, Gross domestic product at market prices [Data code: NAMA_10_GDP]; ACEA, Motor Vehicle Production[113];SIBYL Model: Number of annual motor vehicle registrations).

EU-27 automotive employment	2014	2015	2016	2017	2018
Motor vehicles	984,942	1,004,390	1,011,060	1,044,571	1,120,455
Bodies (coachwork), trailers and semi-trailers	136,102	137,524	141,153	145,219	158,186
Motor vehicles, bodywork, trailers	**1,121,044**	**1,141,914**	**1,152,213**	**1,189,790**	**1,278,641**
Parts and accessories (for motor vehicles)	1,090,527	1,140,305	1,172,798	1,250,930	1,296,480
Indirect manufacturing[114]	892,885	910,004	899,647	958,152	967,925
Indirect manufacturing & parts/accessories	**1,983,412**	**2,050,309**	**2,072,445**	**2,209,082**	**2,264,405**
Total persons employed	**3,104,456**	**3,192,223**	**3,224,658**	**3,398,872**	**3,543,046**
Relevant Indicators					
GDP (EU27) - b€	**11,781**	**12,211**	**12,550**	**13,070**	**13,518**
New Registrations (MVeh)	11.65	12.91	14.15	14.85	14.94
Production of vehicles (MVeh)	17.22	18.50	19.12	19.33	19.45

Evidence of standards impact on employment from Euro 6/VI

[112] IFO Institute, 2021. Labour Input in the automotive industry (Accessed March 2021).
[113] ACEA, Motor vehicle production, Accessed on March 2021
[114] Includes motor vehicle peripheral systems such as: rubber tyres & tubes, computers, electronics, bearings, driving elements, gears, cooling/ventilation components)

This growth in employment and vehicle sales (dominated by passenger cars) came in the period that Euro 6/VI standards were introduced in the EU. Despite the increased cost of vehicles at Euro 6/VI (see Table 5-46) sales and employment increased fuelled by an increase of GDP in the same period. It is similar to be expected that PO2, which results to vehicle costs lower to what incurred at Euro 6/VI, would also not have any dominant effects in the EU employment in the automotive sector.

The Euro 6/VI evaluation report did not identify any compelling evidence indicating a direct impact of Euro 6/VI standards on employment and this was not an issue raised by any stakeholder as part of the 1st targeted stakeholder consultation. The Euro 6/VI standards may have created new employment in R&D related activities and in activities directly associated with the type-approval/regulatory process or for those suppliers directly affected by increase in the demand for control equipment. This meant that, overall, the adoption of the Euro 6/VI standards has been positive for the automotive supply chain.

Feedback from stakeholders (2nd targeted consultation)

During the 2nd targeted consultation, vehicle OEMs underlined the fact that the impact on employability ultimately depends on the final content and requirements of the new Euro 7 standard and costs required to adapt to the standards. That said, vehicle OEMs highlighted that they are overly concerned that stringent limits and testing over any driving/operating conditions may lead to a strong rise in electric vehicles (EV), i.e. BEV, FCEV, which will have a negative impact on employment, in case that the majority of components are imported from outside the EU. In general, about half of the industrial stakeholders (25 out of 44) claimed that businesses focused on 'traditional' ICE and/or exhaust aftertreatment parts will be negatively affected in terms of number of jobs, mainly due to a growing adoption of EV, which is also driven by EU GHG targets/policy. Regarding national authorities/TS, 6 out of 16 stakeholders agreed with this, while all respondents in civil society and R&D institutions disagreed with such an argument or did not offer a specific opinion.

PO2 leads to a marginal increase of vehicle costs that do not represent more than 2.7% for cars/vans and 5.5% for lorries/busses respectively, of estimated average vehicle prices, even in the more stringent PO2.Sc3 (see Table 5-66). We do not find this to be an adequately compelling reason to justify accelerated shifts to EV. Of course, introducing yet a new emission standard may indirectly affect certain business decisions on the sustainability of particular model lines and their prospective powertrains. However, the correct way to assess whether the responsibility for such decisions need to be born by CO_2 or emission standards is to compare production costs between the alternative options. EVs are much more expensive to build today[115] and are expected to remain more costly to build than ICEs by minimum 9% in 2030[116]. **Therefore, from a shear production cost point of view, it does not make sense to invest to EVs today or in the prompt future over ICEs even when the PO2 package is included in ICE vehicle production costs. Any decisions to shift to EVs are therefore fully steered by targets, financial incentives and business cases owed to CO_2 objectives rather than on applicable emission standards. This is the only way to justify an investment in more costly production. In that respect, any impacts to employment because of shifts to electrification cannot be born by adoption of PO2.**

[115] McKinsey, Making electric vehicles profitable, Accessed March 2021

[116] Financial Times, Electric car costs to remain higher than traditional engines., Accessed March 2021.

On the other hand, a direct positive impact of PO2 on employment may come from the suppliers sector. In the 2nd targeted stakeholder consultation almost half of component/equipment suppliers[117] (13 out of 28 respondents) and almost all MS/national authorities & TS/civil society (14 out of 16 respondents) expressed that the new emission standard, especially in the increased technology level required by PO2.Sc3 will create new business opportunities and quality jobs, particularly in relation to new technologies required such as vehicle exhaust aftertreatment systems, engine optimization and powertrain hybridisation components, that require an increased number of individual components to build.

Evidence from earlier impact assessment studies

We identified and studied previous impact assessments of environmental policies in the automotive sector on their reported impacts on employment. The only relevant studies identified after an extensive review were:

1. Thematic Strategy on Air Pollution and Euro 5/6 standards proposal[118,119]
2. Amending Regulations (EC) No 715/2007 and (EC) No 595/2009[120]
3. Setting post-2020 CO_2 emission performance standards for new cars and vans [121]
4. Stepping up Europe's 2030 climate ambition[122]

Overall, based on individual findings in each impact assessment, one could develop the consensus that on an aggregate/net level, thus accounting for the effects on indirectly affected sector (e.g. energy, digital industry, etc.), there are no significant effects on employment by any of the previous environmental policies introduced. Although some of these impact assessments were in the area of GHG/CO_2, these still comprise a very good proxy for the impacts on employment that advanced technologies, like the ones introduced in PO2, would bring. Hence, the conclusion of this meta-analysis is that although some job functions may change and some industry segments may be negatively or positively affected, the net impact of such environmental policies on employment is negligible.

Additional cost as a hamper of vehicle sales

Due to the small incremental cost of PO2 over Euro 6/VII we felt that a quantification of relative impacts (e.g. using a macroeconomic model based on elasticities) would be rather insensitive and highly uncertain. However, in order to obtain an order of magnitude of potential impacts of larger production costs on employment, we can make analogies to previous studies.

- Case 1 (cars & vans): The IA[123] for the cars/vans CO_2 targets for 2021 estimated a net equipment cost increase in the range of 419-2,752 €/car, the average of which is 1586 €/car, which is almost 4 times higher than those average equipment costs (hardware and R&D) estimated in PO2.Sc3. The same IA, for a particular

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[117] Incl. their associations

[118] European Commission, 2005. "Annex to Thematic Strategy on air pollution and The Directive on Ambient Air Quality and Cleaner Air for Europe", {COM(2005)446 final}{COM(2005)447 final}

[119] European Commission, 2005. "Impact Assessment of Euro 5 proposal"{COM(2005) 683 final}

[120] European Commission, 2014. "Amending Regulations (EC) No 715/2007 and (EC) No 595/2009 as regards the reduction of pollutant emissions from road vehicles", {COM(2014) 28 final}, {SWD(2014) 32 final}

[121] European Commission, 2017. "Setting emission performance standards for new passenger cars and for new light commercial to reduce CO_2 emissions". {COM(2017) 676 final} - {SWD(2017) 651 final}

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

scenario, foresees the following net economic savings over the vehicle lifetime from a societal perspective in 2030

- For cars: 878€
- For vans: 2,247€

Averaging the above values, an aggregated benefit of 1562.5€ is assumed for cars/vans combined. Based on the modelling exercise of the IA, this had a positive +0.02% impact on total/net employment in 2030 (i.e. 43k more jobs), assuming that battery cells are manufactured in the EU. In our case (Euro 7 standards), equipment costs (hardware, R&D and calibration costs), based on:

- PO2.Sc1 and PO2.Sc2 for cars and vans are estimated in the range of 185-450€ per vehicle (depending if a vehicle is PI or CI).
- PO2.Sc3 for cars and vans are estimated in the range of 360-500€ per vehicle (depending if a vehicle is PI or CI).

For this example, we assume an aggregate 300€ irrespective of engine technology. Hence, production costs are expected to increase by 1/5 of the net benefits of the CO_2 legislation for cars and vans combined. This equals to about 8.3k lost jobs, overall representing 0.23% of the workforce in the automotive business (based on Table 5-63, 2018 data).

- Case 2 (lorries & buses): a relevant IA[123] concerning new HDV CO_2 policy/measures estimated net savings of the order of 43-63k €/lorry in 2030 and this was estimated to result to net increase of 0.09% of jobs (217k more jobs). In our case, equipment costs for HDVs (on average assumed as 2540€ per lorry/bus) are expected to increase by less than 1/20 of the net benefits, equalling to 10k lost jobs overall, representing 0.28% of the workforce in the automotive business. We doubt however that any reliable figures of these low levels can be reliably estimated by any kind of model.

Table 5-64: Qualitative assessment of PO2 impact on employment

[123] European Commission, 2018. "Proposal for a Regulation setting CO_2 emission performance standards for new heavy duty vehicles", Table 3, Scenario TL30, range shown for base-high cost assumptions

Policy Option 2 - Employment			
Key Factors	**Category**	**Scale of impact**	**Comments**
Impact on overall employment levels	**Vehicle OEMs**	0	PO2 is associated with a higher increase of costs per vehicle, however this rise was estimated as no more than 2.7% (even for PO2.Sc3) of discounted prices for cars/vans over the modelling horizon[124] due to the new technology that compresses profit margins for OEMs and may have slight negative impacts.
	Automotive component suppliers (i.e.Tier 1 suppliers)	1	2nd Targ. Consultation: Apart from vehicle OEMs, several stakeholders supported that new jobs will be created due to the new technologies/R&D required. PO2 has increased requirements in terms of technology, hence it is estimated that there will be a positive impact on employment
	Testing equipment and R&D services (incl. SMEs)	1	
	Type approval services (e.g. TS)	-1	Simplification intends to reduce complexity and improve efficiency of the legislation. This will entail a decrease in the number of type approvals, which may negatively impact employment levels of type approval services. However, the effect would be low due to the expected activity rise of other (lifetime) compliance testing (ISC, MaS) during Euro 7.

Training systems/skills

Focusing on road transport activity, it is expected that new skills will be required to accompany the technological transition towards low-emission mobility[125]. Since PO2 introduces lower emission limits and extend the coverage of regulated pollutants it is highly likely that the workforce in the automotive supply chain, will need at least to some extent, additional and/or different skills (often referred as "upskilling" and "reskilling") to cope with the development and production of new components and manufacturing processes.

The GEARS3030 Report[126], which focuses on competitiveness and sustainable growth of the automotive industry in the EU, foresees an increased demand for new skills and experience which will be coupled by a fall in demand for other more traditional skills. For example, the move towards electrified powertrains will increase demand for software and digital engineers but is likely to be matched by a reduction in demand for those skilled in the production of more 'traditional' powertrains.

[124] See subsection: Social inclusion and affordability
[125] European Commission, 2016. "A European Strategy for Low-Emission Mobility".{SWD(2016) 244 final}
[126] European Commission, 2017. "GEAR 2030 Report", High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the EU

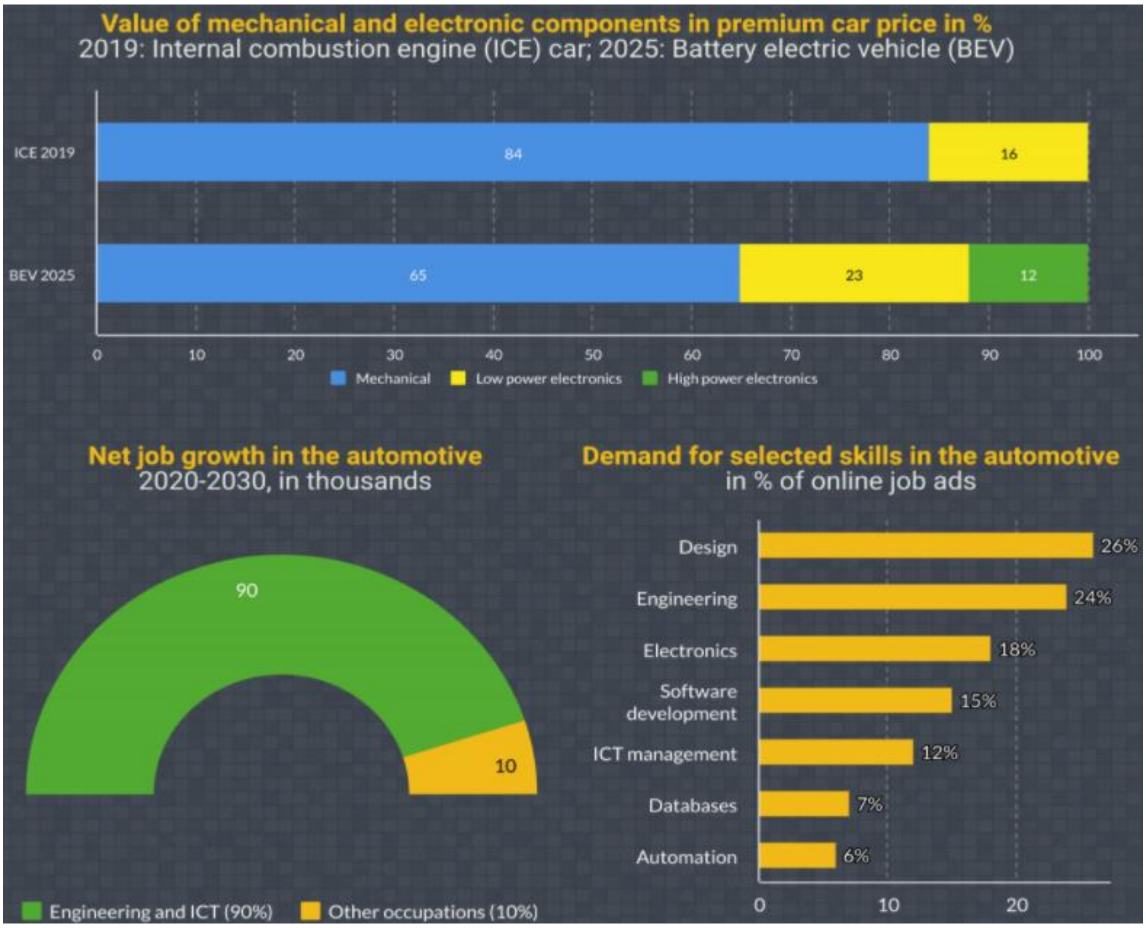

Figure 5-16: The increasing effect of digitalization of car production in terms of technology, skills and employment (Source: CEDEFOP, Skills Panorama)

The ongoing technological innovation means cars are becoming "computers on wheels", as electronics and software may represent up to 35% of a car's value in next 5 years and possibly 50% in 2030[127]. Hence, the ongoing digital transformation in the EU industry presents new opportunities, such as an improved working environment or completely new jobs. Overall, employment quality would improve together with needs for retraining, for example, better technology is required to achieve reductions in vehicle emissions and so this could correlate with a shift towards relatively hi-tech production.

However, this can create need for re-training, for example, a recently published IA on the Sustainable and Smart Mobility Strategy[128], mentions that SMEs in the transport sector on average do not consider their labour force well equipped for the transition to automation and digitalisation. This is in symphony with the feedback received in the 2nd Targeted Consultation, in which most stakeholders indicated that a higher-level education (38 out of 66) and new skills (47 out of 66) will be mostly required for most of the personnel employed in the entire automotive supply chain due to the adoption of the Euro 7 standards.

Table 5-65: Qualitative assessment of PO2 impact on training systems/skills

[127] CEDEFOP, 2021. "Automotive industry at a crossroads". Skills Panorama,2021.
[128] European Commission, 2020. "Sustainable and Smart Mobility Strategy – putting European transport on track for the future", {SWD(2020) 331 final}

Policy Option 2 – Training/Skills			
Key Factors	**Category**	**Scale of impact[129]**	**Comments**
Impact on required education/ skill level of personnel	**Vehicle OEMs**	1	PO2 has increased requirements in terms of technology, mainly due to the lower emission limits, the extension of regulatory coverage to additional pollutants and extended real-world testing conditions. This will require partial reskilling of employees. **2nd Targ. Consultation**: Most respondents indicated that a higher-level education will be mostly required, with the introduction the Euro 7 standards, especially with increased stringency, which is stipulated in PO2. For type-approval services, no appreciable difference to the skills required as this policy does not affect their approach to type-approval over what is required already at Euro 6/VI.
	Automotive component suppliers (i.e.Tier 1 suppliers)	1	
	Testing equipment and R&D services (incl. SMEs)	1	
	Type approval services (e.g. TS)	0	

Social inclusion and affordability

Based on the findings of the *Evaluation report*, most likely the regulatory costs incurred due to a new Euro emission standard[130] should be expected to be passed to consumers, at least in the long term. In that respect, the analysis suggests that in most cases the estimated regulatory costs are in the range of 1%-3% for Euro 6 cars. However, it is very challenging to identify the level of impact the introduction of new standards, with concrete evidence. Pricing policies and the pass-through strategies of incremental costs make it difficult to establish a clear correlation between costs and vehicle prices. Overall, the *Evaluation report*, estimated that level of increase in prices was in the range of 1.7%-4.4% for cars/vans and 3.-7.5% for lorries and less so for buses. It also concluded that there is no tangible evidence to suggest that the impact of the regulatory costs associated with Euro 6/VI are not affordable for consumers.

In order to assess the impact on consumer affordability, current vehicle prices are compared with the estimated net increase in cost per vehicle type, to establish what share of a vehicle price they represent. The following tables illustrate the estimated regulatory cost per vehicle for PO2.

Table 5-66: Analysis of relative regulatory costs of PO2 Sc1, Sc2 and Sc3 over the baseline: economic affordability of consumers

[129] For the legend/custom scale interpretation of impacts see Paragraph 9.7.2

[130] This was also the assumption made in the IA SWDs for both Euro 6 and Euro VI

Economic Affordability of Consumers: Policy Option 2									
	Engine	Vehicle segment	Regulatory cost per vehicle (in euro)			Average vehicle price (in euro)**	Share of vehicle price		
			Sc 1	Sc 2	Sc 3		Sc 1	Sc 2	Sc3
Cars	PI	Small	128.09	145.78	307.87	15,275	0.84%	0.95%	2.02%
		Medium	143.01	162.05	326.40	28,344	0.50%	0.57%	1.15%
		Large	157.92	178.32	344.92	60,430	0.26%	0.30%	0.57%
	CI	Small	344.66	349.17	407.44	15,153	2.27%	2.30%	2.69%
		Medium	373.50	378.01	435.79	28,118	1.33%	1.34%	1.55%
		Large	411.60	416.11	474.28	59,948	0.69%	0.69%	0.79%
Cars	PI-CI*	Small	231.47	243.13	355.35	15,217	1.52%	1.60%	2.34%
		Medium	253.06	265.16	378.63	28,236	0.90%	0.94%	1.34%
		Large	279.07	291.70	407.09	60,200	0.46%	0.48%	0.68%
Lorries	PI-CI*	Small	2,481.4	2,487.97	3,855.85	70,169	3.54%	3.55%	5.50%
		Medium	2,617.10	2,623.61	4,082.62	91,219	2.87%	2.88%	4.48%
		Large	2,796.34	2,802.84	4,390.38	140,337	1.99%	2.00%	3.13%
Buses	PI-CI*	Small	2,328.11	2,333.91	3,621.52	134,522	1.73%	1.73%	2.69%
		Medium	2,453.26	2,459.05	3,832.92	168,152	1.46%	1.46%	2.28%
		Large	2,618.62	2,624.41	4,119.83	201,782	1.30%	1.30%	2.04%

* Weighted average of costs over new registrations.
** Weighted to the number of sales per year and discounted over the time horizon of 2050.

Price elasticity factor

The most used measure of consumers' sensitivity to price is known as "price elasticity of demand." It is the proportionate change in demand given a change in price:

$$Price\ Elasticity\ of\ Demand = \frac{\%\ Change\ in\ Quantity\ Demanded}{\%\ Change\ in\ Price}$$

Based on literature review, certain studies[131,132,133] were identified to estimate the elasticity of demand for cars. It is indicated that total price elasticity of cars is generally close to 1 (100%). For example, assuming an elasticity of 1, a 3% rise in vehicle price, will result in 3% decrease in demand (sales).

One would therefore expect a maximum decrease of sales of the order of the relative increase in vehicle price. However, the estimate is much more difficult than this. First, we have not seen in the past evidence that the emission's standard cost has result to an appreciable decrease in the number of sales (see relevant analysis in the *Evaluation report*). This is because the price elasticity of demand can be felt when all other factors remain equal but this never happens with vehicles. For example, an emission standard introduction often comes with additional vehicle functionalities, therefore it is extremely infrequent that an emission standard's effect can independently be judged. Second, for cars in the higher segments, the cost over price ratio is less than 1% so this cannot be considered to substantially affect sales.

Therefore, price increase could be a limiting factor for the lower segment vehicles, where the cost increase can be a higher percentage of vehicle price. Indeed, this is the entry

[131] Zirogiannis, et. al., 2019. "The effect of CAFE standards on vehicle sales projections: A Total Cost of Ownership approach". Transport Policy Volume 75, March 2019, Pages 70-87
[132] Anderson, et. al., 1997. "Price Elasticity of Demand"
[133] Fridstrøm and Østli, 2021. "Direct and cross price elasticities of demand for gasoline, diesel, hybrid and battery electric cars: the case of Norway", European Transport Research Review. 2021, (13), 1-24.

category for judging the affordability of purchasing a new vehicle. Although we recognise that this can be a true concern, we need again to provide evidence that sales of vehicles rather scales with GDP as shown in Table 5-63 and not to emission standard. Moreover, in the past, the average segment of vehicles sold has been rising rather than lowering, despite the increase in cost. For example, data from ACEA[134] show that in the first year of introduction of Euro 6 standards (2015) EU registered 3.1 million SUV and 4.4 million small (Segment A+B) vehicles. However, in the first year of Euro 5 introduction (2010), the corresponding numbers were 1.5 million SUVs and 5.1 million small vehicles. So the number both grew in size (Table 5-63) and on the average size of vehicle sold, despite the increase in costs. Again, the affordability of purchasing a small car at price increases as low as 0.5-2.5% is mostly determined by how the economy develops rather than the vehicle price.

We note that input from the 2nd targeted consultation by industry representatives, mainly vehicle OEMs, suggests that there would be an increase on vehicles prices due to more stringent Euro 7 limits (as the ones prescribed in PO2), and this will negatively impact consumer demand. On the other hand, one particular civil society stakeholder, strongly disagreed, noting that the introduction of previous Euro steps did not lead to some type of market collapse and was overall cost beneficial as well as leading to major environmental performance improvements (e.g. RDE provisions made vehicles significantly cleaner but not disproportionately more expensive).

Consumer trust

The Euro 7 standard, and PO2 in particular, poses as an opportunity for European vehicle OEMs manufacturers to further modernise, embrace new technologies more strongly and ultimately regain the trust of consumers, which was negatively affected in light of the Dieselgate. In the 2nd Targeted consultation, one civil society stakeholder, highlighted that the growing evidence of non-compliance of vehicles to the current limits (especially regarding on-road testing) has massively damaged the trust in the whole type approval system.

In the *Evaluation report*, it is highlighted that based on feedback received in the 1st targeted consultation, the Euro 6 standards (especially since the introduction of RDE testing) was significant when one also reflects on the important issue of the trust for consumers when it comes to vehicle purchase. This again was linked with the aftermath of the 'Dieselgate' scandal in that respect and thus the importance of a more rigorous testing regime, that positively affected consumer trust. In essence, the introduction of RDE testing along with new type-approval framework that strengthens independent testing, MaS and enforcement procedures, provided increased assurance to consumers that limit values for air pollutant emissions are respected in real-world conditions in the streets and not only in testing labs. As a result, it should be acknowledged that the latest provisions of Euro 6/VI (e.g. as reflected in new Euro 6d-temp/6d cars/vans), has contributed in improving the public's perception on the real level environmental performance of such vehicles on EU roads.

Since the proposed PO2 aims to introduce a large set of new elements, such as lower future limits, additional regulated pollutants, while and increasing current real-world testing (RDE) coverage to reflect all relevant European real-world driving conditions, higher levels of public health and environmental protection are expected to be achieved. This can be expected to have a similar effect as the introduction of RDE, an admittedly

[134] ACEA. New cars by segment in the EU. Accessed March 2021.

revolutionary and highly successful measure, had in the Euro 6 era, thus positively affecting consumer trust in new vehicles, especially towards vehicles equipped with ICE. Based on the above, Table 5-67 provides a summarized estimation on the effect of PO2 in terms of consumers, which is expected to be higher than PO1.

Table 5-67: Qualitative assessment of PO2 impact on consumer trust

Policy Option 2 – Consumer Trust		
Key Factors	**Scale of impact**	**Comments**
Impact on consumer trust in the EU (automotive supply chain)	2	**2nd Targ. Consultation**: Apart from vehicle OEMs, most stakeholders (especially civil society) supported that the new standards will improve consumer trust. For PO2 this positive effect is estimated as higher than PO1 (Score: 2), as it introduces advanced changes, closely resembling the introduction of RDE provisions in the Euro 6 era.

5.3. Policy Option 3

5.3.1. Environmental impacts

PO3 limits are identical to PO2.Sc1/2 and boundary conditions and durability are similar between Scenarios 1 and 2 in PO2 and PO3, for both cars & vans and lorries & buses. However, PO3 introduces the concept of OBM, i.e. the measurement of emissions on-board the vehicle and the demonstration of compliance (or non-compliance) over the useful life of the vehicle. This creates a number of emission benefits, the most important ones being the following ones:

- The deterioration of emission control becomes much lower because the system is constantly monitored therefore any (even minor) malfunction can be early detected thus not affecting the health of aftertreatment devices.
- Vehicles tuning can be optimised and the engine and aftertreatment can be actively recalibrated to respect the limit at any period during the vehicle useful life, without the need to retain high safety margin from the limit while the vehicle is new.
- There are no needs for high thresholds, as is currently the case with OBD-induced compliance monitoring and limits violation can be early detected.
- Emissions control tampering becomes very difficult, as this will be easily detected by the OBM. Currently, OBM functionality can be easily tricked using emulators in place of the actual sensing sensor. However, it is very difficult to emulate the signal of an actual measurement sensor. Moreover, connection of the vehicle through the air for transmission of emission information creates an additional safeguard because an emulated signal (pattern) can be detected. Therefore, tampering will become both technically difficult and financially questionable to conduct.

PO3 has been simulated with two scenarios. In both scenarios, OBM is only materialised for NO_x and NH_3 while PM is only conducted for transmitting the DPF/GPF condition and not the actual emission levels. Such technical possibilities are feasible with today's sensors and no new sensor development is required. PO3.Sc2 extends this advanced

OBM functionality over a wider area of monitoring because of the extended boundary conditions.

Figure 5-17 and Figure 5-18 show the evolution of NO_x emissions in PO3.Sc1 for the normal and conservative evolution of Euro VI emission factors, respectively, while Figure 5-19 and Figure 5-20 show the corresponding reductions for $PM_{2.5}$. For CI cars & vans, this scenario achieves the lowest levels of NO_x from all policy options because it is considered to effectively control emissions throughout the useful life of the vehicle. Moreover, it is assumed to introduce a safeguard over tampering of NO_x emissions control.

We have assumed that no degradation of emission levels is observed if such a scenario is fully materialised as well as that emission control tampering is not anymore practiced. Both these are the result of the actual measurement of the emission levels. By measuring emission levels one can detect an early onset of degradation due to malfunction and inform the driver/enforcement authorities that corrective actions are indeed before the emission control system operation is compromised. In terms of normal degradation, we have in any case observed that this is very mild for current emission control systems – actually PM emission levels may even improve with time as ash accumulates in DPFs and, particularly, GPFs. Moreover, measurement of the actual emission levels may be used to actively adjust the operation of engine and emission control systems (e.g. EGR rate, urea-injection rate) to counterbalance any (expected mild) system degradation. Finally, we have assumed complete elimination of tampering. This is for two reasons, first, it will be technically very difficult to remove all the sensors and replace them with emulated electronic signals that are not detected by the vehicle's ECU or by algorithms that can be located at the cloud server to detect such artificial emission patterns. Second, even if this is made possible, it needs to be at a level of sophistication and cost that we doubt will be of any financial interest to the vehicle owner.

The following figures (Figure 5-21 through Figure 5-24) and Table 5-71 to Table 5-72 show the reductions achieved in this scenario in graphical and numerical forms, respectively. Practically emissions of NO_x for cars and vans go to near-zero emission levels already starting 2040, compared to similar levels reached in 2050 in the baseline emission development. For other pollutants, emission reductions are also measurable and PO3 scenarios bring levels anticipated in 2050 already in 2045. Most importantly, for HDVs, final emission levels reached would have never been materialised in the baseline evolution. Benefits of fuel savings (Table 5-72) due to evaporation control are larger than in PO2 due to the introduction of leak detection to OBD functionalities.

In fact, our calculations on the environmental effectiveness of such an advanced OBM approach may be quite conservative. For example, we have assumed that the tampering rate in Euro 7 will not change compared to Euro 6/VI. It may however be the case that as emission limits decrease - as proposed in PO2 and PO3 - this creates additional motivation to tamper the emission control system in order to eliminate urea consumption and to decrease maintenance costs. Reverting this trend would bring higher environmental benefits than what we have calculated in the current execution of the scenarios.

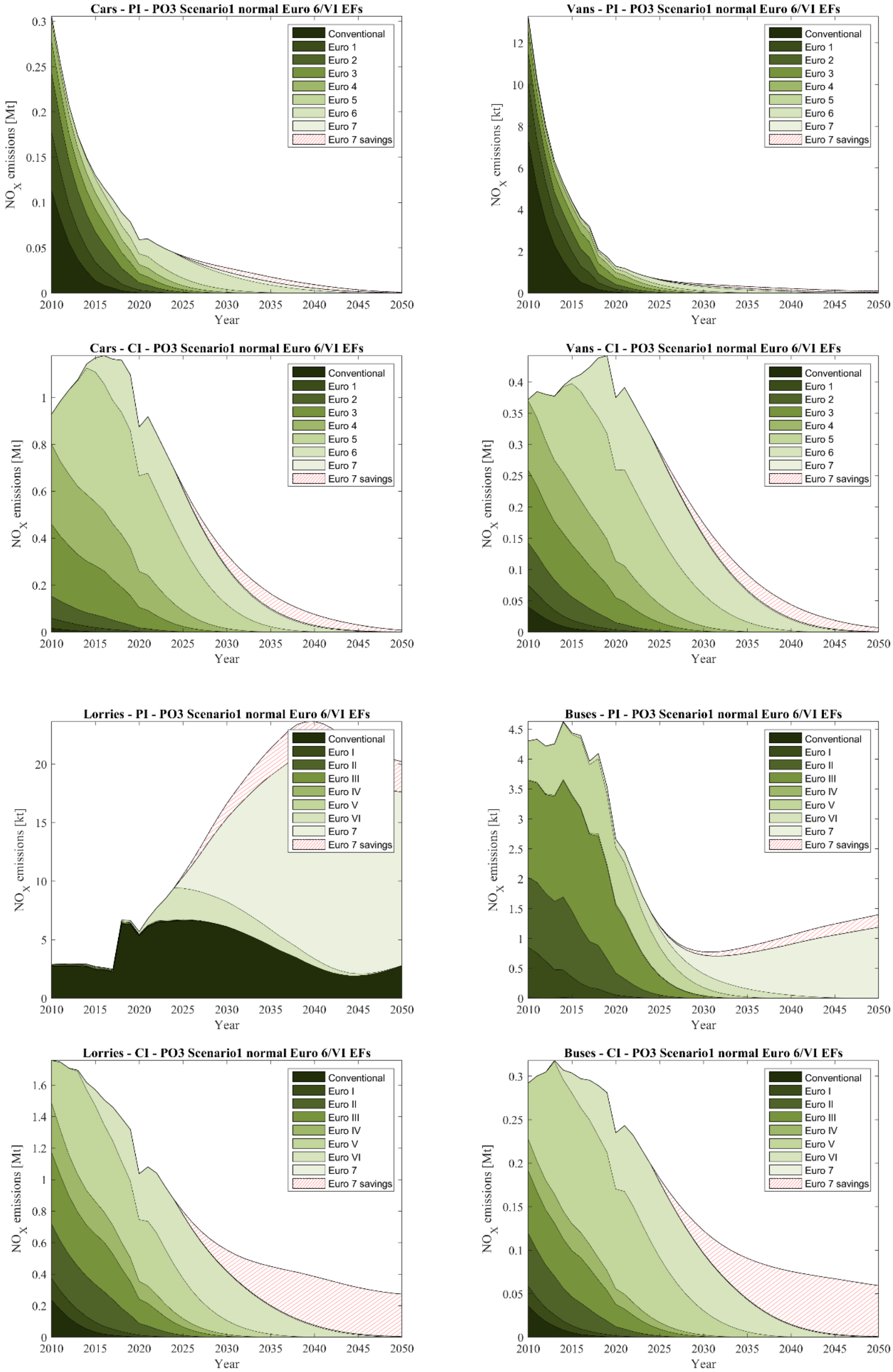

Figure 5-17: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO3.Sc1 over the baseline and normal evolution of Euro 6/VI emission factors.

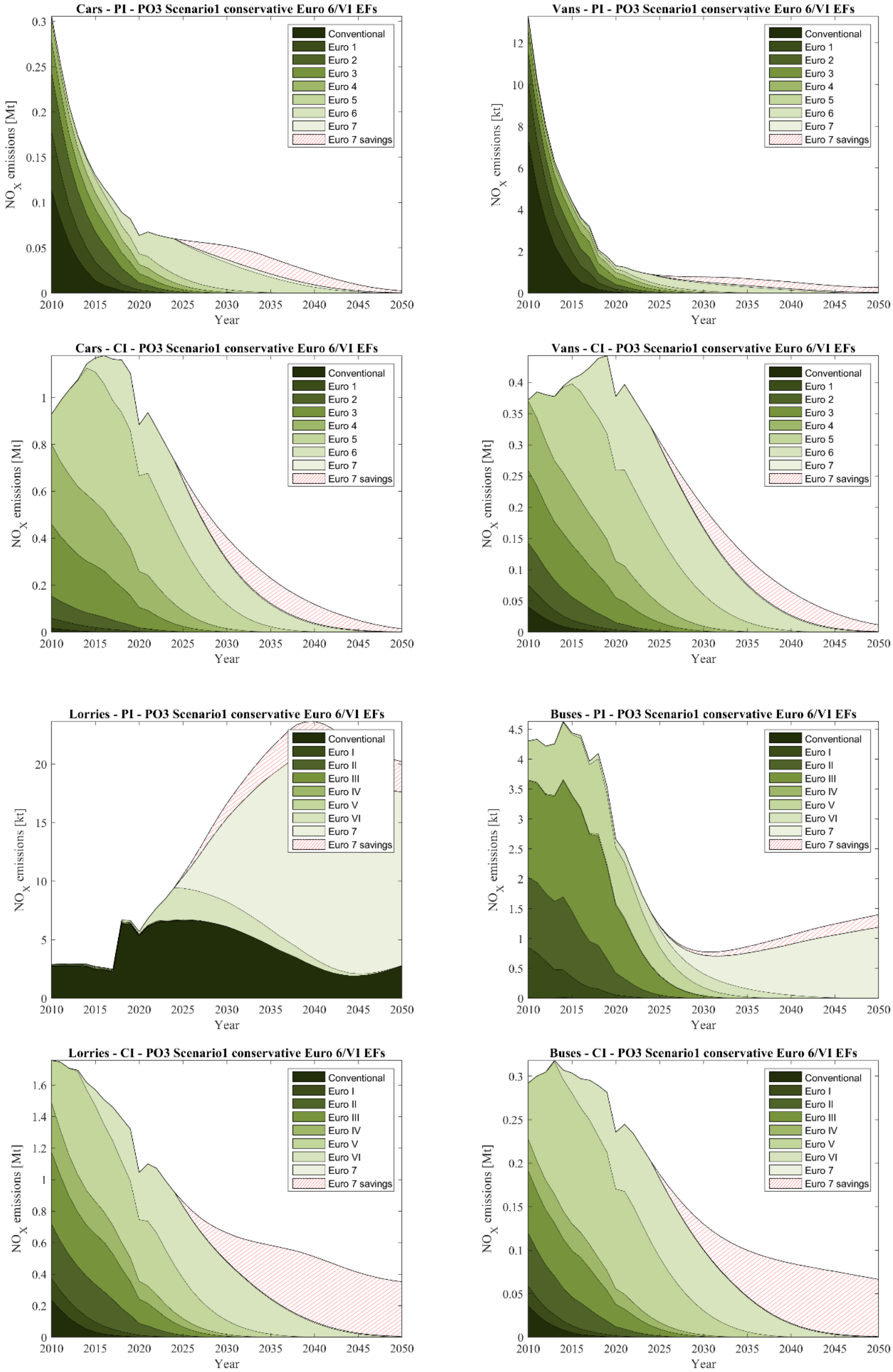

Figure 5-18: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO3.Sc1 over the baseline and conservative evolution of Euro 6/VI emission factors.

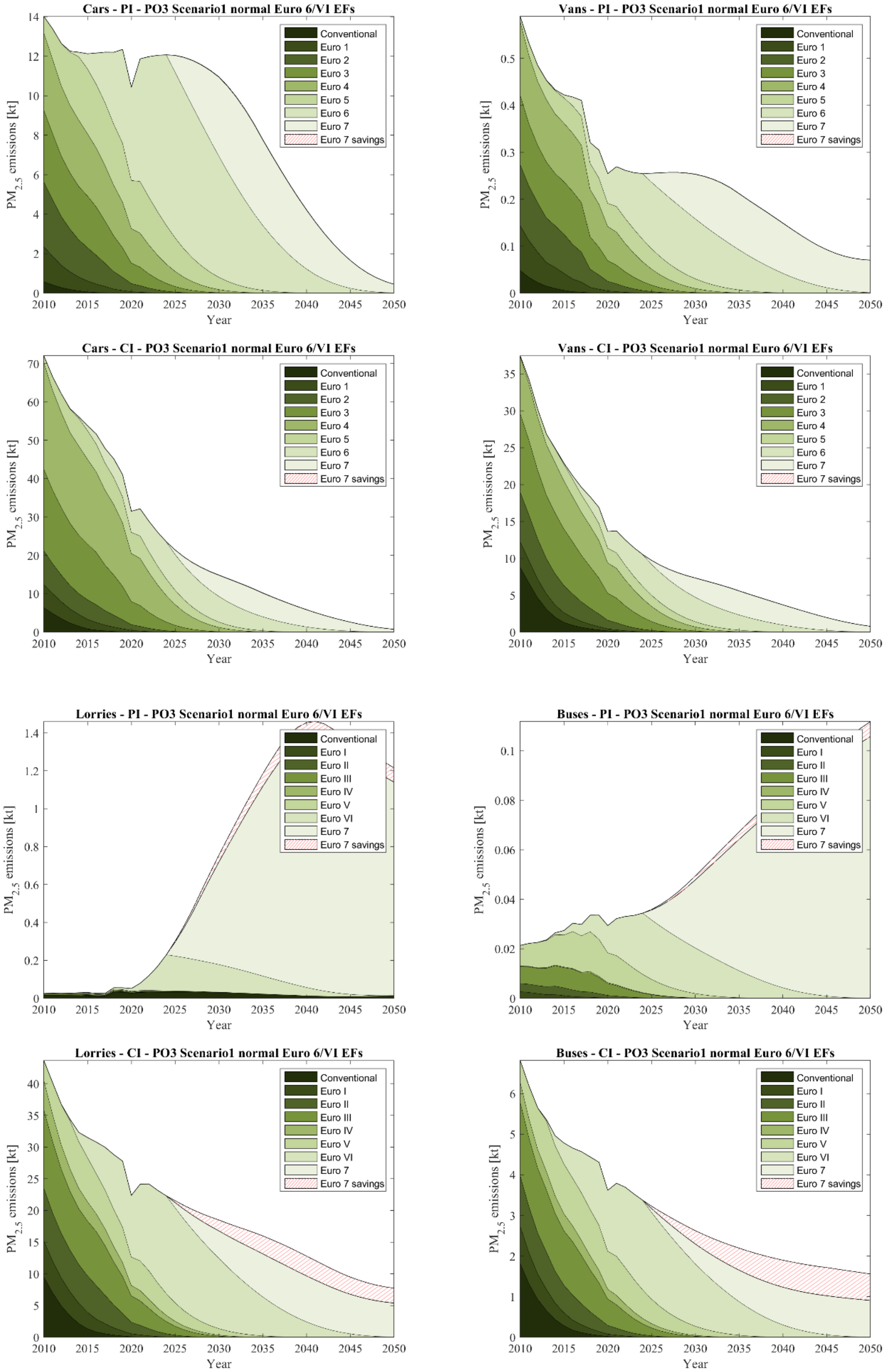

Figure 5-19: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO3.Sc1 over the baseline and normal evolution of Euro 6/VI emission factors.

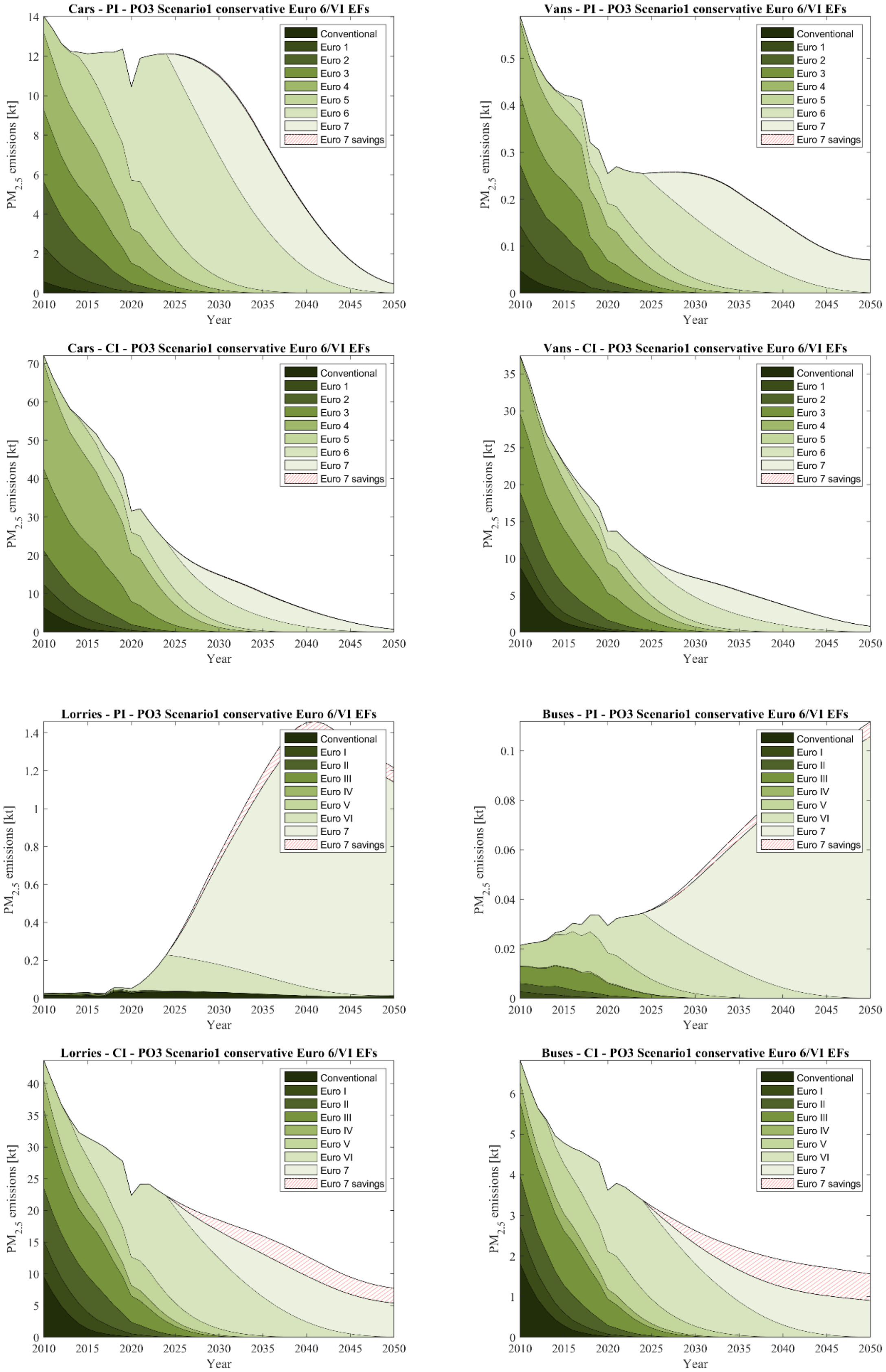

Figure 5-20: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO3.Sc1 over the baseline and conservative evolution of Euro 6/VI emission factors.

Table 5-68: Summary of emission reductions (kT and in % 2025-2050) in PO3.Sc1 for main pollutants and vehicle categories over the baseline and normal evolution of Euro 6/VI emissions.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	2.7	2,466	-12.1	64.5	20.0	20.7	-81.2	373
	%	0.21	20.7	-1.97	27.0	7.23	26.0	-6.20	26.3
NO_x	kt	1,032	85	445	2.00	1,187	3.13	5,841	56.5
	%	21.7	20.5	17.9	25.8	47.9	11.6	50.4	11.06
VOC	kt	86	453	28.5	9.1	14.3	0	63.4	0
	%	22.8	16.2	21.3	19.9	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	91	28.5	1.85	14.3	0	63.4	0
	%	22.8	15.8	21.3	17.5	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	0.474	0.201	0.125	0.0035	13.4	0.09	60.5	1.62
	%	0.205	0.125	0.101	0.077	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	0.474	0.201	0.125	0.0035	13.4	0.09	60.5	1.62
	%	1.35	2.28	0.82	2.13	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	0.474	0.201	0.125	0.0035	13.4	0.09	60.5	1.62
	%	0.115	0.067	0.055	0.040	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	0.474	0.201	0.125	0.0035	13.4	0.090	60.5	1.62
	%	1.35	2.28	0.82	2.13	37.3	25.7	34.8	27.8
SPN_{10}	#	7.35E+20	8.60E+21	2.44E+20	1.82E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	1.78	36.4	1.61	42.5	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	-1,005	54.8	-1,634	0.437	40,005	0	203,404	0
	%	-1.33	0.853	-5.30	0.363	41.5	0.0	38.2	0.0
NMVOC	kt	3.65	452	0.79	9.1	14.7	0	67.8	0
	%	6.7	16.9	3.05	20.8	44.7	0.0	39.2	0.0
NH_3	kt	0.1	80	0.0	2.24	12.0	0.125	66.4	0
	%	0.3	27.3	0.3	36.7	49.6	2.56	49.5	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	-9	0.1	-8	0.001	138	0	702	0
	%	-4.0	0.7	-7.7	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	362	0	7.29	0	0	0	0
	%	-	16.4	-	20.7	-	0.0	-	0.0

Table 5-69: Summary of emission reductions (kT and in % 2025-2050) in PO3.Sc1 for main pollutants and vehicle categories over the baseline and conservative evolution of Euro 6/VI.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries-CI	Lorries - PI
CO	kt	91	2,466	26.2	64.5	20.0	20.7	-81.2	373
	%	6.1	20.7	3.82	27.0	7.23	26.0	-6.20	26.3
NO_x	kt	1,755	289	757	6.76	1,340	3.13	7,766	56.5
	%	29.6	36.3	25.4	44.7	49.9	11.6	54.1	11.06
VOC	kt	86	453	28.5	9.1	14.3	0	63.4	0
	%	22.8	16.2	21.3	19.9	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	91	28.5	1.85	14.3	0	63.4	0
	%	22.8	15.8	21.3	17.5	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	0.805	0.592	0.483	0.429	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	5.01	9.4	3.75	10.3	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	0.453	0.317	0.265	0.225	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	1.88	0.96	0.600	0.020	13.4	0.09	60.5	1.62
	%	5.01	9.4	3.75	10.3	37.3	25.7	34.8	27.8
SPN_{10}	#	1.25E+21	1.20E+22	4.19E+20	2.55E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	2.98	40.0	2.72	47.1	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	41,391	54.8	20,111	0.437	40,005	0	203,404	0
	%	27.4	0.853	30.4	0.363	41.5	0.0	38.2	0.0
NMVOC	kt	3.65	452	0.79	9.1	14.7	0	67.8	0
	%	6.7	16.9	3.05	20.8	44.7	0.0	39.2	0.0
NH_3	kt	0.1	126	0.0	3.74	12.0	0.125	66.4	0
	%	0.3	31.1	0.3	42.6	49.6	2.56	49.5	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	137	0.1	67.3	0.001	138	0	702	0
	%	27.5	0.7	30.6	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	362	0	7.29	0	0	0	0
	%	-	16.4	-	20.7	-	0.0	-	0.0

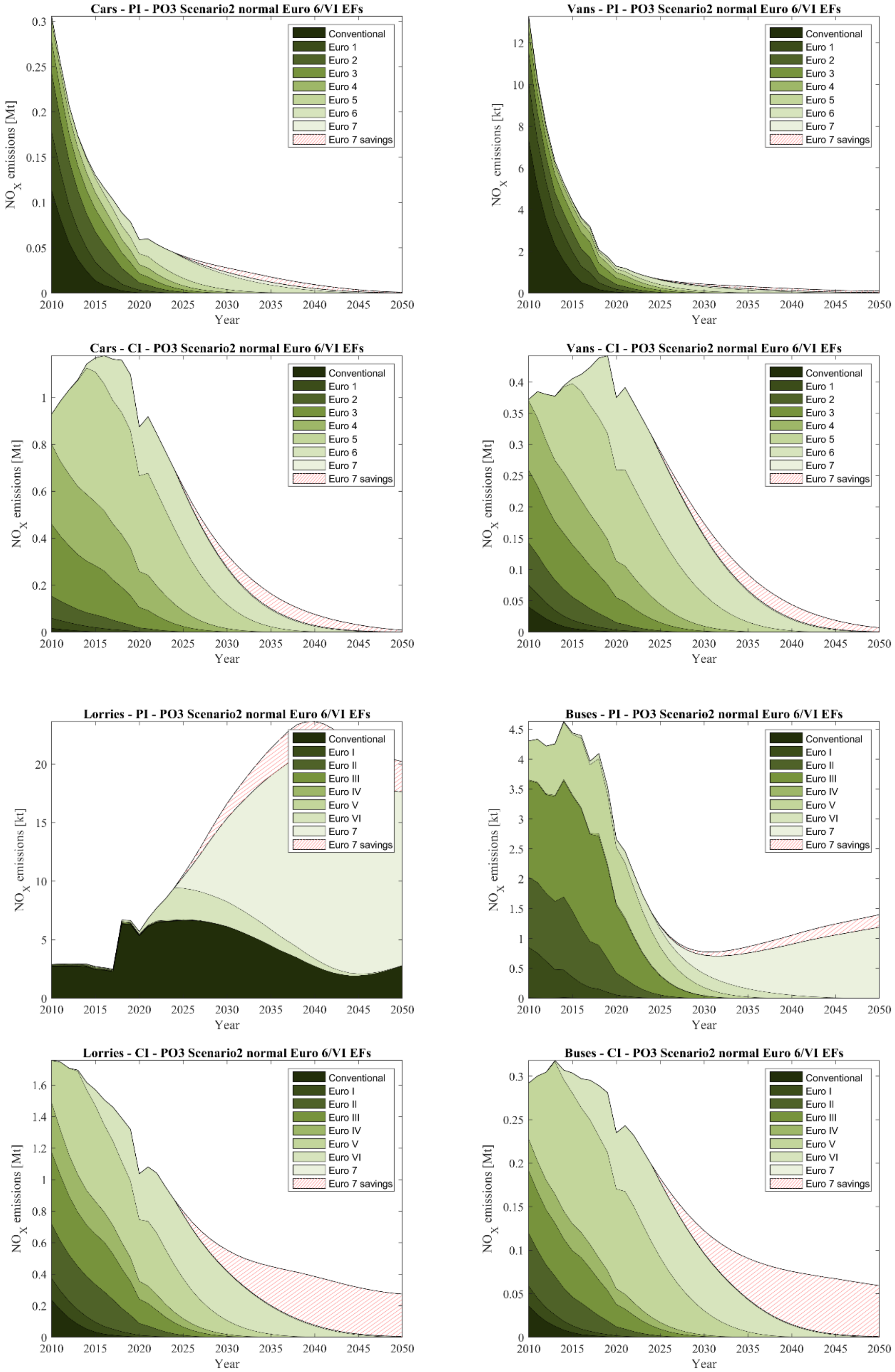

Figure 5-21: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO3.Sc2 over the baseline and normal evolution of Euro 6/VI emission factors.

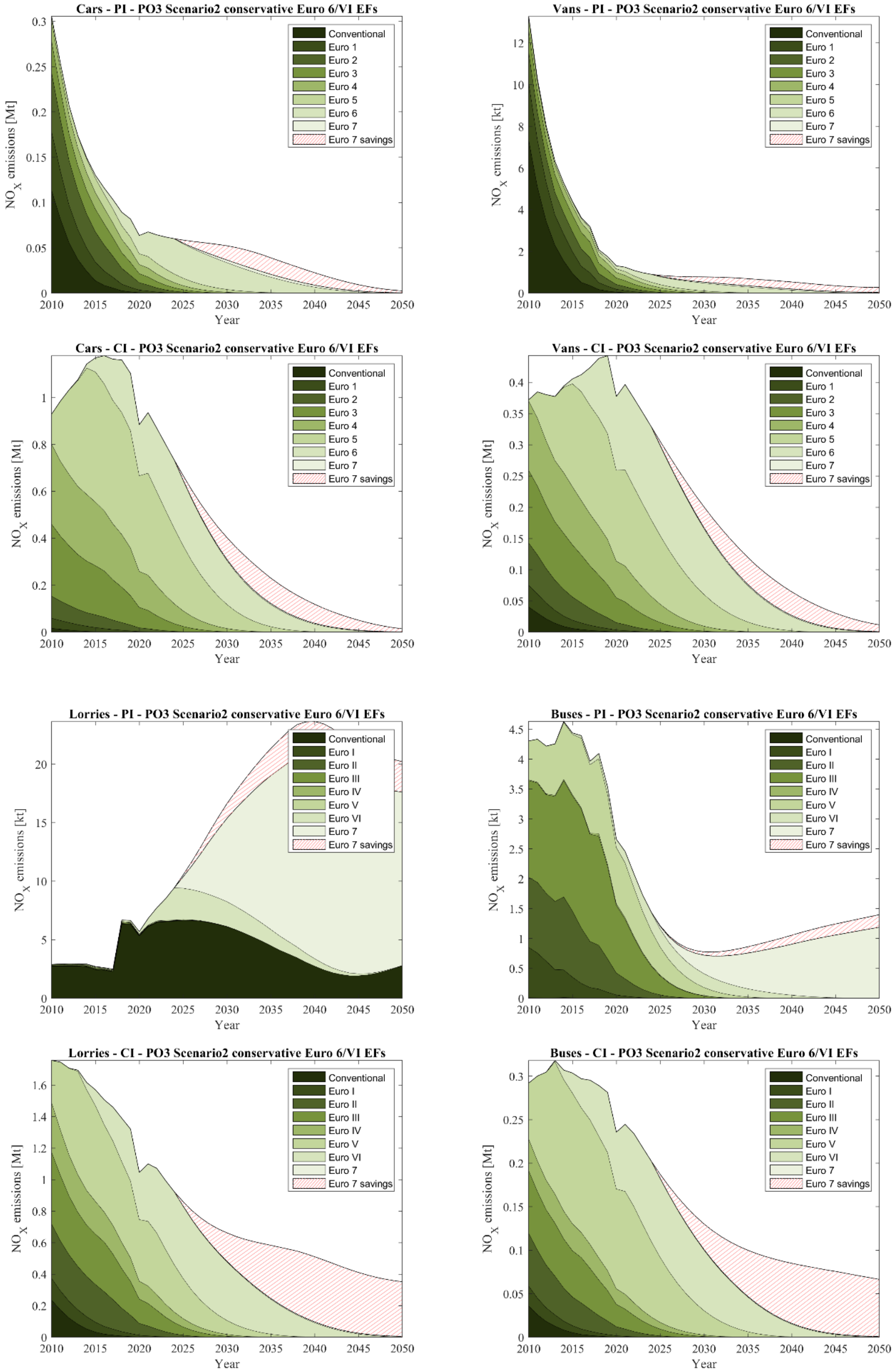

Figure 5-22: Decrease in the evolution of NO_x for cars, vans, lorries and buses for PO3.Sc2 over the baseline and conservative evolution of Euro 6/VI emission factors.

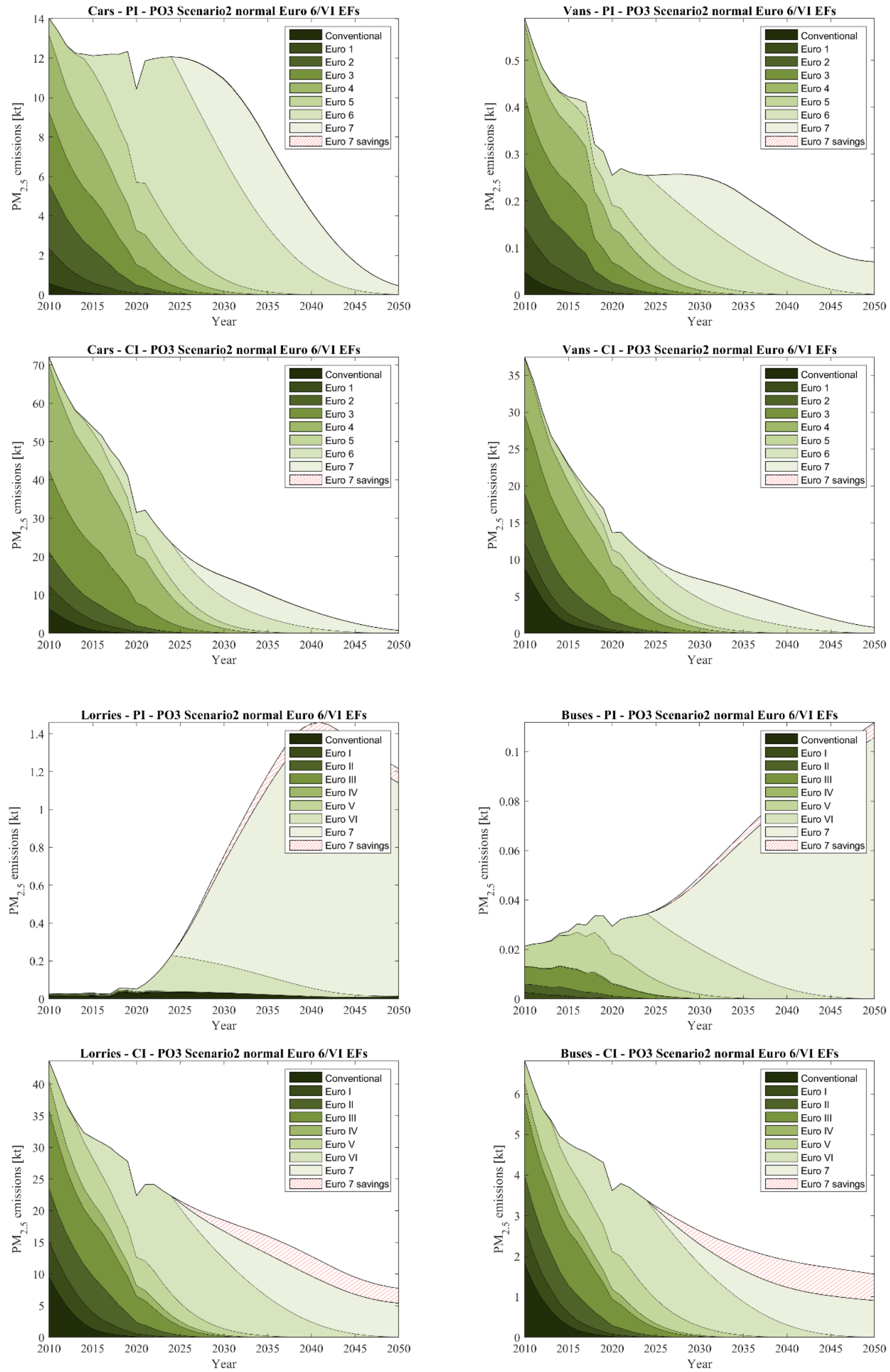

Figure 5-23: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO3.Sc2 over the baseline and normal evolution of Euro 6/VI emission factors.

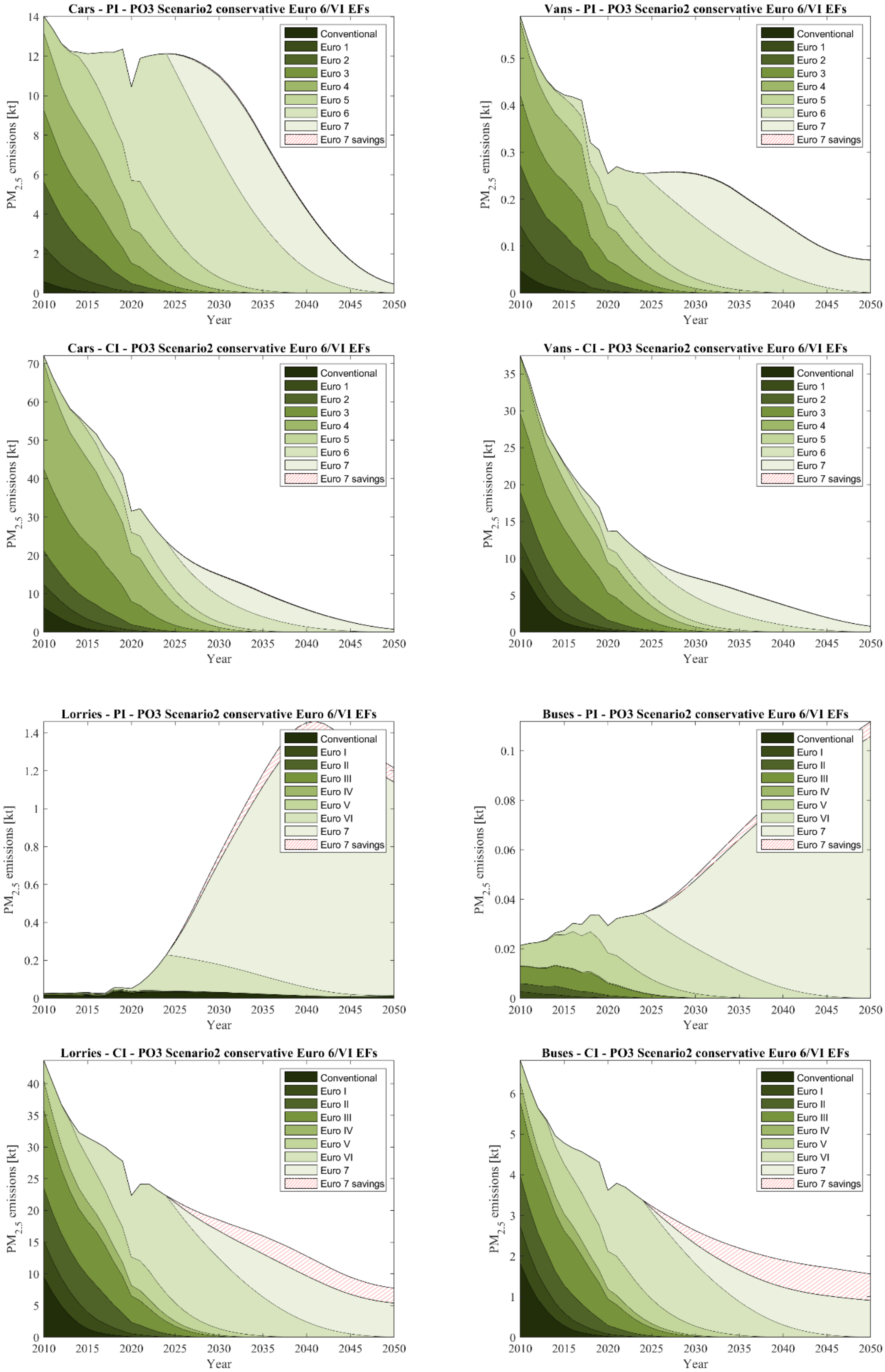

Figure 5-24: Decrease in the evolution of $PM_{2.5}$ for cars, vans, lorries and buses for PO3.Sc2 over the baseline and conservative evolution of Euro 6/VI emission factors.

Table 5-70: Summary of emission reductions (kT and in % 2025-2050) in PO3.Sc2 for main pollutants and vehicle categories over the baseline and normal evolution of Euro 6/VI emission.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	12.5	2,509	-7.6	65.7	20.0	20.7	-81.2	373
	%	0.95	21.0	-1.24	27.5	7.23	26.0	-6.20	26.3
NOx	kt	1,041	92	449	2.15	1,187	3.13	5,841	56.5
	%	21.9	22.1	18.0	27.7	47.9	11.6	50.4	11.06
VOC	kt	86	456	28.5	9.2	14.3	0	63.4	0
	%	22.9	16.3	21.4	20.1	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	94	28.5	1.91	14.3	0	63.4	0
	%	22.9	16.3	21.4	18.0	42.2	0.0	35.6	0.0
PM2.5-TOTAL	kt	0.722	0.342	0.211	0.0065	13.4	0.09	60.5	1.62
	%	0.313	0.213	0.171	0.144	23.8	4.63	16.3	5.68
PM2.5-EXH	kt	0.722	0.342	0.211	0.0065	13.4	0.09	60.5	1.62
	%	2.05	3.87	1.38	3.97	37.3	25.7	34.8	27.8
PM10-TOTAL	kt	0.722	0.342	0.211	0.0065	13.4	0.09	60.5	1.62
	%	0.175	0.113	0.093	0.075	17.4	2.44	11.4	3.33
PM10-EXH	kt	0.722	0.342	0.211	0.0065	13.4	0.090	60.5	1.62
	%	2.05	3.87	1.38	3.97	37.3	25.7	34.8	27.8
SPN10	#	7.95E+20	8.62E+21	2.65E+20	1.83E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	1.93	36.5	1.75	42.6	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	-1,005	54.8	-1,634	0.436	40,005	0	203,404	0
	%	-1.33	0.853	-5.30	0.362	41.5	0.0	38.2	0.0
NMVOC	kt	3.88	455	0.87	9.2	14.7	0	67.8	0
	%	7.2	17.0	3.36	21.0	44.7	0.0	39.2	0.0
NH3	kt	0.1	80	0.0	2.24	12.0	0.125	66.4	0
	%	0.3	27.3	0.3	36.7	49.6	2.56	49.5	0.0
CH4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N2O	kt	-9	0.1	-8	0.001	138	0	702	0
	%	-4.0	0.7	-7.7	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	362	0	7.29	0	0	0	0
	%	-	16.4	-	20.7	-	0.0	-	0.0

Table 5-71: Summary of emission reductions (kT and in % 2025-2050) in PO3.Sc2 for main pollutants and vehicle categories over the baseline and conservative evolution of Euro 6/VI.

Pollutant		Cars - CI	Cars - PI	Vans - CI	Vans - PI	Buses - CI	Buses - PI	Lorries- CI	Lorries - PI
CO	kt	101	2,509	30.7	65.7	20.0	20.7	-81.2	373
	%	6.7	21.0	4.48	27.5	7.23	26.0	-6.20	26.3
NO_x	kt	1,764	296	761	6.91	1,340	3.13	7,766	56.5
	%	29.7	37.1	25.5	45.7	49.9	11.6	54.1	11.06
VOC	kt	86	456	28.5	9.2	14.3	0	63.4	0
	%	22.9	16.3	21.4	20.1	42.2	0.0	35.6	0.0
VOC-EXH	kt	86	94	28.5	1.91	14.3	0	63.4	0
	%	22.9	16.3	21.4	18.0	42.2	0.0	35.6	0.0
$PM_{2.5}$-TOTAL	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	0.911	0.678	0.552	0.496	23.8	4.63	16.3	5.68
$PM_{2.5}$-EXH	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	5.67	10.7	4.29	11.9	37.3	25.7	34.8	27.8
PM_{10}-TOTAL	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	0.513	0.363	0.303	0.260	17.4	2.44	11.4	3.33
PM_{10}-EXH	kt	2.13	1.10	0.686	0.023	13.4	0.09	60.5	1.62
	%	5.67	10.7	4.29	11.9	37.3	25.7	34.8	27.8
SPN_{10}	#	1.31E+21	1.21E+22	4.40E+20	2.56E+20	4.12E+20	3.09E+20	1.88E+21	5.56E+21
	%	3.12	40.1	2.85	47.1	8.31	74.0	6.90	78.8
CH_4+N_2O	kt	41,391	54.8	20,111	0.436	40,005	0	203,404	0
	%	27.4	0.853	30.4	0.362	41.5	0.0	38.2	0.0
NMVOC	kt	3.88	455	0.87	9.2	14.7	0	67.8	0
	%	7.2	17.0	3.36	21.0	44.7	0.0	39.2	0.0
NH_3	kt	0.1	126	0.0	3.75	12.0	0.125	66.4	0
	%	0.3	31.1	0.3	42.6	49.6	2.56	49.5	0.0
CH_4	kt	82	1.38	27.7	0.011	-0.415	0	-4.43	0
	%	25.6	1.14	25.8	0.55	-44.8	0.0	-84.7	0.0
N_2O	kt	137	0.1	67.3	0.001	138	0	702	0
	%	27.5	0.7	30.6	0.3	41.5	0.0	38.3	0.0
VOC-EVAP	kt	0	362	0	7.29	0	0	0	0
	%	-	16.4	-	20.7	-	0.0	-	0.0

Moreover, our assumptions on the ratio of emissions levels of tampered vs untampered vehicles (currently considered in the order of 20:1 for NOx) may again be very low and depends how the tampering will be done. Our current assumption on emission rates for tampered over untampered vehicles is one that would assume that only the tailpipe emission control 'box' will have been removed, in particular for NO_x. However, in PO2 and PO3, an engine-out emission control 'box' will also be required to effectively control cold-start emissions. If this is also manipulated during tampering, then NO_x emission levels of a tampered vehicle may result to be closer to 100 times higher than of a well-operating vehicle (i.e. at engine-out levels). In this case, controlling anti-tampering, as assumed in PO3, will again have a much more significant effect than what we considered in the scenario.

In this version of the report, we have not attempted to conduct more advanced estimates of the potential environmental benefits of PO3. This is not just limited to anti-tampering but, as earlier said, it may also have a number of additional benefits that could be studied by means of a dedicated sensitivity analysis. In summary the additional environmental benefits that PO3 may introduce include:

- Early detection of failures or malfunctions of singular vehicles and comprehensive information to the driver so that any issues can be fast be maintained thus avoiding more severe damage to the powertrain and to the environment.

- Enabling preventive maintenance based on the monitoring of the emission performance thus decreasing maintenance costs for the owner and maintaining an overall better condition of the complete powertrain and its emissions levels.
- Enabling limp mode operation whenever exceedance of general emission levels are detected and no correction measures have been introduced within a reasonable time frame.

It should also be clarified that the two scenarios on further controlling wear emissions of brakes, as these were presented in PO2, can be equally considered in PO3 with the same total environmental benefit as presented in section 5.2.1 (Table 5-28).

Table 5-72: Environmental impacts in monetised terms for PO3 for LDVs.

Environmental impacts in monetised terms for PO3 for LDVs (billion EUR)			
Scenario	**Euro 6/VI EF**	**CH_4+N_2O**	**Fuel savings EVAP**
PO3.Sc1	Normal	-0.28	0.07
	Conservative	9.77	0.07
PO3.Sc2	Normal	-0.28	0.07
	Conservative	9.77	0.07

Table 5-73: Environmental impacts in monetised terms for PO3 for HDVs.

Environmental impacts in monetised terms for PO3 for HDVs (billion EUR)			
Scenario	**Euro 6/VI EF**	**CH_4+N_2O**	**Fuel savings EVAP**
PO3.Sc1	Normal	36.63	0.00
	Conservative	36.63	0.00
PO3.Sc2	Normal	36.63	0.00
	Conservative	36.63	0.00

5.3.2. Economic impacts

Regulatory costs

Particularly for the emissions control technologies, Table 5-74 and Table 5-75 present the cost breakdown for PI and CI cars/vans, respectively. In the case of PI, both gasoline and CNG vehicles are considered, while the technologies related to evaporative emissions control are considered only for gasoline vehicles. Similarly, Table 5-76 and Table 5-77 present the technology cost breakdown for PI (natural gas) and CI lorries/buses, respectively. As in PO2, for both vehicle categories, an additional cost is considered for the more demanding durability requirements, i.e. from 160k km to 200k km. This cost refers to the total volume of the component and it is assumed equal to 5% of its total original cost. Particularly for lorries/buses, and due to increased durability requirements, it is assumed that 15% of the fleet vehicles will also need to replace several of the aftertreatment components during their lifetime, similar to the corresponding scenarios in PO2. Further, a higher cost for OTA data transmission is assumed for lorries/buses than cars/vans, owing to the higher complexity of the CAN-bus and data monitoring system of a lorry over a car.

Table 5-74: Hardware cost breakdown for the average PI car/van (not discounted values expressed in €$_{2021}$) in PO3 (incremental over Euro 6d).

Technology	PO3.Sc1					PO3.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/l	€	Euro 6d	Euro 7	Δ	€/l	€
TWC	1.8/1.6	2.7/2.4	0.9/0.8	80	72.2/64	1.8/1.6	2.7/2.4	0.9/0.8	80	72/64
TWC durability for 200k km	0	2.7/2.4	2.7/2.4	4	10.8/9.6	0	2.7/2.4	2.7/2.4	4	10.8/9.6
Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/unit	€	Euro 6d	Euro 7	Δ	€/unit	€
Optimised coated GPF for gasoline (no size increase)	0	1	1	5	5	0	1	1	15	15
ORVR canister	0	1	1	10	10	0	1	1	10	10
Anti-spitback/vapour valve	0	1	1	2	2	0	1	1	2	2
High flow purge valve	0	1	1	2	2	0	1	1	2	2
Pump for OBD leak check	0	1	1	25	25	0	1	1	25	25
OTA data transmission	0	1	1	40	40	0	1	1	40	40

Table 5-75: Hardware cost breakdown for the average CI car/van (not discounted values expressed in €$_{2021}$) in PO3 (incremental over Euro 6d).

Technology	PO3.Sc1					PO3.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/l	€	Euro 6d	Euro 7	Δ	€/l	€
MHEV and PHEV										
DOC	1.5/1.8	2.2/2.7	0.7/0.9	42	29.4/37.8	1.5/1.8	2.2/2.7	0.7/0.9	42	29.4/37.8
DOC durability for 200k km	0	2.2/2.7	2.2/2.7	2.1	4.6/5.7	0	2.2/2.7	2.2/2.7	2.1	4.6/5.7
SCR	3.7/4.5	5.5/6.8	1.8 2.3	30	54.0/69.0	3.7/4.5	5.5/6.8	1.8/2.3	30	54.0/69
SCR durability for 200k km	0	5.5/6.8	5.5/6.8	1.5	8.3/10.2	0	5.5/6.8	5.5/6.8	1.5	8.3/10.2
SCRF	2.7/3.4	4.1/5.1	1.4/1.7	55	77.0/93.6	2.7/3.4	4.1/5.1	1.4/1.7	55	77/93.6
ASC (NH_3 slip catalyst)	0.9/1.1	1.4/1.7	0.5/0.6	23	11.5/13.8	0.9/1.1	1.4/1.7	0.5/0.6	23	11.5/13.8
ASC durability for 200k km	0	1.4/1.7	1.4/1.7	1.2	1.6/2.0	0	1.4/1.7	1.4/1.7	1.2	1.6/2.0
Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro 6d	Euro 7	Δ	€/unit	€	Euro 6d	Euro 7	Δ	€/unit	€
MHEV										
e-cat (EHC)	0	1	1	125	125	0	1	1	125	125
PHEV										
e-cat (EHC)	0	2	2	125	250	0	2	2	125	250
Turbine bypass	0	1	1	15	15	0	1	1	15	15
OTA Data Transmission	0	1	1	40	40	0	1	1	40	40

Table 5-76: Hardware cost breakdown for the average PI lorry/bus (not discounted values expressed in €$_{2021}$) in PO3 (incremental over Euro VI E).

Technology	PO3.Sc1					PO3.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/l	€	Euro VI	Euro 7	Δ	€/l	€
TWC (for CNG λ=1)	10	15	5	80	400	10	15	5	80	400
Improved TWC durability	0	15	15	4	60	0	15	15	4	60
15% fleet TWC replacement	0	15	15	80	180	0	15	15	80	180
PF for CNG	0	12.8	128	57.2	732.7	0	12.8	128	57.2	732.7
Oxidation Catalyst (OC)	11.4	14	2.6	43.9	114.2	11.4	14	2.6	43.9	114.2
Improved OC durability	0	14	14	2.2	30.8	0	14	14	2.2	30.8
15% fleet OC replacement	0	14	14	43.9	92.2	0	14	14	43.9	92.2
SCR	21.3	37.5	16.2	20.4	330.5	21.3	37.5	16.2	20.4	330.5
Improved SCR durability	0	37.5	37.5	1	37.5	0	37.5	37.5	1	37.5
15% fleet SCR replacement	0	37.5	37.5	20.4	114.8	0	37.5	37.5	20.4	114.8
ASC	7.1	12.5	5.4	16	86.4	7.1	12.5	5.4	16	86.4
Improved ASC durability	0	12.5	12.5	0.8	10	0	12.5	12.5	0.8	10
Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/unit	€	Euro VI	Euro 7	Δ	€/unit	€
Optimised PF for LNG	0	1	1	60	60	0	1	1	60	60
Engine-out box	0	1	1	500	500	0	1	1	500	500
2nd urea injector	1	2	1	100	100	1	2	1	100	100
OTA data transmission	0	1	1	60	60	0	1	1	60	60

Table 5-77: Hardware cost breakdown for the average CI lorry/bus (not discounted values expressed in €2021) in PO3 (incremental over Euro VI).

Technology	PO3.Sc1					PO3.Sc2				
	Volume [l]			Unit cost	Cost	Volume [l]			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/l	€	Euro VI	Euro 7	Δ	€/l	€
DOC	11.4	14	2.6	43.9	114.2	11.4	14	2.6	43.9	114.2
Improved DOC durability	0	14	14	2.2	30.8	0	14	14	2.2	30.8
15% fleet DOC replacement	0	14	14	43.9	92.2	0	14	14	43.9	92.2
SCR	21.3	37.5	16.2	20.4	330.5	21.3	37.5	16.2	20.4	330.5
Improved SCR durability	0	37.5	37.5	1	37.5	0	37.5	37.5	1	37.5
15% fleet SCR replacement	0	37.5	37.5	20.4	114.8	0	37.5	37.5	20.4	114.8
ASC	7.1	12.5	5.4	16	86.4	7.1	12.5	5.4	16	86.4
Improved ASC durability	0	12.5	12.5	0.8	10	0	12.5	12.5	0.8	10
Technology	Quantity (units)			Unit cost	Cost	Quantity (units)			Unit cost	Cost
	Euro VI	Euro 7	Δ	€/unit	€	Euro VI	Euro 7	Δ	€/unit	€
Optimised coated DPF	0	1	1	60	60	0	1	1	60	60
Engine-out box	0	1	1	500	500	0	1	1	500	500
2nd urea injector	1	2	1	100	100	1	2	1	100	100
48V EHC peripherals	0	1	1	800	800	0	1	1	800	800
e-cat (EHC)	0	1	1	250	250	0	1	1	250	250
OTA data transmission	0	1	1	60	60	0	1	1	60	60

Table 5-78 and Table 5-79 show the total regulatory costs for PO3. With PO3, higher benefits appear both in terms of simplification and reduced air pollutants emissions, compared to the previous two policy options. The latter is justified as PO3 introduced the concept of OBM and, int this was achieved better overall environmental performance of vehicles as in detailed analysed in the previous sections. The benefits from simplification of the type approval procedure come from the fact that we have estimated a further drop of 30% in the number of necessary type approvals for PO3. This drop is considered to reflect the fact that OBM can enable a wider family concept, i.e. under a single OBM family. In that respect, if emissions are measured and the OBM family is validated, the type approval authority will not need to go over all details of the emission control system; the basic thing will be to make sure that the OBM system measures and reports correctly. All possible incompliances can then be monitored even without knowing the details of the system. OBM families are considered to be much less than emission control families, in the sense that the basic architecture can only be the same. Actually, in an ideal application of OBM implementation, only one type approval per powertrain concept per manufacturer would be needed. Our approach is a more conservative one assuming limitations in the lower number of OBM families possible, for practical reasons (dimensions, sensors placing, etc.).

It should be again repeated that all these tables present discounted values over the complete modelling time frame. Moreover, when benefits are shown per model/engine family, one will have to consider that this refers to the remaining families in the policy option which is lower than in the baseline for reasons outlined above. Hence the benefit of simplification per remaining family appears higher than what this would have been if all families in the baseline remained in circulation.

Table 5-78: Cumulative regulatory costs over 2025-2050 (discounted – NPV2025) for PO3.Sc1 (increments over baseline)

Euro 7 regulatory costs compared to Euro 6/VI						
	LDVs PI	**LDVs CI**	**LDVs Total**	**HDVs PI**	**HDVs CI**	**HDVs Total**
Equipment costs						
1) Hardware costs						
Additional cost per vehicle (€)	128.94	353.93	**249.08**	1,161	1,507	**1,440**
Total additional cost (billion €)	5.08	15.97	**21.05**	1.43	7.67	**9.10**
2) R&D and related calibration costs including facilities and tooling costs						
Additional cost per vehicle (€)	78.68	104.90	**92.68**	1,334	1,332	**1,333**
Total additional cost (billion €)	3.10	4.73	**7.83**	1.65	6.78	**8.42**
Implementation costs						
1) Testing costs						
Additional cost per model / engine family (thousand €)	-3,328	-11,631	**-5,127**	-11,306	-4,775	**-5,948**
Additional cost per vehicle (€)	-31.66	-26.70	**-29.01**	-107.64	-50.33	**-61.52**
Total additional cost (million €)	-1,247	-1,205	**-2,451**	-132.73	-256.03	**-388.76**
2) Witnessing costs						
Additional cost per model / engine family (thousand €)	-230.11	-776.87	**-348.56**	-400.41	-169.12	**-210.67**
Additional cost per vehicle (€)	-2.19	-1.78	**-1.97**	-3.81	-1.78	**-2.18**
Total additional cost (million €)	-86.19	-80.48	**-166.66**	-4.70	-9.07	**-13.77**
3) Type approval fees						
Additional cost per type-approval (thousand €)	-3.83	-4.19	**-4.00**	-1.12	-1.10	**-1.11**
Additional cost per vehicle (€)	-0.50	-0.40	**-0.45**	-0.79	-0.37	**-0.45**
Total additional cost (million €)	-19.56	-18.26	**-37.82**	-0.97	-1.88	**-2.85**
4) Administrative costs related to the implementation process						
Additional cost per type-approval (thousand €)	-204.42	-223.60	**-213.25**	-67.35	-66.30	**-66.65**
Additional cost per vehicle (€)	-26.49	-21.59	**-23.87**	-47.30	-22.12	**-27.03**
Total additional cost (million €)	-1,043	-974.00	**-2,017**	-58.33	-112.50	**-170.83**
Total additional regulatory costs						
Total additional regulatory cost per vehicle until 2050 (€)	146.79	408.36	**286.46**	2,335	2,765	**2,681**
Total additional regulatory cost until 2050 (billion €)	5.78	18.43	**24.21**	2.88	14.06	**16.94**

Table 5-79: Cumulative regulatory costs over 2025-2050 (discounted – NPV2025) for PO3.Sc2 (increments over baseline)

Euro 7 regulatory costs compared to Euro 6/VI						
	LDVs PI	**LDVs CI**	**LDVs Total**	**HDVs PI**	**HDVs CI**	**HDVs Total**
Equipment costs						
1) Hardware costs						
Additional cost per vehicle (€)	136.31	353.93	**252.52**	1,161	1,507	**1,440**
Total additional cost (billion €)	5.37	15.97	**21.34**	1.43	7.67	**9.10**
2) R&D and related calibration costs including facilities and tooling costs						
Additional cost per vehicle (€)	88.98	109.31	**99.84**	1,340	1,339	**1,339**
Total additional cost (billion €)	3.50	4.93	**8.44**	1.65	6.81	**8.46**
Implementation costs						
1) Testing costs						
Additional cost per model / engine family (thousand €)	-3,629	-12,247	**-5,496**	-12,376	-5,227	**-6,512**
Additional cost per vehicle (€)	-34.52	-28.12	**-31.10**	-117.83	-55.10	**-67.34**
Total additional cost (million €)	-1,359	-1,269	**-2,628**	-145.30	-280.27	**-425.57**
2) Witnessing costs						
Additional cost per model / engine family (thousand €)	-250.23	-818.04	**-373.24**	-438.31	-185.14	**-230.62**
Additional cost per vehicle (€)	-2.38	-1.88	**-2.11**	-4.17	-1.95	**-2.38**
Total additional cost (million €)	-93.72	-84.74	**-178.46**	-5.15	-9.93	**-15.07**
3) Type approval fees						
Additional cost per type-approval (thousand €)	-5.83	-6.18	**-5.99**	-1.72	-1.69	**-1.70**
Additional cost per vehicle (€)	-0.54	-0.43	**-0.48**	-0.86	-0.40	**-0.49**
Total additional cost (million €)	-21.27	-19.23	**-40.50**	-1.06	-2.05	**-3.12**
4) Administrative costs related to the implementation process						
Additional cost per type-approval (thousand €)	-311.04	-329.36	**-319.47**	-103.48	-101.61	**-102.24**
Additional cost per vehicle (€)	-28.81	-22.73	**-25.56**	-51.78	-24.21	**-29.59**
Total additional cost (million €)	-1,134	-1,026	**-2,160**	-63.85	-123.16	**-187.00**
Total additional regulatory costs						
Total additional regulatory cost per vehicle until 2050 (€)	159.05	410.09	**293.10**	2,326	2,765	**2,679**
Total additional regulatory cost until 2050 (billion €)	6.26	18.50	**24.77**	2.87	14.06	**16.93**

The total regulatory costs earlier presented are analysed in terms of timing of occurrence in Table 5-80 for PO3.Sc1 and in Table 5-81 for PO3.Sc2. Similar to the previous policy options, costs are significantly high at the beginning of introducing the new emission standard due to the significant one-off R&D costs that are amortized within a vehicle model's cycle. These R&D costs are marginally higher in the case of PO3.Sc2 over PO3.Sc1 due to the wider normal conditions in this scenario.

The same values are integrated in five-year intervals in Table 5-82 and Table 5-83 for PO3.Sc1 and PO3.Sc2, respectively. The significant cost decreases post 2035 for cars and vans mainly arise from the fact that the number of new registrations of PI and CI cars is considered to be negligible post 2035 so any remaining costs are practically amortised costs from previous years vehicle registrations.

Table 5-80: Total annual regulatory costs (discounted – NPV2025) for PO3.Sc1 (increments over baseline) – negative values express total benefits

Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	2,822	4,171	47.93	1,349	1,046	4,509	62.44	492.97	8,391	6,110
2026	1,277	2,378	20.43	838.67	414.35	1,968	23.98	208.44	4,514	2,614
2027	627.67	1,657	9.28	618.56	189.24	1,025	9.93	102.78	2,913	1,327
2028	353.89	1,329	4.77	505.34	120.68	665.29	5.05	62.70	2,193	853.72
2029	220.63	1,148	2.95	433.37	88.72	516.73	3.37	45.85	1,805	654.66
2030	142.33	1,024	1.83	378.50	76.03	445.21	2.79	37.94	1,547	561.97
2031	103.70	784.06	1.34	290.83	70.40	402.36	2.53	33.88	1,179.93	509.17
2032	74.26	566.41	1.00	210.46	67.69	372.79	2.45	31.30	852.12	474.23
2033	45.80	362.27	0.53	134.96	64.64	343.21	2.34	28.82	543.56	439.03
2034	22.02	174.79	0.26	65.21	61.46	308.93	2.32	26.80	262.28	399.51
2035	0.00	0.03	0.00	0.00	58.39	276.62	2.29	24.89	0.04	362.19
2036	0.00	0.02	0.00	0.07	55.40	246.35	2.06	23.30	0.10	327.11
2037	0.00	0.02	0.00	0.14	52.61	218.07	2.04	21.68	0.16	294.40
2038	0.00	0.01	0.00	0.20	49.99	191.48	2.02	20.08	0.22	263.57
2039	0.00	0.01	0.00	0.26	43.90	170.81	2.00	18.76	0.27	235.47
2040	0.00	0.00	0.00	0.31	38.20	151.43	2.01	17.51	0.31	209.16
2041	0.00	0.00	0.00	0.41	32.79	133.16	1.91	16.16	0.41	184.03
2042	0.00	0.00	0.00	0.50	27.84	116.17	1.88	14.96	0.50	160.85
2043	0.00	0.00	0.00	0.58	23.19	100.20	1.84	13.93	0.58	139.15
2044	0.00	0.00	0.00	0.56	22.83	95.85	1.80	12.81	0.57	133.29
2045	0.00	0.00	0.00	0.64	22.41	91.62	1.77	11.76	0.64	127.57
2046	0.00	0.00	0.00	0.65	22.00	87.60	1.73	10.92	0.65	122.25
2047	0.00	0.00	0.00	0.65	21.56	83.79	1.70	10.04	0.66	117.09
2048	0.00	0.00	0.00	0.66	21.21	80.08	1.67	9.18	0.67	112.13
2049	0.00	0.00	0.00	0.67	20.77	76.54	1.63	8.49	0.67	107.43
2050	0.00	0.00	0.00	0.67	19.98	73.64	1.61	7.72	0.68	102.95

Table 5-81: Total annual regulatory costs (discounted – NPV2025) for PO3.Sc2 (increments over baseline) – negative values express total benefits

Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	2,969	4,179	49.78	1,352	1,046	4,515	62.18	493.22	8,550	6,116
2026	1,348	2,388	21.32	841.54	413.20	1,967	23.81	208.10	4,599	2,613
2027	688.89	1,666	10.26	621.09	188.11	1,025	10.05	102.44	2,987	1,326
2028	405.94	1,337	5.48	507.65	120.25	665.01	5.17	62.26	2,256	852.70
2029	263.99	1,155	3.52	435.32	88.32	516.49	3.22	45.69	1,858	653.72
2030	177.90	1,031	2.27	380.17	75.65	444.90	2.65	37.62	1,591	560.83
2031	131.07	789.02	1.62	292.22	69.91	402.14	2.40	33.81	1,214	508.27
2032	94.04	570.06	1.26	211.51	67.23	372.54	2.32	31.14	876.88	473.23
2033	58.47	364.63	0.78	135.62	64.25	343.07	2.14	28.45	559.50	437.90
2034	28.14	175.81	0.38	65.49	61.04	308.67	2.12	26.65	269.82	398.48
2035	0.00	0.03	0.00	0.00	57.98	276.46	2.09	24.74	0.04	361.28
2036	0.00	0.02	0.00	0.07	55.00	246.28	2.07	23.03	0.10	326.39
2037	0.00	0.02	0.00	0.14	52.22	217.95	2.05	21.54	0.16	293.77
2038	0.00	0.01	0.00	0.20	49.58	191.36	2.03	19.95	0.22	262.91
2039	0.00	0.01	0.00	0.26	43.58	170.70	2.01	18.62	0.27	234.90
2040	0.00	0.00	0.00	0.32	37.92	151.29	1.86	17.37	0.32	208.45
2041	0.00	0.00	0.00	0.41	32.63	133.15	1.82	16.03	0.41	183.64
2042	0.00	0.00	0.00	0.50	27.64	116.08	1.79	14.93	0.50	160.44
2043	0.00	0.00	0.00	0.49	23.03	100.16	1.76	13.80	0.49	138.75
2044	0.00	0.00	0.00	0.57	22.63	95.77	1.72	12.69	0.57	132.81
2045	0.00	0.00	0.00	0.64	22.27	91.61	1.69	11.78	0.65	127.35
2046	0.00	0.00	0.00	0.65	21.86	87.56	1.66	10.80	0.66	121.88
2047	0.00	0.00	0.00	0.66	21.45	83.69	1.63	10.01	0.66	116.78
2048	0.00	0.00	0.00	0.67	21.02	80.04	1.60	9.14	0.67	111.81
2049	0.00	0.00	0.00	0.67	20.61	76.49	1.57	8.38	0.68	107.06
2050	0.00	0.00	0.00	0.68	19.83	73.60	1.54	7.73	0.68	102.71

Table 5-82: Cumulative regulatory costs (discounted – NPV2025) for PO3.Sc1 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	2,822	4,171	47.93	1,349	1,046	4,509	62.44	492.97	8,391	6,110
2026-2030	2,622	7,536	39.26	2,774	889.02	4,620	45.13	457.70	12,971	6,012
2031-2035	245.79	1,888	3.13	701.46	322.58	1,704	11.93	145.69	2,838	2,184
2036-2040	0.00	0.06	0.00	0.99	240.11	978.14	10.13	101.33	1.06	1,330
2041-2045	0.00	0.01	0.01	2.68	129.07	537.00	9.20	69.63	2.70	744.89
2046-2050	0.00	0.01	0.01	3.30	105.52	401.64	8.34	46.35	3.32	561.85

Table 5-83: Cumulative regulatory costs (discounted – NPV2025) for PO3.Sc2 (increments over baseline) – negative values express total benefits

Cumulative Regulatory costs discounted over NPV (million EUR)	Cars PI	Cars CI	Vans PI	Vans CI	Lorries PI	Lorries CI	Buses PI	Buses CI	LDVs	HDVs
2025	2,969	4,179	49.78	1,352	1,046	4,515	62.18	493.22	8,550	6,116
2026-2030	2,885	7,577	42.84	2,786	885.52	4,619	44.91	456.11	13,290	6,006
2031-2035	311.73	1,900	4.05	704.84	320.41	1,703	11.07	144.80	2,920	2,179
2036-2040	0.00	0.06	0.00	1.00	238.30	977.58	10.03	100.52	1.07	1,326
2041-2045	0.00	0.01	0.01	2.61	128.20	536.75	8.79	69.24	2.63	742.98
2046-2050	0.00	0.01	0.01	3.33	104.78	401.38	8.00	46.06	3.35	560.23

Competitiveness of the EU automotive industry

PO3 introduces several new concepts for emissions control compared to the rest policy options. Most importantly, it introduces the sector of information and communication technologies (ICT) in emissions control and compliance monitoring. On board sensors available on the market today are scheduled to be used to monitor emissions of NO_x and NH_3 together with DPF condition and transmit this information in intermittent manner on cloud servers. This information is then processed to deliver several useful functionalities as presented in

Parameter	**Specifications**

Table 4-15.

Developing a system to measure emissions and a platform for signal transmission

Scenario Characteristics	Introduction of OBM functionalities infrastructure in the short-term using the OBFCM communication and using exhaust sensors which are available today
Communications platform	Based on OBFCM protocol, intermittent signal transmission
Pollutants OBM	**NOx and NH3**: Monitoring of emission performance and identification of malfunctions in combination with OBD. **PM**: Only health condition of DPF (no actual PM measurement)
Functionalities	5. Limits exceedance reporting via MIL/enhanced OBD 6. Enhanced malfunction detection over OBD 7. Information for ISC/MaS candidate testing 8. Feedback to adjust emission control system performance (real-time calibration) 9. Geofencing for PHEV 10. Enabling limp model for emissions exceedance 11. Tampering detection
Emission compliance demonstration	Demonstrate compliance over normal operation conditions for the pollutants measured

between the vehicle and centralised servers with the aim of monitoring emissions compliance, fulfils a number of objectives with the potential to significantly increase the competitiveness of the EU industry. These include:

- Significant cost reductions by decreased needs for calibration while emissions are being measured and not need to be inferred by operation conditions.
- The vehicle may actively adapt its operation for optimum fuel consumption by keeping the necessary safety margin over the NOx limit without a need to keep a high safety margin under all conditions.
- Measurement of the emission levels may indicate overall engine and emission control condition and this way significantly contribute towards improved preventive maintenance practices, potentially saving significant amounts from warranty and repair costs.
- Usage of the information collected and transmission of additional information using the established communication protocol may enhance safety, decrease theft, and make the vehicles more desirable for private and professional users.
- New business models using the information collected can be developed to support the concept of Smart Cities[135] and to offer new solutions regarding the improvement of air quality.

For these reasons we expect that PO3 has the potential to significantly increase the desirability of vehicles and hence the competitiveness of the EU automotive industry. The *Review on Int'l regulations* report presented activities in China to offer such an approach for China VI trucks, and EU manufacturers are preparing in this direction to offer improved products to their clients hence increasing their competitiveness of their services. Overall, the recent developments in the field of OBM for other regions (i.e. US with REAL initiative[136], China with Remote OBD) have demonstrated the significant potential benefits of advanced OBM on vehicular emission monitoring[137].

Further to the OEMS, the potential which PO3 gives for improving the competitiveness of suppliers is significant, at least for the following categories:

- Developers and manufacturers of sensors will have further develop and calibrate existing sensors with improved characteristics that will better place them in other markets worldwide also developing sensor-based emission compliance[138] methods.
- Suppliers of (vehicular) communication systems will work on developing secure protocols for the transmission of emission information to the designated authorities
- Companies that will create new business models around this new pool of emission information generated and which can serve the concept of Smart Cities. It is expected that the future vehicle OEMs will gain added revenue due to connected services and monetization of large amounts of vehicle data[139].

Table 5-84: Qualitative assessment of PO3 impact on competitiveness

[135] Smart cities | European Commission (europa.eu)

[136] CARB,2018."CARB gets "REAL" to further cut pollution from diesel and gas vehicles"

[137] Combined Report

[138] How to create a paradigm shift in vehicle emission regulation | Inside UCR

[139] Deloitte, 2017. "The future of the Automotive Value Chain 2025 and beyond ",

Policy Option 1 - Competitiveness		
Key Impacts	**Scale of impact**	**Comments**
Cost savings	-1	Net costs for all vehicle categories in order to introduce the required technology on the vehicles. The height of the costs is up to 5% of vehicle price for SC1 and 7% for SC2 for small vehicles. For larger vehicles, the relative increase is lower.
International market access (parity with other advanced emission standards)	3	Emission limits superseding those in the rest of the world. With the developed technology, EU OEMs will have no bottlenecks to penetrate ay of the international markets EU suppliers developing components for EU industry that can supersede specifications in the rest of the world.
Innovation capacity (R&D investment, new technologies)	2	Innovation required in terms of emission control systems, sensors and communication protocol. As such it is estimated that it would bring the EU automotive supply chain in the forefront globally in terms of innovation and R&D. PO3.Sc1 scores 2 due to the existing sensors required

Functioning of the internal market

Similar to what identified in the *evaluation report* and repeated in the description of the previous policy options, a significant risk for the coherence of the internal market operation originates from local and regional incentives towards banning certain vehicle technologies from environmentally sensitive zones. Several cities try to quantify the contribution of different powertrains on local emissions and to take measures on which vehicle technologies may be allowed for operation within specific city zones[140].

With PO3, actual emissions from vehicles compliant with Euro 7 are being measured and information on specific vehicles, not just vehicle models, can be made known. This can significantly help in correcting the function of the internal market. For example, charging schemes may be developed on the basis of the true pollution that each vehicle contributes. With such pay-as-you-pollute principles, cities will have less motive to ban certain vehicle powertrains from environmentally sensitive zones. Moreover, monitoring emission levels may assist in later enabling the concept of geofencing thus allowing a wider range of powertrains than true zero emission vehicles in the city centres. This again promotes the functioning of the internal market by allowing more vehicle technologies to become market available while respecting the environmental targets in each city and, correspondingly, at a national level.

SMEs

SME Group 1 (vehicle manufacturing) are limited to a number of approximately 35 companies in EU27. Further to the emission limit requirements that may have an impact on vehicle design, as discussed in PO2, PO3 also introduces some additional

[140] The TRUE Initiative

requirements in terms of on-board sensors and communicating emission information to relevant authorities. To the extent that such companies have used engines from larger OEMs, with the capability to support OBFCM, we expect that PO3 will not be a particular challenge sine the communication functionality should already be part of the engine electronic control and functionalities.

SME Group 2 (suppliers, sales, repair and aftermarket) will significantly benefit by introducing PO3 in the emissions standards regulation. This is because several SMEs in this group are active in the provision of R&D and other services to large suppliers or directly to OEMs regarding sensor communication protocols, signal transmission, data compressing and handling algorithms, safety and security protocols, cloud and possibly meta-analysis services, etc. PO3 can create an entirely new world for such SMEs. For the traditional, more hardware and engineering oriented SMEs, PO3 is not considerably considered to affect their operations. Moreover, several aftermarket SMEs may take advantage of the new information generated to create new business models.

SME Group 3 (type approval, testing and sensors) will have to be further split in those offering type approval services and the ones active in testing systems and sensors. Activities at type approval related SMEs may change approach but not expected to change volume. Type approval will be focussed on verifying sensor system integration at initial type approval. Most of the efforts will then be invested in verifying system performance during ISC and MaS activities. In fact, such activities will become much more efficient by comparing emission information from different vehicles of the same type. This will allow developing criteria for which model families will have to be examined with independent verificatory testing. It would be expected that at the initial years of introducing such a measure, ISC activities will actually increase before experience with the calibration and operation of the system leads to a decrease in the number of independent testing required.

For SMEs active in testing and sensor development, PO3 offers a unique opportunity for enhancing and growing their businesses. The first involves the development of new sensor systems that will be required for monitoring of emissions performance. New sensors will be required in the fields of PN monitoring and potentially for multicomponent measurement potentially based on an array of advanced techniques (Optoacoustics, Laser Induced Incandescence, Fourier Transform Infrared, etc.). Advancing of the TRL of these technologies will require the involvement of several SMEs active in sensing, optics, electronics, materials, etc. Second, the low limits introduced, similar to PO2, will require the involvement of SMEs active in the measurement and instrumentation business as new sensing and measurement components will be required to develop improved testing solutions with advanced sensitivity, better packaging and enhanced accuracy.

Economic affordability for SME users

Especially for PO3, in order to assess the impact on affordability of SME users, we assume that the equipment costs are passed-on directly to vehicle prices[141]. As described in Section 5.3.4, (subsection *Social inclusion and affordability)*, the effect of the equipment costs to PO3 in current vehicles prices reaches up to 3.65% of the vehicle price for LDVs and up to 3% for HDVs. This increase cannot be seen as negligible, as it poses as a visible rise in current vehicle pricing. This may discourage some SME users, and especially in the business/commercial world, to replace their commercial vehicles with a brand-new ones, and may potentially opt to keep their older vehicles longer or buy a second-hand one.

[141] The same assumption was made for Euro 6/VI standards, in the Evaluation report

However, new communication functionalities offered by the sensors, the potential for predictive maintenance that can reduce operation costs, etc. may be enough counter-reasons not to postpone the decision for a new vehicle purchase.

5.3.3. Cost-benefit analysis

The tables in this section summarise the costs and associated benefits of the two scenarios in PO3. Again, the assumptions that went into formulating the corresponding tables for PO1 and PO2 (Section 5.1.3 and 5.2.3, respectively) also hold in case of PO3. It is further repeated that ranges shown for any benefits correspond to the normal and conservative development of Euro 6/VI emission levels. Any costs shown only correspond to the central cost estimates within the uncertainty of the calculation.

Compared to PO2, both initial R&D investment and recurrent costs increase for PO3.

Table 5-85: Overview of benefits considered in PO3.Sc1 over the baseline and normal or conservative evolution of Euro 6/VI emission factors.

	Overview of Benefits (total for all provisions) – PO3 Scenario1		
	Description	**Amount**	**Comments**
billion EUR / year	***Direct benefits***		
LDVs-PI	Compliance cost reductions (recurrent)	0.092	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.108 - 0.227	Main recipient of the benefit: Citizens
LDVs-CI	Compliance cost reductions (recurrent)	0.088	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.668 - 1.54	Main recipient of the benefit: Citizens
LDVs	Compliance cost reductions (recurrent)	0.180	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.776 - 1.76	Main recipient of the benefit: Citizens
HDVs-PI (CNG)	Compliance cost reductions (recurrent)	0.008	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.0263 - 0.0263	Main recipient of the benefit: Citizens
HDVs-CI	Compliance cost reductions (recurrent)	0.015	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.33 - 5.11	Main recipient of the benefit: Citizens
HDVs	Compliance cost reductions (recurrent)	0.022	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.36 - 5.13	Main recipient of the benefit: Citizens

Table 5-86: Overview of Costs considered in PO3.Sc1 over the baseline

Overview of Costs – PO3 Scenario1								
billion EUR		Citizens/Consumers		Businesses		Administrations		
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually	
LDVs-PI	Direct costs	0.000	0.000	3.910	0.072	0.000	0.000
	Indirect costs	0.000	0.222	0.000	0.000	0.000	0.000
LDVs-CI	Direct costs	0.000	0.000	5.132	0.511	0.000	0.000
	Indirect costs	0.000	0.709	0.000	0.000	0.000	0.000
LDVs	Direct costs	0.000	0.000	9.042	0.583	0.000	0.000
	Indirect costs	0.000	0.931	0.000	0.000	0.000	0.000
HDVs-PI (CNG)	Direct costs	0.000	0.000	1.659	0.047	0.000	0.000
	Indirect costs	0.000	0.111	0.000	0.000	0.000	0.000
HDVs-CI	Direct costs	0.000	0.000	6.845	0.278	0.000	0.000
	Indirect costs	0.000	0.541	0.000	0.000	0.000	0.000
HDVs	Direct costs	0.000	0.000	8.504	0.325	0.000	0.000
	Indirect costs	0.000	0.652	0.000	0.000	0.000	0.000

Table 5-87: Overview of benefits considered in PO3.Sc2 over the baseline and normal or conservative evolution of Euro 6/VI emission factors.

	Overview of Benefits (total for all provisions) – PO3 Scenario2		
	Description	**Amount**	**Comments**
billion EUR / year	***Direct benefits***		
LDVs-PI	Compliance cost reductions (recurrent)	0.100	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.112 - 0.231	Main recipient of the benefit: Citizens
LDVs-CI	Compliance cost reductions (recurrent)	0.092	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.675 - 1.54	Main recipient of the benefit: Citizens
LDVs	Compliance cost reductions (recurrent)	0.193	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.787 - 1.77	Main recipient of the benefit: Citizens
HDVs-PI (CNG)	Compliance cost reductions (recurrent)	0.008	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	0.0263 - 0.0263	Main recipient of the benefit: Citizens
HDVs-CI	Compliance cost reductions (recurrent)	0.016	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.33 - 5.11	Main recipient of the benefit: Citizens
HDVs	Compliance cost reductions (recurrent)	0.024	Main recipient of the benefit: Citizens/Consumers Regulatory charges: Fees for type approval. Admin costs: TA tests costs, certification costs, TAA administrative costs.
	Reduced air pollution emissions (recurrent)	4.36 - 5.13	Main recipient of the benefit: Citizens

Table 5-88: Overview of Costs considered in PO3.Sc2 over the baseline

Overview of Costs – PO3 Scenario2								
billion EUR		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent annually	One-off	Recurrent annually	One-off	Recurrent annually
LDVs-PI	Direct costs	0.000	0.000	3.910	0.091	0.000	0.000
	Indirect costs	0.000	0.241	0.000	0.000	0.000	0.000
LDVs-CI	Direct costs	0.000	0.000	5.132	0.514	0.000	0.000
	Indirect costs	0.000	0.712	0.000	0.000	0.000	0.000
LDVs	Direct costs	0.000	0.000	9.042	0.605	0.000	0.000
	Indirect costs	0.000	0.953	0.000	0.000	0.000	0.000
HDVs-PI (CNG)	Direct costs	0.000	0.000	1.659	0.046	0.000	0.000
	Indirect costs	0.000	0.110	0.000	0.000	0.000	0.000
HDVs-CI	Direct costs	0.000	0.000	6.845	0.278	0.000	0.000
	Indirect costs	0.000	0.541	0.000	0.000	0.000	0.000
HDVs	Direct costs	0.000	0.000	8.504	0.324	0.000	0.000
	Indirect costs	0.000	0.651	0.000	0.000	0.000	0.000

5.3.4. Social impacts

Health benefit

Table 5-89 and Table 5-90 show a summary of the total health benefits introduced by PO3, separately for the two scenarios. Compared to PO2.Sc1, PO3.Sc1 achieves additional marginal improvements by monitoring the emission performance of vehicles and that maintaining a better overall fleet condition and by decreasing emission control system degradation. PO3.Sc2 achieves the highest environmental benefits of all scenarios examined. By means of monitoring PM/PN levels at the tailpipe (and not just DPF condition as PO3.Sc1) maintains lower overall emission levels this exhibiting the highest benefits also in terms of PM.

Table 5-89: Health impacts in monetised terms originating from PO3 in LDVs.

Health impacts in monetised terms for PO3 for LDVs (billion EUR)						
Scenario	Euro 6/VI EF	NO_x	PM_{exh}	PM_{nonexh}	NH_3	NMHC
PO3.Sc1	Normal	18.62	0.09	0.00	1.00	0.67
	Conservative	33.45	0.37	0.00	1.51	0.67
PO3.Sc2	Normal	18.86	0.14	0.00	1.00	0.68
	Conservative	33.69	0.42	0.00	1.51	0.68

Table 5-90: Health impacts in monetised terms originating from PO3 in HDVs.

Health impacts in monetised terms for PO3 for HDVs (billion EUR)						
Scenario	Euro 6/VI EF	NO_x	PM_{exh}	PM_{nonexh}	NH_3	NMHC
PO3.Sc1	Normal	69.41	6.22	0.00	0.91	0.10
	Conservative	89.63	6.22	0.00	0.91	0.10
PO3.Sc2	Normal	69.41	6.22	0.00	0.91	0.10
	Conservative	89.63	6.22	0.00	0.91	0.10

Employment

PO3 impacts on employment largely follow the analysis deployed for PO2. PO3 is likely to result in higher equipment costs for producers in the short term, however the incurred costs of monitoring of real-world emissions are unlikely to be prohibitive (see Section 0). This also partly due to the fact that OBM functionality will potentially simplify and modernise the current on-board diagnostics (OBD) and will be based to significant extent on existing (or currently under development) on-board sensor technology, thus resulting in synergies. Moreover, PO3 is expected to require a higher degree of R&D and innovation activity, due to technological prerequisites focusing mainly on on-board sensors and intelligent vehicle communication protocols.

Table 5-91: Qualitative assessment of PO3 impact on employment

Policy option 3			
Key Factors	**Category**	**Scale of impact**	**Comments**
Impact on overall employment levels	Vehicle OEMs	1	PO3 will result to the highest levels of equipment costs, but will introduce the highest degree of R&D activity, mainly focused on the employment of accurate sensors on board the vehicle. The 'digitization' of vehicles with the accompanied production of data will deliver new specialised jobs and can have a minor positive impact (1).
	Automotive component suppliers (i.e.Tier 1 suppliers)	2	PO3 incorporates the higher requirements in terms of technology, especially on-board emissions sensors hence employment increase due to R&D activity will be maximized
	Testing equipment and R&D services (incl. SMEs)	2	Less testing equipment may be required for type approval centres but testing for the OEMs that are the large consumers of equipment will not change.
	Homologation services (e.g. TS)	-1	As the simplification effect is present in PO3 as well, the same trend is expected as PO1, PO2.

Training systems/skills

As already mentioned in the relevant section for PO2 (0) Electronics and software may will comprise a significant portion of cars value for the next 10 years. PO3 which introduce monitoring of vehicle emission performance by on-board emission measurement sensors, will significant increase in the role of automotive electronics. The automotive industry is already expanding its capabilities by adding significant resources for module integration, software development and even semiconductor design[142]. Overall PO3 will contribute to the increasing demand for intelligent vehicles with advanced electronic information, which will likely require new skills in the near future. New areas of expertise, including those which result from the ongoing shift to highly sophisticated, digital manufacturing, will therefore need to be added in order to bridge the existing knowledge gap between the automotive and the Information and Communication Technology (ICT) sector[143]. Therefore, PO3 is expected to require re-training and upskilling of the workforce in the EU automotive supply chain to a significant extent.

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[142] "The car will become a computer on wheels". Available at: https://www.rolandberger.com/en/Publications/The-car-will-become-a-computer-on-wheels.html (assessed on Mar. 21)

[143] European Commission, 2017. "Blueprint for sectoral cooperation on skills: Automotive"

Table 5-92: Qualitative assessment of PO3 impact on training/skills

Policy option 3			
Key Factors	**Category**	**Scale of impact**	**Comments**
Impact on required education/ skill level of personnel	Vehicle OEMs	2	Overall, PO3 has the highest requirements in terms of new technology, new communication needs and integration of sensors in vehicle operation hence, a higher impact is expected on re-training or upskilling personal in practically all relevant industry sectors.
	Automotive component suppliers (i.e. Tier 1 suppliers)	2	
	Testing equipment and R&D services (incl. SMEs)	2	In particular for type approval services, some retraining on sensors operation and verification may be required. This is because TA, ISC and MaS in this case are expected to mostly depend on the verification of the correct sensor operation of the family of vehicles rather than on the verification of the emission level of a small number of vehicles received for testing.
	Homologation services (e.g. TS)	1	

Social inclusion and affordability

As mentioned in the previous PO, regulatory costs incurred due to a new Euro emission standard should be expected to be passed to consumers, at least in the long term. Similarly, to assess the impact on consumer affordability, current vehicle prices are compared with the estimated net increase in cost per, to establish what share of a vehicle price they represent. The following tables illustrate the estimated regulatory cost per vehicle for PO3.

Table 5-93: Analysis of relative regulatory costs of PO3 Sc1 and Sc2 over the baseline: economic affordability of consumers

Economic Affordability of Consumers: Policy Option 3							
	Engine	**Vehicle segment**	**Regulatory cost per vehicle (in euro)**		**Average vehicle price (in euro)****	**Share of vehicle price**	
			Scenario 1	**Scenario 2**		**Scenario 1**	**Scenario 2**
Cars	PI	Small	122.54	133.44	15,275	0.80%	0.87%
		Medium	146.26	158.51	28,344	0.52%	0.56%
		Large	169.98	183.58	60,430	0.28%	0.30%
	CI	Small	351.14	352.86	15,153	2.32%	2.33%
		Medium	382.41	384.12	28,118	1.36%	1.37%
		Large	423.72	425.44	59,948	0.71%	0.71%
Cars	PI-CI*	Small	233.13	239.91	15,217	1.53%	1.58%
		Medium	259.02	266.24	28,236	0.92%	0.94%
		Large	290.20	297.95	60,200	0.48%	0.49%
Lorries	PI-CI*	Small	2,560.56	2,559.31	70,169	3.65%	3.65%
		Medium	2,698.66	2,697.41	91,219	2.96%	2.96%
		Large	2,881.14	2,879.89	140,337	2.05%	2.05%
Buses	PI-CI*	Small	2,380.35	2,370.22	134,522	1.77%	1.76%
		Medium	2,507.82	2,497.69	168,152	1.49%	1.49%
		Large	2,676.26	2,666.13	201,782	1.33%	1.32%

* Weighted average of costs over new registrations.
** Weighted to the number of sales per year and discounted over the time horizon of 2050.

Consumer trust

In line with the EU's Green Deal initiative objectives, more emphasis is required on encouraging companies to provide more sustainable services or operations on the one side, and customers to enhance the sustainability of their transportation choices on the other[144], including vehicle purchase. Since, PO3 promotes on-board monitoring, more information will be made available for consumers on environmental performance of road transport vehicles, highlighting the advantages of digital solutions are also supported by the general public. PO3 is expected to significantly reduce air pollutant emissions by detecting non-compliance and malfunctions early. This is expected to have a positive impact on improving consumer trust in the automotive industry.

Table 5-94: Qualitative assessment of PO3 impact on consumer trust

Policy option 3		
Key Factors	**Scale of impact**	**Comments**
Impact on consumer trust in the EU (automotive supply chain)	2	In addition to the provisions of PO2,PO3 introduces mechanisms can guarantee lifetime compliance with any emission limit, therefore providing added verification to the consumers/public that vehicles continue to be clean during their full useful life.

[144] European Commission, 2020. "Sustainable and Smart Mobility Strategy – putting European transport on track for the Future", {SWD(2020) 331 final}.

6. Comparison of Policy Options

The methodology followed the standard evaluation framework for an assessment of legislation and the key evaluation criteria related to effectiveness, efficiency, relevance, coherence and proportionality. In more detail, the options considered are compared against the following criteria:

- Effectiveness: the extent to which different options would achieve the objectives;
- Efficiency: the benefits versus the costs; i.e. "the extent to which objectives can be achieved for a given level of resource/at least cost".
- Coherence: with the overarching objectives of EU policies;
- Proportionality: EU added value

6.1. Effectiveness

Environmental and Health Impacts

All policy options result to significant environmental benefits, depending on the scenario considered in each policy option, especially when a conservative evolution of Euro 6/VI emission factors is to be anticipated. The environmental benefit in terms of cumulative pollutant reductions in the period 2025-2050 for each policy option is shown in tables Table 6-1 to

	Cumulative environmental benefits to 2050 (kt of pollutant emission reductions) (conservative Euro 6/VI EFs)						
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NOx	1,728	2,741	2,767	2,790	2,809	2,828
	PM2.5	3.15	3.46	3.93	4.16	3.46	3.93
	PM10	3.15	3.46	3.93	4.16	3.46	3.93
	NMVOC	3.56	432	435	480	465	468
	CO	557	2,648	2,706	2,899	2,648	2,706
	CH4	5.47	111	111	125	111	111
	N2O	9.71	204	204	309	204	204
	NH3	80.1	124	124	125	130	130
Lorries & Buses	NOx	2,149	9,081	9,081	9,134	9,166	9,166
	PM2.5	0	75.6	75.6	76.7	75.6	75.6
	PM10	0	75.6	75.6	76.7	75.6	75.6
	NMVOC	0	82.5	82.5	87.1	82.5	82.5
	CO	0	333	333	537	333	333
	CH4	0	-4.85	-4.85	-4.01	-4.85	-4.85
	N2O	0	840	840	862	840	840
	NH3	0	67.8	67.8	69.3	78.5	78.5

Table 6-3, including the separate scenarios on brake wear control. All tables show the central estimate of reduction and the standard deviation, considering the two possible Euro 6/VI emission level evolutions (normal, conservative). For those pollutants that no standard deviation is given, we did not consider that Euro 6/VI can develop differently in the future, or we could not assess the impact of a possible different evolution.

Table 6-4 and

Table 6-5 show the corresponding reductions in cumulative emissions in relative terms over the same period. All policy options result to significant reductions to air pollution over Euro 6/VI which become particularly significant for lorries and buses.

The key observations from these tables can be summarised to the following points:

- Total reductions for HDVs are generally higher than for cars and vans. This is for two main reasons. First, HDVs equipped with ICEs continue to be placed in the market even beyond 2035, in contrast to cars and vans. Therefore, the environmental benefit of introducing a new emission standard is larger for such vehicles. Second, they are driven for much longer distances than smaller vehicles, hence environmental benefit per vehicle are much larger.
- Main environmental benefits appear for NOx and, secondarily N_2O. PM is already very well controlled within Euro 6/VI and the additional potential in terms of mass of emissions that can be reduced is marginal.
- PO2 and PO3 achieve much higher overall pollution reductions than PO1. Individual differences between the different scenarios in PO2 and PO3 are of less importance. PO3 achieves the highest reductions in NO_x from all policy options, even if the emission limits proposed at PO3 are less relaxed than PO2.Sc3. This is because of the satisfactory control of tampering and uncontrolled system degradation in PO3.
- CH_4 emissions are calculated to marginally increase in some of the policy options for lorries and buses. This is a projected effect of mostly of fast catalyst heat-up requirements. These projected impacts are of negligible environmental consequence as shown in
- Table 6-4 because N_2O reductions largely supersede any marginal increases in CH_4, when it comes to equivalent GHG impacts of the different options.
- Total emission reductions achieved in $PM_{2.5}$ and PM_{10} from the two brake wear control scenarios are two order of magnitudes larger than what achieved by any of the policy options on exhaust emission control.

Table 6-1: Cumulative environmental impacts of Policy Options 1-3 over the baseline and normal evolution of Euro 6/VI emission factors.

	Cumulative environmental benefits to 2050 (kt of pollutant emission reductions) (normal Euro 6/VI EFs)						
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NO_x	465	1,496	1,522	1,545	1,563	1,583
	$PM_{2.5}$	0.50	0.80	1.28	1.51	0.80	1.28
	PM_{10}	0.50	0.80	1.28	1.51	0.80	1.28
	NMVOC	3.56	432	435	480	465	468
	CO	425	2,521	2,580	2,773	2,521	2,580

	CH_4	5.47	111	111	125	111	111
	N_2O	4.09	-17.0	-17.0	87.7	-17.0	-17.0
	NH_3	20.2	76.8	76.9	78.1	82.5	82.6
Lorries & Buses	NO_x	0	7,003	7,003	7,056	7,088	7,088
	$PM_{2.5}$	0	75.6	75.6	76.7	75.6	75.6
	PM_{10}	0	75.6	75.6	76.7	75.6	75.6
	NMVOC	0	82.5	82.5	87.1	82.5	82.5
	CO	0	333	333	537	333	333
	CH_4	0	-4.85	-4.85	-4.01	-4.85	-4.85
	N_2O	0	840	840	862	840	840
	NH_3	0	67.8	67.8	69.3	78.5	78.5

Table 6-2: Cumulative environmental impacts of Policy Options 1-3 over the baseline and conservative evolution of Euro 6/VI emission factors.

	Cumulative environmental benefits to 2050 (kt of pollutant emission reductions) (conservative Euro 6/VI EFs)						
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NO_x	1,728	2,741	2,767	2,790	2,809	2,828
	$PM_{2.5}$	3.15	3.46	3.93	4.16	3.46	3.93
	PM_{10}	3.15	3.46	3.93	4.16	3.46	3.93
	NMVOC	3.56	432	435	480	465	468
	CO	557	2,648	2,706	2,899	2,648	2,706
	CH_4	5.47	111	111	125	111	111
	N_2O	9.71	204	204	309	204	204
	NH_3	80.1	124	124	125	130	130
Lorries & Buses	NO_x	2,149	9,081	9,081	9,134	9,166	9,166
	$PM_{2.5}$	0	75.6	75.6	76.7	75.6	75.6
	PM_{10}	0	75.6	75.6	76.7	75.6	75.6
	NMVOC	0	82.5	82.5	87.1	82.5	82.5
	CO	0	333	333	537	333	333
	CH_4	0	-4.85	-4.85	-4.01	-4.85	-4.85
	N_2O	0	840	840	862	840	840
	NH_3	0	67.8	67.8	69.3	78.5	78.5

Table 6-3: Cumulative environmental impacts of Policy Option X (brake wear) over the baseline.

Cumulative environmental benefits to 2050 (kt of pollutant emission reductions)			
Vehicle category	Pollutant	POx	
		ScB1	ScB2
Cars & Vans	$PM_{2.5}$	112	167
	PM_{10}	281	421

Table 6-4: Cumulative emissions reduction (%) for Policy Options 1-3 over the baseline of normal evolution of Euro 6/VI emission factors.

	Cumulative emissions reduction over baseline of normal Euro 6/VI EFs (%)						
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NO_x	6	20	20	20	20	21
	$PM_{2.5}$	0	0	0	0	0	0
	PM_{10}	0	0	0	0	0	0
	NMVOC	0	15	16	17	17	17
	CO	3	18	18	20	18	18
	CH_4	1	20	20	23	20	20

	Cumulative emissions reduction over baseline of normal Euro 6/VI EFs (%)						
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
	N_2O	1	-5	-5	25	-5	-5
	NH_3	6	23	23	23	25	25
Lorries & Buses	NO_x	0	48	48	48	48	48
	$PM_{2.5}$	0	17	17	17	17	17
	PM_{10}	0	11	11	12	11	11
	NMVOC	0	20	20	21	20	20
	CO	0	11	11	17	11	11
	CH_4	0	-2	-2	-2	-2	-2
	N_2O	0	38	38	39	38	38
	NH_3	0	31	31	31	35	35

Table 6-5: Cumulative emissions reduction (%) for Policy Options 1-3 over the baseline of conservative evolution of Euro 6/VI emission factors.

	Cumulative emissions reduction over baseline of conservative Euro 6/VI EFs (%)						
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NO_x	18	28	28	29	29	29
	$PM_{2.5}$	1	1	1	1	1	1
	PM_{10}	0	0	0	0	0	0
	NMVOC	0	15	16	17	17	17
	CO	4	18	19	20	18	19
	CH_4	1	20	20	23	20	20
	N_2O	1	28	28	42	28	28
	NH_3	18	28	28	28	29	29
Lorries & Buses	NO_x	12	52	52	52	52	52
	$PM_{2.5}$	0	17	17	17	17	17
	PM_{10}	0	11	11	12	11	11
	NMVOC	0	20	20	21	20	20
	CO	0	11	11	17	11	11
	CH_4	0	-2	-2	-2	-2	-2
	N_2O	0	38	38	39	38	38
	NH_3	0	31	31	31	35	35

Table 6-6 and Table 6-7 show the environmental benefit by the different scenarios expressed in monetised benefits, according to the externalities of air pollution[145] and additional adjustments, as described in section 9.6. These adjustments have mostly to do

[145] Handbook on the external costs of transport, Version 2019 – 1.1

with the contribution of NMVOG to the formation of Secondary Organic Aerosol by means of photo-oxidation in the atmosphere. Although CH_4 and N_2O do have air pollution[146] and stratospheric ozone depletion[147] impacts, respectively, with subsequent negative effects on health, these have not yet been recognised in the Handbook of external costs used. Therefore, the monetised benefits of these pollutants are only assumed to originate from their climatic impacts and from direct health impacts. One would expect that their damage costs are higher than what currently considered. CO is not associated with any external costs. Therefore, health impacts originate from NO_x, PM_{10}, NMVOC and NH_3. Similar to total emission reductions, positive health impacts scale proportionally to the stringency in emission control introduced by each scenario. The main conclusions drawn from this analysis are the following:

- The majority of benefits in monetary terms originates from NOx reductions which account for about 80% (LDVs) to 60% (HDVs) of total benefits.
- Control of CH_4 and N_2O is the second most important source of benefit with a contribution that ranges from approximately 15% (LDVs) to 30% (HDVs), with exact values depending on the scenario.
- Ammonia-related benefits are also measurable in all scenarios and can reach up to 3% of total benefits considered.
- PM exhaust benefits contribute much less in all scenarios. However it should be reminded that these are estimated by calculating the mass reduction attributed to PN number and size threshold drop. There are no external costs estimated to be assigned to PN directly so the monetised benefits of controlling PN emissions in the different scenarios may be severely underestimated.
- Control of evaporation emissions accounts for €68 M in the period of calculation which accounts for approximately €3 M annual fuel costs that are paid but not consumed by customers.

Table 6-6: Environmental benefits of Policy Options 1-3 in monetised terms (NPV2025 values) over the baseline and normal evolution of Euro 6/VI emission factors.

Cumulative monetised environmental benefits to 2050 (normal Euro 6/VI EFs) (MEUR)							
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NO_x	5,544	17,838	18,151	18,406	18,619	18,856
	$PM_{2.5}$ exh.	52.7	92.0	142	160	92.0	142
	PM_{10} non-exh.	0.0	0.0	0.0	0.0	0.0	0.0
	NMHC	5.24	633	637	702	675	679
	CO	0.0	0.0	0.0	0.0	0.0	0.0
	CH_4	0.0	0.0	0.0	0.0	0.0	0.0
	N_2O	0.0	0.0	0.0	0.0	0.0	0.0
	non-CO_2 GHG CO_2-eq.	204	-283	-283	4,408	-283	-283
	NH_3	239	940	942	953	1,000	1,002
	Fuel savings EVAP	0.0	20.5	20.5	23.7	68.3	68.3
Lorries & Buses	NO_x	-3.63	68,576	68,576	69,090	69,406	69,406

[146] Van Dingenen et al., 2018. Global trends of CH_4 emissions and their impacts on ozone concentrations.
[147] Mueller, R. 2020. The impact of the rise in atmospheric nitrous oxide on stratospheric ozone.

	PM2.5 exh.	-1.33	6,220	6,220	6,292	6,220	6,220
	PM10 non-exh.	0.0	0.0	0.0	0.0	0.0	0.0
	NMHC	0.0	101	101	106	101	101
	CO	0.0	0.0	0.0	0.0	0.0	0.0
	CH_4	0.0	0.0	0.0	0.0	0.0	0.0
	N_2O	0.0	0.0	0.0	0.0	0.0	0.0
	non-CO_2 GHG CO_2-eq.	0.0	36,634	36,634	37,492	36,634	36,634
	NH_3	0.0	785	785	799	905	905
	Fuel savings EVAP	0.0	0.0	0.0	0.0	0.0	0.0

Table 6-7: Environmental benefits of Policy Options 1-3 in monetised terms (NPV2025 values) over the baseline and conservative evolution of Euro 6/VI emission factors.

Cumulative monetised environmental benefits to 2050 (conservative Euro 6/VI EFs) (MEUR)							
Vehicle category	Pollutant	PO1	PO2			PO3	
		Sc1	Sc1	Sc2	Sc3	Sc1	Sc2
Cars & Vans	NO_x	20,627	32,668	32,981	33,236	33,449	33,686
	$PM_{2.5}$ exh.	334	373	423	441	373	423
	PM_{10} non-exh.	0.0	0.0	0.0	0.0	0.0	0.0
	NMHC	5.24	633	637	702	675	679
	CO	0.0	0.0	0.0	0.0	0.0	0.0
	CH_4	0.0	0.0	0.0	0.0	0.0	0.0
	N_2O	0.0	0.0	0.0	0.0	0.0	0.0
	non-CO_2 GHG CO_2-eq.	462	9,773	9,773	14,464	9,773	9,773
	NH_3	939	1,451	1,453	1,464	1,511	1,513
	Fuel savings EVAP	0.0	20.5	20.5	23.7	68.3	68.3
Lorries & Buses	NO_x	21,140	88,802	88,802	89,317	89,633	89,633
	$PM_{2.5}$ exh.	-1.33	6,220	6,220	6,292	6,220	6,220
	PM_{10} non-exh.	0.0	0.0	0.0	0.0	0.0	0.0
	NMHC	0.0	101	101	106	101	101
	CO	0.0	0.0	0.0	0.0	0.0	0.0
	CH_4	0.0	0.0	0.0	0.0	0.0	0.0
	N_2O	0.0	0.0	0.0	0.0	0.0	0.0
	non-CO_2 GHG CO_2-eq.	0.0	36,634	36,634	37,492	36,634	36,634
	NH_3	0.0	785	785	799	905	905
	Fuel savings EVAP	0.0	0.0	0.0	0.0	0.0	0.0

Competitiveness of the EU automotive sector

The overall impact of each policy option on the competitiveness of the automotive sector can be assessed by looking on its individual impacts on cost savings, innovation capacity, and global market access. In the advent of complete electrification of road transport, the EU automotive sector is going through structural changes in terms of manufacturing and business operations. Moreover, competition from non-EU automotive manufacturers that used to have limited access to the EU market is rapidly increasing. The competitiveness of the EU automotive industry is therefore on a sensitive balance with two opposing forces exerted on this:

- Requesting additional investment on a technology which is requested to be phased out by 2035, i.e. mobility based on ICE engines, may seem to make no sense from a business point of view. This is because new investment to a product for which exogenous variables limit the market volume is not a desirable decision, according to any good business practice. Therefore, one force introduced by more stringent emission standards pushes the balance towards accelerating the efforts for electrification. In the short run, this might be negatively affecting the EU automotive industry competitiveness as the EU industry is largely dependent on batteries of non-EU know-how.
- The opposite force comes from the fact that electrification is not yet ready to substitute all mobility and, for certain segments, it is not at all expected to substitute traditional ICE-based mobility. There are significant efforts currently focussing on the development and market placement of sustainable fuels, such as H_2, methanol, and other hydrocarbon e-fuels. Those exhibit sustainability potentials which appear competitive to electrification on a lifecycle perspective. Costs of such fuels are expected to significantly drop over the next decades and these fuels are expected to become popular for freight transport but also, to a certain extent, for passenger mobility. In such a scenario, investing in further decreasing air pollutants from ICE engines brings a competitive advantage to the EU automotive industry while at the same time guarantees a 'fail-safe' approach for air pollution if, for whatever reasons, electro-mobility delays to deliver its full potential (for example, difficulties in building the infrastructure in rural areas or EU regions with low GDP).

Any policy option proposed that leads to higher costs to the industry should therefore be seen in consideration of this sensitive balance. Doing nothing may bring short term relief to business decision makers within the EU industry, avoiding the need to make a new investment – parallel to the one already done to produce electric vehicles. But doing nothing may also mean losing competitiveness in the medium-to-long term for those vehicle types that electrification will not provide all answers, including larger passenger mobility vehicles (cars and coaches) and freight vehicles (vans and both regional and primarily long-haul lorries) that will have to be based on ICE engines.

Introduction of a new emission standard can therefore be overall positive for the competitiveness of the EU automotive industry if it is introduced in a manner that does not require too heavy investments over a too short time frame. Table 6-8 tries to make a fair estimate on the relative scale of effects of the different policy options on EU automotive industry competitiveness, using the relative scale criteria, as these are discussed in section 9.7. Scores in the tables are explained in the following paragraphs and range in the scale from -3 to +3 in correspondence to the extent of negative to positive impacts of each policy option.

PO1 encompasses a narrow revision of the current Euro 6/VI standards by reducing their complexity, whilst keeping a focus on real-world testing. It moderately decreases the costs to the industry by introducing a simplified and more uniform type approval context. However, new technology requirements to control emissions outside of the RDE conditions are brought in. This entails a cost increase which is due to a larger size of existing components but not really a new and innovative technological development. As a result, PO1 introduces additional net costs to the industry, without this investment leading to any particular innovation. PO1, can offer a low overall disadvantage to the competitiveness of the overall supply chain but both not to an extent that can lead to appreciable changes in the overall ranking of the EU automotive industry in terms of competitiveness. As a result, PO1 does not bring the EU automotive industry to a better place in offering solutions of extremely low NO_x (as those requested in the US) or real-time measurement of emissions, as requested in China for lorries.

Table 6-8: Expected qualitative impact of PO 1-3 on competitiveness of the EU automotive industry

Competitiveness on EU automotive sector (complete supply chain)			
Key Impacts	Scale of impact		
	PO1	PO2	PO3
Cost savings	0	-1	-1
Innovation	0	1	2
International market access	0	2	3
Overall assessment	0	1	2

New technology and significant R&D investment is required to achieve the emission reductions in PO2. These costs are required to introduce new components (such as electrically-assisted catalysts, Clean-up catalysts), improved devices (such as DPFs), enhanced methods of aftertreatment integration with electrified powertrains (mild-hybrids or plug-in-hybrids), and others. Such technology brings emission levels ahead of other major regions/markets such as China and USA/California in terms of emission reductions, but also in terms of the associated innovation and technology needed to achieve the low emission levels required. PO2 is therefore considered to enhance the competitiveness of the EU automotive industry by both promoting innovation and by creating the necessary infrastructure for allowing better access to markets with emission limits more stringent than Euro 6/VI. We have not introduced a higher score in the competitiveness impacts of this PO because, as earlier mentioned, the competitiveness in the automotive industry is currently dominated by the ability to innovate in electrified powertrains and in communication technologies, including autonomous driving, rather than improving in terms of conventional powertrains. Therefore, a score of “1” seems more appropriate for the extent of change foreseen.

PO2.Sc3 requires more investment and more advanced technology than PO2.Sc1/2 and one would be tempted to assign a higher score in terms of competitiveness benefits this may offer. However, one will also have to consider the sensitive balance between costs and competitiveness that was earlier mentioned. PO2.Sc3 introduces significant net costs to the industry which are later transferred to the customer. Whether the extent of investment required for the various OEMs will be justified on the basis of projected sales for their model series is a complex business decision that we cannot assess in the current study. Also, it is difficult to assess the level of investment beyond which positive effects of investment to competitiveness turn to negative. We can however recognise the additional risks that a disproportionate investment may entail in the short run, especially if this does not lead to new business opportunities.

Such new business opportunities may arise by PO3 which, building on the provisions of PO2, requires the use of state-of-the-art sensors to measure and communicate emissions levels[148]. The details of such communication are not yet known in our present study but work on the OBFCM field develops towards over-the-air transmission of information. New services and business models can be developed on the basis of the new requirement, including preventive maintenance schedules, big-data analytics and use of this information for improving road transport sustainability. These opportunities are not assessed in the current study but definitely suggest that innovation can be promoted by such solutions. In any case, the area of environmental/vehicular sensors and measurement is a multi-billion market[149]. PO3 is considered to affect competition in a positive manner, hence a score of “2” has been given. Given the developments in California, and China to develop real-measurement based regulation, we argue that such a policy can boost the EU industry and give it a competitive advantage to continue to excel in international markets and a score “3” is given.

Employment

Employment is considered to scale proportionally to competitiveness, when it comes to the production of vehicles powered with ICEs (conventional, mild-hybrid and plug-in hybrid). A highly competitive industry with access to global markets produces a large number of vehicles and employs a large number of employees. If the industry starts to lose in competition, sales decrease and staff size has to decrease as well. Moreover, advanced powertrains require a large number of components, and this increases the number of staff up to the degree that costs, and subsequent vehicle prices, increase disproportionally to the value of the end-product, and this harms sales and employment. Therefore, the dilemma on doing nothing vs doing too much presented regarding the industry’s competitiveness holds here as well.

The increased technological requirements of PO2 and PO3, will result in increased R&D activity and the development of new products/patents/technologies. First and foremost, this will positively affect employment in suppliers specialising in production of components used in automotive pollution control technologies. Component suppliers have a key role in researching and developing technologies and marketing them to vehicle OEMs, while EU employment levels in this particular industrial sector are as large as in the vehicle manufacturing industry (according to Table 5-63). This effect maximizes in PO3, which aims to reap the benefits of digitisation in the field of transport, as it introduces direct on-board emission monitoring (OBM) which will stimulate the further development and optimization of existing sensor technology and communication protocols. The same effect is expected to apply to manufacturers and SMEs active in the field of testing equipment and R&D services as on-board sensor technologies require intense protype testing, calibrations and added research.

One of the operational objectives is to simplify the emission testing regime whilst keeping a focus on real-world testing. In this direction, the simplification aspect, which is present in all proposed PO, aims to bring a set of related changes to emissions standards legislation (including the implementing regulations) resulting in net reduction of test and/or administrative burden, while improving the environmental performance of vehicles. The reduction of test and/or administrative burden will benefit the automotive industry most but may negatively affect the employment levels of type approval services/actors (e.g.

[148] European Commission, 2020. “Sustainable and Smart Mobility Strategy – putting European transport on track for the Future”, {SWD(2020) 331 final}.

[149] Based on several market reports, the environmental sensors market is estimated at more than $15 billion (2020 values) with a annual growth rate of 5-10% (e.g. Environmental Sensing and Monitoring Technologies: Global Markets; Environmental Sensors Market – Growth, Trends, COVID-19 impact and forecasts (2021 - 2026). (All reports accessed March 2021).

technical services) due to more streamlined/simplified regulatory testing requirements, for all POs. That said, the requirements for ISC and MaS brought along with Regulation (EU) 2018/858 are estimated to somewhat compensate any potential loss of jobs.

Table 6-9 shows the expected impact of the different policy options on employment on a relative scale for the main industry sectors involved. For OEMs, none of the policies are expected to lead to any significant difference in the levels of employment, at least for conventional manufacturing of vehicles. We argue that current R&D teams are sufficient to design and implement the next-generation emission control systems required in all POs and requirements for vehicle assembly will hardly change. PO3 may require new investment in communication technologies and may have positive effects, especially if new business opportunities arise and OEMs participate to the new business models. Otherwise, such business models on big-data usage can be exploited by newcomers (companies offering several transport and environmental services) thus also having a positive impact on their employment (not shown on table). The score “1” is given because the main workforce of the automotive industry in the assembly and production so new teams for OBM that may be required are not considered to corresponds to a large fraction of the total workforce.

For suppliers and testing equipment manufacturers, more components in PO2 and, additionally, sensors with advanced communication protocols and new functionalities in ECUs in PO3 are also assumed to have a proportionally positive impact on employment. Finally, simplification measures may have a negative impact on the work-load of type-approval services and hence to employment in the sector. However, increased effort towards in-service conformity and market surveillance is expected to counterbalance for a large share of any loss. The net impact is therefore expected to be marginally negative.

Based on these considerations, and the fact that main investment is now done on electric powertrains and vehicle communications, our assessment suggests that only PO3 may have some minor positive impacts for the various business sectors of the automotive industry.

Table 6-9: Impact of Policy Options 1-3 on employment

Employment				
Key Factors	**Business Sector**	**Scale of impact**		
		PO1	**PO2**	**PO3**
Impact on overall employment levels	**Vehicle OEMs**	0	0	1
	Automotive component suppliers (i.e. Tier 1 suppliers)	0	1	2
	Testing equipment and R&D services (incl. SMEs)	0	1	2
	Type approval services (e.g. TS)	-1	-1	-1
Overall assessment		0	0	1

Note: *In this and follow up similar tables, scores range from negative (-3) to positive (+3) and position the different options on a relative scale to each other*

Skills

The automotive industry is constantly undergoing changes as manufacturing and assembling processes are advancing. Integrating the results of R&D activities, performed by highly specialised staff, to end-products and the manufacturing process, which require less-specialised staff, is a normality in the automotive sector. However, a new element in today's world is the degree of sophistication, owed primarily to digitalisation, and the pace at which these technological changes are being adopted in the manufacturing of the end-products.

In this context, it is important that the automotive industry and its supply chain has always available suitably skilled workforce in order to avoid skills shortages. From the analysis of the answers (and comments/justification) of all respondents/stakeholders during the 2nd targeted consultation, it appears that the required skills are considered dependent on the contents and technological requirements of the final Euro 7 emission standards. For example, one particular industrial stakeholder indicated that the required degree of electrification of future vehicles may require upskilling of the workforce, due to the increased manufacturing of electronic components. All in all, during the 2nd targeted consultation most stakeholders (47 out of 66 in total) agreed in principle, that some type of new skills will be required by the personnel in the 'traditional' automotive industry in the EU, due to the Euro 7 standards.

Table 6-10 shows the expected impacts of the different policy options on the change of skills required for the different business sectors. PO1 introduces the lowest requirements in terms of new technology, hence, no significant impact is expected on re-training or upskilling employees in the automotive industry supply chain. Any new job positions in all business sectors are projected to require mostly the same level of education/skills as required today.

Table 6-10: Impact of Policy Options 1-3 on skills for the various automotive industry sectors

Training systems/skills				
Key Factors	Business Sector	Scale of impact		
		PO1	PO2	PO3
Impact on required education/ skill level of personnel	Vehicle OEMs	0	1	2
	Automotive component suppliers (i.e. Tier 1 suppliers)	0	1	2
	Testing equipment and R&D services (incl. SMEs)	0	1	2
	Type approval services (e.g. TS)	0	1	2
Overall assessment		0	1	2

PO2 as already discussed, will be more research-intensive and will introduce advanced drivetrains (e.g. hybridisation/electrification), as well as exhaust aftertreatment technologies, to cope with more stringent emission limits and testing conditions. However, it should be acknowledged that such advanced systems have already been developed to a certain extent, while others are currently in experimental/development phase already at Euro 6/VI. Furthermore, although the further development of existing innovative technologies will require upskilling or additional training on a portion of the workforce, existing requirements for new medium skilled personnel would still remain, for example in the mass production process. As such, it is expected that a higher level of skillset and education will be required by PO2, but this demand will likely spread to the different sectors of the automotive industry supply chain, hence the overall impact on, EU level, should be considered low. This is also dependant on transition/implementation speed of the new Euro 7 emissions standards, in terms of enforcement date. An early enforcement will require more intense reskilling of the personnel while a later introduction will allow a more gradual training of the personnel as technology advances. The introduction date considered in this report (1.1.2025) will require significant investment in upscaling skills of existing personnel. For type-approval services and suppliers, the extension of boundary conditions of testing and the decrease of limits will require new skills in performing on-road measurements and for the adaptation of analytical equipment to suitably perform in the new conditions.

PO3, is characterized by the introduction of ICT in vehicle emission control monitoring. This will increase the participation of on-board electronics and software to the automotive product which is in any case is expected to increase its value in the years to come[150]. This requires skills that have more and more been requested as core competences of automotive engineering. Therefore, additional technical skills will be required to develop, deploy, operate and maintain digital technologies and sensing devices. Overall, to certain extent, alongside training new employees the automotive industry supply chain would likely have to increasing investment in work-based learning and in reskilling and upskilling a portion of existing workers. Moreover, the EU and Member States actions on developing digital skills and supporting (re-)qualification programmes, would facilitate the need for higher skill in the automotive sector. Such requirements will intensify, especially if new business models around this large dataset of information can be developed, e.g. using big data analytics for improving sustainability of transport. Such options can only be promoted with OBM technologies in PO3.

Internal market

Article 114 of the TFEU[151] is the legal basis for harmonisation measures aiming to establish the internal market. It emphasises the objective of ensuring a high level of protection (including consumer protection) and keeping up with new developments. In this direction**,** EU action may be deemed necessary because of the need to avoid the emergence of barriers to the single market notably in the field of the automotive industry. Emission standards are ‘horizontal’ regulatory tools equally applying to all related business and across member states. Therefore, introducing a more or less stringent package of measures with an emission standard is not expected to directly affect the operation of the internal market.

However, one emerging barrier at EU level, in which emission standards may have an indirect impact, is the introduction of complete bans of certain vehicle technologies by city authorities when designing their air quality policies. The proliferation of such low or zero emission zones may contribute to the fragmentation of the EU internal market as not all vehicle technologies (even of new vehicles) are allowed to operate in all territories in the EU. To that end, one should consider the potential impacts of the available POs in helping removing such local or regional initiatives, at least for new vehicle types.

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[150] McKinsey,2019. Automotive software and electronics 2030. Accessed March 2021.
[151] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A12008E114

Such bans have been aiming to improve air quality within the area these are enforced[152], however the true benefits of such zones on regional air quality[153,154] and human health are not proven beyond doubt[155]. Decreasing pollution over a portion of the city may increase pollution in its periphery (for example when older vehicles are used for commuting and delivery only outside of the low emission zone) so the net effects are difficult to discern. Therefore, bans have been in large fuelled by the Dieselgate and the public perception on certain vehicle categories rather than on robust scientific guidance on net benefits of such measures, i.e. including impacts on people living within but also in the periphery of the environmental zones. A new emission standard may therefore change the perception for certain vehicle categories and remove public pressure from enforcing specific bans on those vehicle categories. Citizens should also be informed that a new emission standard is also expected to have overall much more positive environmental benefits than limiting certain parts of a city to specific vehicle types.

PO1, despite introducing fuel neutral limits, might not be able to fully prevent all upcoming market distortions, such as the specific bans of ICE in certain urban areas (e.g. ULEZ, ZEZ), as the emissions limits remained unchanged over Euro 6/VI. However, only introducing Euro 7 as a new 'brand' name may have a low, still visible, impact on the public perception about the cleanliness of Euro 7 compliant vehicles.

PO2 will introduce admittedly considerably more stringent requirements than PO1. In particular it focuses on significantly improving the performance of new vehicles in terms of air pollutants (under all driving conditions), thus will potentially have a higher impact on providing the necessary assurance to certain EU countries/cities to reconsider/redesign such aforementioned bans. Furthermore, one can argue that if current limits/provisions of the Euro 6/VI emissions standards were considered as sufficient by urban communities/authorities, especially in terms of air quality and public health, the proliferation of such zero emission zones would not be a top priority in their policymaking. PO2.Sc3 in particular introduces very low emission levels for NOx.

With PO3 provisions, real-world emissions from vehicles compliant with Euro 7 are being measured on-board and thus such information on specific vehicles, can be made available. This can enable monitoring of emissions and enhanced emission control over the lifetime of future vehicles. We expect that monitoring emissions levels of vehicles may be used by cities for intelligent charging schemes while it could be useful in the efforts to verify zero-emission operation within environmental zones, within new business models that can be developed. We expect that such possibilities should fully eliminate access bans from Euro 7 vehicles and thus enable a smooth operation of the internal market. However, this will need time and investment and it is not clear whether such infrastructure will be materialised in the expectation of phasing out ICEs by 2035. Hence, we have retained a more conservative score of "2" in how much PO3 will help lifting such barriers in its actual implementation.

Table 6-11 provides a summary of the expected impacts of each of the policy options on the functioning of the internal market. Although all policy options are expected to have a positive effect for reasons outlined before, only PO3 has the potential to lead to a degree of change potentially marked with "2". A value of "3" is not given due to the political pressure for the complete ban of combustion engines[156]. Such statements, although primarily target a decrease of greenhouse gases, fuel the public perception of internal

[152] Mayor of London, 2020. Air quality in London 2016-2020.
[153] Holman et al, 2015. Review of the efficacy of low emission zones to improve urban air quality in European cities
[154] Ellison et al., 2013. Five years of London's low emission zone: Effects on vehicle fleet composition and air quality.
[155] Mudway et al., 2019. Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study.
[156] Automotive News Europe: EU pressed to set phase-out date for combustion engine cars. Accessed March 2021.

combustion vehicles disproportionally degrading air quality, regardless of emission standard. This is because often the public cannot make the difference between vehicle impacts on air quality and climate change[157] while at the same time may not grasp the correct dimensions of air quality problems[158]. Due to such stereotypes, even advancing the emission standard and verifying with actual measurements that emission levels are low may not have an appreciable impact on the decision of retaining low/zero emission zones and hence the subsequent impact on the internal market operation.

Table 6-11: Quantitative table with impact of Policy Options 1-3 on the internal market

Internal market			
	Scale of impact		
Key Factors	**PO1**	**PO2**	**PO3**
Impact on the functioning of the EU internal market	1	1 - 2	2

6.2. Efficiency

Any regulatory option should not be at a cost which is disproportionate to the environmental benefit this entails. Additional cost elements may be those incurred in ensuring compliance with the new provisions (substantive compliance costs) as well as other regulatory costs, including costs associated with enforcement (type approval, conformity of production and in-service conformity process), any fees and other administrative costs. The calculation of costs for each policy options has been in detail presented in the corresponding *Economic impacts* section in Chapter 5 while the individual elements of those have been presented in section 9.5. Such costs are net costs for the manufacturers which, assuming in the long run these will be passed to the customers through an increase in vehicle price, correspond to the total costs to the society.

These costs are invested in order to produce a benefit which, in the case of emission standards is primarily reflected to a reduction of air pollution. This benefit can be monetised using the notion of external costs, which reflect the damage costs by air pollution to health and the environment. Decreasing pollution leads to a decrease of damage hence to an overall benefit. The detailed calculation of how environmental benefits have been estimated is provided in section 9.6. Such benefits correspond to the total benefits to the society.

[157] Tvinnereim et al. 2016. Public perceptions of air pollution and climate change: different manifestations, similar causes, and concerns.
[158] Maione et al., 2020. Public perception of air pollution sources across Europe.

The ratio of net benefits over net costs (often expressed as the cost-to-benefit ratio, although the correct is the benefit-over-cost ratio, i.e. B/C) is a measure of the efficiency of each policy option. The following conditions may apply:

- B/C > 1 – an efficient policy option where benefits outperform costs. The higher the ratio, the most efficient the specific policy is.
- B/C =1 – benefits equal costs, assuming there is also a given uncertainty, the specific policy option may or may not be efficient in delivering its targets.
- 0<B/C<1 – benefits are below costs so the specific policy option is inefficient.
- B/C<0 – this case may mathematically be derived when either the benefits are negative (net damage) or when costs are negative (therefore this means the new regulation results into a reduction of net costs). In principle, a negative B/C ratio is node defined. In such cases, the 'net benefits' approach (i.e. benefits minus costs) may be a better option[159].

It should also be clarified that a high B/C ratio does not necessarily correspond to a high benefit, it merely compares the benefits compared to the costs. That is, an efficient policy option may have low cost and achieve measurable benefits thus leading to a high B/C ratio but still benefits may not be enough to achieve environmental targets that may have set. On the contrary, a different policy option may exhibit a lower B/C because costs are substantial but may be a better option overall because the benefits achieve the target set, despite high costs. Therefore, the efficiency of any policy option should be considered on par with the absolute scale of environmental benefits this delivers.

With these considerations, Table 6-12 to Table 6-18 present the results of the cost-benefit analysis (CBA) performed in the current study. These tables show for each policy option:

- The total Costs and total Benefits in monetised terms,
- The ratio of Benefit-over-Cost,
- The net (monetised) benefits expressed as Benefits minus Costs.

When costs appear negative, this means that the specific policy option results to be more economical than Euro 6/VI. In such cases, the B/C ratio would turn negative; this actually means it cannot be defined. The same tables also show the cost-effectiveness values for NO_x and $PM_{2.5}$, that is the total cost allocated to the reduction of NO_x and $PM_{2.5}$, respectively, in order to be able to compare the policy options to each other. Each table has two parts, one referring to total costs and benefits of implementation and the other referring to these costs or benefits allocated per vehicle, i.e. dividing the total costs incurring in the period until 2050 with the total number of vehicles of each corresponding category that has been registered in the same period. All values are discounted over the period of implementation and are presented with their Net Present Value (NPV) equivalent.

The following general comments and clarifications can be made with respect to the values of these tables:

- The "High Benefit / Low Cost" values correspond to benefits obtained over the conservative Euro 6/VI emission factor evolution and costs calculated with the lowest value of their uncertainty range[160]. On the contrary, the "Low-benefit/High-

[159] European Commission, Better Regulation Toolbox, Tool #57.

[160] The lowest and highest cost values are presented in section 9.5 (Annex I).

Cost" values are calculated assuming Euro 6/VI emission levels will continue normally in the future (at their current levels, according to the measurements presented in the *Combined report*) and costs are calculated with the highest value of the uncertainty range. The combination of these two parameters provides the extremes of the uncertainty range that, in statistical terms, this would correspond to six standard deviations.

- The "Central" value comes out as the average of the uncertainty produced by the "High-Benefit / Low-Cost" and "Low-Benefit / High-Cost range and corresponds to the average estimate of how benefits and costs may evolve, given the uncertainty in our estimates.
- Total net benefits are much larger for lorries and trucks than for cars and vans. This is a for combination of reasons that are in more detail analysed in the description of each individual policy option. Most importantly, this is because of the much longer lifetime and distance driven by lorries and busses, compared to cars and vans so reductions in emission factors have much higher impact for the longer-lasting and longer-driven lorries and buses. Moreover, in our scenarios, ICE-equipped HDVs remain in registrations until 2050, while ICE-equipped LDVs practically disappear from the market in 2035 and their sales decrease substantially until then. Additionally, there is much less cold-start per day for trucks than cars and much higher contribution of steady-speed motorway driving (especially for long-haulers) than cars. Hence, a decrease in emission limits is, by definition, proportionally reflected to actual emission levels of heavy duty vehicles.
- Costs and benefits per vehicle appear much higher for HDVs than for cars and vans due to the much lower volume of sales of lorries and buses compared to cars and vans. Some of the costs, such as R&D and calibration expenses do not scale with vehicle registrations. As a result, specific costs per vehicle increase as the number of vehicles registered decreases.
- Costs or benefits from CI vehicles appear higher than for PI. This is because the NO_x emissions at Euro 6/VI level were higher for CI than for PI so the benefits for CI vehicles when introducing a policy option are higher. At the same time, the technical effort to decrease their emissions is larger so that their costs are higher.
- Cost-effectiveness for $PM_{2.5}$ appears much higher than for NO_x (much higher cost per unit of pollutant decreased). This is because exhaust $PM_{2.5}$ is already controlled with DPFs and GPFs (for GDI vehicles) at Euro 6/VI so additional reductions are minor. On the other hand, NO_x reductions can be substantial, especially for CI vehicles.

Moreover, specific observations for the different policy options and scenarios can be made:

- PO1 results to a visible net benefit to the society which mostly comes from a reduction in the emission levels of HDVs vehicles, especially if these are expected to evolve according to the conservative Euro 6/VI projection. For HDVs, there are benefits introduced by decreasing costs of the type-approval and by introducing an enhanced OBD and simplified procedures that can enable a more stringent IsC and MaS framework. This framework requires retaining a low enough engineering target for the emission levels of vehicles because these may be checked for compliance over their complete useful life. This hinders future emission levels to evolve according to the conservative projection. For LDVs, additional benefits materialise due to the widening of boundary conditions and the streamlining of emission limits between CI and PI vehicles. Therefore, main benefits come from CI LDVs. One potentially interesting feature of PO1 is that even under our extreme estimate of high implementation cost and no worsening of the Euro 6/VI emission levels in the future, it results to very little overall net damage. This means that PO1 is a very safe option but- at best - delivers little, compared to other options, net benefits.

- PO2 produces significant net benefits which, again, mostly originate from HDVs and secondarily from CI cars & vans. PO2 in general exhibits low benefit and high cost for PI LDVs. The central values for those appear negative (B/C is equal to 0.74, 0.67 and 0.35 for scenarios Sc1, Sc2 and Sc3, respectively) but considering the high net benefits from CI cars, this PO results to appreciable net positive benefits for cars and vans. More than 2/3 of the high benefits from lorries and buses come from NO_x reductions which are significant over Euro VI. However, PO2 also achieves reductions for PM which come from a better control of semi-volatile PM during cold start, decrease of the particle number limit and inclusion of the regeneration in emissions control. Approximately 8 and 4 of the benefit comes from exhaust PM control for buses and lorries CI, respectively, while these percentages become higher when considering PI, i.e. 21 and 18 for buses and lorries, respectively. However, a significant benefit (approximately 28 of the total for lorries CI and 25 of the total for buses CI) comes from the better control of N_2O – this is an environmental benefit due to the reduction of the total radiative forcing activity of N_2O and not due to health benefits. Some smaller-scale benefits come from the other pollutants. PO2.Sc3 also exhibits net benefits for lorries and buses but its benefits for LDVs become marginal (B/C=1.11) and, especially for PI cars and vans, the B/C ratio becomes less than 0.5. This is due to the significant additional costs this entails, compared to the improvement this offers. PO2.Sc3 provides an almost equal probability that it will be a net benefit or a net cost to the society for cars and vans. Especially if future PI registrations are higher than what the projection used in this study predicts[161], this may even result to significant overall net costs to the society from cars and vans.
- PO3 also leads to significant net benefits, despite its higher cost, originating (in addition to PO2) from the better control of degradation and malfunctions due to OBM. Actually, PO3 results to the overall highest net benefits both for LDV and HDV, even more so than PO2.SC3 that has been formulated with the lowest emission limits but no OBM implementation. This suggests that OBM can bring real-world benefits due to the decrease of tampering and making sure that the emission control system operates within specifications that supersede its implementation costs.

[161] Details on the projection are given in 9.2**Error! Reference source not found.** and the future technology mix originates f rom the work of DG CLIMA in SWD(2020) 176 final.

Table 6-12: Cost-benefit considered in PO1 over the baseline

PO1	Euro 7 over Euro 6 (billion EUR)			Euro 7 over Euro 6 per vehicle (EUR)		
	Central	High Benefit / Low Cost	Low Benefit / High Cost	Central	High Benefit / Low Cost	Low Benefit / High Cost
	LDVs_Total					
Net Benefits NPV	**9.15**	**20.12**	**-1.82**	**108.26**	**238.08**	**-21.56**
Benefits NPV	14.21	22.37	6.05	168.11	264.69	71.54
Costs NPV	5.06	2.25	7.87	59.85	26.61	93.10
Benefit/Cost Ratio	2.81	9.95	0.77	2.81	9.95	0.77
Cost-Effectiveness NO_x [b EUR/Mt]	10.55	4.55	16.93	10.55	4.55	16.93
Cost-Effectiveness $PM_{2.5}$ [b EUR/Mt]	-	2,497.81	-	-	2,497.81	-
	LDVs_CI					
Net Benefits NPV	**7.82**	**15.88**	**-0.24**	**173.29**	**351.91**	**-5.33**
Benefits NPV	12.14	18.62	5.66	268.98	412.58	125.37
Costs NPV	4.32	2.74	5.90	95.68	60.67	130.70
Benefit/Cost Ratio	2.81	6.80	0.96	2.81	6.80	0.96
Cost-Effectiveness NOx [b EUR/Mt]	7.49	3.92	12.98	7.49	3.92	12.98
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	2,638.66	-	-	2,638.66	-
	LDVs_PI					
Net Benefits NPV	**1.33**	**4.24**	**-1.58**	**33.74**	**107.64**	**-40.17**
Benefits NPV	2.07	3.75	0.39	52.53	95.21	9.85
Costs NPV	0.74	-0.49	1.97	18.80	-12.43	50.02
Benefit/Cost Ratio	2.79	-	0.20	2.79	-	0.20
Cost-Effectiveness NOx [b EUR/Mt]	-	8.77	193.57	-	8.77	193.57
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	2,153.63	-	-	2,153.63	-
	HDVs_Total					
Net Benefits NPV	**10.29**	**21.39**	**-0.81**	**1,628.80**	**3,385.14**	**-127.54**
Benefits NPV	10.57	21.14	0.00	1,672.48	3,344.97	0.00
Costs NPV	0.28	-0.25	0.81	43.68	-40.18	127.54
Benefit/Cost Ratio	38.29	-	0.00	38.29	-	0.00
Cost-Effectiveness NOx [b EUR/Mt]	-	0.38	-	-	0.38	-
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	-	-	-	-	-
	HDVs_CI					
Net Benefits NPV	**10.29**	**21.27**	**-0.68**	**2,023.39**	**4,181.30**	**-134.51**
Benefits NPV	10.57	21.14	0.00	2,077.95	4,155.89	0.00
Costs NPV	0.28	-0.13	0.68	54.55	-25.41	134.51
Benefit/Cost Ratio	38.09	-	0.00	38.09	-	0.00
Cost-Effectiveness NOx [b EUR/Mt]	-	0.32	-	-	0.32	-
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	-	-	-	-	-
	HDVs_PI					
Net Benefits NPV	**0.00**	**0.12**	**-0.12**	**1.14**	**101.07**	**-98.79**
Benefits NPV	0.00	0.00	0.00	0.00	0.00	0.00
Costs NPV	0.00	-0.12	0.12	-1.14	-101.07	98.79
Benefit/Cost Ratio	0.00	0.00	0.00	0.00	0.00	0.00
Cost-Effectiveness NOx [b EUR/Mt]	-	-	-	-	-	-
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	-	-	-	-	-

Table 6-13: Cost-benefit considered in PO2.Sc1 over the baseline

PO2 Scenario 1	Euro 7 over Euro 6 (billion EUR)			Euro 7 over Euro 6 per vehicle (EUR)		
	Central	High Benefit / Low Cost	Low Benefit / High Cost	Central	High Benefit / Low Cost	Low Benefit / High Cost
	LDVs_Total					
Net Benefits NPV	**8.39**	**27.43**	**-10.64**	**99.32**	**324.55**	**-125.90**
Benefits NPV	32.08	44.92	19.24	379.62	531.55	227.69
Costs NPV	23.69	17.49	29.88	280.29	207.00	353.58
Benefit/Cost Ratio	1.35	2.57	0.64	1.35	2.57	0.64
Cost-Effectiveness NO_x [b EUR/Mt]	15.28	10.90	19.97	15.28	10.90	19.97
Cost-Effectiveness $PM_{2.5}$ [b EUR/Mt]	-	8,645.19	-	-	8,645.19	-
	LDVs_CI					
Net Benefits NPV	**9.85**	**24.67**	**-4.97**	**218.29**	**546.67**	**-110.08**
Benefits NPV	27.88	39.16	16.59	617.80	867.95	367.66
Costs NPV	18.03	14.50	21.56	399.51	321.28	477.74
Benefit/Cost Ratio	1.55	2.70	0.77	1.55	2.70	0.77
Cost-Effectiveness NOx [b EUR/Mt]	11.80	8.81	15.29	11.80	8.81	15.29
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	8,702.25	-	-	8,702.25	-
	LDVs_PI					
Net Benefits NPV	**-1.46**	**2.76**	**-5.67**	**-37.00**	**70.02**	**-144.02**
Benefits NPV	4.20	5.75	2.65	106.69	146.09	67.30
Costs NPV	5.66	3.00	8.32	143.69	76.06	211.32
Benefit/Cost Ratio	0.74	1.92	0.32	0.74	1.92	0.32
Cost-Effectiveness NOx [b EUR/Mt]	58.90	28.19	96.88	58.90	28.19	96.88
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	8,500.79	-	-	8,500.79	-
	HDVs_Total					
Net Benefits NPV	**105.98**	**118.84**	**93.12**	**16,770.31**	**18,805.58**	**14,735.03**
Benefits NPV	122.43	132.54	112.31	19,372.86	20,973.17	17,772.55
Costs NPV	16.45	13.70	19.20	2,602.56	2,167.59	3,037.52
Benefit/Cost Ratio	7.44	9.68	5.85	7.44	9.68	5.85
Cost-Effectiveness NOx [b EUR/Mt]	2.44	2.11	2.74	2.44	2.11	2.74
Cost-Effectiveness PM2.5 [b EUR/Mt]	253.77	253.77	253.77	253.77	253.77	253.77
	HDVs_CI					
Net Benefits NPV	**108.11**	**120.41**	**95.80**	**21,254.15**	**23,673.49**	**18,834.81**
Benefits NPV	121.74	131.86	111.63	23,935.10	25,923.38	21,946.83
Costs NPV	13.64	11.44	15.83	2,680.95	2,249.88	3,112.02
Benefit/Cost Ratio	8.93	11.52	7.05	8.93	11.52	7.05
Cost-Effectiveness NOx [b EUR/Mt]	2.03	1.75	2.28	2.03	1.75	2.28
Cost-Effectiveness PM2.5 [b EUR/Mt]	214.10	214.10	214.10	214.10	214.10	214.10
	HDVs_PI					
Net Benefits NPV	**-2.13**	**-1.57**	**-2.68**	**-1,725.06**	**-1,274.03**	**-2,176.10**
Benefits NPV	0.68	0.68	0.68	554.14	554.14	554.14
Costs NPV	2.81	2.25	3.37	2,279.20	1,828.17	2,730.24
Benefit/Cost Ratio	0.24	0.30	0.20	0.24	0.30	0.20
Cost-Effectiveness NOx [b EUR/Mt]	56.50	56.50	56.50	56.50	56.50	56.50
Cost-Effectiveness PM2.5 [b EUR/Mt]	1,968.28	1,968.28	1,968.28	1,968.28	1,968.28	1,968.28

Table 6-14: Cost-benefit considered in PO2.Sc2 over the baseline

PO2 Scenario 2	Euro 7 over Euro 6 (billion EUR)			Euro 7 over Euro 6 per vehicle (EUR)		
	Central	High Benefit / Low Cost	Low Benefit / High Cost	Central	High Benefit / Low Cost	Low Benefit / High Cost
	LDVs_Total					
Net Benefits NPV	**7.81**	**26.84**	**-11.22**	**92.42**	**317.64**	**-132.81**
Benefits NPV	32.45	45.29	19.61	384.00	535.93	232.07
Costs NPV	24.64	18.45	30.83	291.58	218.29	364.87
Benefit/Cost Ratio	1.32	2.46	0.64	1.32	2.46	0.64
Cost-Effectiveness NO_x [b EUR/Mt]	15.51	11.14	20.25	15.51	11.14	20.25
Cost-Effectiveness $PM_{2.5}$ [b EUR/Mt]	-	7,839.72	-	-	7,839.72	-
	LDVs_CI					
Net Benefits NPV	**9.91**	**24.73**	**-4.91**	**219.58**	**547.96**	**-108.79**
Benefits NPV	28.14	39.43	16.85	623.61	873.75	373.46
Costs NPV	18.23	14.70	21.76	404.02	325.79	482.25
Benefit/Cost Ratio	1.54	2.68	0.77	1.54	2.68	0.77
Cost-Effectiveness NOx [b EUR/Mt]	11.78	8.83	15.22	11.78	8.83	15.22
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	7,742.53	-	-	7,742.53	-
	LDVs_PI					
Net Benefits NPV	**-2.10**	**2.12**	**-6.31**	**-53.30**	**53.72**	**-160.33**
Benefits NPV	4.31	5.86	2.76	109.44	148.83	70.05
Costs NPV	6.41	3.75	9.07	162.74	95.11	230.38
Benefit/Cost Ratio	0.67	1.56	0.30	0.67	1.56	0.30
Cost-Effectiveness NOx [b EUR/Mt]	58.83	30.00	97.49	58.83	30.00	97.49
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	8,083.11	-	-	8,083.11	-
	HDVs_Total					
Net Benefits NPV	**105.94**	**118.80**	**93.08**	**16,763.86**	**18,799.14**	**14,728.59**
Benefits NPV	122.43	132.54	112.31	19,372.86	20,973.17	17,772.55
Costs NPV	16.49	13.74	19.24	2,609.00	2,174.03	3,043.96
Benefit/Cost Ratio	7.43	9.65	5.84	7.43	9.65	5.84
Cost-Effectiveness NOx [b EUR/Mt]	2.44	2.12	2.75	2.44	2.12	2.75
Cost-Effectiveness PM2.5 [b EUR/Mt]	254.31	254.31	254.31	254.31	254.31	254.31
	HDVs_CI					
Net Benefits NPV	**108.07**	**120.38**	**95.77**	**21,247.18**	**23,666.52**	**18,827.83**
Benefits NPV	121.74	131.86	111.63	23,935.10	25,923.38	21,946.83
Costs NPV	13.67	11.48	15.86	2,687.92	2,256.85	3,118.99
Benefit/Cost Ratio	8.90	11.49	7.04	8.90	11.49	7.04
Cost-Effectiveness NOx [b EUR/Mt]	2.03	1.76	2.28	2.03	1.76	2.28
Cost-Effectiveness PM2.5 [b EUR/Mt]	214.58	214.58	214.58	214.58	214.58	214.58
	HDVs_PI					
Net Benefits NPV	**-2.13**	**-1.58**	**-2.69**	**-1,729.31**	**-1,278.28**	**-2,180.35**
Benefits NPV	0.68	0.68	0.68	554.14	554.14	554.14
Costs NPV	2.82	2.26	3.37	2,283.45	1,832.42	2,734.49
Benefit/Cost Ratio	0.24	0.30	0.20	0.24	0.30	0.20
Cost-Effectiveness NOx [b EUR/Mt]	56.59	56.59	56.59	56.59	56.59	56.59
Cost-Effectiveness PM2.5 [b EUR/Mt]	1,971.34	1,971.34	1,971.34	1,971.34	1,971.34	1,971.34

Table 6-15: Cost-benefit considered in PO2.Sc3 over the baseline

PO2 Scenario 3	Euro 7 over Euro 6 (billion EUR)			Euro 7 over Euro 6 per vehicle (EUR)		
	Central	High Benefit / Low Cost	Low Benefit / High Cost	Central	High Benefit / Low Cost	Low Benefit / High Cost
	LDVs_Total					
Net Benefits NPV	**3.72**	**22.96**	**-15.51**	**44.08**	**271.67**	**-183.52**
Benefits NPV	37.49	50.33	24.65	443.67	595.61	291.74
Costs NPV	33.77	27.37	40.16	399.59	323.93	475.26
Benefit/Cost Ratio	1.11	1.84	0.61	1.11	1.84	0.61
Cost-Effectiveness NO_x [b EUR/Mt]	19.60	14.40	26.00	19.60	14.40	26.00
Cost-Effectiveness $PM_{2.5}$ [b EUR/Mt]	-	9,650.34	-	-	9,650.34	-
	LDVs_CI					
Net Benefits NPV	**12.12**	**26.94**	**-2.70**	**268.64**	**597.02**	**-59.73**
Benefits NPV	33.01	44.30	21.72	731.56	981.71	481.41
Costs NPV	20.89	17.36	24.42	462.91	384.68	541.14
Benefit/Cost Ratio	1.58	2.55	0.89	1.58	2.55	0.89
Cost-Effectiveness NOx [b EUR/Mt]	13.03	9.85	16.91	13.03	9.85	16.91
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	8,074.77	-	-	8,074.77	-
	LDVs_PI					
Net Benefits NPV	**-8.40**	**-3.98**	**-12.81**	**-213.25**	**-101.14**	**-325.36**
Benefits NPV	4.48	6.03	2.93	113.79	153.18	74.40
Costs NPV	12.88	10.01	15.74	327.04	254.32	399.76
Benefit/Cost Ratio	0.35	0.60	0.19	0.35	0.60	0.19
Cost-Effectiveness NOx [b EUR/Mt]	86.30	50.73	155.80	86.30	50.73	155.80
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	-	-	-	-	-
	HDVs_Total					
Net Benefits NPV	**98.23**	**111.10**	**85.37**	**15,544.35**	**17,579.65**	**13,509.06**
Benefits NPV	123.89	134.01	113.78	19,604.52	21,204.84	18,004.19
Costs NPV	25.66	22.91	28.41	4,060.16	3,625.20	4,495.13
Benefit/Cost Ratio	4.83	5.85	4.01	4.83	5.85	4.01
Cost-Effectiveness NOx [b EUR/Mt]	3.56	3.11	4.03	3.56	3.11	4.03
Cost-Effectiveness PM2.5 [b EUR/Mt]	370.36	370.36	370.36	370.36	370.36	370.36
	HDVs_CI					
Net Benefits NPV	**101.43**	**113.74**	**89.13**	**19,941.98**	**22,361.34**	**17,522.61**
Benefits NPV	123.21	133.32	113.10	24,222.91	26,211.21	22,234.62
Costs NPV	21.77	19.58	23.97	4,280.93	3,849.87	4,712.00
Benefit/Cost Ratio	5.66	6.81	4.72	5.66	6.81	4.72
Cost-Effectiveness NOx [b EUR/Mt]	3.02	2.64	3.43	3.02	2.64	3.43
Cost-Effectiveness PM2.5 [b EUR/Mt]	319.60	319.60	319.60	319.60	319.60	319.60
	HDVs_PI					
Net Benefits NPV	**-3.20**	**-2.64**	**-3.76**	**-2,595.36**	**-2,144.32**	**-3,046.39**
Benefits NPV	0.68	0.68	0.68	554.14	554.14	554.14
Costs NPV	3.88	3.33	4.44	3,149.49	2,698.46	3,600.53
Benefit/Cost Ratio	0.18	0.21	0.15	0.18	0.21	0.15
Cost-Effectiveness NOx [b EUR/Mt]	74.51	74.51	74.51	74.51	74.51	74.51
Cost-Effectiveness PM2.5 [b EUR/Mt]	2,595.69	2,595.69	2,595.69	2,595.69	2,595.69	2,595.69

Table 6-16: Cost-benefit considered in PO3.Sc1 over the baseline

PO3 Scenario 1	Euro 7 over Euro 6 (billion EUR)			Euro 7 over Euro 6 per vehicle (EUR)		
	Central	High Benefit / Low Cost	Low Benefit / High Cost	Central	High Benefit / Low Cost	Low Benefit / High Cost
	LDVs_Total					
Net Benefits NPV	**8.79**	**28.50**	**-10.93**	**103.97**	**337.26**	**-129.32**
Benefits NPV	33.01	45.85	20.17	390.64	542.57	238.71
Costs NPV	24.22	17.35	31.10	286.67	205.31	368.02
Benefit/Cost Ratio	1.36	2.64	0.65	1.36	2.64	0.65
Cost-Effectiveness NO_x [b EUR/Mt]	15.48	11.07	19.89	15.48	11.07	19.89
Cost-Effectiveness $PM_{2.5}$ [b EUR/Mt]	-	8,998.22	-	-	8,998.22	-
	LDVs_CI					
Net Benefits NPV	**10.22**	**25.22**	**-4.78**	**226.48**	**558.80**	**-105.84**
Benefits NPV	28.65	39.94	17.37	635.03	885.17	384.88
Costs NPV	18.43	14.73	22.14	408.54	326.37	490.72
Benefit/Cost Ratio	1.55	2.71	0.78	1.55	2.71	0.78
Cost-Effectiveness NOx [b EUR/Mt]	11.71	8.81	15.00	11.71	8.81	15.00
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	8,938.73	-	-	8,938.73	-
	LDVs_PI					
Net Benefits NPV	**-1.43**	**3.28**	**-6.15**	**-36.41**	**83.40**	**-156.22**
Benefits NPV	4.36	5.91	2.80	110.60	149.99	71.21
Costs NPV	5.79	2.62	8.96	147.01	66.60	227.43
Benefit/Cost Ratio	0.75	2.25	0.31	0.75	2.25	0.31
Cost-Effectiveness NOx [b EUR/Mt]	66.72	30.24	103.14	66.72	30.24	103.14
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	9,148.77	-	-	9,148.77	-
	HDVs_Total					
Net Benefits NPV	**106.43**	**119.39**	**93.47**	**16,841.35**	**18,891.65**	**14,791.05**
Benefits NPV	123.38	133.49	113.27	19,523.27	21,123.57	17,922.97
Costs NPV	16.95	14.10	19.79	2,681.92	2,231.92	3,131.92
Benefit/Cost Ratio	7.28	9.46	5.72	7.28	9.46	5.72
Cost-Effectiveness NOx [b EUR/Mt]	2.49	2.16	2.79	2.49	2.16	2.79
Cost-Effectiveness PM2.5 [b EUR/Mt]	261.65	261.65	261.65	261.65	261.65	261.65
	HDVs_CI					
Net Benefits NPV	**108.63**	**121.00**	**96.26**	**21,356.37**	**23,788.74**	**18,923.99**
Benefits NPV	122.70	132.81	112.58	24,121.97	26,110.23	22,133.71
Costs NPV	14.07	11.81	16.33	2,765.60	2,321.49	3,209.72
Benefit/Cost Ratio	8.72	11.25	6.90	8.72	11.25	6.90
Cost-Effectiveness NOx [b EUR/Mt]	2.07	1.79	2.32	2.07	1.79	2.32
Cost-Effectiveness PM2.5 [b EUR/Mt]	220.82	220.82	220.82	220.82	220.82	220.82
	HDVs_PI					
Net Benefits NPV	**-2.20**	**-1.61**	**-2.78**	**-1,782.61**	**-1,308.32**	**-2,256.89**
Benefits NPV	0.68	0.68	0.68	554.14	554.14	554.14
Costs NPV	2.88	2.30	3.47	2,336.74	1,862.46	2,811.02
Benefit/Cost Ratio	0.24	0.30	0.20	0.24	0.30	0.20
Cost-Effectiveness NOx [b EUR/Mt]	58.17	58.17	58.17	58.17	58.17	58.17
Cost-Effectiveness PM2.5 [b EUR/Mt]	2,026.52	2,026.52	2,026.52	2,026.52	2,026.52	2,026.52

Table 6-17: Cost-benefit considered in PO3.Sc2 over the baseline

PO3 Scenario 2	Euro 7 over Euro 6 (billion EUR)			Euro 7 over Euro 6 per vehicle (EUR)		
	Central	High Benefit / Low Cost	Low Benefit / High Cost	Central	High Benefit / Low Cost	Low Benefit / High Cost
	LDVs_Total					
Net Benefits NPV	**8.52**	**28.37**	**-11.33**	**100.79**	**335.68**	**-134.10**
Benefits NPV	33.30	46.14	20.47	394.12	546.05	242.18
Costs NPV	24.79	17.78	31.80	293.32	210.37	376.28
Benefit/Cost Ratio	1.34	2.60	0.64	1.34	2.60	0.64
Cost-Effectiveness NO_x [b EUR/Mt]	15.67	11.24	20.09	15.67	11.24	20.09
Cost-Effectiveness $PM_{2.5}$ [b EUR/Mt]	-	8,084.75	-	-	8,084.75	-
	LDVs_CI					
Net Benefits NPV	**10.33**	**25.37**	**-4.72**	**228.87**	**562.27**	**-104.53**
Benefits NPV	28.84	40.13	17.55	639.16	889.31	389.01
Costs NPV	18.51	14.76	22.27	410.29	327.03	493.55
Benefit/Cost Ratio	1.56	2.72	0.79	1.56	2.72	0.79
Cost-Effectiveness NOx [b EUR/Mt]	11.71	8.82	14.95	11.71	8.82	14.95
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	7,923.89	-	-	7,923.89	-
	LDVs_PI					
Net Benefits NPV	**-1.81**	**2.99**	**-6.61**	**-45.97**	**76.04**	**-167.97**
Benefits NPV	4.46	6.01	2.91	113.33	152.72	73.93
Costs NPV	6.27	3.02	9.53	159.29	76.68	241.90
Benefit/Cost Ratio	0.71	1.99	0.31	0.71	1.99	0.31
Cost-Effectiveness NOx [b EUR/Mt]	66.02	31.42	101.43	66.02	31.42	101.43
Cost-Effectiveness PM2.5 [b EUR/Mt]	-	8,487.56	-	-	8,487.56	-
	HDVs_Total					
Net Benefits NPV	**106.44**	**119.42**	**93.47**	**16,843.34**	**18,896.70**	**14,789.97**
Benefits NPV	123.38	133.49	113.27	19,523.27	21,123.57	17,922.97
Costs NPV	16.94	14.07	19.80	2,679.93	2,226.87	3,133.00
Benefit/Cost Ratio	7.28	9.49	5.72	7.28	9.49	5.72
Cost-Effectiveness NOx [b EUR/Mt]	2.49	2.16	2.79	2.49	2.16	2.79
Cost-Effectiveness PM2.5 [b EUR/Mt]	261.74	261.74	261.74	261.74	261.74	261.74
	HDVs_CI					
Net Benefits NPV	**108.63**	**121.01**	**96.24**	**21,356.59**	**23,791.48**	**18,921.71**
Benefits NPV	122.70	132.81	112.58	24,121.97	26,110.23	22,133.71
Costs NPV	14.07	11.79	16.34	2,765.38	2,318.75	3,212.00
Benefit/Cost Ratio	8.72	11.26	6.89	8.72	11.26	6.89
Cost-Effectiveness NOx [b EUR/Mt]	2.07	1.79	2.32	2.07	1.79	2.32
Cost-Effectiveness PM2.5 [b EUR/Mt]	220.98	220.98	220.98	220.98	220.98	220.98
	HDVs_PI					
Net Benefits NPV	**-2.19**	**-1.60**	**-2.78**	**-1,773.35**	**-1,293.71**	**-2,253.00**
Benefits NPV	0.68	0.68	0.68	554.14	554.14	554.14
Costs NPV	2.87	2.28	3.46	2,327.49	1,847.84	2,807.14
Benefit/Cost Ratio	0.24	0.30	0.20	0.24	0.30	0.20
Cost-Effectiveness NOx [b EUR/Mt]	58.09	58.09	58.09	58.09	58.09	58.09
Cost-Effectiveness PM2.5 [b EUR/Mt]	2,023.72	2,023.72	2,023.72	2,023.72	2,023.72	2,023.72

The following table presents the cost-benefit ratio for the introduction of brake wear emissions. The B/C ratios are calculated to be above one in scenario POx.ScB1 and below one in scenario POx.ScB2. This is because, despite significant reductions in total PM mass in the two scenarios, there is significant cost for implementing these measures. As technology costs for brake wear decrease fast with time due to the immaturity of some of the relevant technologies, exact limits of brake wear may need to be reassessed when a specific time frame for regulatory intervention has been decided.

Table 6-18: Cost-benefit considered in the brake wear scenario B1 and B2 over the baseline

LDVs	Euro 7 over Euro 6 (billion EUR)	Euro 7 over Euro 6 per vehicle (EUR)
	POx.ScB1	
Net Benefits NPV	**3.31**	**8.35**
Benefits NPV	9.90	25.01
Costs NPV	6.60	16.66
Benefit/Cost Ratio	1.50	1.50
Cost-Effectiveness PM2.5 [b EUR/Mt]	59.09	59.09
	Pox.ScB2	
Net Benefits NPV	**-15.24**	**-38.48**
Benefits NPV	14.85	37.51
Costs NPV	30.09	75.99
Benefit/Cost Ratio	0.49	0.49
Cost-Effectiveness PM2.5 [b EUR/Mt]	179.71	179.71

6.3. Coherence

Internal coherence

This section explores the consistency of the Euro 7 Policy options with the overall EU policy framework regarding vehicle emissions. In the Evaluation report, some inconsistencies were identified, particularly the lack of fuel and technology neutrality, and differences in applicability of the Euro 6/VI standards in terms of introduction dates for cars and vans.

PO1 which addresses key simplification and consistency challenges, includes measures to be incorporated in the Euro 7 emission standard, largely based on the proposals of the Simplification report. In the context of internal coherence, these primarily include:

- **Fuel/technology neutral limits**: Fuel-related specificities have been removed from limits values, in all POs. From the 1st targeted consultation and the public consultation, most stakeholders agreed that introducing limits that are technology and fuel- neutral will reduce the overall complexity of the emissions standards. Furthermore, during the public consultation, the majority of respondents, from all stakeholder groups (89 out of 128) also highlighted that the differences in emissions limits based on fuel and technology are at least somewhat complex.

Hence, the introduction of fuel neutrality can be considered a change that will significantly improve internal coherence of the regulations.

- **Merging the main regulations of cars/vans[162] and lorries/buses[163] into a single regulation piece:** This is because these main regulations only set the general scope for emission testing in type approval and on many occasions look very similar and therefore offer potential to merge. This was confirmed in the follow-up interviews of the 2nd stakeholder consultation. The concern of the stakeholders was mostly on merging the delegated parts of the regulation for the different vehicle categories. More specifically the industry was mostly negative for a potential merge (30 out of 44 respondents), as their main argument that cars/vans and lorries/buses are significantly different (particularly in terms of operating duties and cycles), and therefore cannot be merged into one regulation. National authorities/technical services and civil society were more supportive even for such a potential merge (10 out of 22). However, any concerns can be addressed by explicitly presenting the outlines of the separate implementing and delegated acts for cars/vans and lorries/buses[164], as proposed in Figure 6-1.

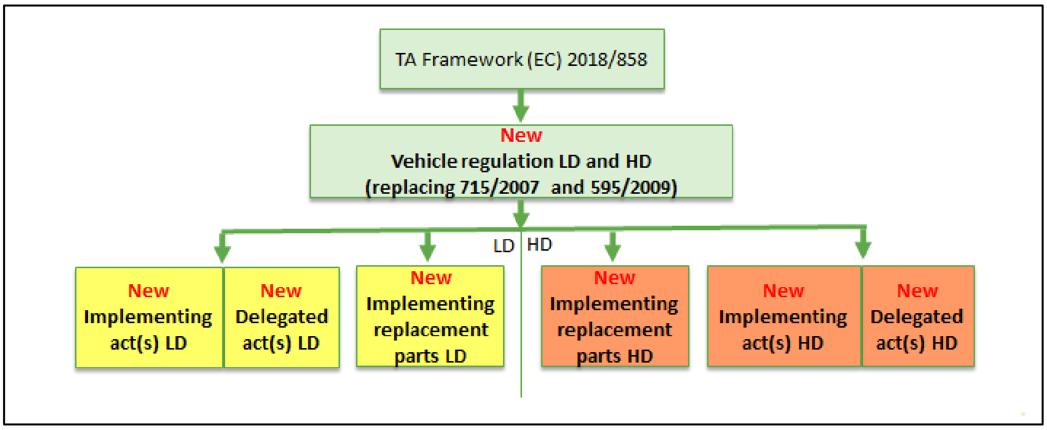

Figure 6-1: New structure of European vehicle emissions legislation if emission Regulation 715/2007 (cars/vans) and 595/2009 (lorries/buses) is replaced by one single regulation (Source: Simplification Report)

- **Define new border between LDV and HDV emissions legislation**: This incorporates potential replacement of the reference mass in the scope definition by a parameter (e.g. TPMLM) that is better suited to distinguish between cars, vans and lorries, buses. Based on the findings of the Simplification report, the potential introduction of TPMLM at a value of 3.5 tonnes will reduce the differences in vehicle categorisation and is suitable to facilitate multistage type approvals. From the 2nd targeted consultation, the proposal for eliminating the distinction based on reference mass, was welcomed as generally positive. The industry, in 17 out of 44 participants considered this positively. Same with national authorities/TS (8 positive responses out 16) and civil society (5 out 6).

- **Introduce a single date of Euro 7 introduction per vehicle category:** In the Evaluation report it was highlighted that the existing mechanism with the two-step mandatory dates for new vehicle type approvals, has made the regulatory framework more complex. Thus already from PO1, it is proposed to be changed in a single date of introduction. That said, the option to type-approve ahead of the

[162] Regulation (EC) 715/2007

[163] Regulation (EC) 595/2009

[164] Simplification report

required date will continue to exist in Euro 7. Based on the 2nd targeted consultation, regarding the (qualitative) impacts of this measure, 14 (out of 67) stakeholders suggested that it will reduce administrative costs. However, only 5 component suppliers supported this statement, while 7 OEMs expressed the different opinion.

All PO incorporate the above elements, hence whatever the eventual decision on the chosen PO, there would be a positive impact on strengthening the internal coherence of emissions-related regulations, between cars, vans, lorries, buses. This was expected as there was a clear mandate (i.e. Task 2- Simplification) in exploring, identifying and proposing ways to reduce the complexity of future emissions standards, while maintaining the highest level of regulatory coherence and environmental protection possible on an EU-27 level.

External coherence

This section explores the extent to which the of the Euro 7 Policy Options are coherent/consistent with other key EU policies/interventions. Hence, the Policy Options are examined in the light of the objectives and provisions of relevant pieces of legislation including:

European Green deal: The European Green deal, which is an integral part of EU's strategy to tackle climate and environmental-related challenges, stipulates that: "Transport should become drastically less polluting, especially in cities. A combination of measures should address emissions, urban congestion, and improved public transport. The Commission will propose more stringent air pollutant emissions standards for combustion-engine vehicles". Based on this statement it is clear that the primary aim of the new Euro 7 standards is to significantly reduce (road) transport pollutant emissions, hence the level of coherence is linked with the benefits in terms of emissions reduction. To this end, based on the assessment made in Section 6.1 (i.e Table 6-1 to

- Table 6-5), PO1 is estimated to produce the lowest level of environmental benefits, followed by PO2 and PO3 which results into the highest degree of overall environmental benefit. Furthermore, the coverage of additional pollutants and better control over evaporative emissions, puts PO2 and PO3 ahead of PO1 in terms of environmental protection.
- **Ambient Air Quality Directives**: Emission standards of vehicles are one of the key instruments in maintaining clean air in cities along the strategies and the targets of the Ambient Air Quality Directives, in particular Directive 2008/50/EC addressing transport-relevant pollutants. As earlier presented in the report, there are still exceedances of air pollution limits, both in terms of NO_2 (3-4% EU population above limits) and PM_{10} (10-15% of EU population above limits). Reductions in emissions calculated for the different policy options of Euro 7 will assist in further decreasing those exceedances, although the extent of reduction also depends on the contribution of other sources. Hence, an estimate of the degree of exceedance reduction offered by the different policy options far exceeds the objectives of the current report. It should be noted that the Ambient Air Quality Directives are currently under review, primarily due to revised guidelines from WHO on lower levels of ambient concentration limits for NO_2 and PM. The exact targets to be adopted at the EU level are not known yet but the relevant Inception

Impact Assessment by the EC[165] suggests that EU air quality standards allow higher air pollutant concentrations than is scientifically advisable and a policy area is a closer alignment of EU air quality standards with latest recommendations from WHO. With current EU standards exceeding the level value of 2005 WHO recommendations and with a declared wish to move closer to 2021 WHO recommendations, this suggests a potentially significant reduction of air quality limits in the EU. In such a case, Euro 7 policy options are deemed to be instrumental in achieving this targets both in terms of NO_2 – especially PO2 and PO3 where lower limits are proposed – but also in terms of PM_{10} due to the proposal to limit emissions of brake wear.

- **Vehicle roadworthiness legislation:** The general objective of this legislation is to contribute to the reduction of air pollutants from road transport through measures aiming at detecting over-polluting vehicles due to potential technical defects**.** That said, periodic testing and inspections (PTI) and roadside inspections (RSI) do not support direct compliance with emission limits as set out in the Euro standards. The introduction enhanced OBD, already in PO1, will effectively contribute in identify malfunctions and may become complementary to the PTI & RSI emissions tests. Especially regarding PO3, an effective OBM mechanism, could gradually become a primary tool in the roadworthiness framework and modernize the current PTI procedures (*Simplification report*). In addition, during the 2nd targeted stakeholder consultation, some component suppliers commented that the introduction of OBM could lead to simplification of PTI, if it is reliable and robust. One specific component supplier commented that the introduction of a tampering proof OBM mechanism, combined with Over-the-air (OTA) data transmission may effectively replace current RSI.
- **Vehicle CO_2 standards:** PO1, in the context of simplification the potential introduction of TPMLM, as the primary parameter to distinguish cars/vans from lorries/buses can be potentially beneficial for CO_2 standards as well. This is based on the *Evaluation report* which highlighted a potential inconsistency due to the use of different masses (reference mass or TPMLM) to define the testing regime that a vehicle is subjected to, some N2 vehicles with the same TPMLM could be subjected to different testing regimes for their CO2 emissions, depending on their reference mass.PO2 (and by extension PO3) proposes the inclusion of additional CH_4+N_2O, which could be covered individually and/or also as CO2-equivalents (CO_{2e}).

Based on the estimated consistency links of each PO with other key regulation pieces, Table 6-19 attempts to summarize the contribution of the PO in improving external coherence.

6.4. Proportionality

The compliance of the different PO with the proportionality principle, is assessed based on the benefits of developing EU-wide legislation (that applies to all Member States) in comparison to individual Member State actions/provisions in developing their own comparable legislation (e.g. pollutant emission limits, testing requirements) or in

[165] https://ec.europa.eu/environment/air/documents/Inception%20impact%20assessment%20-%20Ares(2020)7689281.pdf

combination with international directives, such as those prescribed by the United Nations Economic Commission for Europe (UNECE).

- In the absence of harmonized rules across the EU to deal with vehicle-related pollution, Member States would most likely either take independent action at national level to introduce their own air pollutant limits or implement other measures to reduce vehicle-related pollution. As concluded by the *Evaluation report* on the Euro 6/VI standards, this approach would contribute to further fragmentation of the internal market and is unlikely to have produced the same level of results in achieving EU-wide reductions in air pollutants. This was in line with the opinion of the majority of stakeholders (1st targeted consultation) who appeared to agree that centralized EU action is more effective in terms of reducing road transport pollution. The same should be expected in the case of the upcoming Euro 7 standards, as regardless of their requirements, all PO foresee the implementation and enforcement of harmonised measures/regulatory provisions for all EU-27 Member states, without exceptions. In that sense, all PO are expected to continue to provide added value and maintain a high degree of harmonisation at an EU level. In parallel, this harmonized approach provided clarity and a 'steady' environment for the EU automotive industry, in order to develop, manufacture and sell its products in a uniform fashion for all EU Member states.

Table 6-19: Coherence of each Policy Option with other relevant EU policies

External coherence of Policy Options 1-3			
	Qualitative Assessment		
Areas	**PO1**	**PO2**	**PO3**
European Green Deal	**Scale: 1** Introduces fuel neutral limits and extended RDE conditions ,however lacks extension of coverage to additional pollutants	**Scale: 2** Introduces significant emission reductions and incldues coverage to an extended list of pollutants for all vehicle types (NMOG, CH_4, NH_3, Formaldehyde (HCHO), brake wear and N_2O)	**Scale: 3** On top of what PO2 introduces, it also brings forward methods of lifetime monitoring of real-world emissions
Roadworthiness Directive (PTI/RSI)	**Scale: 1** -Introduction of enhanced on-board diagnostics (OBD) requirements as a support element to enable testing for ISC/MaS.	**Scale: 1** Same effect expected as PO1	**Scale: 3** -Identification of over-emitters (e.g. limp mode, MIL activation) - PTI based on enhanced OBD information -May lead to more robust tampering detection
Vehicle CO_2 standards	**Scale: 1** Introduction of TPMLM to retain consistency with CO_2 regulations in vehicle category classification	**Scale: 2** On top of PO1, inclusion of additional CH_4+N_2O	**Scale: 2** On top of PO2, transmission of emission related information using OBFCM functionalities

- Considering the cross-border nature of road transport and air pollution, EU intervention in this sector supports the correct functioning of the EU internal market and establishing a level playing field. In the 1st targeted consultation, out of 45 stakeholders, 39 agreed that without EU intervention on harmonised pan-EU standards supported the correct functioning of the EU market. As a notable example, in the absence of uniform EU standards, one may argue that authorities at regional/local level may potentially have more incentive or even mandates, to further expand emerging measures such as access bans on certain types of vehicle entering cities or creation of low/zero emission zones. In this context as already discussed, in section 6.1 (subsection: Internal Market), PO3 has the highest impact in contributing to the proper functioning of the EU internal market.
- The Euro 7 standard in all indication will be primarily introduced as a framework legislation, which will be followed/supported by implementing/delegating acts. As stipulated in the 2nd targeted consultation, the majority of the industrial stakeholders (34 out of 44) and about the half of national authorities/TS (7 out of 16) were supportive of the replacement of EU implementing regulations with references to UNECE regulations, as far as appropriate/possible, arguing that it will contribute to global harmonization efforts. Some respondents believe that UNECE regulations have to be introduced earlier than the EU regulations whereas some others express some concerns regarding the interpretation of the regulation. However, the *Evaluation report* indicated that if action where to happen at international level, the overall process would be at a slower pace (than EU action) and less effective in terms of reducing vehicle-related emissions, due to variating policies and stringency level among Member states regarding vehicle emission control, which may result in a potentially lower common denominator of requirements on an EU level overall. Although the Euro 7 standard (and this IA) is solely focused on the EU-27 area and its internal market, it should be highlighted that PO2 (and by extension PO3) introduce two scenarios regarding control of brake wear emissions, based on the work done in the PMP group[166]. Hence, focusing on non-exhaust particles, PO2 can potentially offer a higher degree of harmonization (on a global scale), laying the groundwork for the future.

[166] Particle Measurement Program UNECE Informal Group

7. Acknowledgments

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8. Glossary

ACEA	European automobile manufacturers association
AECC	Association for Emissions Control by Catalyst
AES	Auxiliary emission strategies
AGVES	Advisory Group on Vehicle Emission Standards
AISPEC	Federchimica Chimica da Biomasse Industrial Group
AQD	Air quality directive
ASC	Ammonia slip catalyst
ATCT	Ambient temperature correction test
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CAFE	Clean Air for Europe
cc	Close-coupled
CEDEFOP	European Centre for the Development of Vocational Training
CH_4	Methane
CI	Compression ignition
CITA	International motor vehicle inspection committee
CNG	Compressed natural gas
CLOVE database/db.	Database which includes testing/measurement data from CLOVE partners (both from testing activity within the current framework contract and from own data) as well as from JRC
CO	Carbon monoxide
COVID-19	Global pandemic caused by a coronavirus unknown before the outbreak began in Wuhan, China, in December 2019.
CoP	Conformity of Production
CSEE	Cold start excess emissions
CUC	Clean up catalyst
DOC	Diesel oxidation catalyst
DPF	Diesel particulate filters
EATS	Exhaust aftertreatment system
EC	European Commission
EEA	European Economic Area
EGR	Exhaust gas recirculation
EHC	Electrically heated catalyst
ELR	European Load Response
EOBD	European onboard diagnostics
EPA	United States Environmental Protection Agency
ESC	European Stationary Cycle
EU	European Union
EUPC	European plastic converters
EVAP	Evaporative emissions control system
FQD	Fuel quality directive
GDI	Gasoline direct injection
GHG	Greenhouse Gas(es)
GPF	Gasoline particulate filter
GTAAs	Granting type approval authorities
GTR	Global technical regulation
HBEFA	Handbook Emission Factors for Road Transport
HC	Hydrocarbons
HDV	Heavy duty vehicle

IA	Impact assessment
ICCT	International Council on Clean Transportation
ICE	Internal combustion engine
ICT	Information and communication technology
IIA	Inception Impact Assessment
ILO	International Labour Organization
ISC	In-service Conformity
JRC-GEM-E3	General Equilibrium Model for Energy Economy Environment interactions: a computable general equilibrium model, version operated by the JRC
LDV	Light duty vehicle
LEZ	Low emission zone
LNG	Liquified natural gas
LNT	Lean NOx Trap
M category	Passenger vehicles, including categories M1, M2 and M3
MS	Member State(s)
M1 vehicles	Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat
M2 vehicles	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes
M3 vehicles	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes.
MaSA	Market surveillance authorities
MAW	Moving average window
MECA	Manufacturers of Emission Controls Association
MHEV	Mild hybrid electric vehicle
N2	Nitrogen
N category	Goods vehicles, including categories N1, N2 and N3
N1 vehicles	Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes
N2 vehicles	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes
N3 vehicles	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes
NECD	National emissions ceiling directive
NEDC	New European driving cycle
NGO	Non-governmental organisation
NH3	Ammonia
NMHC	Non-methane hydrocarbons
NMOG	Non methane organic gases
NMVOCs	Non-methane volatile organic compounds
NOx	Nitrogen oxides
NPV	Net present value
NTE	Not-to-exceed
O_3	Ozone
OBD	On-board diagnostics
OBFCM	On-board Fuel and Energy Consumption Monitor
OBM	On-board monitoring
OCE	Off-cycle emissions
OEM(s)	Original equipment manufacturer(s)
ORVR	Onboard refuelling vapor recovery
OTA	Over the air
Part A	Study on post-EURO 6/VI emission standards in Europe (Part A)
Part B	Study on post EURO-6 emission standards in Europe (Part B)
PC	Public Consultation
PEMS	Portable emission measurement system
PFI	Port fuel injection
PHEV	Plugin hybrid electric vehicle
PI	Positive ignition
PM	Particulate matter mass
PMP	Particle Measurement Program (UNECE)
PN	Particle number
PPP	Purchasing power parity
PO	Policy Option

POx.Scx	Policy Option x: Scenario x
PTI	Periodic technical inspection
R&D	Research and development
RDE	Real driving emissions
RM	Reference mass
RS	Remote sensing
RSI	Roadside inspection
SAI	Secondary air injection
SCR	Selective catalytic reduction
SCRF	SCR with a soot filter
SDPF	SCR-Catalysed Diesel Particulate Filter
SEMS	Smart emission measurement system
SI	Spark-ignited
SWD	Staff working document (European Commission)
TA	Type approval
TAAEG	Type-approval authorities' expert group
TAAs	Type approval authorities
TFEU	Treaty on the Functioning of the EU
THC	Total hydrocarbons
TPMLM	Total permissible maximum laden mass
TS	Technical Service
TWC	Three-way catalytic converters
UITP	International Association of Public Transport
ULEZ	Ultra-low emission zone
UNECE	United Nations Economic Commission for Europe
VECTO	Vehicle Energy Consumption Calculation Tool
VOC	Volatile organic compound
WHO	World health organisation
WHSC	Worldwide harmonised stationary cycle
WHTC	World harmonised transient cycle
WLTC	Worldwide harmonised light vehicles test cycle
WLTP	World harmonised light vehicle test procedure
WVTA	Whole vehicle type approval
ZE(Z)	Zero emission (zone)

Annexes

9. Annex I: Analytical methods used

9.1. Introduction of COPERT/SIBYL tools

COPERT[167]

EMISIA continuously develops COPERT road transport emission software, a recognised and widely used tool for calculating road transport greenhouse gases (GHG) and air pollutant emission inventories based on real-world emissions. It uses vehicle population, mileage, speed and other data such as ambient temperature, and calculates emissions and energy consumption for a specific country or region.

The development of COPERT is coordinated by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACM). The European Commission's Joint Research Centre manages the scientific development of the model. COPERT has been developed for official road transport emission inventory preparation in EEA member countries. However, it is applicable to all relevant research, scientific and academic applications.

The COPERT methodology is part of the EMEP/EEA air pollutant emission inventory guidebook for the calculation of air pollutant emissions and is consistent with the 2006 IPCC Guidelines for the calculation of greenhouse gas emissions. The use of a software tool to calculate road transport emissions allows for a transparent and standardized, hence consistent and comparable data collecting and emissions reporting procedure, in accordance with the requirements of international conventions and protocols and EU legislation.

COPERT key characteristics:

- Internationally recognised: it is used by the large majority of European countries for reporting official emissions data.
- Reliable and widely recognized emission factors.
- The emission factors are developed within the collaboration and supervision of the members of the European Research for Mobile Emission Sources (ERMES) group.
- Speed dependent emission factors.
- Calculates emissions at a national, regional or local scale, and for annual to daily estimates.
- Technologically advanced and transparent: its methodology is published and peer-reviewed by experts of the UNECE LRTAP Convention.
- Used in the framework of many research projects worldwide.
- Includes all main pollutants: greenhouse gases, air pollutants and toxic species.

[167] https://www.emisia.com/utilities/copert/

SIBYL[168]

SIBYL is a specialised tool to project vehicle technology impacts to future fleets, energy, emissions and cost. It was designed to be able to conduct policy impact assessments either for legislators, or vehicle manufacturers or consultants that need to estimate the impact policy options to road transport emissions. SIBYL is also the core calculation module of the DIONE model maintained for policy assessment by JRC.

EMISIA uses the SIBYL model for the projection of emissions from road transport. SIBYL has the ability to project emissions based on fleet dynamics, expected market trends and forecasted fleet growth scenario. With SIBYL it is possible to make fleet, activity, energy, and emissions estimations and projections up to 2050. Based on these features and by utilizing proper emission and consumption factors, SIBYL can project emission and energy evolution from road vehicles. SIBYL projections are calibrated against higher-tier energy and/or activity projections and hence can be used to further understand potential problems or inconsistencies observed for individual Member States. Figure 9-1 depicts the scenario building procedure in SIBYL. It includes a range of options for the development of user-defined scenarios with a variety of conventional and more advanced vehicle types.

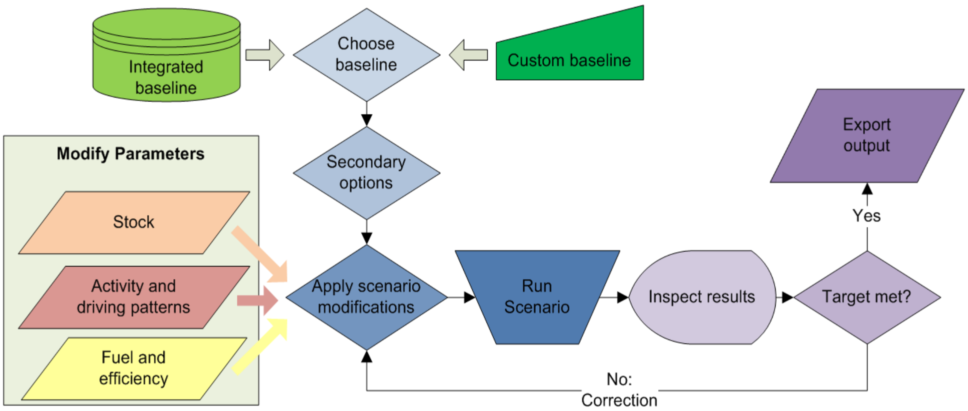

Figure 9-1: Scenario building and testing in SIBYL.

COPERT / SIBYL interaction

SIBYL's outputs are imported to COPERT and to cost assessment models, in order to calculate the total emissions and benefits as well as the associated new technology implementation costs, towards the cost-benefit calculation. The data extracted from SIBYL that are directly used as inputs to COPERT are shown in Figure 9-2:

[168] https://www.emisia.com/utilities/sibyl-baseline/

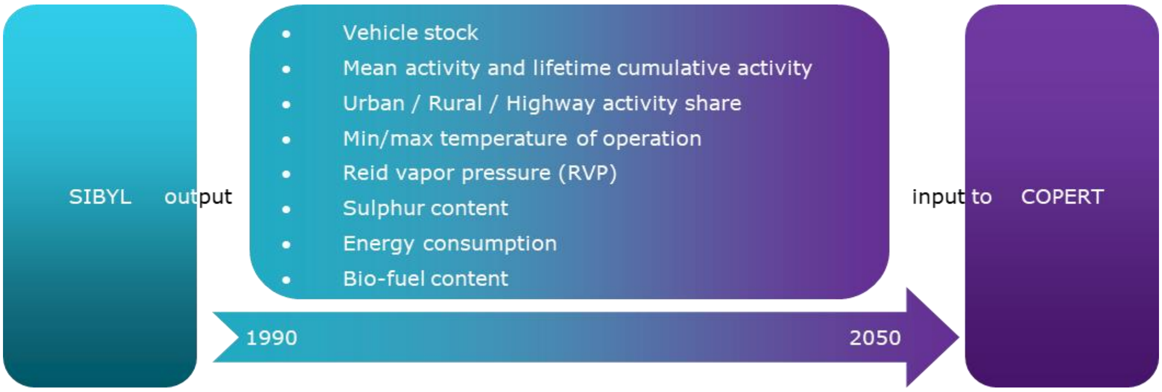

Figure 9-2: Scenario building and testing in SIBYL.

In total, 34 European countries are included in the software (EU27 Member States, UK, Iceland, Norway, Switzerland, Liechtenstein, FYROM, Turkey), and additionally a single EU27 data file is available for emission modelling at European level. This file has been created e.g. by summing up all EU27 countries' populations, calculating the weighted average of their mileage (based on vehicle-kilometre activity data), average U/R/H speeds and shares, monthly temperatures, etc. Therefore, this file is expected to provide a very good approximation of aggregated emissions in Europe as a whole. Similarly, the EU27 dataset, has been built and used in the Evaluation Assessment of Euro 6/VI study (*Evaluation report*).

COPERT and SIBYL contain the following broad vehicle categories:

- Cars
- Vans
- Lorries
- Buses
- L-category vehicles (including mopeds, motorcycles, quadricycles and mini-cars)

and for each category a number of different segments are included, such as small/medium/large-SUV-executive cars, N1-I/N1-II/N1-III vans, etc.

COPERT and SIBYL include the following fuel/powertrain vehicle technologies:

- Petrol
- Diesel
- Petrol Hybrid
- LPG Bifuel
- CNG Bifuel
- CNG
- Diesel Hybrid
- Petrol PHEV
- Diesel PHEV
- Battery Electric Vehicle (Electricity)
- Fuel Cell Electric Vehicle (Hydrogen)

- Flexi-fuel Vehicle (Bioethanol).

The combination of the above vehicle categories, segments and fuel/powertrain technologies results to 65 different vehicle categories in total. If we also consider the Euro standard technologies included in COPERT, then the total number of vehicle types for which emission factors are necessary exceeds 450 ones.

9.2. Fleet modelling

Outline of fleet modelling

One of the purposes of this study is to provide legislators with a comprehensive picture of the road transport sector technology mix, in order to help build a regulatory course that will curb emissions while meeting society's transportation requirements and expenditure capacity.

To this end, a detailed, complete and consistent vehicle stock and activity dataset will greatly help to thoroughly grasp the current situation and understand how emissions patterns will evolve in the coming years. Sibyl baseline is the dataset with which EMISIA develops and actively maintains a reliable and up-to-date vehicle fleet and road transport activity dataset, suitable for use in air pollutant and GHG emission calculation tools. Sibyl baseline data has been harmonized with official European statistics (see Following the above steps, the outcome of the processing methodology is a complete and consistent stock and activity dataset with no gaps, harmonised with official statistical data. The dataset takes into account all recent information on the penetration of alternatively fuelled vehicles (LPG, CNG, hybrids, electric) in all categories. The flowchart in Figure 9-4 shows the procedure followed for the calibration of Sibyl baseline for the historic years. This process, iterated for each historic year and MS, provides trends to build the baseline projection.

A significant parameter that the dataset must take into account is the age distribution of the fleet. Specifically, the average age of each vehicle category must be consistent with statistical data, since this ensures better modelling of the fleet structure and technologies/Euro standards per country. The main methodological steps that have been followed in order to produce an age distribution for the total stock of each vehicle category are summarised below.

Table 9-2), so as to reflect the state-of-art in our knowledge regarding Euro standard mix, vehicle age, and fuel and powertrain stratification for the road transport stock.

The Sibyl baseline provides a good basis for reliable projections, in order to accurately investigate the impact of various policies, technological advances and interventions on future emissions levels. Modifications to the Sibyl baseline in scenarios offer the ability to create and examine a variety of options in a relatively easy way so that legislators are able to make informed decisions that lead to the best outcome for the transport sector, the environment and society. The most effective options to reduce emissions from road transport can be identified and assessed based on detailed simulation of their expected impacts.

Road vehicles and fuel types

The main road vehicle categories available in the Sibyl baseline are listed below. The brackets in this vehicle list contain the corresponding category letter and number according to the EU/UNECE classification system. The categories examined in the current study are underlined.

- Passenger cars [M1]
- Buses [M2, M3]
- Light commercial vehicles (vans) [N1]
- Heavy duty trucks (lorries) [N2, N3]
- Mopeds (two-and three-wheel) [L1, L2]
- Motorcycles (two-wheel and tricycles) [L3, L4, L5]
- On-road quadricycles (mini-or micro-cars) [L6]
- ATVs (all-terrain vehicles and side-by-side buggies) [L7]

Sibyl baseline contains several technological concepts and fuels used in vehicle propulsion systems that currently dominate the road transport but also powertrains that are expected to play a significant role in the future. Table 9-1 shows the category and powertrain combinations that exist in the Sibyl baseline.

Table 9-1: Category / fuel type combinations in Sibyl baseline.

Category\Fuel type	Petrol	Diesel	LPG	CNG/ LNG	Petrol Hybrid	Diesel Hybrid	Petrol PHEV	Diesel PHEV	FCEV	BEV
Cars	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vans	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lorries	✓	✓	✓	✓		✓		✓	✓	✓
Buses		✓	✓	✓		✓		✓	✓	✓
L-Category[169]	✓									✓

Apart from the above categorisation based on the fuel (energy) type, vehicles can be further disaggregated into segments and technology (Euro) standards. Segments are usually related with the size, weight, engine capacity and other characteristics of the vehicle. Euro standards define the emission performance of vehicle types. Segments and Euro standards together with the fuel (energy) type, determine to a large extent the assignment of appropriate emission factors in order to calculate total emissions.

Vehicle fleet in different Euro 6/VI stages

Euro 6/VI emission standards developed in different stages (6a, 6b/c, 6d-temp, 6d, Euro VI A-E) and several of them were significantly different to each other. For example, Euro 6b/c was only based on lab tests for type approval compared to 6d-temp and 6d, based on on-road testing). Therefore, the actual emission levels of these vehicles significantly differ. One therefore needs to have a detailed structure where Euro 6 and VI stages are distinguished in new vehicle registration. SIBYL includes this information taking into consideration the introduction dates of different Euro stages. However, as several stages often overlap, it is difficult to exactly know how many vehicles of each stage are registered each year in each member state unless precise market data are available.

[169] L-Category vehicles are not in the scope of this study.

Such market data are generally not publicly available. At national level, only the German authorities (KBA) appear to publish detailed information. CLOVE contacted ACEA to request data for other countries, but such data are not collected from ACEA either. Market data did not provide a thorough structure of the market either, since several registrations are only marked as Euro 6, without further distinction of individual stages[170]. In order to cross-check our data, CLOVE looked at what is available at national level, by contacting authorities and experts in individual EU member states. Overall, the sources that provided input for the cross-check and potential refinement of the data were from the following countries:

- Austria - Source: CLOVE (TUG – HBEFA),
- France - Source: CITEPA[171], State operator for the French Environment Ministry,
- Germany - Source: KBA database[172],
- Sweden - Source: IVL, Swedish Environmental Research Institute, and
- The Netherlands - Source: CLOVE (TNO).

While not covering the complete geography of EU, and the fact that these MS represent advanced economies with GDP per capita above the EU average, their respective rate of renewal of passenger cars was close to the EU average[173]. Therefore, we decided that data from these countries can be used to adjust the mix of Euro 6 stages in our estimates. The detailed methodology that was followed to perform the update using the above data is analytically presented in the main body and the Annex of the *Evaluation report.* Euro VI adjustments were not required, due to the lower yearly overlap of the individual HD Euro VI stages.

Historic data that go into the baseline

Figure 9-3 summarizes the process followed for the development of Sibyl baseline. Initially, the stock was equilibrated with the statistical data by taking into consideration the new registrations (also the 2nd hand registrations) and scrappage statistics. The vehicles are then classified to the various Euro technology standards with the help of a "Technology Matrix" which assigns new registrations to distinct Euro standards (or individual stages of Euro standards), according to the year of first registration into the fleet. The annual mileage is then calibrated so that the energy demand is consistent with the statistical energy consumption. For the projected years, the stock and mileage are calibrated to follow the activity growth that has been agreed at an EU level.

In the context of this study, the Sibyl baseline (for EU27) was modified to reflect key parameters set by the Fit-for-55 baseline which takes into account the targets and plans of the revised 2030 Climate target plan (Fit-for 55 package), as this was reflected in the

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170 Such as IHS Markit (www.ihsmarkit.com).

171 https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-les-immatriculations-des-vehicules

172 Multiple tables provided in vehicle statistics dataset:

https://www.kba.de/DE/Statistik/Fahrzeuge/fahrzeuge_node.html

Themensammlungen (FZ 13) and Themensammlungen (FZ 14).

173 Based on data on renewal rates (i.e. new registrations as share of total vehicle fleet) for the period 2009- 2018 from Eurostat (new registrations and vehicle stock). With a 5.3% renewal rate for the period 2014-2019, Netherlands has been below the EU average of 5.8%. In comparison, the renewal rates for Germany, Austria and Sweden have been higher than the EU average (7.1%, 6.8% and 7.7%) (see also: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Table_5_Renewal_rate_of_passenger_cars,_by_country_update_2020.png)

MIX Scenario 2021 of SWD(2021) 613 final. These main parameters are the future technology mix of the specific vehicle powertrains and the evolution of the activity agreed at European level.

The SIBYL baseline contains a complete and consistent dataset of past transport data per country since 1990. The data sources utilised to formulate this bases are summarized in Following the above steps, the outcome of the processing methodology is a complete and consistent stock and activity dataset with no gaps, harmonised with official statistical data. The dataset takes into account all recent information on the penetration of alternatively fuelled vehicles (LPG, CNG, hybrids, electric) in all categories. The flowchart in Figure 9-4 shows the procedure followed for the calibration of Sibyl baseline for the historic years. This process, iterated for each historic year and MS, provides trends to build the baseline projection.

A significant parameter that the dataset must take into account is the age distribution of the fleet. Specifically, the average age of each vehicle category must be consistent with statistical data, since this ensures better modelling of the fleet structure and technologies/Euro standards per country. The main methodological steps that have been followed in order to produce an age distribution for the total stock of each vehicle category are summarised below.

Table 9-2. No single source provides all data at the level of detail required, while there are also gaps or incomplete time series with whole countries or missing years. Furthermore, the collected information is sometimes inconsistent, since values from different sources seldom agree, while there is no common vehicle classification.

In order to correct these inconsistencies, a processing methodology has been developed to synthesize the primary information from various sources. The main methodological steps that have been followed, in order to produce vehicle fleet total numbers (for each vehicle category) and splits per fuel and disaggregation into segments are summarised below:

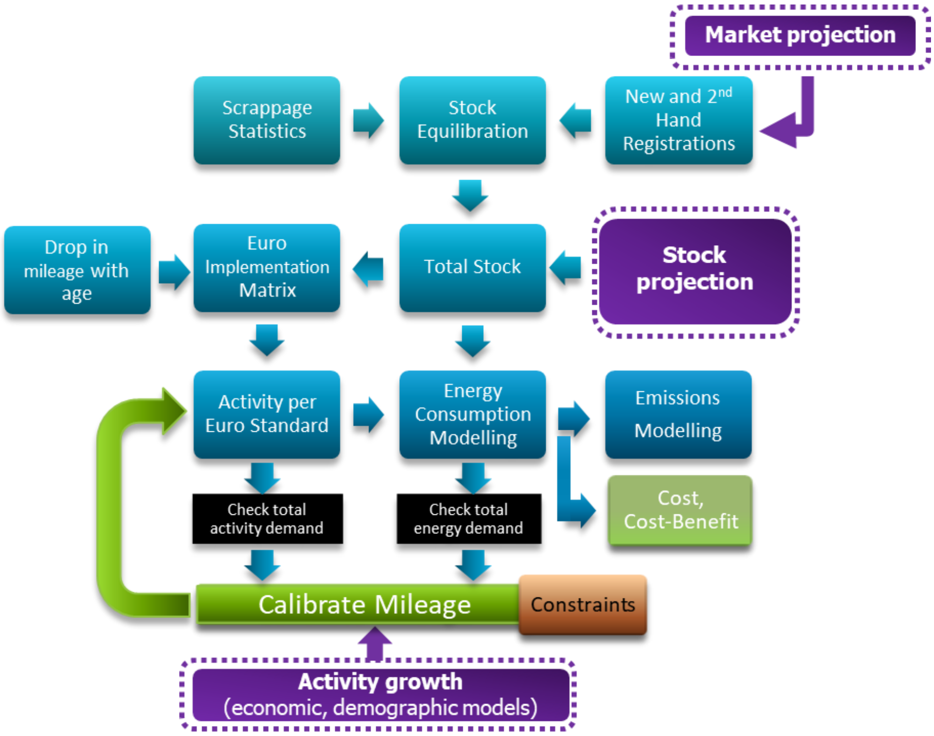

Figure 9-3: Sibyl baseline calibration approach schematic.

- Comparison of sources – **one** of them is selected as the main source to start with (based on data quantity and quality).
- Gap-filling from other sources paying attention for possible inconsistencies. For example, in case of significant differences between two sources, the relative trend instead of the absolute value is used.
- If gaps still exist, then the techniques for filling them in are:
  - Interpolation.
  - Relative trend or data from another country (e.g. percentages for split/disaggregation).
  - Estimates and expert judgement calculations.
- Checking rules:
  - All fuels add up to total consumption known at national level.
  - All types of a fuel add up to this specific fuel.
  - No negative values exist.
  - Percentages that should add up to 100% are checked to do so.

Following the above steps, the outcome of the processing methodology is a complete and consistent stock and activity dataset with no gaps, harmonised with official statistical data. The dataset takes into account all recent information on the penetration of alternatively fuelled vehicles (LPG, CNG, hybrids, electric) in all categories. The flowchart in Figure 9-4 shows the procedure followed for the calibration of Sibyl baseline for the historic years. This process, iterated for each historic year and MS, provides trends to build the baseline projection.

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Table 9-2: Data sources used for the baseline creation.

Source	Main information provided
Eurostat[174]	Stock and new registrations per fuel and engine capacity / GVW
EC Statistical Pocketbook[175] (EU Transport in figures)	Stock and new registrations
ACEA[176]	Stock per fuel, new registrations per fuel and per segment / GVW
CO_2 monitoring database[177]	New registrations per fuel and segment (PCs and LCVs)
EAFO[178] (European Alternative Fuels Observatory)	Stock and new registrations of alternative fuels (LPG, NG, electric, H_2)
NGVA Europe[179] (Natural Gas Vehicle Association) NGV Global[180] (Natural Gas Vehicle Knowledge Base)	Stock of natural gas vehicles
UNFCCC[181]	Fuel sold, based on Eurostat and disaggregated per vehicle category
Other sources: literature, studies, reports, national statistics web sites	Various information (level of detail is country-dependent)

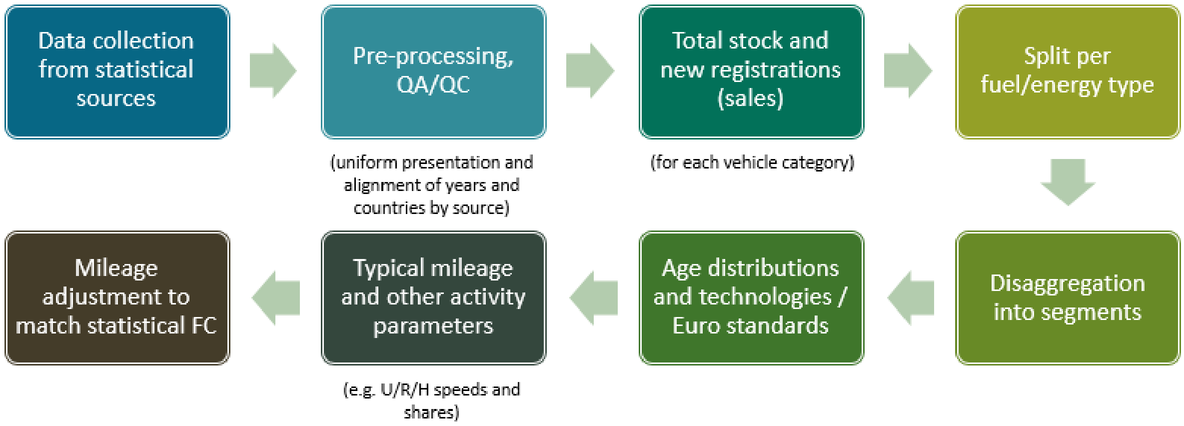

Figure 9-4: SIBYL baseline calibration for historic years.

There are 30 age bins in the dataset, namely, from age 0 which corresponds to new registrations, to age 29. All stock vehicles are allocated to these bins, so that the sum of vehicles of age 0, plus age 1, …, plus age 29 equals to the total number of vehicles.

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174 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_eqr_carmot&lang=en

175 European Commission, 2020."Statistical pocketbook 2020"

176 https://www.acea.be/statistics/tag/category/by-country-registrations

177 EEA, 2020."Monitoring of CO2 emissions from passenger cars – Regulation (EU) 2019/631",2020

178 EAFO,2017."The transition to a Zero Emission Vehicles fleet for cars in the EU by 2050",2017

179 https://www.ngva.eu/

180 https://www.ngvglobal.org/

181 UNFCC,2020, "National Inventory Submissions 2020"

- An estimation for the age distribution in 1990 has been made, based on the new registrations of this year and expert judgement of a normal distribution of vehicle ages.
- Age distributions for the following years (after 1990) have been derived with lifetime functions (example shown in Figure 9-5), which model how vehicles are deregistered from the fleet according to their age. For example, an increasing vehicle age leads to an increased probability of breakdown or vehicle export, hence, the probability $\varphi(k)$ that this vehicle will survive k years after its registration gets lower as k increases.
- When the previous step was finalised for a specific year, modifications were made in the age distribution, by internal 'transferring' of vehicles among age groups, so as to achieve matching with statistical average age (available from the data sources). For example, a country with an average age of 14 years has more vehicles in the age groups 10-20 and 20-29 than in the age group 0-10, compared to a country with an average age of 9 years.

The outcome of the above steps is an age distribution for the total stock of each vehicle category, which has an average age consistent with the corresponding statistical value. The age distribution of total stock has been used as a 'guide' in order to produce age distributions per fuel and segment, taking into account the peculiarities of individual vehicle subcategories, for example:

- Many LPG vehicles are conversions from petrol ones, not actual sales (brand new vehicles).
- Electric vehicles have entered into the fleet only recently, hence, their age distribution is completely different compared to conventional (petrol/diesel) vehicles.
- The differentiation in the age distributions of petrol/diesel vehicles has been mostly driven by past sales patterns. The petrol fleet is older than the diesel fleet due to past sales patterns. For example, sales of diesel cars have increased significantly since 2000, compared to the 90's, while sales of petrol cars have declined from 2000 to 2012 (at an EU28 level). As a result, the diesel fleet is younger than the petrol fleet in most countries and years. This trend has started to reversing again since 2019, due to the significant drop of new diesel car registrations compared to other powertrains.

The outcome of this phase is the derivation of age distributions per fuel and segment for each vehicle category, so that the checking rules (described earlier) are satisfied for all age bins.

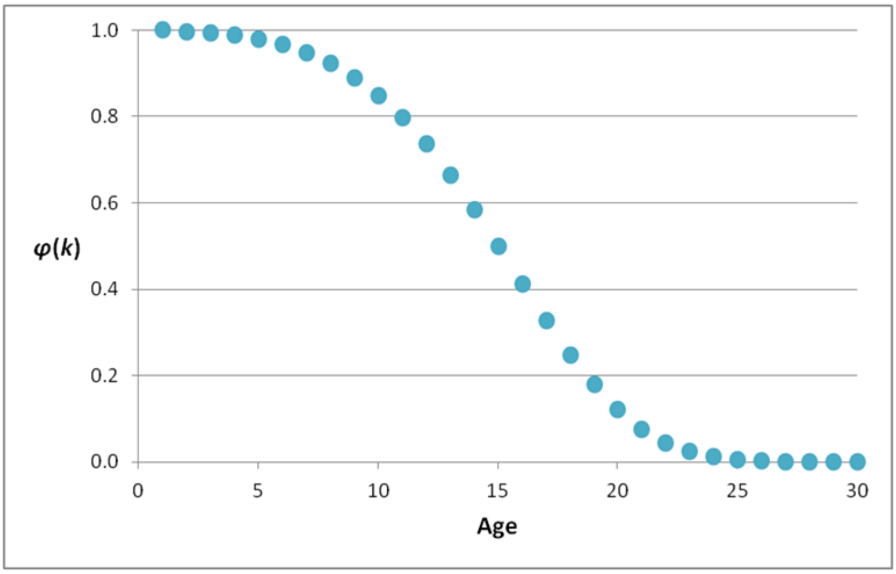

Figure 9-5: Example of a lifetime function.

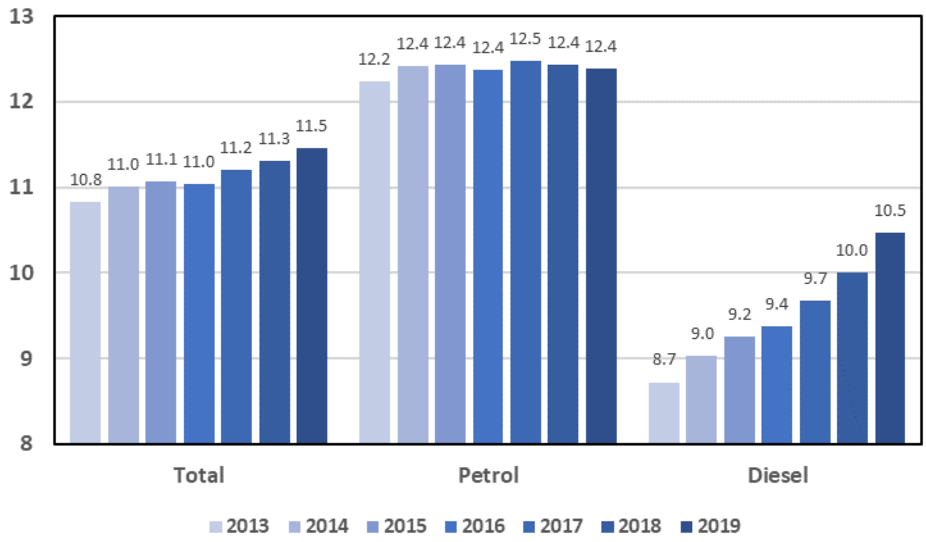

Figure 9-6: Average age of passenger car stock (total, petrol, diesel) in EU27 since 2013.

Once the age distributions have been formulated, vehicles can be allocated to Euro (emission) standards based on technology matrices, which take into account the relevant legislation on the introduction date of each Euro standard. For example, all new vehicles entering the fleet after 2015 are Euro 6, while those that have been registered between 2010 and 2014 were Euro 5, etc.

Before being finalized, the dataset was checked for consistency with national inventory submissions of fuel consumption in UNFCCC[182] . Since 2015, fuel consumption data, disaggregated down to the vehicle category level, i.e., cars, LDTs, HDTs and buses, motorcycles, has been submitted. Micro-adjustments in the mileage of the vehicles

[182] EEA, 2020. "Contribution of the transport sector to total emissions of the main air pollutants", European Environment Agency.

(average annual distance driven in km/year) have been performed in order to match the calculated fuel consumption with the statistical one.

Making Projections

In the current report, the total activity growth and future technology mix were received as exogenous parameters, originating from the MIX Scenario 2021 of SWD(2021) 613 final. Based on these, Figure 9-7 shows how the future fleet structure is projected in SIBYL. The main parameters to consider in a road transport scenario for the future are:

- The evolution of total stock and new registrations (sales).
- The survival rates of the fleet, i.e., lifetime functions and age distribution.
- The penetration of alternative fuels and, especially, electric vehicles in the market.
- The evolution of the stock per fuel and segment subcategories.

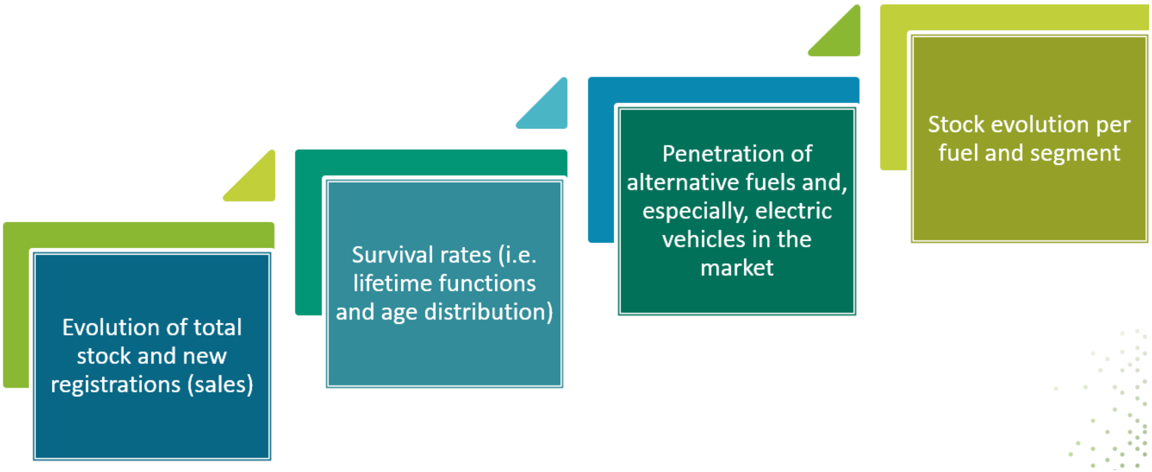

Figure 9-7: Main parameters that are considered for the baseline scenario (future's prediction).

Evolution of total stock

Figure 9-8 shows how the fleet develops across all vehicle categories for the baseline. The main observation is that the EU27 road vehicles stock projection exhibits a steady increase from year to year, until 2050. The growth rate of the stock per vehicle category was received - for this work - exogenously from the MIX 2021 scenario.

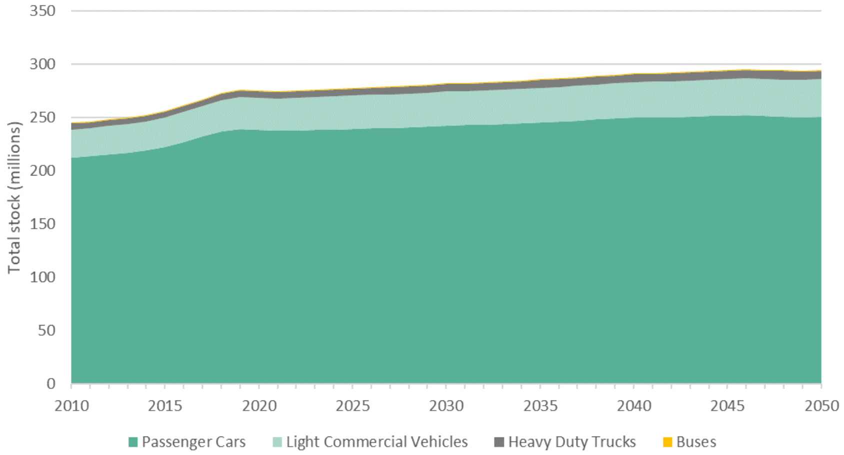

Figure 9-8: Evolution of total stock.

Evolution of sales

Figure 9-9 presents the projection of EU27 passenger cars total sales. From this figure, it can be observed that sales from 2010 until now are between 10M and 14M vehicles. In general, there is a trend in the literature to correlate vehicle sales with GDP[183]; but, it is still difficult to make a watertight prediction to 2050. This increase is also in accordance with the activity increase based on counterfactual baseline.

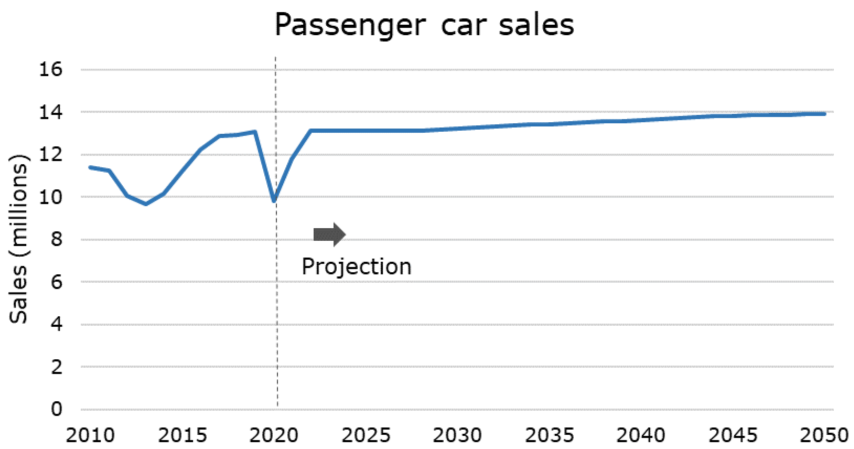

Figure 9-9: EU27 passenger cars total sales projection.

9.3. COVID-19 modelling

The COVID-19 crisis continues to have an effect on road transport in the EU. This has a side-effect impacting the vehicles activity and sales of new technologies, and consequently the level of emissions and energy consumption throughout Europe. By the time this report is being written, the crisis is in full development, hence its final cumulative impact is not easy to be modelled. In the present circumstances it is necessary to consider the short- and long-term consequences of the COVID-19 crisis.

An approach to model the COVID-19 impact has been performed by the European Commission[184] using the available data at the end of 2020. The short-term forecast points to a sharp drop in output in 2020 followed by significant recovery in 2021, while the crisis is projected in this setting to result in a permanent loss of output of around 2.3% by 2030 compared to the pre-COVID projections. Figure 9-10 presents this comparison of the per-COVID and post-COVID estimated projections for the medium-term EU GDP.

Road transport is by far the sector that contributes the most to the fall in emissions in 2020 under COVID-19 compared to pre-COVID baseline estimations, with a difference between the two scenarios of 128 MtCO2-eq (a 17.2% drop).

The current study is modelling the COVID-19 impact to the vehicle activity and new registrations with inputs provided by the European Commission.

[183] Ntziachristos L., et. al., (2017). “Effect study of the environmental step Euro 5 for L-category vehicles,” TNO 2017 R10565, Report for EC DG-GROW, doi:10.2873/397876.

[184] European Commission, (2020). SWD(2020) 176 final

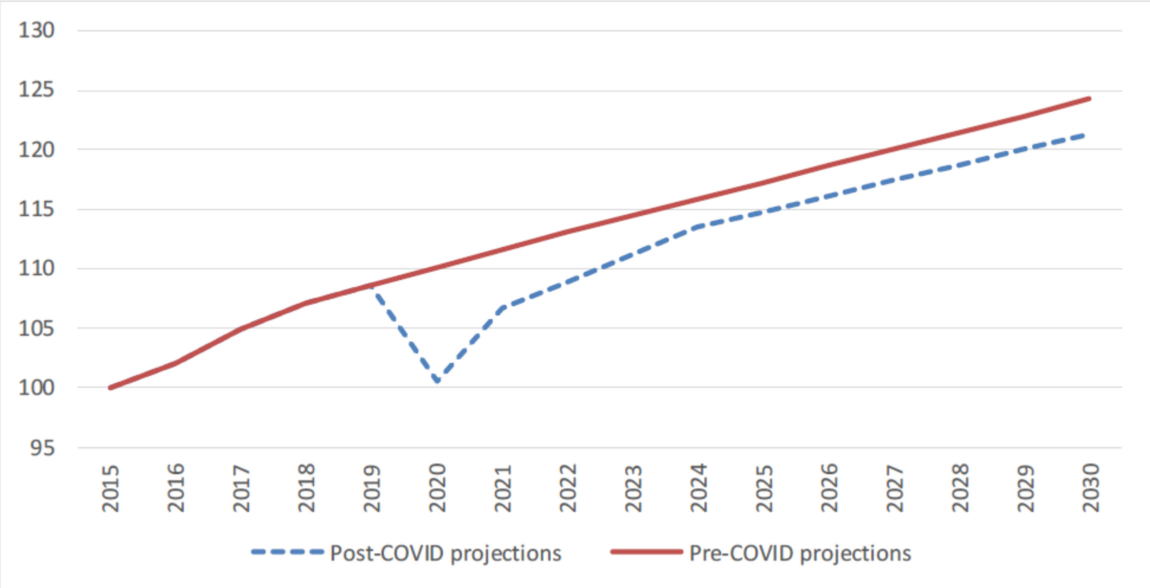

Figure 9-10: Medium-term EU real GDP projections, pre-COVID and post-COVID (2015=100) [5].

9.4. Emissions modelling

9.4.1. Overall methodological approach

The general scheme for calculating emissions of a pollutant for a specific year and a specific vehicle category is the following:

$$E_{p,j,x} = N_{j,x} \times M_{j,x} \times EF_{p,j,x} \quad (1)$$

Where:

- E = Total annual emissions
- N = No of vehicles in operation
- M = Annual mileage per vehicle
- EF = Estimated emission factor in g/km
- p= Pollutant (AP & GHG)
- j= Vehicle category
- x = Year of calculation

In the above equation, the terms Nj,x and Mj,x are derived from fleet modelling (section 9.2). The emission factors (EFp,j,x) come from different sources depending on the Euro standard vehicle technology. In addition, the emission factors are different for each policy options and scenarios, as presented below in detail.

EF's source for existing technologies

A. Up to Euro 6 a/b/c & Euro VI A/B/C: COPERT

For the existing Euro standard technologies up to Euro 6 a/b/c & Euro VI A/B/C the emission factor comes from COPERT. COPERT is a road vehicle emission calculation model used worldwide to calculate air pollutant and GHG emissions from road transport. The development of COPERT is coordinated by the European Environment Agency (EEA). COPERT has been developed for official road transport emission inventory preparation in EEA member countries.

Starting with Euro 5, in the context of this study, the emission factors of Euro 5 vehicles have been revised in order to be in line with the latest information. Vehicles (Euro 5) from several manufacturers had a software installed that reduced the engagement of NO_x emission control technologies outside of the chassis dyno type approval operation conditions ("defeat devices"). In the course of mandatory recall campaigns, software-updates have been installed by the OEMs to fix this issue and therefore the emission factor has been affected. The Euro 5 emission factors used in the current study are the ones assuming corrected software. Furthermore, RDE type of driving on Euro 5 emission performance has been considered in order to follow a compatible approach as for Euro 6 vehicles described below. The update of the emission factors was performed after cross-checking derived levels with the HBEFA 4.1[185] emission factor dataset.

Moreover, the baseline emission factors for all Euro 5 - V and Euro 6 a/b/c - VI A/B/C technologies were re-calculated in order to take into account mode details analysis conducted in the current study regarding the effect of cold-start phase, the operation under hot (engine and after-treatment system) conditions, the degradation of emission control systems due to high mileage/age, as well as the impact of tampering and malfunctions not detected by OBD. The data needed for these constituents of the final emission factor came from the COPERT, measurement data included in the emissions database developed in the context of part A study and input from several stakeholders, while an engineering judgement was made in the cases that no data were available from the above-mentioned sources.

B. Euro 6d-temp and Euro 6d: Based on experimental data from the Part A study (i.e. CLOVE database)

In the context of the Part A and part B studies, an emission performance analysis and testing of latest technology vehicles (i.e. Euro 6d-temp / 6d) have been conducted. In an effort to assess the emission levels of the Euro 6d-temp / 6d standards and to support the update of existing EF databases, emission data from a pool of 72 LDVs with results from >540 tests were collected and analysed. This often referred as the experimental CLOVE database (db.), sourced data from 9 partners (CLOVE, JRC, H2020 projects, stakeholders)[186]. Table 9-3 presents the mix of the vehicle technologies measured in real world conditions and/or in the laboratory (the latter for the evaluation of currently non-regulated emissions). The detailed data from these measurements were used instead of the current emission models (COPERT, HBEFA, VERSIT[187]) in order to achieve a more accurate description of the current status of emission factors.

Table 9-3: Number of vehicles in the CLOVE database per technology

Vehicle technology	Number of Euro 6d vehicles	Number of Euro 6d-temp vehicles	Total number of vehicles in database
GDI	2	15	17

[185] The latest updates to the emission factor dataset are presented in detail in the HBEFA website: https://www.hbefa.net/e/index.html .

[186] More details in the *Combined report*.

[187] TNO, 2007."VERSIT+ state-of-the art road traffic emission model".

mHEV[22]-GDI	2	3	5
PHEV-GDI	2	5	7
PFI	1	4	5
HEV-PFI	3	2	5
HEV-PFI-GDI	1	0	1
PHEV-PFI	0	1	1
Diesel	8	16	24
mHEV-Diesel	0	2	2
PHEV-Diesel	0	1	1
CNG	0	3	3
LPG	0	1~~0~~	1
TOTAL	19	53	72

In the case of HDVs, the needed input for the emission factors of Euro VI D/E vehicles was derived from HBEFA, while experimental data provided by CLOVE partners were used for the calculation of EFs under test conditions not covered by HBEFA, e.g. in terms of trip characteristics/composition.

Emission factors calculation equation

The emission factors of the various pollutants for each vehicle category depend on many parameters including driving patterns, environmental conditions, road gradient and the level of maintenance of the vehicle. In order to be able to estimate the impact of different policy options, the emission factor to be used should separate the contribution from different emission processes or components (i.e. cold and hot start emissions, within normal and outside normal driving conditions, evaporation, impact of degradation, tampering and malfunctions).

Therefore, in the simulations, only relevant parts of the emission factor will be affected when a new piece of regulation is introduced (for example, when introducing a new piece of regulation for OBD only the malfunctions relevant component will be affected and not the base emission factor)

The general scheme for calculating the emission factor is as follows:

$$EF = [(w_1\,EF_{hotRDE} + w_2\,EF_{hotNonRDE}) \times DF(M) + w1\,EF_{coldRDE} + w_2\,EF_{coldNonRDE}] \times (1\text{-}Tamp.\ share) + (w_1\,EF_{hotRDE} + w_2\,EF_{EXThotRDE}) \times (Tamp.\ share) \times (Tamp.\ rate) \quad (2)$$

Where:

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

The above equation decomposes the final emission factor into the various components that are meaningful for the purpose of impact assessment of the different policy options. More specifically, it is considered that the vehicles are driven in one of the following driving conditions and have the corresponding emission factors for each case:

i. Hot & Cold – in RDE driving

ii. Hot & Cold – outside RDE driving

Emission control systems have been found to degrade with use resulting in increasing emission rates with vehicle age / cumulative mileage. The coefficient DF (M) simulates this behaviour. Finally, the impact of tampering and malfunctions not detected by OBD are considered in the final tampering share and rate. Each of the above terms is calculated in a separate modelling activity based on available data.

Operation within specified testing boundaries

Coefficients w1, w2 correspond to the share of vehicle mileage that falls within and outside, respectively, of the operation boundaries specified in regulations (EU 2017/1151 for cars & vans and EU 582/2011 for lorries & buses) for Euro 6/VI. For Euro 7 scenarios, these coefficients correspond to the fraction mileage with normal and outside of normal driving conditions. As explained in the *Combined report*, exact statistics of mileage within and outside boundaries are not publicly available and their determination would require a specific study involving speed and location recordings from a large sample of vehicles, including recordings of environmental (T) and geospatial (altitude) information. Although CLOVE could not locate such data in a consistent and reliable fashion within the time constraints of the study, we still had to assess relevant w-values. This was necessary in order to estimate the expected benefits of extending the boundaries to cover wider operation conditions in the different policy options. The relevant sources used for such estimates as well as assumptions for the different parameters of boundary conditions are shown in Table 9-4.

The values in Table 9-4 are not mutually exclusive, i.e. when 3.17% of driving is performed outside the current RDE boundaries some of that may also be performed at e.g. speeds above 145 km/h. So, the values should not be directly added, to avoid double-counting. Based on anecdotal evidence when developing the RDE regulation, the boundaries were decided so that 95% of the mileage is included within the limits of each parameter. Hence, cross-probabilities can be accounted for by correcting summation with 0.95^p, where p is the number of parameters combined in extending boundaries. This correction is not required when adding the minimum ISC testing mileage in this summation, as this is on top of any other operation condition.

Even when extending the boundaries, there will still be mileage beyond the proposed extended boundaries. The following considerations have been done to estimate mileage beyond the proposed extended boundary conditions:

- For a useful life of 160000 km as foreseen in Euro 6, limiting testing to vehicles above 3000 km corresponds to 1.88% of total distance.
- 0.5% of mileage may occur with aerodynamic modifications or towing in real use. This adds extra vehicle load, not included in extended boundaries.
- A small fraction of 0.05% is performed at altitudes above 1600 m, based on the altitude distribution data
- 0.5% of mileage in EU highways may still be conducted at speeds above 160 km/h
- Based on the temperature distribution data, 1.2% is conducted in temperatures below -10°C and above 45°C.

- 2% of mileage in other conditions (low fuel, overloading, reversing, remaining AES conditions, etc).

Table 9-4: Estimation of mileage share between current RDE boundaries and those proposed in the different policy options for cars & vans

Parameter	Expectation from new normal boundary conditions	RDE as in (EU) 2017/1151	Additional mileage (%) compared to RDE coverage	Justification
Ambient temperature (°C)	-7 – 35	Moderate: 0 – 30 Extended: -7 – 0°C & 30 – 35°C	3.17	Based on Figure 9-14
Maximum speed (km/h)	160 (PO2.Sc2/3)	145	0.82	Based on COPERT data[188], 5.7% of total EU vkm is in German highways with no speed limit. Assuming 10% is 145-160 km/h, this makes 0.1*5.7=0.57%. In other countries, assuming 1% of highway driving is 145-160 km/h, this adds another 25%*1%. In total, 0.57+0.25
Engine loading	No limit	Speed based limits of v×a[95th]	1	We assess this as a conservative approach reflecting conditions of fast accelerations after traffic lights, entrance to highways, etc. Unpublished industry data shared with CLOVE also show that high power driving is approx. 1%
Maximum altitude (m)	1300 (PO1) 1600 (PO2&3)	Moderate: 0 – 700 Extended: 700 – 1300	0.75 0.86	Based on data in the Combined report: 700-800 m =0.48% and >800 m=0.39%. Assuming that 70% of >800 m is <1300m, this makes: 0.48+0.7*0.39=0.75 up to 1300 m and 0.86 up to 1600 m
Positive elevation gain [m/100 km]	No limitation	1200	1	Very little data available; assumed to be 1% as a conservative estimate
Minimum ISC testing mileage (km)	3 000 10 000 (PO1)	15 000	3.1 7.5	Addition of 5000 km or 12 000 km over the useful life of 160 000 km is 3.1% and 7.5% of mileage, respectively. The initial grace distance is given for emission control systems to achieve their maximum efficiency so compromised performance over this initial mileage is to be expected.

If one subtracts all mileage fractions included in Table 9-4 and in the list above from 100% (i.e. the total distance driven by the average LDV), that leaves 81.1% of the mileage to be within the Euro 6 RDE boundaries. If one includes the so-called ‘extended’ conditions of

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[188] COPERT Data | EMISIA SA

the Euro 6 RDE, this share becomes 84.6%, with the additional 3.5% estimated according to the values of Table 9-4 (i.e. [3.17+0.82]*0.95^2). In extended conditions the NTE value of Euro 6 includes a coefficient of 1.6 on the individual pollutant limits. Hence, this 3.5% fraction for Euro 6 vehicles is added in eq.(2) with an emission factor 1.6 times higher than the one used within the normal RDE boundaries.

The values in **Table 9-4** can be combined with the boundaries proposed in the different policy options to come up with an estimate of the total mileage expected to be included within the boundaries of each policy option.

Table 9-5: Estimation of mileage share of cars & vans within the boundary conditions proposed in each policy option

Policy Option	Mileage share within normal condition boundaries (%)	Boundary conditions
PO1.Sc1	88.4	-7 – 35°C, 145 km/h, v×apos, 1300 m, 10000 km
PO2.Sc1, PO3.Sc1	88.5	-7 – 35°C, 145 km/h, v×apos, 1600 m, 10000 km
PO2.Sc2, PO2.Sc3, PO3.Sc2	93.9	-7 – 35°C, 160 km/h, 1600 m, 3000 km

For lorries and buses, boundary conditions of current ISC test are much wider and there is limited scope for extension in the different policy options. In principle, the only additional condition which is proposed to be included within the new boundaries is driving at power windows <10% of rated power, which are currently excluded. These conditions are relevant for stop-and-go driving and for some special purpose vehicles. In our analysis, the impact of these conditions was embedded in the emission factors used. The share of mileage that was used for driving at power ≥10% (w1) and power <10% (w2) is shown in the following list and was estimated based on PHEM data that have gone into developing the HBEFA emission factors:

HDVs - Long haul trucks

- w1=98.1%
- w2=1.9%

HDVs - Rigid trucks

- w1=93.3%
- w2=6.7%

HDVs – Urban buses

- w1=97.6%
- w2=2.4%

9.4.2. Emission Factors (EFs) calculation/modelling

9.4.2.1. Hot emission factors for Euro 6 d-temp/6d LDVs

The general scheme for calculating the final emission factor as presented in equation (2), includes the calculation of hot emission factors (for gasoline, diesel, CNG) over and outside RDE driving (EF_{hotRDE} and $EF_{EXThotRDE}$ respectively). As described above, the necessary input data for this calculation were derived from the CLOVE database, which is described in detail in the *Combined report*[189]. The main topics of the methodology followed for this calculation can be summarized as follows:

- Hot EFs were calculated from all the cold-start tests excluding the cold start phase, which corresponds to the first 5 minutes of ICE operation. Hot-start tests were not included in the current analysis to exclude any potential effect of semi-hot/warm start tests.
- EFs for NO_x, CO, SPN_{10} were calculated based on on-road tests as measurement data were available for all the studied vehicles. EXThotRDE EFs include all the on-road tests that do not comply with the current RDE regulation boundaries (e.g. in terms of v*apos[95th][190], share of urban, rural, motorway, positive elevation gain, ambient temperature etc.), without distinguishing the different reasons of non-compliance. SPN_{10} emissions, in particular, were calculated based on the ratio of SPN_{10}/SPN_{23} emissions from the DownToTen[191] database, as there are no available data on sub-23nm particles from on-road tests.
- For all the other species included in the evaluation that couldn't be measured on-road (i.e. PM, THC, CH_4, NH_3 and N_2O) EFs were calculated based on laboratory tests, which included several driving cycles such as WLTC, TfL, BAB130 and RDE tests on-dyno. No separation between compliant and non-compliant tests was performed for laboratory tests, as this classification is not directly applicable on those pollutants. Thus, hotRDE and EXThotRDE EFs are identical for these species.
- For each EF, the share of urban (34%), rural (43%) and motorway (23%) driving was taken into account. These share values were derived from the fleet operation statistics which are included in the SIBYL model as weighted average over EU27.
- In the case of gasoline vehicles, a weighted average EF of the different gasoline powertrain types was calculated, based on the registrations share for the year 2019: conventional and mHEV 84%, hybrid 11%, PHEV 5%, which are based on the share of registrations of these vehicles in the SIBYL model. This weighting was deemed necessary so that the vehicle types share in EF calculation is consistent to the market share of each powertrain type.
- In the case of diesel vehicles, in particular, the effect of DPF regeneration was taken into account for the calculation of hot and cold PN EFs of tests outside RDE driving (i.e. in the calculation of EXThotRDE EF). The exact methodology and calculation approach for this is described in detail in the Combined report. In brief, this calculation determines the excess number of particles emitted during the

[189] CLOVE, 2021. "Post Euro 6/VI study: Combined report of Part A & Part B," CLOVE Consortium.

[190] As defined in Regulation 2017/1151 (Annex IIIA, Appendix 7a, paragraph 3.1.4).

[191] DownToTen Horizon2020 project: http://www.downtoten.com/

regeneration phase and a short period immediately after it until a sufficient soot cake is formed in the DPF, and the filtration efficiency is increased to pre-regeneration levels. Based on this PN excess and the DPF regeneration frequency a new EF is calculated and added to the initial EF (which was calculated excluding the DPF regeneration tests). Although NO_x emissions can also be increased during DPF regeneration, it was decided (at least at this point) not to include this effect in the calculation of the respective EFs, as it is expected that NO_x emissions can be effectively controlled during DPF regeneration already with the current Euro 6 technology.

- In the case of CNG vehicles, the available data in CLOVE database were quite limited, thus EFs for CNG were taken equal to gasoline, except from THC, CH_4, PM and SPN_{10}.
- The analysis of CLOVE database revealed that the contribution of some OEMs (in terms of number of vehicles tested) was higher than their market share (based on ACEA registrations statistics[192]). Thus, a weighting factor was applied on the EFs, so that the market share of each OEM is taken into account.
- As regards LCVs, only limited data were available in CLOVE database (2 N1 class II vehicles), thus in this case, the following approach was followed: the Euro 6 emission limits ratio between passenger cars and N1 vehicles was calculated for each N1 class (applicable to class II and III, for class I this ratio is 1). Then, this ratio was applied on passenger cars EFs for the calculation of LCVs EFs.

As mentioned in section 4.1 of the current report two sets of emission factors were produced, one referred to as the 'normal Euro 6/VI' and the second one as 'conservative Euro 6/VI' that reflects a potential worsening of the emission levels of vehicles in the future as a possible result of several factors. For the calculation of this conservative set of emission factors, the following assumptions were made:

- The cold+hot NOx emission factor corresponding to RDE conditions at useful life was et equal to the emission limit minus an engineering margin of 10 mg/km. Therefore, for passenger cars, the mean cold+hot NOx emission factor at 160 000 km was assumed to be 50 mg/km for petrol vehicles and 70 mg/km for diesel vehicles.
- For EXThotRDE EF, the emission factor was considered to double over the value that was determined from experimental tests while the cold overemission was not assumed to differ over the one estimated from the experimental results. The rationale of these corrections is that cold non-RDE conditions even today are not controlled so there is not point of adjusting them further in a conservative approach. For hot operation, although this is in principle not included in today's RDE, we have assumed that if future hot RDE operation is adjusted, this will also affect the operation outside of RDE because the engine calibration is a continuoum and its calibration cannot be isolated only within RDE and then outside of RDE boundaries.
- For PN and PM we have assumed an increase of 50% due to further calibration of DPFs and GPFs to operate with even lower average soot conditions than in current Euro 6 vehicles. This is for the benefit of CO_2 emissions. Such an operation may be achieved with more frequent regenerations in diesel vehicles and engine calibration in the petrol case.

[192] Consolidated Registrations - By Manufacturer (https://www.acea.be/statistics/tag/category/by-manufacturer-registrations)

- Ammonia emissions from petrol vehicles are also assumed to degrade faster than what we have assumed in the baseline set of emission factors. This can be a consequence of the further engine tuning to achieve lower CO2 emissions (higher stress to the catalyst).

Hot EFs calculated based on the above-described methodology are summarized in the following tables.

Table 9-6: Hot EFs for RDE driving (normal) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Hot EFs – RDE [mg/km, p/km]					Chassis dyno			
Data source	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
CLOVE db. gasoline	10.2	186.6	0.160	7.6E+11	5.1	2.4	11.3	0.3
CLOVE db. diesel	33.1	31.6	0.150	3.3E+10	12.8	11.5	0.3	12.4
CLOVE db. CNG	10.2	186.6	0.080	3.5E+11	37.7	20.8	11.3	0.3

Table 9-7: Hot EFs for RDE driving (conservative) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Hot EFs – RDE [mg/km, p/km]					Chassis dyno			
Data source	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
CLOVE db. gasoline	35.0	186.6	0.240	1.1E+12	5.1	2.4	11.3	0.3
CLOVE db. diesel	50.0	37.9	0.225	5.0E+10	12.8	11.5	0.3	12.4
CLOVE db. CNG	35.0	186.6	0.120	5.3E+11	37.7	20.8	11.3	0.3

Table 9-8: Hot EFs for outside RDE driving (normal) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Hot EFs – outside RDE [mg/km, p/km]					Chassis dyno			
Data source	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
CLOVE db. gasoline	22.1	1202.6	0.450	1.1E+12	5.1	2.4	11.3	0.3
CLOVE db. diesel	190.9	43.4	0.375	1.4E+11	12.8	11.5	0.3	12.4
CLOVE db. CNG	22.1	1202.6	0.225	7.0E+11	37.7	20.8	11.3	0.3

Table 9-9: Hot EFs for outside RDE driving (conservative) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Hot EFs – outside RDE [mg/km, p/km]					Chassis dyno			
Data source	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	44.3	1,202.6	0.675	1.7E+12	5.1	2.4	11.3	0.3
CLOVE db. diesel	381.7	52.0	0.563	2.0E+11	12.8	11.5	0.3	12.4
CLOVE db. CNG	44.3	1,202.6	0.338	1.0E+12	37.7	20.8	11.3	0.3

9.4.2.2. Cold emission factors for Euro 6 d-temp/6d LDVs

This section is dedicated to the modelling of the cold start excess emission (CSEE), which is expressed in terms of distance.

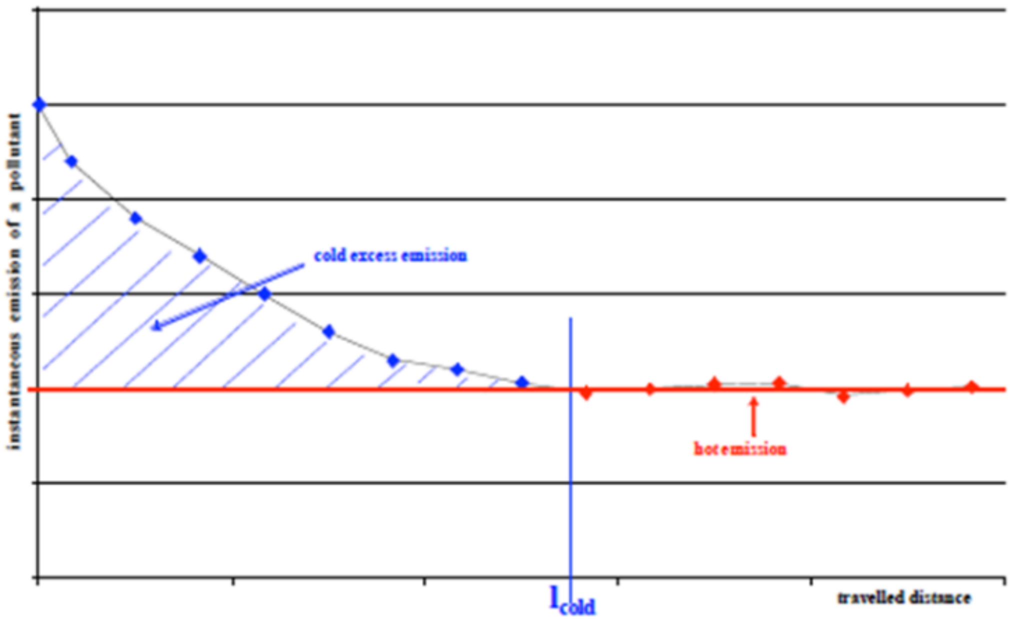

Figure 9-11: Emissions evolution according to travelled distance.

As shown in equation 2, one term of the final EF is the cold start emissions. As long as a vehicle does not reach its running temperature, the emissions of air pollutants are increased compared to the emissions when the normal engine temperature is reached (stability phase). The time needed for reaching the stability phase can be defined as t_{cold}. The time can be transformed into distance travelled in cold condition (l_{cold}) through the average vehicle speed.

The calculation equation of the cold start excess emissions is the following[193] :

$$CSEE\ (T,\delta,t) = \omega_{reference} * f(T) * h(\delta) * g(t)\ (3)$$

Where:

- $\omega_{reference}$: Excess emissions at reference temperature

[193] J.-M. André, R. Joumard, 2005., "Modelling of cold start excess emissions for passenger cars,".

- f(T): Temperature influence function
- h(δ): Distance influence function
- g(t): Parking-time influence function

Excess emissions at reference temperature ($\omega_{reference}$) and influence of ambient temperature (f(T))

The followings tables (Table 9-11, Table 9-12) contain the $\omega_{reference}$ obtained from experimental CLOVE database (db.) measurements[194], for RDE driving and outside of RDE driving. Specifically, vehicle measurements were performed with starts in both cold and hot conditions. The first 5 minutes of the test (in cold conditions) were considered as t_{cold} (Table 9-10), and $\omega_{reference}$ resulting from the difference in the emission levels of the two tests. Based on an extracted average speed from the CLOVE db., over the urban RDE part, the distance where the cold start phase has been completed (l_{cold}) was calculated.

Table 9-10: Assumptions in order to calculate ω (CLOVE database).

Parameter	Value	Notes
t_{cold} (min)	5	Assumption for time needed by vehicle to reach its normal running temperature
urban RDE v (km/h)	21.5	Average speed of the Urban RDE trips. Based on the CLOVE db. tests.
l_{cold} (km)	1.79	Assumption for distance needed by vehicle to reach its normal running temperature

The $\omega_{reference}$ was calculated from the averages of both RDE compliant and non-RDE compliant measurements of Euro 6d-temp/d vehicles. As for currently non-regulated pollutants the relevant values where mostly based on chassis-dyno tests (CLOVE db.).

Table 9-11: Overemission of cold-start above 0°C ($\omega_{reference}$), Euro 6d-temp/6d RDE driving.

Cars and vans (only N1-I) $\omega_{reference}$ – RDE [mg/start, p/km]					Chassis dyno			
Data source	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	129.1	1856.3	2.25	3.51E+12	423.2	30.5	29.9	12.8
CLOVE db. diesel	407.0	529.2	3.85	3.51E+12	19.2	2.8	0.2	21.1
CLOVE db. CNG	129.1	1856.3	1.14	3.51E+12	434.9	229.5	69.1	18.0

Table 9-12: Overemission of cold-start above 0°C ($\omega_{reference}$), Euro 6d-temp/6d outside RDE driving.

[194] The database included both Euro 6d-temp and Euro 6d vehicles

Cars and vans (only N1-I) $\omega_{reference}$ – outside RDE [mg/start, p/km]					Chassis dyno			
Data source	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	547.3	6211.2	4.27	7.35E+12	423.2	30.5	29.9	12.8
CLOVE db. diesel	1765.9	601.6	9.97	2.69E+11	19.2	2.8	0.2	21.1
CLOVE db. CNG	547.3	6211.2	2.14	6.13E+11	434.9	229.5	69.1	18.0

Due to the small sample size in the CLOVE db. of LPG vehicles, an assumption was made that the ω values are the same as gasoline. Similarly, for CNG cars, apart from SPN_{10} and CH_4, the values were also assumed equal to the gasoline values. It should be also highlighted that from the above values the equivalent 'hot emission' part (in the cold start phase, i.e. the first 5 mins) has been deducted from the $\omega_{reference}$.

It was also considered that the $\omega_{reference}$ does not change for starts within the temperature range 0 °C up to 30+ °C. Instead, it was assumed that there is an almost linear increase of the $\omega_{reference}$ for starts at temperatures below 0°C (Table 9-13). The values regarding the influence of the ambient temperature were based on specific measurements of two individual vehicles (diesel and gasoline) from the CLOVE testing database (db.), which were measured below 0°C.

Table 9-13:Influence of ambient temperature (f(T)).

Assumed increase in ω per 1°C below 0°C							
Data source	NO_x	CO	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	6.0%	20.0%	5.0%	17.0%	20.0%	6.0%	0.0%
CLOVE db. diesel	34.0%	67.0%	5.0%	17.0%	4.0%	13.0%	16.0%

Excess emission as a function of the travelled distance h(δ)

The evolution of the excess emission over the travelled distance is an important parameter to consider for the cold start modelling. Based on the same study[195], an exponential function has been used to describe this evolution, and this function is used also in our modelling. The excess emission is increasing till the end of the cold distance (l_{cold}), and then equal to the reference excess emissions as presented in the following figure.

[195] J.-M. André, R. Joumard, 2005., "Modelling of cold start excess emissions for passenger cars".

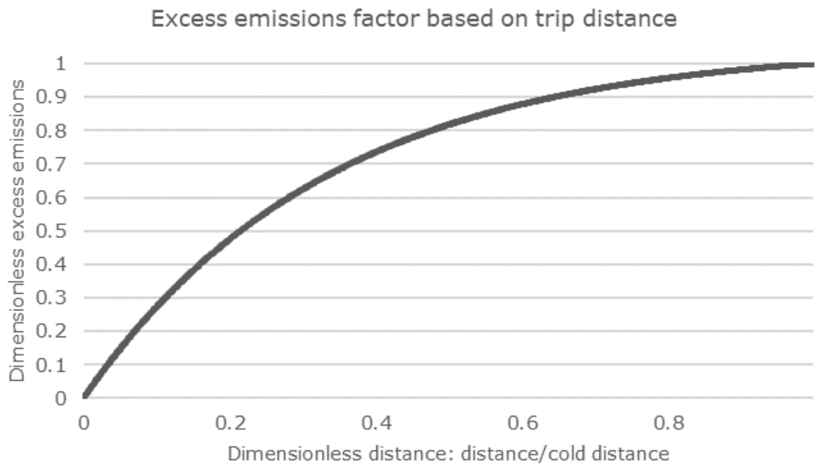

Figure 9-12: Excess emissions factor based on trip distance.

Excess emission as a function of the parking time g(t)

Parking time is an important parameter that influences the engine and emission control components temperature the moment when the vehicle starts its operation, and thus the excess emissions are affected as well. In the Figure 9-13 below there is the reduction factor g (t) of the cold start excess emissions versus the parking time[196] . The factor g is equal to 1 meaning that the cold start over emissions will not be affected for > 12 h parking.

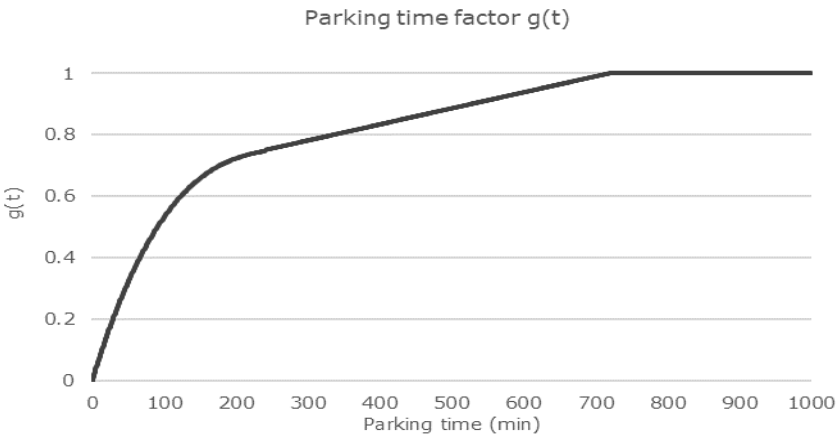

Figure 9-13: Excess emission as a function of the parking time.

Cross-probability of trip distance vs temperature

Equation (3) for calculating cold start excess emissions is expressed in more detail as follows:

$$CSEE\ (T,\delta,t) = \sum_{i=1}^{T}\sum_{j=1}^{Trip\ dist.} p_{i,j} * \omega_{reference} * f(T)_i * h(\delta)_j * g(t)$$

Where:

$\boldsymbol{p_{i,j}}$: probability of making a trip within a specific temperature range and trip length range.

[196] J.-M. André, R. Joumard, 2005., "Modelling of cold start excess emissions for passenger cars".

In order to apply the above calculation methodology for the cold start emissions, the distribution of vehicle kilometers in the various bins of ambient temperatures and bins of trip distances should be estimated (Figure 9-14). In this way, weighted average excess emissions can be calculated based on this distribution. The allocation of vehicle-kilometers (vkms) travelled by ambient temperature was derived from Emisia's internal data while the allocation of vkms travelled by trip distance was derived from statistics collected by the JRC[197] .

Distribution of the vkm [%] based on T and trip distance

(T, Trip distribution)	0 ... 1 km	1 ... 2 km	2 ... 3 km	3 ... 4 km	4 ... 5 km	5 ... 6 km	6 ... 7 km	7 ... 8 km	8 ... 9 km	9 ... 10 km	10 ... 50 km	50 ... 100 km	100 ... 500 km	more than 500 km	Total
< -20 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**
-20 ... -10 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	**0.03%**
-10 ... -8 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.01%	0.00%	**0.05%**
-8 ... -6 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.02%	0.01%	0.00%	**0.11%**
-6 ... -4 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%	0.02%	0.02%	0.00%	**0.16%**
-4 ... -2 °C	0.01%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.31%	0.10%	0.08%	0.00%	**0.64%**
-2 ... 0 °C	0.03%	0.05%	0.06%	0.06%	0.06%	0.05%	0.05%	0.05%	0.05%	0.05%	1.09%	0.35%	0.28%	0.00%	**2.23%**
0 ... 2 °C	0.05%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%	0.08%	0.08%	1.83%	0.58%	0.47%	0.00%	**3.72%**
2 ... 4 °C	0.06%	0.11%	0.12%	0.12%	0.12%	0.11%	0.11%	0.11%	0.11%	0.10%	2.32%	0.74%	0.59%	0.00%	**4.73%**
4 ... 6 °C	0.10%	0.20%	0.20%	0.20%	0.20%	0.20%	0.19%	0.19%	0.19%	0.18%	3.98%	1.27%	1.02%	0.00%	**8.12%**
6 ... 8 °C	0.11%	0.21%	0.22%	0.22%	0.22%	0.21%	0.21%	0.21%	0.20%	0.19%	4.28%	1.37%	1.09%	0.00%	**8.73%**
8 ... 10 °C	0.11%	0.21%	0.22%	0.21%	0.21%	0.21%	0.21%	0.20%	0.20%	0.19%	4.21%	1.34%	1.07%	0.00%	**8.58%**
10 ... 20 °C	0.58%	1.12%	1.17%	1.16%	1.15%	1.12%	1.11%	1.09%	1.06%	1.01%	22.75%	7.26%	5.81%	0.00%	**46.38%**
20 ... 22 °C	0.08%	0.16%	0.17%	0.17%	0.16%	0.16%	0.16%	0.16%	0.15%	0.14%	3.26%	1.04%	0.83%	0.00%	**6.64%**
22 ... 24 °C	0.06%	0.11%	0.11%	0.11%	0.11%	0.11%	0.11%	0.11%	0.10%	0.10%	2.19%	0.70%	0.56%	0.00%	**4.46%**
24 ... 26 °C	0.04%	0.08%	0.08%	0.08%	0.08%	0.08%	0.07%	0.07%	0.07%	0.07%	1.53%	0.49%	0.39%	0.00%	**3.12%**
26 ... 28 °C	0.02%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%	0.86%	0.27%	0.22%	0.00%	**1.75%**
28 ... 30 °C	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.23%	0.07%	0.06%	0.00%	**0.47%**
30 ... 40 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.01%	0.00%	**0.07%**
> 40 °C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**
Total	**1.2%**	**2.4%**	**2.5%**	**2.5%**	**2.5%**	**2.4%**	**2.4%**	**2.4%**	**2.3%**	**2.2%**	**49.0%**	**15.7%**	**12.5%**	**0.0%**	**100.0%**

Figure 9-14: Distribution of vkms [%] on T and trip distance bins.

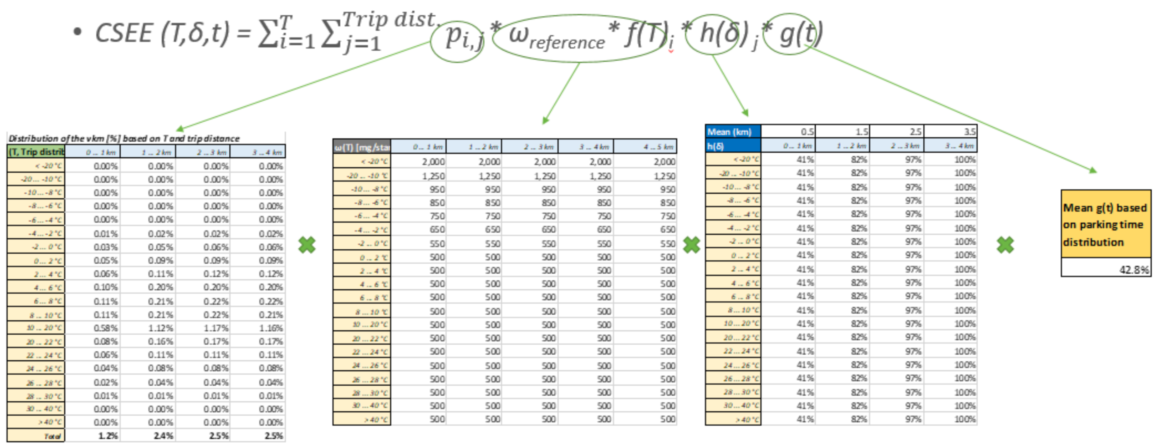

Figure 9-15: Example of CSEE calculation.

Results

In order to produce the average CSEE expressed in terms of distance (e.g. g/km), a mean annual milage was estimated as well as the average trips per day for cars. The sources for the annual mean mileage was COPERT and the average trip per day a relevant JRC study on mobility patterns[198].

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[197] E. Paffumi, M. De Gennaro, and G. Martini,2018. "European-wide study on big data for supporting road transport policy," Case Stud. Transp. Policy, doi: 10.1016/j.cstp.2018.10.001

[198] E. Paffumi, M. De Gennaro, and G. Martini,2018. "European-wide study on big data for supporting road transport policy," Case Stud. Transp. Policy, doi: 10.1016/j.cstp.2018.10.001

Table 9-14: Mileage/trips per day input.

Mileage/trips per day input		
Cars (Euro 6d/d-temp) and N1-I vans	Mean Mileage (km/per year)	Average trips per day
Gasoline	14.500	3.79
Diesel	18.600	3.79
CNG	14.500	3.79

The cold start EFs calculated based on the above-described methodology are summarized in the following tables (Table 9-15,Table 9-16):

Table 9-15: Average cold EFs for RDE driving (normal) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Cold EFs – RDE [mg/km, p/km]					Chassis dyno			
Data source	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	5.0	75.0	0.090	2.8E+11	17.1	1.2	1.2	0.5
CLOVE db. diesel	12.5	17.2	0.120	1.3E+10	0.6	0.1	0.005	0.6
CLOVE db. CNG	5.0	75.0	0.045	2.0E+11	17.5	9.3	1.2	0.5

Table 9-16: Average cold EFs for RDE driving (conservative) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Cold EFs – RDE [mg/km, p/km]					Chassis dyno			
Data source	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	8.7	75.0	0.090	2.8E+11	17.1	1.2	1.2	0.5
CLOVE db. diesel	14.5	17.2	0.120	1.3E+10	0.6	0.1	0.005	0.6
CLOVE db. CNG	8.7	75.0	0.045	2.0E+11	17.5	9.3	1.2	0.5

Table 9-17: Average cold EFs for outside RDE driving (normal)– Euro 6d-temp/6d.

Cars and vans (only N1-I) Cold EFs – outside RDE [mg/km, p/km]					Chassis dyno			
Data source	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
CLOVE db. gasoline	21.2	250.8	0.170	5.9E+11	17.1	1.2	1.2	0.5
CLOVE db. diesel	54.4	19.5	0.310	9.6E+09	0.6	0.1	0.0	0.6
CLOVE db. CNG	21.2	250.8	0.085	1.9E+11	17.5	9.3	1.2	0.5

The normal and conservative average cold EFs for outside RDE driving have been considered the same.

9.4.2.3. Deterioration factors for Euro 6 d-temp/6d LDVs

The following Table 9-18 lists the deterioration factors derived from the CONOX database for cars and vans at different cumulative mileages. For the pollutants SPN_{10}, PM and N_2O the deterioration factor is considered "1" for the entire vehicle lifetime. The deterioration factors have been considered the same in normal and conservative EFs except in NH_3 for SI vehicles.

Table 9-18: Deterioration factors [-] for specific cumulative mileages [km] – Euro 6d-temp/6d.

Cars and vans Deterioration factors [-] for specific cumulative mileages [km]						
Pollutant	**Fuel**	**0**	**50,000**	**160,000**	**240,000**	**400,000 (or higher)**
NO_x	Gasoline	1	1	1.18	1.38	1.70
	Diesel	1	1	1.11	1.19	1.35
CO	Gasoline	1	1	1.24	1.38	1.70
	Diesel	1	1	1.30	1.51	1.93
THC	Gasoline	1	1	1.24	1.38	1.70
	Diesel	1	1	1.30	1.51	1.93
CH_4	Gasoline	1	1	1.24	1.38	1.70
	Diesel	1	1	1.30	1.51	1.93
NH_3	Gasoline (normal)	1	1	1.84	2.45	3.66
	Gasoline (conservative)	1	1	3	4	5
	Diesel	1	1	1	1	1

9.4.2.4. Tampering factors for Euro 6 d-temp/6d LDVs

The share of the vehicles tampered and the emission rate (tampered vehicle / non-tampered vehicle) are shown in the Table 9-19. For the compounds CO, THC and CH4 there was no data for tampering effect. In addition, SCR tampering can lead to lower NH_3 and N_2O emissions (SCR removed). Nevertheless, there are emulators and ECU reprogramming approaches which reduce the injected quantity or in general, partially deactivate the system. The emissions can be as high or higher than a normal system due to insufficient control of urea injection. No measurement data or other evidence are available and therefore no tampering effect considered for NH_3 and N_2O.

Table 9-19: Tampering share [%] and rate [-] – Euro 6d-temp/6d.

Cars and vans Tampering share [%] and rate [-]						
Fuel	**NO_x**		**PM**		**SPN_{10}**	
	Tampering share [%]	**Tampering rate [-]**	**Tampering share [%]**	**Tampering rate [-]**	**Tampering share [%]**	**Tampering rate [-]**
Gasoline	0	0	3	5	3	10
Diesel	6	10	6	10	6	20

9.4.2.5. Final emission factors for Euro 6 d-temp/6d LDVs

The above individual EFs compose the final EFs through equation 2. The following Table 9-20 and Table 9-21 contain the final normal and conservative Euro 6 emission factors.

Table 9-20: Final EFs (normal) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Final exhaust Efs @160k km [mg/km, p/km] - Normal								
Data source	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
CLOVE db. gasoline	22.04	534.22	0.334	1.38E+12	23.95	4.30	22.37	0.80
CLOVE db. diesel	113.60	62.20	0.432	1.19E+11	17.63	15.40	0.33	13.34
CLOVE db. CNG	22.04	534.22	0.167	7.22E+11	65.70	35.85	22.37	0.80

Table 9-21: Final EFs (conservative) – Euro 6d-temp/6d.

Cars and vans (only N1-I) Final exhaust Efs @160k km [mg/km, p/km] - Conservative								
Data source	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
CLOVE db. gasoline	54.72	534.22	0.451	1.91E+12	23.95	4.30	35.73	0.80
CLOVE db. diesel	187.63	71.05	0.577	1.72E+11	17.63	15.40	0.33	26.03
CLOVE db. CNG	54.72	534.22	0.225	9.86E+11	65.70	35.85	35.73	0.80

9.4.2.6. Euro 7 Emissions factors for LDVs

As already mentioned, various policy options and scenarios for the implementation of Euro 7 emission standards were considered. As a result, each scenario, depending on its characteristics is associated with different emission factors.

- PO1 and PO2:
    - For each scenario in this case, a combination of future technologies was developed, as described in section 4.3 of the current report and the *Combined report*[199]. The emission performance of these technologies was determined based on simulation models developed by CLOVE consortium. Further details and description of these models are provided in the *Combined report*. The methodology followed for the calculation of Euro 7 EFs is the same as the one presented above for the Euro 6d-temp/6d technologies i.e. including the determination of hot and cold EFs for driving conditions within and outside RDE. The degradation due to high mileage/age, and the impact of tampering and malfunctions not detected by OBD are also considered in Euro 7 technologies.

[199] CLOVE, 2021. "Post Euro 6/VI study: Combined report of Part A & Part B," CLOVE Consortium.

    - Simulation runs were performed for two different types of test cycles so that separate EFs can be derived for conditions within and outside normal driving. A moderate RDE test (at 23ºC and -10ºC) was used to assess the emission performance of each technology during normal driving. A weighted average of the results over this cycle at 23ºC (90%) and -10ºC (10%) was used for the calculation of hotRDE EF. An RDE test at -10ºC was used as a proxy of test conditions outside normal driving. The velocity profiles and all the details of these test cycles are presented in the *Combined report*.
    - As regards the different species that were evaluated, simulation data were available for NO_x, CO, THC, SPN_{10} (only for SI). For the other gaseous species (CH_4, NH_3, N_2O) EFs were calculated based on the emission performance of the current best available technologies and engineering judgement to reach the proposed limits in each case. PM was calculated based on the following equation: $PM = PM_{vof} + PM_{sol}$, where PM_{vof} refers to the volatile fraction and PM_{sol} refers to the solid (non-volatile) fraction of PM. PM_{vof} was taken equal to the respective part of the EFs used in Euro 6 baseline EFs and PM_{sol} was calculated based on (solid) PN EFs and the particle size distribution for each fuel type. The particle size distribution data were taken from the DownToTen project[200].

- Policy Option 3: Hot and cold EFs for Policy Option 3 were taken equal to Policy Option 2 Scenario 1 & 2 EFs as there is no change in the proposed limits. Differences are encountered for the degradation and malfunction, as later explained.

9.4.2.7. Hot emission factors for Euro 7 LDVs

The EFs derived based on the above-described methodology are presented in the following tables.

Table 9-22: Hot EFs for RDE driving – Euro 7 policy option scenarios.

[200] DownToTen Horizon2020 project: http://www.downtoten.com/

Cars and vans (only N1-I) Hot EFs – RDE [mg/km, p/km]									
PO.SC	Fuel type	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
PO1.SC1	Gasoline	10.2	186.6	0.160	7.6E+11	5.1	2.4	11.3	0.3
	Diesel	33.1	31.6	0.150	3.3E+10	12.8	11.5	0.3	12.4
	CNG	10.2	186.6	0.080	3.5E+11	37.7	20.8	11.3	0.3
PO2.SC1	Gasoline	1.6	33.9	0.151	9.6E+09	0.3	2.4	5.3	0.3
	Diesel	3	31.6	0.135	1.1E+10	6.5	5.2	0.3	12.4
	CNG	1.6	33.9	0.076	3.8E+10	0.3	20.8	5.3	0.3
PO2.SC2	Gasoline	1.6	33.9	0.151	9.6E+09	0.3	2.4	5.3	0.3
	Diesel	3	31.6	0.135	1.1E+10	6.5	5.2	0.3	12.4
	CNG	1.6	33.9	0.076	3.8E+10	0.3	20.8	5.3	0.3
PO2.SC3	Gasoline	1.6	33.9	0.151	9.6E+09	0.3	2.4	5.3	0.3
	Diesel	3	31.6	0.135	1.1E+10	6.5	5.2	0.3	6.6
	CNG	1.6	33.9	0.076	3.8E+10	0.3	20.8	5.3	0.3

Table 9-23: Hot EFs for outside RDE driving – Euro 7 policy option scenarios.

Cars and vans (only N1-I) Hot EFs – outside RDE [mg/km, p/km]									
PO.SC	Fuel type	NO_x	CO	PM	SPN_{10}	THC	CH_4	NH_3	N_2O
PO1.SC1	Gasoline	22.1	1202.6	0.45	1.13E+12	5.1	2.4	11.3	0.3
	Diesel	100.5	43.4	0.38	1.36E+11	12.8	11.5	0.3	12.4
	CNG	22.1	1202.6	0.23	6.97E+11	37.7	20.8	11.3	0.3
PO2.SC1	Gasoline	4.2	114.9	0.43	3.42E+10	0.8	2.4	5.6	0.3
	Diesel	10.0	43.4	0.31	6.27E+10	6.5	5.2	0.3	12.4
	CNG	4.2	114.9	0.22	1.36E+11	0.8	20.8	5.6	0.3
PO2.SC2	Gasoline	4.2	114.9	0.43	3.42E+10	0.8	2.4	5.6	0.3
	Diesel	10.0	43.4	0.31	6.27E+10	6.5	5.2	0.3	12.4
	CNG	4.2	114.9	0.22	1.36E+11	0.8	20.8	5.6	0.3
PO2.SC3	Gasoline	4.2	114.9	0.43	3.25E+10	0.8	2.4	5.6	0.3
	Diesel	10.0	43.4	0.31	6.27E+10	6.5	5.2	0.3	6.6
	CNG	4.2	114.9	0.22	1.29E+11	0.8	20.8	5.6	0.3

9.4.2.8. Cold emission factors for Euro 7 LDVs

The Cold EFs of Euro 7 technology packages were calculated with exactly the same methodology as in the case of Euro 6d-temp/6d. The cold start EFs used are summarized in the following tables.

Table 9-24: Cold EFs for RDE driving – Euro 7 policy option scenarios.

Cars and vans (only N1-I) Cold EFs – RDE [mg/km, p/km]									
PO.SC	**Fuel type**	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
PO1.SC1	Gasoline	5.0	75.0	0.09	2.81E+11	17.1	1.2	1.2	0.5
	Diesel	12.5	17.2	0.12	1.31E+10	0.6	0.1	0.0	0.6
	CNG	5.0	75.0	0.05	1.98E+11	17.5	9.3	1.2	0.5
PO2.SC1	Gasoline	4.5	73.3	0.09	3.74E+10	10.1	1.2	0.6	0.5
	Diesel	3.0	17.2	0.12	4.52E+09	0.2	0.1	0.0	0.6
	CNG	4.5	73.3	0.04	1.49E+11	10.1	9.3	0.6	0.5
PO2.SC2	Gasoline	4.5	73.3	0.09	3.74E+10	10.1	1.2	0.6	0.5
	Diesel	3.0	17.2	0.12	4.52E+09	0.2	0.1	0.0	0.6
	CNG	4.5	73.3	0.04	1.49E+11	10.1	9.3	0.6	0.5
PO2.SC3	Gasoline	3.3	59.0	0.09	3.72E+10	6.8	1.2	0.6	0.5
	Diesel	2.4	17.2	0.12	4.52E+09	0.2	0.1	0.0	0.4
	CNG	3.3	59.0	0.04	1.48E+11	6.8	9.3	0.6	0.5

Table 9-25: Cold EFs for outside RDE driving – Euro 7 policy option scenarios.

Cars and vans (only N1-I) Cold EFs – outside RDE [mg/km, p/km]									
PO.SC	**Fuel type**	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
PO1.SC1	Gasoline	21.2	250.8	0.17	5.88E+11	17.1	1.2	1.2	0.5
	Diesel	35.1	19.5	0.31	9.58E+09	0.6	0.1	0.0	0.6
	CNG	21.2	250.8	0.09	1.95E+11	17.5	9.3	1.2	0.5
PO2.SC1	Gasoline	21.2	105.1	0.17	6.33E+10	17.1	1.2	0.6	0.5
	Diesel	12.9	19.5	0.31	4.40E+09	0.6	0.1	0.0	0.6
	CNG	21.2	105.1	0.09	1.95E+11	17.5	9.3	0.6	0.5
PO2.SC2	Gasoline	21.2	105.1	0.17	6.33E+10	17.1	1.2	0.6	0.5
	Diesel	12.9	19.5	0.31	4.40E+09	0.6	0.1	0.0	0.6
	CNG	21.2	105.1	0.09	1.95E+11	17.5	9.3	0.6	0.5
PO2.SC3	Gasoline	21.2	90.8	0.17	5.81E+10	17.1	1.2	0.6	0.5
	Diesel	10.2	19.5	0.31	4.40E+09	0.6	0.1	0.0	0.4
	CNG	21.2	90.8	0.09	1.95E+11	17.5	9.3	0.6	0.5

9.4.2.9. Deterioration factors for Euro 7 LDVs

The deterioration factors for Euro 7 technology in PO1.Sc1 have been considered the same as for Euro 6d-temp/6d. The only exception is for NH_3 in SI vehicles where the deterioration factors are reduced compared to the corresponding Euro 6d-temp/6d factors, due to the introduction of an NH_3 requirement at Euro 7.

Due to the more demanding durability requirements in PO2 and PO3, compared to PO1, the deterioration factors at 160k km in PO1 were assigned to 200,000 km in PO2 Scenario 1 & 2 and to 240,000 km in PO2 Scenario 3.

Finally, in PO3 Scenario 1 and Scenario 2 the deterioration factors are the same as with PO2 Scenario 1 & 2 except for NO_x and NH_3. Due to the enhanced monitoring of emission performance and identification of malfunctions in combination with OBD that assumed in this scenario, there is no deterioration for these pollutants.

Table 9-26: Deterioration factors – Euro 7 policy option scenarios.

Cars and vans Deterioration factors [-] for specific cumulative mileages [km]							
PO.SC	**Pollutant**	**Fuel**	**0**	**50,000**	**160,000**	**240,000**	**400,000 (or higher)**
PO1.SC1	NO_x	Gasoline	1	1	1.18	1.38	1.70
		Diesel	1	1	1.11	1.19	1.35
	CO	Gasoline	1	1	1.24	1.38	1.70
		Diesel	1	1	1.30	1.51	1.93
	THC	Gasoline	1	1	1.24	1.38	1.70
		Diesel	1	1	1.30	1.51	1.93
	CH_4	Gasoline	1	1	1.24	1.38	1.70
		Diesel	1	1	1.30	1.51	1.93
	NH_3	Gasoline	1	1	1.50	2.00	2.50
		Diesel	1	1	1	1	1
	SPN_{10}	Gasoline	1	1	1	1	1
		Diesel	1	1	1	1	1
	PM	Gasoline	1	1	1	1	1
		Diesel	1	1	1	1	1
	N_2O	Gasoline	1	1	1	1	1
		Diesel	1	1	1	1	1
PO2.SC1 & PO2.SC2	NO_x	Gasoline	1	1	1.10	1.36	2.07
		Diesel	1	1	1.06	1.28	1.94
	CO	Gasoline	1	1	1.14	1.55	2.79
		Diesel	1	1	1.17	1.63	2.93
	THC	Gasoline	1	1	1.14	1.55	2.79
		Diesel	1	1	1.17	1.63	2.93
	CH_4	Gasoline	1	1	1.14	1.55	2.79
		Diesel	1	1	1.17	1.63	2.93
	NH_3	Gasoline	1	1	1.24	1.59	2.42
		Diesel	1	1	1	1.15	1.75
	SPN_{10}	Gasoline	1	1	1	1.15	1.75
		Diesel	1	1	1	1.15	1.75
	PM	Gasoline	1	1	1	1.15	1.75
		Diesel	1	1	1	1.15	1.75
	N_2O	Gasoline	1	1	1	1.15	1.75
		Diesel	1	1	1	1.15	1.75
PO2.SC3	NOx	Gasoline	1	1	1.10	1.18	1.70
		Diesel	1	1	1.06	1.11	1.35
	CO	Gasoline	1	1	1.14	1.24	1.70
		Diesel	1	1	1.17	1.30	1.93
	THC	Gasoline	1	1	1.14	1.24	1.70
		Diesel	1	1	1.17	1.30	1.93
	CH4	Gasoline	1	1	1.14	1.24	1.70
		Diesel	1	1	1.17	1.30	1.93
	NH3	Gasoline	1	1	1.24	1.38	1.70
		Diesel	1	1	1	1	1
	SPN_{10}	Gasoline	1	1	1	1	1
		Diesel	1	1	1	1	1
	PM	Gasoline	1	1	1	1	1
		Diesel	1	1	1	1	1
	N_2O	Gasoline	1	1	1	1	1
		Diesel	1	1	1	1	1

9.4.2.10. Tampering factors for Euro 6 d-temp/6d LDVs

For PO1 Scenario 1, the tampering parameters remain the same as for Euro 6d-temp/6d. The only difference for all PO2 scenarios compared to the PO1 Scenario 1 is that the NOx tampering rate considered is 20 instead of 10, due to the assumed higher efficiency of the SCR at Euro 7 (99.5%), where required NOx levels drop to 20-30 mg/km. Finally, in PO3 scenarios 1 & 2 there is no tampering impact for NOx pollutant because OBM would be able to instantly recognise such tampering attempt.

Table 9-27: Tampering share and rate – Euro 7 policy option scenarios.

Cars and vans Tampering share [%] and rate [-]							
PO.SC	Fuel	NO_x		PM		SPN_{10}	
		Tamping share [%]	Tamping rate [-]	Tamping share [%]	Tamping rate [-]	Tamping share [%]	Tamping rate [-]
PO1.SC1	Gasoline	0	0	3	5	3	10
	Diesel	6	10	6	10	6	20
PO2 (SC1 & SC2 & SC3)	Gasoline	0	0	3	5	3	10
	Diesel	6	20	6	10	6	20
PO3 (SC1 & SC2)	Gasoline	0	0	3	5	3	10
	Diesel	0	20	6	10	6	20

9.4.2.11. Final emission factors for Euro 7 LDVs

The final emission factors of Euro 7 LDV are shown in the Table 9-28 for each scenario. It should be noted that the numbers shown correspond to the various w1 and w2 parameters of each scenario as specified in Table 9-5. Furthermore, the deterioration factors concern the useful life of the vehicles that has been selected in each scenario (section 9.4.2.9). For PO1 the deterioration factors considered are at 160k km, for PO2 scenario 1 & 2 and PO3 scenario 1 & 2 are at 200k km, while only for PO2 scenario 3 the deterioration factors are at 240k km.

Table 9-28: Final EFs– Euro7.

Cars and vans (only N1-I) Final exhaust Euro 7 Efs [mg/km, p/km]									
PO.SC	**Fuel type**	**NO_x**	**CO**	**PM**	**SPN_{10}**	**THC**	**CH_4**	**NH_3**	**N_2O**
PO1.SC1	Gasoline	20.51	472.92	0.313	1.33E+12	23.44	4.20	18.06	0.79
	Diesel	81.46	60.24	0.405	1.09E+11	17.25	15.07	0.33	25.47
	CNG	20.51	472.92	0.157	6.92E+11	64.29	35.08	18.06	0.79
PO2.SC1	Gasoline	8.69	130.58	0.301	5.50E+10	11.31	4.20	7.95	0.79
	Diesel	12.44	60.23	0.369	4.13E+10	8.64	6.85	0.33	13.06
	CNG	8.69	130.58	0.151	2.12E+11	11.36	35.08	7.95	0.79
PO2.SC2	Gasoline	7.62	123.44	0.280	5.19E+10	10.90	4.20	7.92	0.79
	Diesel	11.09	59.27	0.344	3.53E+10	8.61	6.85	0.33	13.06
	CNG	7.62	123.44	0.140	2.03E+11	10.93	35.08	7.92	0.79
PO2.SC3	Gasoline	6.47	109.06	0.280	5.13E+10	7.79	4.20	7.92	0.79
	Diesel	10.41	59.27	0.344	3.53E+10	8.64	6.85	0.33	7.01
	CNG	6.47	109.06	0.140	2.02E+11	7.82	35.08	7.92	0.79
PO3.SC1	Gasoline	8.69	130.58	0.301	5.50E+10	11.31	4.20	7.95	0.79
	Diesel	8.38	60.23	0.369	4.13E+10	8.64	6.85	0.33	13.06
	CNG	8.69	130.58	0.151	2.12E+11	11.36	35.08	7.95	0.79
PO3.SC2	Gasoline	7.62	123.44	0.280	5.19E+10	10.90	4.20	7.92	0.79
	Diesel	7.43	59.27	0.344	3.53E+10	8.61	6.85	0.33	13.06
	CNG	7.62	123.44	0.140	2.03E+11	10.93	35.08	7.92	0.79

9.4.2.12. Lorries/busses emission factors modelling methodology

HDV emission factors represent the real world emission behaviour of the entire HDV fleet. In the case of HDVs, this covers rigid trucks, tractor-trailer combinations, coaches and city busses. In purpose of reaching a higher model accuracy, all of these categories are split further in their different size classes. The brake specific emissions used for the setup of emission factors are the same for all HDV vehicle categories in the specific traffic situations (low load, urban, rural or motorway driving and cold start extra emissions), but the final fleet emissions vary because of the different shares of the main traffic situations. For example, a city bus has a higher share of urban driving compared to a tractor-trailer combination. Of course, additional variations can be found in the number of cold starts per day. These shares are the same independent of the different Euro classes.

The main target of this analysis is to compare the impact of the current vehicle fleet with different possible Euro 7 scenarios on air quality. Hence, emission factors have been elaborated for different Euro classes:

- Euro VI ABC: The changes between Euro VI step A, B and C had only a small effect on real world emission behaviour. Consequently, they are combined together to one class in this analysis. The hot emission factors of Euro VI A, B and C vehicles are based on the Handbook Emission Factors for Road Transport (HBEFA) version 4.1. The HBEFA provides emissions factors exactly for this comprehensive vehicle category split in low load, urban, rural and motorway driving based on 35 HDVs in total[201]. The cold start extra emissions are based on measurement results (WHTC and ISC tests) of 100 vehicles that have been already analysed in this study[202] . In the case of missing emission components, the data has been filled up with additional measurement data available at TUG. The HBEFA 4.1 provides a degradation rate for NO_x emissions. This has been included in this analysis. For other components, the degradation rates have been elaborated based on additional measurement data and expert guesses.

Table 9-29: Euro VI A/B/C emission factors.

Euro VI A/B/C EFs										
Condition	**HDV**	**Driving mode**	**NO_x**	**PM**	**SPN_{10}**	**THC**	**NH_3**	**N_2O**	**CH_4**	**CO**
Hot RDE [g/kWh or #/kWh]	Long haul trucks	Urban hot	1.04	0.0175	9.01E+10	0.0297	0.013	0.244	0.00077	0.302
		Rural	0.554	0.0083	4.12E+10	0.0165	0.010	0.204	0.00032	0.173
		Motorway	0.244	0.0072	4.05E+10	0.0145	0.010	0.193	0.00030	0.139
	Rigid trucks	Urban hot	1.04	0.0175	9.01E+10	0.0297	0.013	0.244	0.00077	0.302
		Rural	0.554	0.0083	4.12E+10	0.0165	0.010	0.204	0.00032	0.173
		Motorway	0.244	0.0072	4.05E+10	0.0145	0.010	0.193	0.00030	0.139
	Urban buses	Urban hot	1.04	0.0175	9.01E+10	0.0297	0.013	0.244	0.00077	0.302
		Rural	0.554	0.0083	4.12E+10	0.0165	0.010	0.204	0.00032	0.173
		Motorway	0.244	0.0072	4.05E+10	0.0145	0.010	0.193	0.00030	0.139
Hot outside RDE [g/kWh or #/kWh]	Long haul trucks	-	5.29	0.0175	9.01E+10	0.0297	0.013	0.051	0.00077	0.302
	Rigid trucks	-	5.29	0.0175	9.01E+10	0.0297	0.013	0.051	0.00077	0.302
	Urban buses	-	5.29	0.0175	9.01E+10	0.0297	0.013	0.051	0.00077	0.302
Cold start [g/start or #/start]	Long haul trucks	-	30	0.1	6.00E+11	0.5	0.010	7	0.025	1.8
	Rigid trucks	-	15.91	0.053	3.18E+11	0.2652	0.005	3.71	0.013	0.955
	Urban buses	-	21.82	0.073	4.36E+11	0.3636	0.007	5.09	0.018	1.31

Table 9-30: Deterioration factors [-] for specific cumulative mileages [km]

Euro VI Lorries and buses Deterioration factors [-] for specific cumulative mileages [km]					
Pollutant	**0**	**50,000**	**300,000**	**700,000**	**900,000 (or higher)**
NO_x	1	1	1.47	2.22	2.60
CO	1	1	1.15	1.38	1.50
PM	1	1	1.15	1.38	1.50
SPN_{10}	1	1	1.15	1.38	1.50
THC	1	1	1.15	1.38	1.50
CH_4	1	1	1	1	1
NH_3	1	1	1	1	1
N_2O	1	1	1	1	1

[201] Matzer, C., Weller, K., Dippold, M., Lipp, S., Röck, M., Rexeis, M., Hausberger, S.: Update of Emission Factors for HBEFA Version 4.1, Graz University of Technology, 2019

[202] Weller, K., Hausberger, S., Hinterplattner, B.: Cold start emissions EURO VI HDV, Graz University of Technology, 2018

Table 9-31: Tampering parameters for Euro VI Lorries and buses

Euro VI Lorries and buses Tampering share [%] and rate [-]								
Parameter	**NO_x**	**PM**	**SPN_{10}**	**THC**	**NH_3**	**N_2O**	**CH_4**	**CO**
Tamping share [%]	5	5	5	5	5	5	5	5
Tamping rate [-]	20	50	200	10	10	10	10	10

- Euro VI DE: Modifications in the emission regulation, especially the lowering of the power threshold from 20 % to 10 % of the rated engine power for a valid trip, lead to a noticeable improvement of the real-world emission behaviour of Euro VI D vehicles compared to Euro VI A, B and C[203]. Consequently, a new vehicle class was set up, which includes also Euro VI step E vehicles, for which no measurement data was available. Consequently, the emission factors (for diesel and LNG trucks) are based on measurement results of well performing Euro VI D vehicles to address also the Euro VI E fleet. In addition, the measurement data provided by TUG and VTT, in total 12 vehicles, contains tests at different ambient temperatures. Consequently, influences of the ambient temperature on the emission behaviour was also elaborated based on that data.

  Since there is no measurement data for vehicles of emission standard Euro VI DE with high mileage available, the degradation rates have been set the same as for Euro VI ABC. This assumption can be explained regarding the similar after-treatment technologies for Euro VI ABC and DE vehicles.

  Beside this average Euro VI DE scenario also a conservative Euro VI DE emission reduction performance was assumed (only for NO_x). Cold start and urban emissions remain the same, but rural and motorway emissions can be higher without causing problems to reach the emission limit for NO_x due to the long motorway part in ISC tests. This scenario is not based on measurement results, but on a safety margin to the limit in ISC tests.

[203] Weller, K., Landl, L., Lipp, S., Matzer, C., Hausberger, S.: Real World Emission Performance of Euro VI D Heavy-Duty Vehicles, TAP conference 2021, Graz)

Table 9-32: Euro VI D/E emission factors.

Euro VI D/E EFs											
Condition	**HDV**	**Driving mode**	**NO_x**	**PM**	**SPN_{10}**	**THC**	**NH_3**	**N_2O**	**CH_4**	**CO**
Hot RDE [g/kWh or #/kWh]	Long haul trucks	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
		Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
		Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
	Rigid trucks	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
		Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
		Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
	Urban buses	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
		Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
		Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
Hot outside RDE [g/kWh or #/kWh]	Long haul trucks	-	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.00144	0.216
	Rigid trucks	-	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.00144	0.216
	Urban buses	-	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.00144	0.216
Cold start [g/start or #/start]	Long haul trucks	-	12	0.1	6.00E+11	0.25	0.012	5.25	0.013	1.85
	Rigid trucks	-	6.36	0.027	3.18E+11	0.1326	0.006	2.78	0.007	0.980
	Urban buses	-	8.73	0.036	4.36E+11	0.1818	0.009	3.82	0.009	1.34

- Euro 7 scenario HD2: The emission factors for this scenario are principally based on engineering targets, which are designed to reach the proposed limits. The engineering targets include aging effects, a margin if the assumed conservative scenario does not represent the real conservative case (30 %) and a safety margin due to the spread in serial production (15 %). The engineering target has to be reached in a conservative on-road test (cold start followed by low load driving) with the length of three WHTCs as proposed minimum test duration for a valid trip in Euro 7. The cold start extra emissions are based on simulation results. The hot emission factors use as base the Euro VI DE emission factors, but they are reduced by a correction factor in order to reach the engineering target. This reduction factor is individual for every emission component.

  Degradation effects are smaller compared to Euro VI DE because improvements can be expected. The values origin from discussions with experts of stakeholders. The difference in emissions according to varying ambient temperatures is also based on simulation data.

Table 9-33: Euro 7 HD2 emission factors.

Euro 7 (HD2) EFs											
Condition	**HDV**	**Driving mode**	**NO_x**	**PM**	**SPN_{10}**	**THC**	**NH_3**	**N_2O**	**CH_4**	**CO**
Hot RDE [g/kWh or #/kWh]	Long haul trucks	Urban hot	0.009	0.0028	2.88E+10	0.0019	0.005	0.082	0.00038	0.018
		Rural	0.007	0.0013	1.32E+10	0.0010	0.004	0.056	0.00016	0.010
		Motorway	0.005	0.0012	1.30E+10	0.0009	0.004	0.045	0.00015	0.008
	Rigid trucks	Urban hot	0.009	0.0028	2.88E+10	0.0019	0.005	0.082	0.00038	0.018
		Rural	0.007	0.0013	1.32E+10	0.0010	0.004	0.056	0.00016	0.010
		Motorway	0.005	0.0012	1.30E+10	0.0009	0.004	0.045	0.00015	0.008
	Urban buses	Urban hot	0.009	0.0028	2.88E+10	0.0019	0.005	0.082	0.00038	0.018
		Rural	0.007	0.0013	1.32E+10	0.0010	0.004	0.056	0.00016	0.010
		Motorway	0.005	0.0012	1.30E+10	0.0009	0.004	0.045	0.00015	0.008
Hot outside RDE [g/kWh or #/kWh]	Long haul trucks	-	0.18	0.0035	3.63E+10	0.0046	0.005	0.018	0.00099	0.068
	Rigid trucks	-	0.18	0.0035	3.63E+10	0.0046	0.005	0.018	0.00099	0.068
	Urban buses	-	0.18	0.0035	3.63E+10	0.0046	0.005	0.018	0.00099	0.068
Cold start [g/start or #/start]	Long haul trucks	-	2.38	0.002	2.40E+10	1.18	0	0.69	0.330	25.23
	Rigid trucks	-	1.26	0.001	1.27E+10	0.6266	0	0.37	0.175	13.377
	Urban buses	-	1.73	0.001	1.75E+10	0.8593	0	0.50	0.240	18.35

- Euro 7 scenario HD3: This scenario is elaborated in the same way as the scenario Euro 7 HD2, but the development targets are lower according to the tighter limits. Other parameters, e.g. cold start extra emissions, are also modified for this scenario based on simulation data, of course.

Table 9-34: Euro 7 HD3 emission factors.

Euro 7 (HD3) EFs										
Condition	HDV	Driving mode	NO_x	PM	SPN_{10}	THC	NH_3	N_2O	CH_4	CO
Hot RDE [g/kWh or #/kWh]	Long haul trucks	Urban hot	0.009	0.0028	2.88E+10	0.0026	0.005	0.082	0.00038	0.018
		Rural	0.007	0.0013	1.32E+10	0.0014	0.004	0.056	0.00016	0.010
		Motorway	0.005	0.0012	1.30E+10	0.0013	0.004	0.045	0.00015	0.008
	Rigid trucks	Urban hot	0.009	0.0028	2.88E+10	0.0026	0.005	0.082	0.00038	0.018
		Rural	0.007	0.0013	1.32E+10	0.0014	0.004	0.056	0.00016	0.010
		Motorway	0.005	0.0012	1.30E+10	0.0013	0.004	0.045	0.00015	0.008
	Urban buses	Urban hot	0.009	0.0028	2.88E+10	0.0026	0.005	0.082	0.00038	0.018
		Rural	0.007	0.0013	1.32E+10	0.0014	0.004	0.056	0.00016	0.010
		Motorway	0.005	0.0012	1.30E+10	0.0013	0.004	0.045	0.00015	0.008
Hot outside RDE [g/kWh or #/kWh]	Long haul trucks	-	0.124	0.0035	3.63E+10	0.0058	0.005	0.018	0.00090	0.060
	Rigid trucks	-	0.124	0.0035	3.63E+10	0.0058	0.005	0.018	0.00090	0.060
	Urban buses	-	0.124	0.0035	3.63E+10	0.0058	0.005	0.018	0.00090	0.060
Cold start [g/start or #/start]	Long haul trucks	-	0.853	0.0020	2.40E+10	0.6148	0	0.693	0.28545	12.53
	Rigid trucks	-	0.452	0.0011	1.27E+10	0.3260	0	0.368	0.15138	6.644
	Urban buses	-	0.620	0.0015	1.75E+10	0.4471	0	0.504	0.20760	9.11

9.4.2.13. Euro 7 Emissions factors for HDVs

The proposed emission limits for the scenario PO1.Sc1 are expected to be met by current technologies, thus, EFs for Policy Option 1 were taken equal to baseline Euro VI DE EFs. The emission factors of HD2 have been used for the PO2.Sc1 and PO2.Sc2 and the emission factors of HD3 for the PO2.Sc3. PO3 limits and testing conditions are identical to PO2.Sc1 and PO2.Sc2 for lorries & buses as explained in section 5.3 of the current report. Therefore, the emission factors for the various scenarios are presented in the following tables:

Table 9-35: Hot EFs for RDE driving – Euro 7 policy option scenarios.

Hot EFs - RDE [g/kWh or #/kWh]									
PO.SC	Driving mode	NO_x	PM	SPN_{10}	THC	NH_3	N_2O	CH_4	CO
PO1.Sc1	Urban hot	0.377	0.0087	9.01E+10	0.0148	0.015	0.235	0.00038	0.060
	Rural	0.128	0.0042	4.12E+10	0.0083	0.012	0.160	0.00016	0.035
	Motorway	0.021	0.0036	4.05E+10	0.0073	0.012	0.128	0.00015	0.028
PO2.Sc1 & PO2.Sc2	Urban hot	0.009	0.0028	2.88E+10	0.0019	0.005	0.082	0.00038	0.018
	Rural	0.007	0.0013	1.32E+10	0.0010	0.004	0.056	0.00016	0.010
	Motorway	0.005	0.0012	1.30E+10	0.0009	0.004	0.045	0.00015	0.008
PO2.Sc3	Urban hot	0.009	0.0028	2.88E+10	0.0026	0.005	0.082	0.00038	0.018
	Rural	0.007	0.0013	1.32E+10	0.0014	0.004	0.056	0.00016	0.010
	Motorway	0.005	0.0012	1.30E+10	0.0013	0.004	0.045	0.00015	0.008

As shown in the above Table 9-35, the hot emission factors are provided separately per driving mode (Urban / Rural / Motorway). Therefore, the final hot emission factor depends on the shares of the main driving modes. These shares came from the Sibyl baseline which contains the corresponding average European values and are presented below:

- **Rigid trucks:** Urban: 24%, Rural: 43%, Motorway: 33%
- **Long haul trucks:** Urban: 14%, Rural: 34%, Motorway: 52%
- **Urban buses:** Urban: 67%, Rural: 26%, Motorway: 7%

Table 9-36: Hot EFs for outside RDE driving – Euro 7 policy option scenarios.

Hot EFs - outside RDE [g/kWh or #/kWh]								
PO.SC	NO_x	PM	SPN_{10}	THC	NH_3	N_2O	CH_4	CO
PO1.Sc1	8.20	0.0137	1.41E+11	0.0551	0.015	0.051	0.0014	0.216
PO2.Sc1 & PO2.Sc2	0.178	0.0035	3.63E+10	0.0046	0.005	0.018	0.0010	0.068
PO2.Sc3	0.124	0.0035	3.63E+10	0.0058	0.005	0.018	0.0009	0.060

For cold start emissions, there was no data separating the cold start emission factors for driving in RDE conditions and outside RDE. For this reason, a common factor was used for both driving conditions.

Table 9-37: Overemission of cold-start – Euro 7 policy option scenarios.

$\omega_{reference}$ - RDE and outside RDE [g/start or #/start]									
HDV	PO.SC	NO_x	PM	SPN_{10}	THC	NH_3	N_2O	CH_4	CO
Long haul trucks	PO1.Sc1	12	0.050	6.00E+11	0.250	0.012	5.25	0.013	1.85
	PO2.Sc1 & PO2.Sc2	2.38	0.002	2.40E+10	1.182	0	0.693	0.330	25.23
	PO2.Sc3	0.853	0.002	2.40E+10	0.615	0	0.693	0.285	12.53
Rigid trucks	PO1.Sc1	6.36	0.0265	3.18E+11	0.1326	0.006	2.784	0.0066	0.980
	PO2.Sc1 & PO2.Sc2	1.26	0.0011	1.27E+10	0.6266	0	0.368	0.175	13.38
	PO2.Sc3	0.452	0.0011	1.27E+10	0.3260	0	0.368	0.151	6.64
Urban buses	PO1.Sc1	8.73	0.0364	4.36E+11	0.1818	0.009	3.818	0.0091	1.344
	PO2.Sc1 & PO2.Sc2	1.73	0.0015	1.75E+10	0.8593	0.0	0.504	0.240	18.35
	PO2.Sc3	0.620	0.0015	1.75E+10	0.4471	0.0	0.504	0.208	9.11

The deterioration factors for Euro 7 technology in PO1 have been considered the same as for Euro VI D/E. In PO2 Scenario 3 the durability requirements are increased, which means the same maximum deterioration factors as in PO1 (except for NO_x) but at higher cumulative mileages (deterioration factors @300k and @700k km in PO1.Sc1 have been shifted to 450k and 1050k km in PO2.Sc3). In PO2 Scenarios 1 & 2 the durability requirements are in between of the PO1 (same requirements as for Euro VI D/E) and PO2.Sc3 (increased durability requirements).

Similar to LDVs, in PO3 Scenarios 1 & 2 the deterioration factors are the same with PO2 Scenarios 1 & 2 except for NO_x and NH_3 which are “1” for the entire lifetime of the vehicle.

Table 9-38: Deterioration factors – Euro 7 policy option scenarios.

Lorries and buses Deterioration factors [-] for specific cumulative mileages [km]						
PO1.SC1	DF @ cumulative mileage	0	50,000	300,000	700,000	900,000 (or higher)
	NO_x	1	1	1.47	2.22	2.60
	CO	1	1	1.15	1.38	1.50
	PM	1	1	1.15	1.38	1.50
	SPN_{10}	1	1	1.15	1.38	1.50
	THC	1	1	1.15	1.38	1.50
	CH_4	1	1	1	1	1
	NH_3	1	1	1	1	1
	N_2O	1	1	1	1	1
PO2.SC1 & PO2.SC2	DF @ cumulative mileage	0	50,000	450,000	1,050,000	1,200,000 (or higher)
	NO_x	1	1	1.18	1.75	2.07
	CO	1	1	1.18	1.75	2.07
	PM	1	1	1.18	1.75	2.07
	SPN_{10}	1	1	1.18	1.75	2.07
	THC	1	1	1.18	1.75	2.07
	CH_4	1	1	1	1.27	1.50
	NH_3	1	1	1	1.27	1.50
	N_2O	1	1	1	1.27	1.50
PO2.SC3	DF @ cumulative mileage	0	50,000	450,000	1,050,000	1,200,000 (or higher)
	NO_x	1	1	1.15	1.38	1.50
	CO	1	1	1.15	1.38	1.50
	PM	1	1	1.15	1.38	1.50
	SPN_{10}	1	1	1.15	1.38	1.50
	THC	1	1	1.15	1.38	1.50
	CH_4	1	1	1	1	1
	NH_3	1	1	1	1	1
	N_2O	1	1	1	1	1

The tampering parameters remain the same as for Euro VI D/E in the PO1 scenario 1 and PO2 scenarios 1 & 2 & 3. Also, there is no tampering impact for NO_x and NH_3 in PO3 scenario 1 and for all pollutants in PO3 scenario 2.

Table 9-39: Tampering share and rate – Euro 7 policy option scenarios.

Euro VI Lorries and buses Tampering share [%] and rate [-]									
PO.SC	**Parameter**	**NO_x**	**PM**	**SPN_{10}**	**THC**	**NH_3**	**N_2O**	**CH_4**	**CO**
PO1 & PO2 scenarios	Tamping share [%]	5	5	5	5	5	5	5	5
	Tamping rate [-]	20	50	200	10	10	10	10	10
PO3.SC1 & PO3.SC2	Tamping share [%]	0	5	5	5	0	5	5	5
	Tamping rate [-]	0	50	200	10	0	10	10	10

As explained in the equation 2, the emission calculation model should have emission factors expressed in terms of distance i.e., in g/km instead of g/kWh. Therefore, it was necessary to multiply the emission factors of the respective HDV broader category (Long haul - Rigid trucks, Buses) with the corresponding energy consumption for each subcategory of HDVs in Copert, so that we could end up with coefficients expressed in g/km. These subcategories are defined according to the configuration of the vehicle and the technical permissible maximum weight (e.g. Articulated 14-20 t or Rigid 12-14 t). The energy consumption values used are presented in the Table 9-40.

In addition, for the calculation of the final cold emission factor from HDVs, the same methodology was applied as for the LDVs explained in section 9.4.2.2.

Table 9-40: Energy consumption values for Copert HDV categories.

Copert HDV subcategories	EC [kWh/km]
Rigid <=7,5 t	0.53
Rigid 7,5 - 12 t	0.77
Rigid 12 - 14 t	0.78
Rigid 14 - 20 t	0.93
Rigid 20 - 26 t	1.14
Rigid 26 - 28 t	1.21
Rigid 28 - 32 t	1.40
Rigid >32 t	1.34
Articulated 14 - 20 t	0.97
Articulated 20 - 28 t	1.23
Articulated 28 - 34 t	1.29
Articulated 34 - 40 t	1.46
Articulated 40 - 50 t	1.63
Articulated 50 - 60 t	2.05
Urban Buses Midi <=15 t	1.92
Urban Buses Standard 15 - 18 t	2.00
Urban Buses Articulated >18 t	1.57
Coaches Standard <=18 t	1.48
Coaches Articulated >18 t	1.88

9.4.3. Evaporative emissions

The calculation equation of evaporative emissions is the following:

$EF_{evap} = EF_{D} + EF_{HS} + EF_{RL} + EF_{REF} + EF_{MF}$

Where:

- EF_{evap}: mean daily evaporation losses (g/day)
- EF_{D}: mean daily diurnal emissions (g/day)
- EF_{HS}: mean daily hot soak emissions (g/day)
- EF_{RL}: mean daily running losses (g/day)
- EF_{REF}: mean daily refuelling emissions (g/day)
- EF_{MF}: mean daily evap emissions due to malfunctions, such as leaks (g/day)

For the calculation of EF_D, EF_{HS} and EF_{RL} the COPERT methodology, described in the relevant chapter of the EEA emission inventory guidebook[204], is used. These emission factors depend on several parameters, including:

A. Fuel: (i) Vapour pressure; (ii) Ethanol content

B. Vehicle: (i) Fuel tank size and structure; (ii) Mass and quality of activated carbon; (iii) Purging strategy

C. Activity: (i) Parking duration; (ii) Distance travelled; (iii) Ambient temperature.

For the modelling of different Euro classes, the basic metrics of the carbon canister, including quantity and quality of activated carbon, and the average purge rate are scaled to fulfil the requirements of the corresponding policy option and scenario. The permeation rate of the different components of the fuel system, including the fuel tank and hoses, is also adjusted.

For refuelling emissions from Stage II installations, the methodology for fugitive emissions from gasoline distribution in the EEA guidebook[205] is used. It is assumed that 65% of total petrol is dispensed by service stations equipped with Stage II control[206] at an average efficiency of 70%. For controlling refuelling emissions through an ORVR system, the same equations for canister emissions during diurnal and hot soak events are applied, properly adjusted for the increased canister size of the ORVR.

For evap-related malfunctions, such as leaks and purge valve failures, emission levels were estimated based on relevant US-EPA experience. For the estimation of a basic emission factor it is assumed that 35% of diurnal vapor escapes into the atmosphere[207]. An annual increase of 0.5% in the rate of leaking vehicles is assumed without an enforced I/M OBD programme[208].

9.4.4. Brake Emissions

The Tier II methodology of the Atmospheric Emissions Inventory Guidebook[209] for estimating brake wear emissions has been used to estimate PM emissions for the baseline development and the different policy options in this study. The baseline TSP emission factor for brake wear from passenger cars in this methodology is 7.5 mg/km. However, latest evidence collected in the framework of relevant PMP activities suggests that such a value is rather low, on the basis of latest experimental information[210]. The brake wear emission factors used for the purposes of the study are presented in the Table 9-41.

Table 9-41: Brake wear emission factors

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204 https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-v/view

205 https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-b-fugitives/1-b-2-a-v/view

206 https://publications.jrc.ec.europa.eu/repository/bitstream/JRC77061/final_evap_report_online_version.pdf

207 EPA Report EPA420-R-08-014, “Feasibility of Evaporative Emission Control,” September 2008

208 https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=OTAQ&dirEntryId=260860

209 Ntziachristos, L., Boulter, P. 2019. Road Transport: Automobile tyre and brake wear, European Environment Agency.

210 Ntziachristos, L., Mellios, G. Non-exhaust emissions: Evaporation and brake-wear. AGVES Meeting, 2021-04-08.

Category	$PM_{2.5}$ Brake wear [mg/km]	PM_{10} Brake wear [mg/km]
Cars	4.37	11
Vans	7.71	19.4
Lorries	11.3 - 11.8	28.5 - 29.5
Buses	11.1 - 19.7	27.9 - 49.6

9.4.5. Emission benefits

The emissions savings are calculated from the total emissions as an accumulated difference with time, over the baseline scenario. Additionally to the total emissions, COPERT also delivers the implied emission factors, used to monitor and assess the evolution of the emission factors.

The avoidance of pollution, i.e. the emission savings, creates a benefit when expressed in monetised terms. The monetised environmental benefit (in €) is calculated by multiplying the emission savings with the external damage costs per tonne of pollutant, for each of the examined pollutant. The damage costs for air pollutants for transport that were used in this study were reported by van Essen et al.[211] in the "Handbook on the external costs of transport" on behalf of the European Commission DG MOVE.

In general, the damage costs used of pollution cover the following four types of impacts caused by the emission of transport related air pollutions, as presented in Annex C.2 of the Handbook:

- Health effects: The inhalation of air pollutants such as particles (PM10, PM2.5), NO_x and others lead to a higher risk of respiratory diseases (e.g. bronchitis, asthma, lung cancer) and cardiovascular diseases. These negative health effects lead to medical treatment costs, production loss at work (due to illness) and partially even to death.
- Crop losses: Ozone as secondary air pollutant (mainly caused by the emission of NO_x and VOC) and other acidic air pollutants (e.g. NO_x) can lead to damage of agricultural crops. As a consequence, an increased concentration of ozone and other substances can lead to lower crop yield (e.g. for wheat).
- Material and building damage: Air pollutants can mainly lead to two types of damage of buildings and other materials: a) pollution of building surfaces through particles and dust; b) damage of building facades and materials due to corrosion processes, caused by acidic substances (e.g. nitrogen oxides NO_x).
- Biodiversity loss: Air pollutants can lead to damage of ecosystems. The most important damages are a) the acidification of soil, precipitation and water (e.g. by NO_x) and b) the eutrophication of ecosystems (e.g. by NO_x, NH_3). Damages at ecosystems can lead to a decrease in biodiversity (fauna, flora)

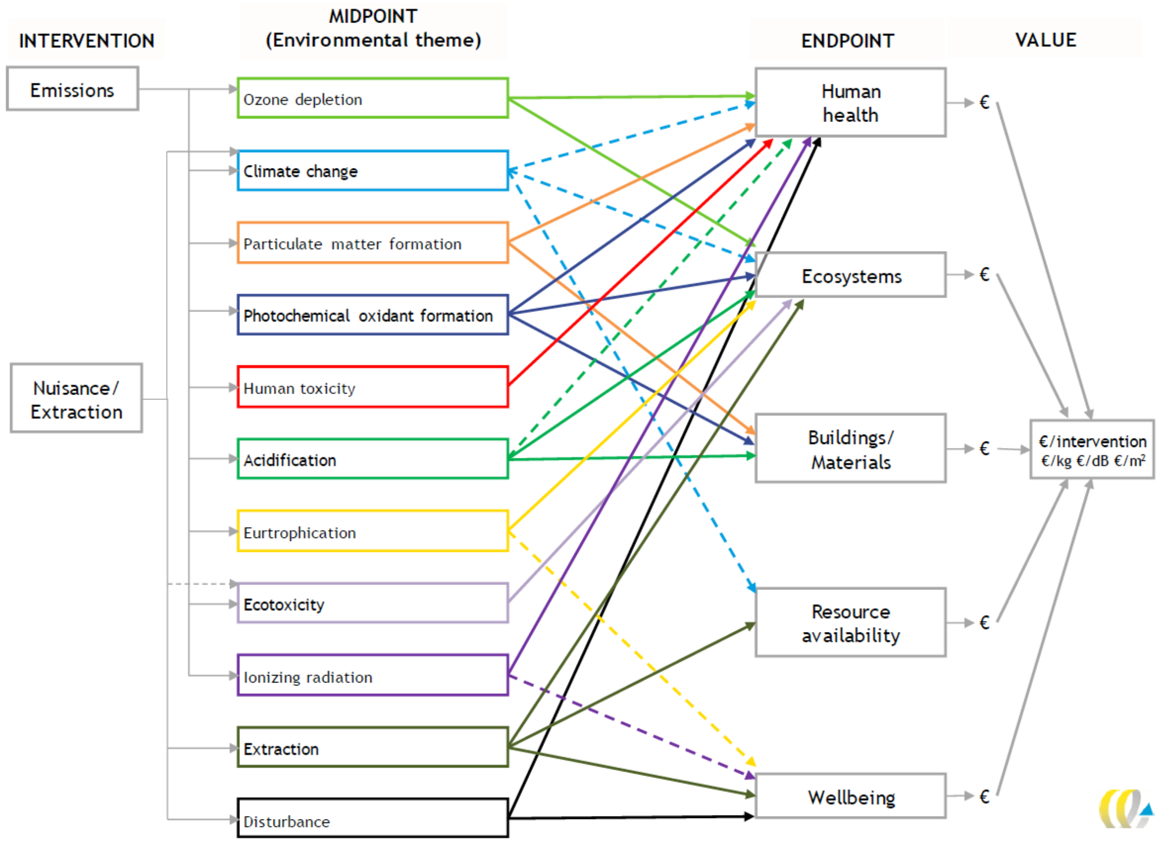
For the pollutants addressed by emission standards (NO_x, NH_3, PM, NMVOC, etc.) external costs, almost in their totality, come from health impacts. Corrosion and acidification mostly come from SO_x emissions, which are not addressed by emission standards. For example, average PM_{10} external costs for health are of the order of € 22 /kg PM_{10}, while its external cost due to buildings deterioration is of the order of € 0.21 / kg

[211] van Essen et al., 2019. "Handbook on the external costs of transport", DG MOVE.

PM_{10} (i.e. two orders of magnitude lower). Given the very small contribution of non-health factors, the uncertainty of these estimates and the fact that the Handbook does not provide detailed distinction of externalities to different categories, we have retained pollution costs to refer only to health effects.

On the other hand, the emission of GHG into the atmosphere leads primarily to global warming, followed by other physical effects, like changes in precipitation patterns, which result in different levels of average and extreme precipitation and changes in the occurrence of extreme weather events. Such radical change will have an important and largely irreversible impact on ecosystems, human health and societies. Due to a large uncertainty in estimating damage costs for each of the many dimensions of climate change, the Handbook uses the approach of avoidance costs to monetise GHG impacts. Avoidance costs are marginal costs of interventions to achieve specific GHG reductions. The avoidance of these costs is considered to lead to environmental benefits in their totality.

Pollution occurs damages to a variety of endpoints. Figure 9-16 illustrates the relationships between intervention, midpoints, endpoints and valuation, reported by CE Delft[212] . For example, an emissions intervention would result to a value for environmental themes such as climate change or particulate matter formation, which would have impact on the third level of the schema, i.e. the endpoint, in human health, ecosystems, materials etc. The valuation of each endpoint would result to the value/cost per intervention. This schema is the basis for the calculation of the damage costs.

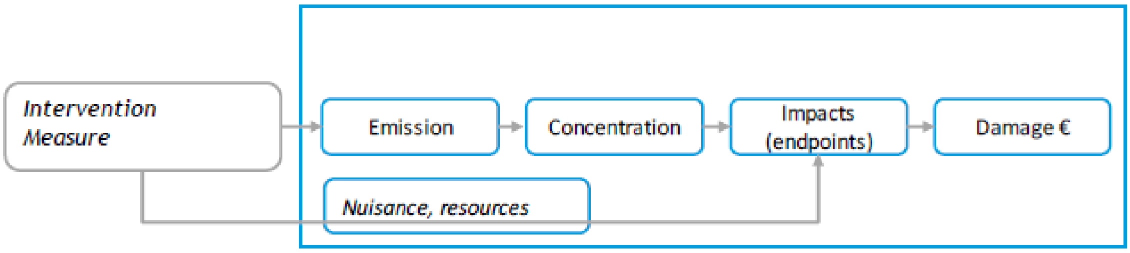


Source: Environmental Prices Handbook, CE Delft, 2018

Figure 9-16: Relationships between interventions, midpoints, endpoints and valuation of environmental policies.

[212] CE Delft, 2018. "Environmental Prices Handbook: EU28 version" CE Delft.

The steps for the calculation of the damage costs are shown in Figure 9-17 as presented in Annex C.2 of the "Handbook on the external costs of transport". In this diagram, emissions refer to air pollutants, and not to emissions to soils or water occurred by tyre wear. These transport emissions are added to the existing atmosphere concentrations of other regions. The concentration then leads to changes in 'endpoints' relevant to human welfare. The changes can be monetarily valued by quantifying the amount of damage caused at the endpoints.



Source: Handbook on the external costs of transport, CE Delft, 2019

Figure 9-17: Damage cost calculations.

The Handbook uses emission data from the COPERT model to estimate the costs per vehicle-kilometre (vkm) activity for the different vehicle categories of road transport. Costs are calculated to reflect health impacts[213] taking into account "concentration response functions", population size and structure based on Eurostat data, population density, relationship factor between damage and emissions for various emission scenarios, and the most recent valuation of human health.

The damage costs reported by van Essen et al. (2019) included 2016 values. These were updated considering the annual inflation rate (Eurostat[214]) of each MS of the EU-27, to reflect 2020 values. The final damage costs that were used in the analysis, considered these 2020 values of each country, and were calculated as the weighted average of the MS's damage costs over the activity of each MS.

The damage costs provided in the Handbook on external costs (EC, 2019) does not include the contribution of NMVOC to the formation of secondary organic aerosol (SOA). This is important to consider taking into account that exhaust emissions of primary PM have decreased so the contribution of gaseous species to secondary PM becomes relatively more important. In order to consider this contribution, we have collected data from an earlier study of EEA on the costs of air pollution from European Industrial facilities. In that study, the NMVOC damage costs are estimated at 1.84 E/kg compared to 1.266 E/kg estimated in the handbook on external costs of transport (both values expressed in E2020 values when correcting for inflation). This shows that the contribution is not negligible.

For taking into account SOA formation impacts one can take into account the following considerations:

1. For PI exhaust Lu et al. (2018)[215] estimated that the SOA yield of NMVOC is in the order of 1%. However, any reduction to NMVOC does not necessarily scale with

[213] WHO, 2013. "Health risks of air pollution in Europe –HRAPIE project: Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide"

[214] Eurostat, 2020. Data extracted on 28/01/2021.

[215] Lu Q., Zhao Y., Robinson A.L., 2018. "Comprehensive organic emission profiles for gasoline, diesel, and gas-turbine engines including intermediate and semi-volatile organic compound emissions". Atmospheric Chemistry and Physics. Vol. 18, No. 23.

reductions to SOA yield potential as the latter comes from heaver species that are more difficult to oxidize in catalysts than lighter ones. Assuming that catalysts are 95% efficient in reducing HC we estimate that they can decrease SOA yield of NMVOC by 60%. Hence, decreasing emissions by a kg of NMVOC would also result to a decrease of PM2.5 emissions formed by SOA by 0.006 kg.

2. For CI exhaust, Lu et al. (2018) estimated that the SOA yield of NMVOC is in the order of 0.5%. However, we assume that DPFs and DOCs are 100% efficient in reducing all NMVOC components proportionally, therefore 1 kg of NMVOC reduction also leads to 0.005 kg decrease in PM2.5 emissions due to less SOA formation.

3. Finally, for gasoline evaporation, He et al. (2020)[216] estimated a SOA yield of 2%. Again, when gasoline evaporates during refuelling or any gasoline breakthrough from canisters mostly involve lighter species and not the heavier ones. However, any gasoline from leakage involves all species while gasoline permeating lines mostly involves aromatic species with high SOA yields. With these considerations, one can assume that only 20% of the evaporating gasoline contributes to SOA. This means that 1 kg of gasoline saved from evaporating also leads on average to 0.004 kg of PM2.5 saved.

The previous analysis shows that for all NMVOC sources, the estimated reduction of $PM_{2.5}$ is from 0.4-0.6% of reduced NMVOC emissions. For simplification in our calculations, we have taken a constant value of 0.5% for all sources as an approximation, also considering the uncertainty of the estimated values.

The damage costs that were used in the analysis are presented in Table 9-42 for the pollutants that were considered in the monetisation scheme. These damage costs are classified based on the area (city/rural) where a vehicle activity is considered to take place. In the CBA calculations, the activity was obtained from the COPERT data.

Table 9-42: Damage costs for air pollutants for transport.

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

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

Source: Handbook on the external costs of transport, CE Delft, 2019

Additionally to the damage costs, the climate change avoidance costs are also considered. The global warming potential (GWP) of each gas is defined in relation to a given weight of carbon dioxide for the period of 100 years, as defined for the purpose of the Kyoto Protocol. The GWP is used to convert emissions of GHG to a relative measure known as carbon dioxide equivalents (hereafter referred to as $CO_{2\text{-eq.}}$ in short). The weighting factors that are used in the current study to calculate the CH_4+N_2O (non-CO_2

[216] He Y., King B., Pothier M., Lewane L., Akherati A., Mattila J., Farmer D. K., McCormick R. L., Thornton M., Pierce J. R., Volckens J., Jathar S. H., 2020. "Secondary organic aerosol formation from evaporated biofuels: comparison to gasoline and correction for vapor wall losses". Environmental Science: Processes & Impacts. Issue 7, 2020

GHG $CO_{2\text{-eq.}}$) are the following: methane (CH_4) = 25, nitrous oxide (N_2O) = 298[217]. The climate change avoidance costs in €/t CO2-eq. (€2016) are calculated considering the central values reported by van Essen et al. [9] and are dependent on the referring period according to the following:

- Short and medium run (up to 2030): 100 €/t;
- Long run (from 2030 to 2050): 269 €/t.

These avoidance costs were also calculated for the 2020 values, considering the annual inflation rate of EU-27 (Eurostat[218]).

In this study, the **environmental impacts** are calculated considering the benefits coming from the savings of the non-CO_2 GHG $CO_{2\text{-eq.}}$ elements, i.e. CH_4 and N_2O, as well as of the savings of the fuel consumption when evaporative emissions are concerned.The other pollutants also have sme minor environmental impacts but these are only a fraction of the climate impacts of CH_4 and N_2O so neglecting them does not change the results of our analysis to any degree. For example, environmental impacts for PM are of the order of € 0.21 / kg compared to € 30 / kg N_2O. Taking into account the much higher emission factors of N2O compared to PM, taking these other pollutants into account would only increase the uncertainty of the estimate but not the actual result.

The **health impacts** are calculated from the benefits of the pollutants considered in this study, i.e. of NO_x, NMVOC, $PM_{2.5}$ and NH_3, which involve damage costs. Again, methane and N2O are only moderately reactive in causing air pollution and this is why we split VOC and NMVOC in current regulations. Although there is currently a discussion to include methane as an air pollution relevant agent, there is still not a unanimous agreement on its reactivity compared to othe VOCs. Moreover, N2O has lately been recognised to have negative impacts on startospheric ozone which, by turn, may lead to health effects. However, there are not yet robust data on the exact contribution of methane and N_2O to air pollution and stratospheric ozone depletion, let alone a quantification of their external costs. Hence, we have adopted a conservative approach to only include the environmental impacts of these species in our cost-benefit analysis.

9.4.6. Calculation of monetised benefits

The calculation of the monetised benefits take into account the weighted averages of the activity shares of the different vehicle categories, weighted over the activity (in km/year) of the different categories and taking into account fleet composition data, in order to split the emissions based on the vehicle activity in urban/rural/motorway traffic conditions, as included in COPERT. The monetised benefits for each pollutant are calculated with the following:

[217] Eurostat, 2020. “Greenhouse gas emission statistics - air emissions accounts. Statistics Explained”.

IPCC, 2005. " AR4 Climate Change 2007: The Physical Science Basis", Chapter 2 “Changes in Atmospheric Constituents and in Radiative Forcing”.

[218] Eurostat, 2020. Data extracted on 28/01/2021.

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

$$NH_3[€] = NH_3[t] * NH_{3,\ all\,areas}[€/t]$$

$$NMVOC[€] = NMVOC[t] * \left(share_{urban}[\%] * \left(NMVOC_{metropolitan}[€/t] * Population_{metropolitan}[\%] + NMVOC_{city}[€/t] * \left(1 - Population_{metropolitan}[\%]\right)\right) + NMVOC_{rural}[€/t] * \left(share_{rural}[\%] + share_{highway}[\%]\right)\right)$$

$$PM_{2.5,\ exh}[€] = PM_{2.5-exh}[t] * \left(share_{urban}[\%] * \left(PM_{metropolitan}[€/t] * Population_{metropolitan}[\%] + PM_{city}[€/t] * \left(1 - Population_{metropolitan}[\%]\right)\right) + PM_{rural}[€/t] * \left(share_{rural}[\%] + share_{highway}[\%]\right)\right)$$

$$PM_{2.5,\ non-exh}[€] = PM_{2.5-non-exh}[t] * \left(share_{urban}[\%] * \left(PM_{metropolitan}[€/t] * Population_{metropolitan}[\%] + PM_{city}[€/t] * \left(1 - Population_{metropolitan}[\%]\right)\right) + PM_{rural}[€/t] * \left(share_{rural}[\%] + share_{highway}[\%]\right)\right)$$

$$PM_{2.5}[€] = PM_{2.5,\ exh}[€] + PM_{2.5,\ non-exh}[€]$$

$$CO_{2-eq.}[€] = CO_{2-eq.}[t] * CO_{2,-eq.\ \ all\,areas}[€/t]\ \text{(differentiated for before and after 2030)}$$

Where

- Pollutant values expressed in [€] indicate the resulting monetised benefits;

- Pollutant values expressed in [t] indicate the emission savings, calculated from COPERT;
- Pollutant values expressed in $[€/t]$ indicate the damage/avoidance costs, presented in Table 9-42, obtained from the "Handbook on the external costs of transport"[219];
- The $share_{urban/rural/highway}$ expressed in [%] indicate the respective vehicle activity, obtained from the COPERT;
- The $Population_{metropolitan}$ expressed in [%] indicates the share of metropolitan areas in EU with agglomeration > 0.5 million inhabitants among the cities/towns in EU with agglomeration > 54 thousand inhabitants. This share is found to be 66%, using data from around 3,500 cities/towns in EU-28 (Eurostat[220]);
- $Population_{cities}\ [\%] = 1 - Population_{metropolitan}\ [\%] = 34\%$;
- We assume that $PM_{10,\,exh} = PM_{2.5,\,exh}$ because the coarse fraction ($PM_{2.5\text{-}10}$) is negligible in vehicle exhausts;
- The $CO_{2,-eq.\ all\,areas}$ expressed in $[€/t]$ indicates the avoidance costs, which are different when referring to years up to 2030 from the period after 2030 as discussed above.

The total monetised benefit is calculated as the sum of the above pollutant-specific monetised benefits.

The evaporative fuel savings are monetised by multiplying the savings with the cost of petrol. In September 2018, the weighted average share of taxes and duties on fuel prices in the EU-15 was 60% for unleaded petrol and 54 % for diesel[221]. The average price of petrol is 1.465 Euro/lt, hence the real cost would be:

$$(1 - 0.6) * 1.465 = 0.586\ Euro/lt$$

9.5. Cost modelling

In this annex we provide a detailed description of the information used to make predictions for the regulatory costs of different scenarios for Euro 7. More specifically we present:

- The type of costs taken into consideration
- The information/data sources used to develop cost estimates
- The approach and assumptions made as part of the calculations
- The cost calculations

[219] Handbook on the external costs of transport, Version 2019 – 1.1

[220] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=urb_cpop1&lang=en

[221] https://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes/assessment-4

9.5.1. Overall method implemented

Estimating the costs (positive/negative) incurring by the introduction of a new regulatory package is a tedious procedure. This is because one will have to assess and justify the implications that the new piece of regulation will bring to a number of cost elements, including technology costs, enforcement costs, R&D, etc.

In such a procedure, one basically has to base oneself on relevant changes incurred by the introduction of past emission standards and make necessary adjustments. The evaluation study for the introduction of Euro 6/VI provided a solid basis on which to base assumptions about the future and was always the starting point of our cost estimate approach. Figure 9-18 provides an outline of the procedure followed. Once a policy option was defined, we made assumptions on the incremental R&D, hardware, enforcement and administrative costs that the new policy option would entail. We made an initial estimate of the incremental cost different (positive/negative) based on the prior assessment of Euro 6/VI for the equivalent technology. This was discussed within the CLOVE consortium, and additional data was brought in by revisiting original literature sources and introducing the (limited) information provided through the second stakeholder consultation procedure.

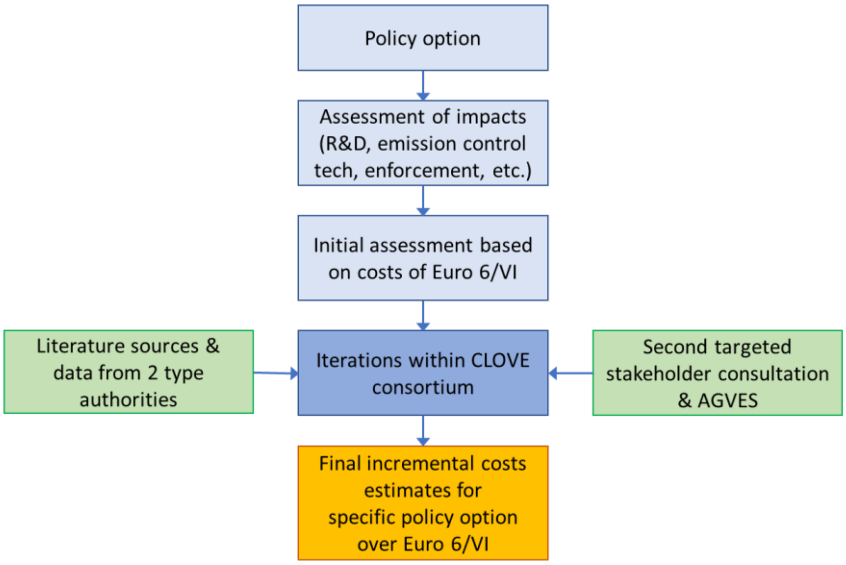


Figure 9-18: Schematic outline of procedure to assess costs for different Euro 7 policy options.

Evidently, all gathered information was discussed and reviewed with all relevant members of the CLOVE consortium. The CLOVE consortium comprises experts with experience in different aspects of the automotive R&D supply chain (academia, R&D providers, etc.) so first-hand information was available. Moreover, the consortium has an extensive network with all major suppliers of emission control technology.

Including responses from the second stakeholder consultation round and follow up exchanges, the total number of OEMs, and associations that provided cost estimates for Euro 7 level technologies and/or R&D costs are shown in the following list:

- Exhaust emissions: 5
- Non-exhaust (evaporation and brake-wear): 10

A significant cost benefit for Euro 7 is materialised through simplification of the complete type-approval procedure, streamlining regulations between cars/vans and lorries/buses and avoiding grey areas that create confusion and induce higher costs. Estimates on cost reductions were sought and collected from a type approval authority (RDW) and a technical service (UTAC) that were further refined and assessed within the CLOVE consortium.

Overall, the CLOVE consortium comprises several partners that closely but independently work with OEMs in introducing, assessing and calibrating new emission control technologies for introduction in new vehicle models. So, these partners possess first-hand experience on both R&D cost estimates as well as the quantity and type of tests required to introduce a new emission control technology. This is a primary source of reliable information that cannot be publicly made available as it comprises an element of commercial confidentiality. However, this has been made available to the CLOVE team collecting and synthesizing the information for Euro 7 and has been used in our estimates of Euro 7 incremental costs.

The cost model involves the total societal cost as incremental costs incurred for the implementation of each new regulatory component. This cost is defined without considering taxes and profit margins:

$$\text{Incremental Cost} = \Delta(\text{Final Price} - \text{Taxes} - \text{Markup})$$

The total costs of implementation of a new policy direction are calculated as the sum of multiple cost categories. All cost items are expressed as incremental cost differences over the baseline. A number of cost categories are considered in the cost analysis, in an effort to make an as accurate estimate as possible of the total cost and to minimise uncertainty. The cost categories that are considered in the cost analysis are presented in Table 9-43.

Table 9-43: Cost categories for emission standard implementation.

Cost category	Description
Substantive compliance costs	
Hardware costs	These are the costs arising from the need to fit engine and emission control and monitoring technologies on the vehicles to meet the tailpipe, the evaporative and the brake emission limits introduced by the various policy options.
R&D, engineering and calibration costs	These include one-off costs associated with the introduction of new systems (engines and emission control systems) or the upgrade of existing ones and other systems (e.g. software) intended to ensure compliance with the new requirements. This takes into account additional man-effort, computer simulation, prototyping and experimental testing work associated with such work. It may also include R&D work conducted in coordination with suppliers of specific equipment or with the support of technical services. These costs are highest when Euro 7 is first time introduced and subsequently decrease to practically in time as OEM and suppliers become acquainted with the new technology. This category also includes calibration costs and related testing for each new model presented and model variant either as a vehicle (cars and vans) or engine (trucks and buses) to ensure that it meets the new requirements. Calibrations cover a lead variant as well as derivative models that typically require less testing. In contrast to R&D, calibration costs are ongoing costs that take place for each new model and do not zero out with time. They should be expected to continue in the future as manufacturers bring new models to the market and will need to ensure that they meet the requirements.
Initial investment in facilities/equipment	Any one-off costs for new facilities, equipment, tools and logistics investments required to support R&D and calibration that can be directly linked to the adoption of a policy option (i.e. as a result of new tests introduced or increased demand for testing).
Costs associated with the implementation activities	
Testing/witnessing costs	Costs for the Type approval, ISC and Conformity of Production (CoP) tests performed either by Type Approval authorities (TAAs) or witnessed in the facilities of OEMs by technical services. These are ongoing costs that are incurred as new models need to be certified according to the new standards before entering the market and scale with the number of models being presented to the market
Fees	
Fees to TAAs	Include the certification fees paid to type approval authorities, excluding the costs of the witnessing mentioned earlier (ongoing costs).
Administrative costs	
Costs associated with reporting and other information obligations	Include costs for reporting and to fulfil other information provision obligations as part of the certification process (ongoing costs)

Table 9-44 summarises the sources used for the various cost variables together with comments on the possible limitations and the level of confidence to the estimates.

Table 9-44: Sources and assumptions made per cost category.

Cost category	Sources used	Observations	Level of confidence
Hardware costs	Input from 15 industrial stakeholders following the stakeholder consultation Estimates from the CLOVE consortium experts on the basis of own experience and available data. Studies: Euro 6/VI evaluation study and references provided therein	Costs were given for specific technologies, components and sensors estimated to be used at Euro 7 but not linked to specific policy option. CLOVE built technology packages per policy option and proposed limits according to these technology packages. Hence, uncertainty of H/W costs is zero by definition.	High
Research and development and calibration (R&D) costs	Studies: Euro 6/VI evaluation study Input from CLOVE partners providing R&D services to OEMs for introduction of new vehicle models Input from ACEA on rather general terms (estimated per new vehicle).	This was in principle estimated by starting from current Euro 6/VI R&D costs and scaling upwards/downwards considering the new technology required to meet Euro 7.	Medium
Testing/Witnessing costs	Complete analysis included in the simplification report, based on proposed changes per policy option Input on testing costs provided by one type approval authority and one technical service centre.	Estimates on incremental cost differences directly based on policy option targets, expected market trends and current (known) costs for testing at Euro 6/VI.	High
Type approval fees	Input from 6 TAAs on fees charged for TA in Euro 6/VI evaluation study	Same values also used at Euro 7.	High
Administrative costs associated with reporting and other information obligations	Comparison to Euro 6/VI study: Input from OEMs (1 for Euro 6 and 2 for Euro VI)., cross-checked with type approval authorities (RDW, UTAC)	Estimates on incremental cost differences directly based on policy option targets to decrease burden to administration (foxed introductory dates, clearer distinction of vehicle categories, etc.).	Medium

9.5.2. Approach to scale up the costs to fleet level

Variables

Table 9-45: Variables used to support the cost estimates, starting from the assumptions of Euro 6/VI and variations introduced for Euro 7.

Variable	Status-quo at Euro 6/VI	Assumptions for Euro 7
Number of OEMs affected	Number of OEMs affected was based on data on vehicle registrations per manufacturer provided by ACEA Total LDV manufacturers: 14 main groups: 9 European groups and 5 other non-EU manufacturers Total HDV manufacturers: 7 major HDV manufacturers (represent more than 90% of EU HDV sales) plus around 10 smaller OEMs	We estimated that the same number of cars/vans and lorries/buses manufacturers will remain in the future. One may consider that the new CO2 targets may introduce new players in the market and perhaps confine the market share of some of the traditional entities. However, this is neither possible to predict with certainty, nether too relevant in our analysis as long as the number of major manufacturers remains roughly the same. Moreover, it may happen that some manufacturers decide to shift their entire production away from ICEs in the future thus significantly reducing overall automotive R&D costs. However, the number of OEMs considered is most relevant to assess immediate investment costs to introduce Euro 7 in the short run and we consider that all current manufacturers will remain active on ICEs in the short-to-medium term (i.e. next 5-7 years).
Number of engine/model families	We have analysed available data from IHS Markit database on number of engine families introduced/modified by OEMs with EU sales for both LDVs and HDVs since 2012 and up to 2020. This has allowed to identify new engines introduced as well as variants (derivatives) that we expected to belong to the same family.	Our analysis covers the costs for introducing Euro 7 for vehicles equipped with an internal combustion engine, that produce exhaust emission. Vehicles with neat electrified powertrains (battery or fuel cell electric vehicles) are not considered exhaust-emission relevant so the exact model families do not need to be considered in that case. We have therefore assumed that the number of engine/model families in the future scale with the number of new registrations of vehicles with ICEs (conventional, hybrid, plug-in hybrid) per year.
Number of calibrations	We have used the data from IHS Markit database on number of engine families to develop an estimate of the number of calibrations taking place per manufacturer and per year	Similar to the justification to scale the number of new engine/model families in time, also the number of calibrations scale with the number of new registrations of vehicles with ICEs every year.
Number of type approvals	Data on number of TAs for cars/vans and lorries/buses were provided by 9 TAAs (FR, BE, IE, DE, LU, CZ, SE, RO, ES) for the period 2012-2020. These 9 TAAs represent around 67% of total WVTAs according to available data. Total number of TAA per year extrapolated on the basis of the data provided.	The number of type approvals of ICE-relevant technologies scale proportionally to the number of new registrations of related technologies. The expected number of relevant type-approvals (for conventional ICE, hybrids and PHEVs) is therefore considered to drop in time
Number of vehicles	SYBIL model data/projections covering period up to 2050 Data by vehicle type (cars, vans, buses, lorries), technology (CI, PI, Alternative engines) and by Euro standard.	Further update of new registrations up to 2050 based on - latest market data for 2020 that became available in the beginning of February 2021 by ACEA - IHS Markit data on new registrations per Euro standard per EU member state that only became available to the study team executing the projections under a confidentiality agreement - Updated projections from DG Clima on road transport activity and fleet mix evolution

Main assumptions for the calculations

Table 9-46: Considerations for cost categories introduced at Euro 7.

Topic	Assumption/Approach
Period covered	The first year of calculations is 2020 with a parametric introduction of the Euro 7 emission step in the scenarios in the period 2025-2027. A 2050 horizon has been used to provide a relatively long horizon for letting the impacts of Euro 7 introduction to mature. In this period, a significant shift from conventional ICEs to electrified and fully-electric vehicles is considered to take place and the majority of vehicles by 2050 are considered to be of zero exhaust emissions technology. For those vehicles that ICEs will remain as part of the powertrain, benefit of Euro 7 will continue to materialise beyond the 2050 horizon. However, as there is significant uncertainty in EU policies beyond the 2050 target and as depreciation significantly weakens the net present value of any benefits to be ripen after 20+ years from introducing the standard, we consider the impact of this residual benefit (and any additional costs) to not change the conclusions of our calculations.
Discount rate	4%
Learning/cost reduction for new hardware	New hardware (catalysts, sensors, electronics, etc.) is associated with relatively high cost estimates upon introduction as suppliers try to compensate for their investment costs to develop and produce the new component. Excluding precious metals going into catalysts, the rest of materials that go into emission control technology are regular commodities and are not associated with significant costs per se. Most of the cost of emission control components come from development, manufacturing, and assembly costs. With time, development costs become zero and manufacturing and assembly costs drop as the production lines are becoming optimised and methods improve (learning curve effect). Moreover, OEMs learn to use the same components in more than one model families, further supressing costs. Therefore, it is normal to consider that hardware costs (except catalysts) drop with time. Our assumption is that new technology incremental costs drop to 50% within a six years time-frame after their first introduction. This is a conservative assumption considered for a rather mature technology like exhaust emissions control. For advanced components, such as batteries, learning rates are in the order of 19% that with the rate of current BEV penetration (at least doubling per year) leads to much higher cost reductions[222]. Some discussion is required regarding the implication of increasing precious metals contained in catalytic converters on total emission control costs. In the past, the increase in the use of PGM in catalysts was correctly seen to be a major cost implication. However, current market reports show that deficits in Platinum Group Metals (PGM) that sky-rocketed prices in the past seem to level out in 2020 because of lower vehicles sales due to COVID-18. Therefore, the expected decrease in the number of ICE-equipped vehicles in the future is expected to level out the cost of precious metals. It is extremely difficult to make an exact projection. However, the expectation would be that the price of PGM would continue to increase in the short-run immediately after the COVID-19 period and then it will deflate due to drop in demand. Therefore, it would be normal to consider that the per-unit of mass value of PGM in catalysts (Three-Way Catalyst – TWC, Diesel Oxidation Catalyst – DOC, Ammonia Slip Catalyst – ASC, etc.) will remain at today's levels. By extension, we also make the same assumption for LNT and SCR, despite these are not based on PGM, assuming the same trends for other catalytic materials these contain (V, Cu, etc.).
Period considered for R&D costs amortization	R&D costs are by definition one-off incremental costs whenever a new technology is introduced. The main R&D investment is practically materialised before the emission standard becomes available and is then amortized over a certain period that is assumed to be between 5-10 years[223]. In our approach we have assumed that R&D costs are linked to the first model families appearing at the year of introducing the new emission standard and are amortized over the lifetime of this first model, which is of the order of 8 years in the EU. Calibration costs appear for all models regardless of when they have appeared in relation to the introduction of the standard. One will only have to consider incremental costs over the previous standard. Moreover, any additional calibration effort is consider to drop to 50% of the initial additional effort as the OEM becomes more experienced with calibrating the new technology. This 50% drop is consider to already come with the second model series after introduction of the new standard.
Testing/witnessing costs	Testing and witnessing costs are considered to not change with model and time since introduction of the emission standard as this refers to a procedure demanded by the regulation and no cost compression is seem possible.
Type approval reporting/administrative costs	This includes incremental costs for the certification of vehicles, as well as incremental administrative costs over Euro 6/VI.

[222] Tsiropoulos et al., 2018. Li-Ion batteries for mobility and stationary storage applications.

[223] Rogozhin et al. 2010. Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry.

Data on the number of emission type approvals

The number of annual type approvals is significant in estimating type approval and administrative costs. Moreover, the number of type approvals can be used to cross-check primary and derivative vehicle models.

The Euro 6/VI evaluation study made an extensive effort to estimate the number of type approvals granted in the EU every year, collecting official data from nine type approval authorities. A summary of the findings is given in Table 9-47. The increased number of type approvals at Euro 6 was associated with the increased number of requirements introduced with Euro 6 both in terms of exhaust and non-exhaust emissions. The same study already recognised that the number of type approvals would decrease to the pre-RDE levels in time as Euro 6 regulations stabilised.

Table 9-47: Evolution of emission type approvals for passenger cars and vans up to the Euro 6/VI standard.

	2012	2013	2014	2015	2016	2017	2018	2019	2020*
	Euro 5		Euro 6 pre-RDE				Euro 6 RDE		
Estimated EU total	3061	3164	2442	3069	1988	2175	4609	6910	6554
Average for the relevant period	3,113		2,419				6,024		

Source: Data provided to the EC by TAAs;
* Expected total for the whole year

In our study, the relevant number of type approvals is considered to decrease with time in the baseline. That is, already by 2023, it is considered that the type approvals would reach the same value as in the pre-RDE stage and would then scale with new registrations of ICE relative to the registrations in 2023. This makes the implicit assumption that the size of a family series will not change with time. Indeed, there is no indication that comes in contrast to this.

Table 9-48: Evolution of emission type approvals for ICE-equipped passenger cars and vans considered in the analysis.

	2015	2020	2025	2030	2035	2040	2045	2050
	Euro 5 & 6		Euro 7					
Estimated EU total	2493	3650	2159	1405	0	0	0	0

In terms of certification in the heavy duty sector, Table 9-49 shows the number of type approvals estimates by the Euro 6/VI evaluation study. The number of type approvals increases with time in Euro VI mostly due to CO2 related requirements and not really due to air pollutant requirements. In contrast to cars/vans, the increased number of TAs is considered to remain also in the post Euro VI period during the baseline scenario. However, for the same reason as with cars and vans, the type approvals relevant for Euro 7 emissions are considered to scale with new registrations of ICE-equipped vehicles (Table 9-49).

Table 9-49: Evolution of emission type approvals for lorries & buses considered in the analysis.

	2015	2020	2025	2030	2035	2040	2045	2050
	Euro VI		Euro 7					
Estimated EU total	187	348	185	190	164	121	90	91

9.5.3. Hardware costs

Exhaust emission control hardware costs

The Euro 6/VI evaluation study provided a detailed assessment of the costs of individual emission control related components. The same unit costs are also assumed in case of Euro 7, but if more and/or larger components are required, the incremental change for this cost needs to be taken into account. Compared to Euro 6/VI, some additional components will be required at Euro 7 level, depending on the policy option considered. These may range from electrically heated catalysts, to second urea injectors and larger SCR systems.

The hardware cost that is associated with the Euro 7 technology packages is calculated as incremental cost to the latest Euro 6d/VI technologies. This cost originates either in the adaptation/optimization of existing technologies (e.g. increased volume of catalysts) or in the introduction of additional emission control technologies (e.g. NH_3 clean up catalyst in gasoline vehicles).

It is reminded that the Euro 6d/VI emissions control technology baseline is as follows:

- Cars/vans
  - Gasoline: TWC + GPF
  - Diesel: DOC + SCRF + SCR + ASC + twin urea dosing
  - CNG: TWC
- Lorries/buses
  - Diesel: DOC + DPF + SCR/ASC
  - Natural gas (CNG): TWC

The calculations are structured in the following steps:

1. Presentation of technology packages (Table 9-50 and Table 9-51)
2. Estimation of individual components/technologies cost (Table 9-52 and Table 9-53)
3. Determination of technology package cost (Table 9-54 and Table 9-55)
4. Shares of technology packages in each policy option/scenarios (Table 9-56 and Table 9-57)
5. Hardware costs for evaporative emission control (Table 9-58 and Table 9-59)
6. Determination of the cost for each policy option/scenario (Table 9-60 and Table 9-61)

At the first step, Table 9-50 and Table 9-51 present the technology packages that are analysed in terms of emissions performance for cars/vans and lorries/buses, respectively. A ‘short name’ is used for each technology package and a brief description of the individual components/technologies integrated is given. The exact description and technical details of each technology package is given in the *Combined report*.

Table 9-50: Technology packages considered for cars/vans (light-duty vehicles).

Short name	Technologies/components integrated
Gasoline	
G1 – Base 2020	Base TWC, base GPF
G2 – Base 2025 opt	Advanced calibration, larger TWC, improved GPF
G3 – MHEV Base 2020	Mild hybrid, base TWC, base GPF
G4 – MHEV 2025 opt	Mild hybrid, advanced calibration, larger TWC, improved GPF
G5 – MHEV 2025 opt e-cat	Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC
G6 – MHEV 2025 opt e-cat 10s	Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 10s preheating, secondary air injection, Clean-Up Catalyst – CUC (NH_3 catalyst)
G7 – MHEV 2025 opt burner 10s	Mild hybrid, advanced calibration, larger TWC, improved GPF, 15kW fuel burner, 10s preheating, secondary air injection, CUC (NH_3 catalyst)
G8 – PHEV Base 2020	Plugin hybrid, base TWC, base GPF
G9 – PHEV 2025 opt	Plugin hybrid, advanced calibration, larger TWC, improved GPF
G10 – PHEV 2025 opt e-cat	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC
G11 – PHEV 2025 opt e-cat 60s	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 60s preheating, secondary air injection, CUC (NH_3 catalyst)
G12 – PHEV 2025 opt burner 30s	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 15kW fuel burner, 30s preheating, secondary air injection, CUC (NH_3 catalyst)
G13 – PHEV 2025 opt e-cat 60s 8kW	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 8kW EHC, 60s preheating, secondary air injection, CUC (NH_3 catalyst), passive SCR, LNT
CNG	
C1 – MHEV 2025 opt	Mild hybrid, advanced calibration, larger TWC
C2 – MHEV 2025 opt GPF	Mild hybrid, advanced calibration, larger TWC, improved GPF
C3 – MHEV 2025 opt e-cat	Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC
C4 – MHEV 2025 opt e-cat 10s	Mild hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 10s preheating, secondary air injection, CUC (NH_3 catalyst)
C5 – PHEV 2025 opt	Plugin hybrid, advanced calibration, larger TWC
C6 – PHEV 2025 opt GPF	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC
C7 – PHEV 2025 opt e-cat	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC
C8 – PHEV 2025 opt e-cat 60s	Plugin hybrid, advanced calibration, larger TWC, improved GPF, 4kW EHC, 60s preheating, secondary air injection, CUC (NH_3 catalyst)
Diesel	
D1 – MHEV P0 2025 opt	Mild hybrid, advanced heating calibration, larger EATS
D2 – MHEV P0 2025 opt e-cat	Mild hybrid, advanced heating calibration, larger EATS, EHC
D3 – MHEV P0 2025 opt e-cat preheating	Mild hybrid, advanced heating calibration, larger EATS, EHC, preheating, secondary air injection
D4 – PHEV P2 2025 opt	Plugin hybrid, advanced heating calibration, larger EATS
D5 – PHEV P2 2025 opt e-cat	Plugin hybrid, advanced heating calibration, larger EATS, EHC, turbine bypass

Table 9-51: Technology packages considered for lorries/buses (heavy-duty vehicles).

Short name	Technologies integrated
Diesel	
HD0 – Average 2020	Average Euro VI D
HD1 – Best 2020	Best Euro VI D, advanced heating calibration
HD2 – ccEATS opt	Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR)
HD2 – ccEATS opt e-cat	Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), EHC
HD3 – ccEATS opt burner preheating	Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), burner, preheating
HD3 – ccEATS opt e-cat preheating	Advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), EHC, preheating
HD4 – HEV ccEATS opt burner preheating	Hybrid, advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), burner, preheating
HD4 – HEV ccEATS opt e-cat preheating	Hybrid, advanced heating calibration, close-coupled EATS, twin urea dosing, optimised DPF, EGR (w/ cold SCR), EHC, preheating
Natural Gas	
HL2 – LNG HPDI	Advanced heating calibration, close-coupled EATS, optimised particulate filter, EGR (w/ cold SCR)
HL2 – LNG HPDI e-cat	Advanced heating calibration, close-coupled EATS, optimised particulate filter, EGR (w/ cold SCR), EHC
HC2 – CNG	λ=1, advanced heating calibration, close-coupled EATS, optimised particulate filter
HC2 – CNG e-cat	λ=1, advanced heating calibration, close-coupled EATS, optimised particulate filter, EHC

The second step of the procedure is the estimation of the individual component/technologies cost. The selection of the exact components and their adaptation for each technology package and the relevant justification is analysed in the *Combined report*. Table 9-52 presents the incremental cost of individual technologies and components foreseen in Euro 7 cars/vans. With reference to particular technologies, the following are clarified:

- Hybridization/electrification is enforced by the CO_2 policy. Here the additional cost considered is the one that is related to the necessary power electronics and the controller of the EHC.
- A particle filter is introduced in CNG vehicles.
- The secondary air system is applied in the cases of preheating (either with an EHC or a burner) and when a NH_3 CUC is used.
- Calibration cost is considered separately.

- The improved durability in the cases of TWC, CUC for NH_3, passive SCR and LNT is examined in two different scenarios: at 200,000 km and at 240,000km, where +5% and +10% of the total component cost is considered, respectively.
- The GPF optimisation is examined in two different cases for more and less demanding definition of normal driving conditions:
    - The main impact on GPF costs comes from the combination of the emission limit with the minimum mileage during testing (the latter affecting the formation of ash layer that improves filtration efficiency). This combination is as follows (limit referring to PN10):
        - Less demanding boundary conditions: 6×10^{11} at 10,000km
        - Moderate (medium) stringency: 1×10^{11} at 10,000km (3×10^{11} from 3,000km to 10,000km)
        - High stringency: 1×10^{11} at 3,000km (3×10^{11} from 300km to 3,000km)
    - The durability mileage plays a secondary role, since mileage accumulation improves filtration efficiency (provided that the filter does not break):
        - Less demanding boundary conditions: 160,000 km
        - Moderate (medium) stringency: 200,000 km
        - High stringency: 240,000 km
    - The GPF cost for the moderate stringency is estimated at 1/3 of the cost for the high stringency.

Table 9-52: Incremental cost of individual technologies/components for Euro 7 cars/vans.

The column 'Unit cost' indicate the cost per liter or the cost per unit for volume increase or for item unit increase, respectively, where applicable. The column 'Total cost' presents the total incremental cost for each technology/component.

Gasoline / CNG					
Technology/ Component	**Variation**	**Vehicle segment**	**Change EU6d → EU7**	**Unit cost [€ or €/l]**	**Total cost [€]**
Hybrid system	MHEV	All	—	40	40
	PHEV	All	—	40	40
TWC	+50% volume	Small	1.4l → 2.1l	80	56
		Medium	1.8l → 2.7l	80	72
		Large	2.2l → 3.3l	80	88
	Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	1.4l → 2.1l	80	8.4 / 16.8
		Medium	1.8l → 2.7l	80	10.8 / 21.6
		Large	2.2l → 3.3l	80	13.2 / 26.4
GPF optimization	Bare optimized: Moderate / high stringency of boundaries	All	0 → 1	3.3 / 10	3.3 / 10
	Coated optimized: Moderate / high stringency of boundaries	All	0 → 1	5 / 15	5 / 15

GPF (introduction for CNG)	For CNG vehicles not already equipped with GPF	Small	0 → 1.4l	57	79.8
		Medium	0 → 1.8l	57	102.6
		Large	0 → 2.2l	57	125.4
e-cat 4kW (EHC)	without preheating	All	0 → 1	85	85
	with preheating	All	0 → 1	85	85
Fuel burner 15kW	without preheating	All	0 → 1	150	800
	with preheating	All	0 → 1	150	800
Secondary air injection	For cases with preheating	All	0 → 1	78	78
CUC for NH_3	Introduction in Euro 7	Small	0 → 0.7l	23	16.1
		Medium	0 → 0.9l	23	20.7
		Large	0 → 1.1l	23	25.3
	Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	0 → 0.7l	23	0.8 /1.6
		Medium	0 → 0.9l	23	1.0 / 2.1
		Large	0 → 1.1l	23	1.3 / 2.5
SCR (passive)	Introduction in Euro 7 Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	0 → 3.6l	30	42 / 84
		Medium	0 → 4.4l	30	54 / 108
		Large	0 → 2.2l	30	66 / 132
LNT	Introduction in Euro 7 Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	0 → 1.4l	42	29.4 / 58.8
		Medium	0 → 1.8l	42	37.8 / 75.6
		Large	0 → 2.2l	42	46.2 / 92.4
Multi-gas sensor	Introduction in Euro 7	All	0 → 1	200	200
OTA data transmission	Introduction in Euro 7	All	0 → 1	40	40
Diesel					
Technology/ Component	**Variation**	**Vehicle segment**	**Change EU6d → EU7**	**Unit cost [€ or €/l]**	**Total cost [€]**
Hybrid system	MHEV	All	—	40	40
	PHEV	All	—	40	40
e-cat 4kW (EHC)	without preheating	All	0 → 1	85	85
	with preheating	All	0 → 1	85	85
Fuel burner 15kW	without preheating	All	0 → 1	150	800
	with preheating	All	0 → 1	150	800
Secondary air injection	For cases with preheating	All	0 → 1	78	78
DOC	+50% volume	Small	1.2l → 1.8l	42	25.2
		Medium	1.4l → 2.1l	42	30.2
		Large	1.8l → 2.7l	42	37.0

	Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	1.2l → 1.8l	42	3.8 / 7.6
		Medium	1.4l → 2.1l	42	4.5 / 9.1
		Large	1.8l → 2.7l	42	5.5 / 11.1
SCR	+50% volume	Small	3.0l → 4.5l	30	45
		Medium	3.6l → 5.4l	30	54
		Large	4.4l → 6.6l	30	66
	Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	3.0l → 4.5l	30	6.8 / 13.5
		Medium	3.6l → 5.4l	30	8.1 / 16.2
		Large	4.4l → 6.6l	30	9.9 / 19.8
SCRF	+50% volume	Small	2.3l → 3.4l	55	61.9
		Medium	2.7l → 4.1l	55	74.3
		Large	3.3l → 5.0l	55	90.8
ASC	+50% volume	Small	0.8l → 1.2l	23	8.6
		Medium	0.9l → 1.4l	23	10.4
		Large	1.1l → 1.7l	23	12.7
	Improved durability: @200,000/240,000km +5% / +10% of total component cost	Small	0.8l → 1.2l	23	1.3 / 2.6
		Medium	0.9l → 1.4l	23	1.6 / 3.1
		Large	1.1l → 1.7l	23	1.9 / 3.8
Turbine bypass	Introduction in Euro 7	All	0 → 1	15	15
Multi-gas sensor	Introduction in Euro 7	All	0 → 1	200	200
OTA data transmission	Introduction in Euro 7	All	0 → 1	40	40

Similarly, Table 9-53 presents the incremental cost of individual technologies and components foreseen in Euro 7 lorries/buses. With reference to particular technologies, the following are clarified:

- Where needed, a typical engine capacity of heavy lorries/buses is used.
- In the case of mild hybridization/electrification with a 48V system, this is integrated in order to support the pre-heating functionality of the EHC. The complete cost of the system is considered here, since it is not enforced by the CO_2 policy, but it is used for pollutant emission control. In the case of full hybridization (HEV), an additional optimisation cost is considered (that is related to the necessary power electronics and the controller of the EHC), assuming that the base cost has been already encountered by the CO_2 emissions reduction technologies integrated on the vehicle.
- Some additional components (such as by-pass valves, HP EGR circuit etc.) are considered for thermal management through EGR when the SCR is still cold.
- A particle filter is introduced for CNG vehicles.
- The secondary air system is applied in the cases of preheating (either with an EHC or a burner) and when a NH_3 CUC is used.
- Calibration cost is considered separately.

- The improved durability is examined in two different scenarios: at durability mileage of 375,000km and at 450,000km for N2, N3<16t, M3<7.5t, where +5% and +10% of the total component cost is considered, respectively, and at 875,000 km and 1,050,000 km for N3>16t, M3>7.5t, where +5% and +10% of the total component cost is considered, respectively.

Table 9-53: Incremental cost of individual technologies/components for Euro 7 lorries/buses.

The column 'Unit cost' indicate the cost per liter or the cost per unit for volume increase or for item unit increase, respectively, where applicable. The column 'Total cost' presents the total incremental cost for each technology/component.

Diesel					
Technology/ Component	**Variation**	**Engine capacity [l]**	**Change EUVI → EU7**	**Unit cost [€ or €/l]**	**Total cost [€]**
Hybrid system	Support of e-cat (wiring, power electronics, controllers)	All	—	800	800
	48 battery (~5-7kWh) for preheating functionality of e-cat	All	0 → 1	1500	1500
	HEV	All	—	500	500
EGR when SCR is cold (thermal management)	Further improvement	All	0 → 1	100	100
DOC	Increased volume	12.8	11.4l → 14.0l	43.9	114.2
	Improved durability: Moderate / high increase	12.8	11.4l → 14.0l	43.9	30.7 / 61.5
	Replacement (in 30% of the fleet) Moderate / high increase	12.8	0 → 14.0l	43.9	92.2 / 184.5
SCR	Increased volume	12.8	21.3l → 37.5l	20.4	330.5
	Improved durability Moderate / high increase	12.8	21.3l → 37.5l	20.4	38.3 / 76.5
	Replacement (in 30% of the fleet) Moderate / high increase	12.8	0 → 37.5l	20.4	114.8 / 229.5
ASC	Increased volume	12.8	7.1l → 12.5l	16.0	86.4
	Improved durability Moderate / high increase	12.8	7.1l → 12.5l	16.0	10.0 / 20.0
Optimized DPF	Coated filter	12.8	—	60	60
Close-coupled components packaging	Introduction in Euro 7	All	0 → 1	500	500
Twin urea dosing	2nd injector	All	1 → 2	100	100

e-cat 15kW (EHC)	without preheating	All	0 → 1	250	250
	with preheating (×4)	All	0 → 4	250	1000
Fuel burner 60kW	without preheating – no new HW (HC doser)	All	0 → 0	1500	0
	with preheating	All	0 → 1	1500	1500
Secondary air injection	For cases with preheating	All	0 → 1	100	100
Natural Gas					
Technology/ Component	**Variation**	**Engine capacity [l]**	**Change EUVI → EU7**	**Unit cost [€ or €/l]**	**Total cost [€]**
Hybrid system	Support of e-cat (wiring, power electronics, controllers)	All	—	800	800
	48 battery (~5-7kWh) for preheating functionality of e-cat	All	0 → 1	1500	1500
	HEV	All	—	500	5000
EGR when SCR is cold (thermal management)	Further improvement	All	0 → 1	100	100
DOC	Increased volume	12.8	11.4l → 14.0l	43.9	114.2
	Improved durability Moderate / high increase	12.8	11.4l → 14.0l	43.9	30.7 / 61.5
	Replacement (in 30% of the fleet) Moderate / high increase	12.8	0 → 14.0l	43.9	92.2 / 184.5
SCR	Increased volume	12.8	21.3l → 37.5l	20.4	330.5
	Improved durability Moderate / high increase	12.8	21.3l → 37.5l	20.4	38.3 / 76.5
	Replacement (in 30% of the fleet) Moderate / high increase	12.8	0 → 37.5l	20.4	114.8 / 229.5
ASC	Increased volume	12.8	7.1l → 12.5l	16.0	86.4
	Improved durability Moderate / high increase	12.8	7.1l → 12.5l	16.0	10.0 / 20.0
Optimized particulate filter	Coated filter	12.8	—	60	60
TWC for CNG λ=1	Increased volume	12.8	10.0l → 15.0l	80	400
	Improved durability Moderate / high increase	12.8	10.0l → 15.0l	80	60 / 120
	Replacement (in 30% of the fleet) Moderate / high increase	12,8	0 → 15.0l	80	180 / 360
GPF	Introduction in Euro 7	All	0l → 12.8l	57.2	732.7
Close-coupled components packaging	Introduction in Euro 7	All	0 → 1	500	500

Twin urea dosing	2nd injector	All	1 → 2	100	100
e-cat 15kW (EHC)	without preheating	All	0 → 1	250	250
	with preheating (×4)	All	0 → 4	250	1000
Fuel burner 60kW	without preheating – no new HW (HC doser)	All	0 → 0	1500	0
	with preheating	All	0 → 1	1500	1500
Secondary air injection	For cases with preheating	All	0 → 1	100	100

In the third step, the total cost of the complete Euro 7 technology packages (Table 9-50 for cars/vans and Table 9-51 for lorries/buses) is calculated, by synthesizing the cost of individual components, as shown in the previous tables. The calculated costs are presented in Table 9-54 for cars/vans and Table 9-55 for lorries/buses.

Table 9-54: Cost of each Euro 7 technology package considered for cars/vans (light-duty vehicles).

Short name	Incremental cost compared to Euro 6d [€] Cars / Vans		
	High ambition of boundaries, durability at 240,000 km	High ambition of boundaries, durability at 200,000 km	Moderate ambition of boundaries, durability at 200,000 km
Gasoline			
G1 – Base 2020	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
G2 – Base 2025 opt	108.8 / 97.8	98.0 / 88.2	88.0 / 78.2
G3 – MHEV Base 2020	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
G4 – MHEV 2025 opt	108.8 / 97.8	98.0 / 88.2	88.0 / 78.2
G5 – MHEV 2025 opt e-cat	233.8 / 222.8	223.0 / 213.2	213.0 / 203.2
G6 – MHEV 2025 opt e-cat 10s	334.6 / 320.9	322.8 / 310.5	312.8 / 300.5
G7 – MHEV 2025 opt burner 10s	1009.6 / 995.9	997.8 / 985.5	987.8 / 975.5
G8 – PHEV Base 2020	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
G9 – PHEV 2025 opt	108.8 / 97.8	98.0 / 88.2	88.0 / 78.2
G10 – PHEV 2025 opt e-cat	233.8 / 222.8	223.0 / 213.2	213.0 / 203.2
G11 – PHEV 2025 opt e-cat 60s	334.6 / 320.9	322.8 / 310.5	312.8 / 300.5
G12 – PHEV 2025 opt burner 30s	1009.6 / 995.9	997.8 / 985.5	987.8 / 975.5
G13 – PHEV 2025 opt e-cat 60s 8kW	827.6 / 770.7	723.8 / 679.0	713.8 / 669.0
CNG			
C1 – MHEV 2025 opt	78.8 / 82.8	69.7 / 73.2	69.7 / 73.2
C2 – MHEV 2025 opt GPF	165.2 / 173.5	156.1 / 164.0	156.1 / 164.0
C3 – MHEV 2025 opt e-cat	290.2 / 298.5	281.1 / 289.0	281.1 /289.0
C4 – MHEV 2025 opt e-cat 10s	386.1 / 394.5	376.1 / 384.0	376.1 / 384.0

C5 – PHEV 2025 opt	78.8 / 82.8	69.7 / 73.2	69.7 / 73.2
C6 – PHEV 2025 opt GPF	165.2 / 173.5	156.1 / 164.0	156.1 / 164.0
C7 – PHEV 2025 opt e-cat	290.2 / 298.5	281.1 / 289.0	281.1 / 289.0
C8 – PHEV 2025 opt e-cat 60s	386.1 / 394.5	376.1 / 384.0	376.1 / 384.0
Diesel			
D1 – MHEV P0 2025 opt	201.7 / 348.5	187.2 / 330.6	187.2 / 330.6
D2 – MHEV P0 2025 opt e-cat	326.7 / 473.5	312.2 / 455.6	312.2 / 455.6
D3 – MHEV P0 2025 opt e-cat preheating	404.7 / 551.5	390.2 / 533.6	390.2 / 533.6
D4 – PHEV P2 2025 opt	201.7 / 348.5	187.2 / 330.6	187.2 / 330.6
D5 – PHEV P2 2025 opt e-cat	501.7 / 648.5	487.2 / 630.6	487.2 / 630.6

Table 9-55: Cost of each Euro 7 technology package considered for lorries/buses (heavy-duty vehicles).

Short name	Incremental cost compared to Euro VI [€]	
	Increased Euro VI durability	Euro 7 durability
Diesel		
HD0 – Average 2020	0.0	0.0
HD1 – Best 2020	0.0	0.0
HD2 – ccEATS opt	1291.1	1863.0
HD2 – ccEATS opt e-cat	2341.1	2913.0
HD3 – ccEATS opt burner preheating	2891.1	3463.0
HD3 – ccEATS opt e-cat preheating	4691.1	5263.0
HD4 – HEV ccEATS opt burner preheating	3391.1	3963.0
HD4 – HEV ccEATS opt e-cat preheating	5191.1	5763.0
Natural Gas		
HL2 – LNG HPDI	1291.1	1863.0
HL2 – LNG HPDI e-cat	2341.1	2913.0
HC2 – CNG	1632.7	2112.7
HC2 – CNG e-cat	2682.7	3162.7

Finally, the share of each technology package for cars/vans in the different policy options (PO) and scenarios (Sc) is presented in Table 9-56. The table is read as follows: in each policy option/scenario, the applicable technology packages for each category are given. For example: in PO2.Sc3, the gasoline MHEVs are by 80% G5 and 20% G6, while the gasoline PHEVs are by 50% G9, 30% G10 and 20% G11. The detailed explanation of the derived shares is provided in the *Combined report*. Similarly, Table 9-57 presents the share of each technology package for lorries/buses in the different policy options (PO) and scenarios (Sc).

Table 9-56: Share of technology packages for cars/vans in the various policy options and scenarios.

Policy Option / Scenario	Category	Gasoline	Diesel	CNG
PO1.Sc1	MHEV	50% G3	50% current technology	100% C1
		50% G4	50% D1	
	PHEV	100% G8	100% D4	100% C5
PO2.Sc1 & PO2.Sc2 & PO3	MHEV	100% G4	100% D2	100% C1
	PHEV	80% G8	100% D5	100% C5
		20% G9		
PO2.Sc3	MHEV	80% G5	20% D2	80% C3
		20% G6	80% D3	20% C4
	PHEV	50% G9	100% D5	50% C6
		30% G10		30% C7
		20% G11		20% C8

Table 9-57: Share of technology packages for lorries/buses in the various policy options and scenarios.

Policy Option / Scenario	Diesel	Natural Gas
PO1.Sc1	Current technology (HD1)	Current technology
PO2.Sc1 & PO2.Sc2 & PO3	50% HD2	50% HL2
	50% HD2 e-cat	50% HC2
PO2.Sc3	50% HD3	50% HL2 e-cat
	50% HD3 e-cat	50% HC2 e-cat

The calculation for the regulatory costs for small/medium/large segment for each vehicle category was performed as follows. We have assumed that the non-hardware cost would be the same in all three segments for each vehicle category. We have considered that the regulatory costs were calculated for the medium segment, while the costs for small and large segments were calculated as a fraction of the cost values of the medium segment vehicles, based on the cost of individual technologies/components of cars presented in **Table 9-52**. The hardware costs were split to the different segments depending on the examined scenario as follows:

- PO1.Sc1: the hardware costs are the same in all segments of each vehicle category-fuel;
- PO2.Sc1, PO2.Sc2, PO3.Sc1 and PO3.Sc2
  - Hardware [Cars-PI-Small] = 71/87 * Hardware [Cars-PI-Medium]

  - Hardware [Cars-PI-Large] = 103/87 * Hardware [Cars-PI-Medium]
  - Hardware [Cars-CI-Small] = 266/294 * Hardware [Cars-CI-Medium]
  - Hardware [Cars-CI-Large] = 311/294 * Hardware [Cars-CI-Medium]
  - Hardware [Lorries-Small] = 266/294 * Hardware [Lorries-Medium]
  - Hardware [Lorries-Large] = 311/294 * Hardware [Lorries-Medium]
  - Hardware [Buses-Small] = 266/294 * Hardware [Buses-Medium]
  - Hardware [Buses-Large] = 311/294 * Hardware [Buses-Medium]
- PO2.Sc3
  - Hardware [Cars-PI-Small] = 215/232 * Hardware [Cars-PI-Medium]
  - Hardware [Cars-PI-Large] = 249/232 * Hardware [Cars-PI-Medium]
  - Hardware [Cars-CI-Small] = 328/356 * Hardware [Cars-CI-Medium]
  - Hardware [Cars-CI-Large] = 394/356 * Hardware [Cars-CI-Medium]
  - Hardware [Lorries-Small] = 328/356 * Hardware [Lorries-Medium]
  - Hardware [Lorries-Large] = 394/356 * Hardware [Lorries-Medium]
  - Hardware [Buses-Small] = 328/356 * Hardware [Buses-Medium]
  - Hardware [Buses-Large] = 394/356 * Hardware [Buses-Medium]

Evaporation emission control hardware costs

Table 9-58 presents the package of technologies foreseen in the different scenarios for PI vehicles emissions control. All costs presented are on a per vehicle (new registration) basis. Table 9-59 presents the cost elements per components that goes into each package.

Table 9-58: Hardware costs for evaporation control in the different policy options/scenarios.

Scenario	Cost element	Cost (€/veh)
PO2.Sc1 & PO2.Sc2	ORVR canister, anti spitback/vapour seal valve, and a high flow purge valve	16
PO2.Sc3	higher capacity canister and low permeability fuel tank and hoses	40
PO3.Sc1 & PO3.Sc2	ORVR canister, anti spitback/vapour seal valve, and a high flow purge valve, pump system for active leak detection (OBD)	41

Table 9-59: Cost of individual components for evaporation control.

Component	Cost (€)
ORVR carbon canister (scenario 1)	10
Anti spitback/vapour seal valve	2
Purge valve	2
Tank vent hose	2
Larger canister for 0.3g/test (scenario 2)	4
Low permeability tank and hoses	20
Pump system for OBD leak check	25

Exhaust and evaporation emission control total hardware costs

Combining the cost of each technology package (Table 9-54) with the respective share (Table 9-56), the final hardware cost per vehicle in each policy option and scenario is calculated for cars/vans, as shown in Table 9-60. In the case of gasoline vehicles, the evaporation emission control hardware cost (Table 9-58) is also included, while in PO3 the cost of sensors used for OBM is added too. Similarly, Table 9-61 presents the final hardware cost per vehicle in each policy option and scenario for lorries/buses.

Table 9-60: Hardware cost per vehicle for cars/vans in each policy option (not discounted €, incremental compared to Euro 6d).

Policy Option / Scenario	Category	Gasoline (cars/vans)	Diesel (cars/vans)	CNG (cars/vans)
PO1.Sc1	MHEV	43.6 / 39.3	86.3 / 156.4	60.6 / 63.7
	PHEV	0 / 0	172.7 / 312.7	60.6 / 63.7
PO2.Sc1	MHEV	88.0 / 78.2	312.2 / 455.6	69.7 / 73.2
	PHEV	17.6 / 15.7	487.2 / 630.6	69.7 / 73.2
PO2.Sc2	MHEV	98.0 / 88.2	312.2 / 455.6	69.7 / 73.2
	PHEV	19.6 / 17.7	487.2 / 630.6	69.7 / 73.2
PO2.Sc3	MHEV	254.0 / 242.4	389.1 / 535.9	309.4 / 317.7
	PHEV	191.5 / 179.9	501.7 / 648.5	246.9 / 255.2
PO3.Sc1	MHEV	88.0 / 78.2	312.2 / 455.6	69.7 / 73.2
	PHEV	17.6 / 15.7	487.2 / 630.6	69.7 / 73.2
PO3.Sc2	MHEV	98.0 / 88.2	312.2 / 455.6	69.7 / 73.2
	PHEV	19.6 / 17.7	487.2 / 630.6	69.7 / 73.2

Table 9-61: Final hardware cost per vehicle for lorries/buses in each policy option (not discounted €, incremental compared to Euro 6d).

Policy Option / Scenario	Diesel	Natural Gas
PO1.Sc1	0.0	0.0
PO2.Sc1	2102.1	1724.9
PO2.Sc2	2102.1	1724.9
PO2.Sc3	4363.0	3037.9
PO3.Sc1	2102.1	1724.9
PO3.Sc2	2102.1	1724.9

Brake wear emission control

There are a number of technologies to decrease PM ware emissions from brakes. Of those, improved pads and specially designed filters to collect worn material are the most promising ones and have already reached commercial stage. Improved pads include Non-

Asbestos Organic materials (NAO) under several compositions and formulations depending on pad manufacturer. NAO pads come at an increased cost compared to conventional pads due to material cost and manufacturing. Industrial information that was exchanged in the relevant discussions in the PMP Group estimated the additional cost to range from 15% to 30% of conventional pad costs, depending on brake size. One can assume an average of 25% of higher cost.

An average conventional passenger car with expected useful life of 240,000 km is expected to require three times pads replacement for the front wheels and two times pad replacement for rear wheels. This makes it in total 10 pairs (sets) of pads during the lifetime of the vehicle. With an estimated average cost of a set of pads at 15 Euros/set, the incremental cost increase of using NAO pads over the lifetime of the vehicle comes to 37.5 Euro/vehicle.

However, electrified vehicles including battery electric ones and plug-in hybrid ones use regenerative braking as a means to save energy and retain a higher operating range. With regenerative braking, no mechanical force is applied on the wheels by means of a brake system under mild to moderate braking activity. Rather, the kinetic energy of the system is converted back to electricity by means of reversing the operation of the electrical powertrain and this recuperated energy is back-stored in the batteries. Brake action occurs only for full stop, and for emergency and harsh braking conditions. Regenerative braking results to less wear for the pads and the disks and produces less wear particles. As a result of the less wear, one can assume a lower replacement frequency than for conventional vehicles. Assuming two frontal axis replacement and one rear one for the life of the vehicle, this makes it 6 pad replacements for the lifetime of the vehicle which amounts to a total cost of the total cost for EVs goes down to 22.5 Euro/vehicle.

The second technology that can be potentially utilized to control brake wear emissions is the use of specially designed filters that collect wear particles after they are produced. There is a number of suppliers of these systems targeting the luxury car segment, promoting their products both as a means of decreasing pollution but also as a means of keeping wheels clean for prolonged periods. The latter can be significant in luxury and sports cars. The market of SUV, luxury and sports car in the EU is currently around 40%, therefore a 50% penetration of such systems in these vehicle segments would mean that a 20% of the new registrations may soon in the future be equipped with such filter systems. The cost for such a system is currently estimated at 200 Euros/vehicle. For the remaining registrations, such systems would have to be enforced by regulations. However, the additional cost for 80% of the fleet, should then be allocated to 100% of the fleet.

Brake wear control can also be achieved by means of regenerative braking. In such systems, deceleration is achieved by converting kinetic energy during braking or coasting to electric one by means of engaging a generator on the transmission before the brake callipers are activated. As a consequence, pad wear decreases and associated PM emissions decrease as well. Regenerative braking is practically present in all electrified cars of today and in several conventional ones as well, perhaps with different energy recuperation potential in the various applications. It is considered to become a mainstream technology in the future in an effort to meet CO_2 targets. Similar to other technologies providing CO_2 benefits, regenerative braking will assist in decreasing brake wear but no cost for its more widespread introduction should be allocated to Euro 7.

Table 9-62: Technology costs for brake wear control scenarios.

Technology	Policy Option 1	Policy Option 2 & 3 Scenario 1	Policy Option 2 & 3 Scenario 2
	€/vehicle	€/vehicle	€/vehicle
NAO Brake Pads – ICE and MHEV	0	37.5	37.5
NAO Brake Pads – PHEV and BEV	0	22.5	22.5
Brake Dust Particle Filter	0	0	160
Regenerative Braking	0	0	0

9.5.4. R&D costs

R&D costs for introducing a new emission standard correspond to all design, simulation, experimentation, testing and other activities required to bring the TRL of a new emission control technology to the production level. R&D costs may be substantial and in general scale with the requested reduction in the emission levels. R&D costs appear at the beginning of introducing the new technology. Thereafter, R&D costs decrease substantially and calibration costs become dominant. This is why R&D costs are considered as an one-off investment that is amortized within a model's cycle.

In our analysis, we estimate those R&D expenses incurred just by the OEMs. We consider that the R&D costs incurred to suppliers to develop a new product are included in the H/W cost of the specific component.

The Euro 6/VI *Evaluation report* collected and synthesized information on R&D costs from a number of OEMs. It was generally recognised that separating R&D costs specific to compliance with an emission standard from other costs regarding powertrain design targets and efficiency targets was not always possible. However, the responses provided by OEMs were understood to deliver an upper estimate of the total costs involved in such a procedure.

For the average Euro 6 vehicle, evidence provided and summarised in the *Evaluation report* from literature sources and OEMs estimated the R&D costs range at € 44-156 for CI vehicles and € 36-108 for SI vehicles without being able to explain the large range provided when combining data by the different sources.

Industrial information provided in the framework of the AGVES meeting for Euro 7 provided estimated R&D costs in the order of €150 - 1232 per new vehicle registered in the first year of introducing the new emission standard, depending on the stringency of Euro 7 policy option. No further distinction per CI and PI powertrains was provided by these industrial sources. By amortizing this investment over a 20-year horizon (assuming constant sales), provides a per vehicle R&D cost in the range of 4.75-61.6 €/veh., depending on the stringency of the scenario.

In fact, R&D costs should not be scaled according to number of registrations. These comprise one-off investment costs and other resources spent when introducing a new emission standard. The amount of investment is proportional to the relative change that is introduced by the new standard and not proportional to the sales that each manufacturer will achieve. Obviously, the amount of resources is not the same for each manufacturer and those with big sales volumes are deemed to spend more but this is mostly because they have the resources to do this. Smaller manufacturers are either buying the new technology from larger ones or from suppliers or limit themselves to certain vehicle segments with less performance requirements and for which they can decrease the amount of R&D required.

In that regard, a total R&D investment for the industry to introduce Euro 7 is more suitable to estimate than a specific cost per vehicle. This investment can be amortized over the average lifetime of a model type, considered to be eight years. For next generations of vehicles, although some R&D costs can still be incurred, we consider that these are included in calibration costs ant not new R&D investment anymore.

Table 9-63 provides a summary of total R&D investment costs estimated in the Euro 6/VI evaluation study together with estimated calibration costs. As we need to separate R&D from calibration costs for projecting costs for Euro 7, we take the minimum of the quoted values as representative of R&D costs at Euro 6/VI and we make our projected R&D costs based on this.

Table 9-63: Total R&D investment for Euro 6/VI and projected R&D investment for Euro 7.

	Total R&D investment for Euro 6/VI (B€)*	Policy Option 1 (B€)	Policy Option 2 (B€)			Policy Option 3 (B€)	
	Min – max	Min – max	Min – max			Min – max	
		Sc.1	Sc.1	Sc.2	Sc3	Sc.1	Sc.2
PI Cars and vans	1.8 – 5.6	0.54 – 1.68	1.8 – 5.6	Sc1	Sc1	2.1 – 5.9	Sc1
CI Cars and vans	2.1 – 7.8	0.63 – 2.34	2.1 – 7.8	Sc1	Sc1	2.4 – 8.1	Sc1
Lorries and Buses	5.35 – 10.7	0.26 – 1.07	5.35 – 10.7	Sc1	Sc1	6.0 – 11.4	Sc1

One can use these base values to estimate R&D costs for the different policy options:

- For PO1, only a fraction of the R&D costs considered at Euro 6 would be needed. There are marginal changes in the emission limits in PO1.Sc1 and no change in the configuration of exhaust lines is considered necessary. The R&D costs in that case are mostly for better setting up the GPF and DPF for complying with limit despite the lower PN threshold, as well as better setting up the deNOx control for CI vehicles to comply with the 60 mg/km NO_x limit. We assume Euro 7 R&D costs equal to 10-15% for cars and vans and 5-10% for lorries and buses over Euro 6/VI ones. An industrial source conducted in the framework of AGVES estimated the R&D costs for a similar scenario to PO1.Sc1 to be of the order of €95/veh for the annual registrations of ICE cars and vans in EU in 2019 (approx. 13.3MVehs) which brings the total to €1.27 billion, i.e. at the same range with our estimate (total PI and CI vehicles of €1.34 billion). Our max estimate also takes into account that additional resources may be needed to decrease the PN threshold to 23 nm. This was not taken into account in the estimate of this industrial source. Additional resources will be needed to research emissions outside the RDE limits. However, this is not a too high effort because the limit in this range is relaxed compared to the RDE operation. Still, the manufacturers will need to change engine strategy and to dimension the larger catalysts to be used. We expect this effort to be 30% of what was the case at Euro 6 for cars and vans.
- For PO2, some vehicle models will require new components in the exhaust line and possibly new configuration for the exhaust components. Moreover, engine out changes will be needed and new thermal management will have to be developed. The fact that the majority of cars (and most probably vans) at Euro 7 will be hybrid,

means that the engineering difficulty increases. Lorries and buses will require a new NOx-reduction box to be installed closed-coupled to the engine and proper heat equipment (burner, e-cat) will be needed to achieve faster light-off. PM/PN emission control is practically identical to Euro VI. In terms of engineering effort, Euro 7 is therefore expected to require the same effort per OEM of what Euro 6/VI required. An industrial source conducted in the framework of AGVES estimated the R&D costs for a scenario similar to PO2 to be of the order of €1232/veh for the annual registrations of ICE cars and vans in EU in 2019 (approx. 13.3MVehs) which brings the total to €16.4 billion, i.e. at the same range with our estimate (total PI and CI vehicles of €13.4 billion). Our estimate also takes into account the announcement of some vehicle manufacturers that they will stop the further development of diesel engines (which entail the highest R&D costs). This makes our more moderate estimate suitable to the assumption that some engine series will turn to petrol ones. We did not receive any R&D cost estimates for lorries and trucks but we assume our estimate to be correct in the sense that the development of a new 'aftertreatment box' would need the same kind of R&D effort as Euro VI 'aftertreatment box' one.

- For PO3, additional R&D will be required to adapt the necessary sensors and the OBM system of the vehicle. As a result, we estimate that on top of the R&D costs considered for PO2, around €1.3 billion will need to be split to develop the fundamentals of the sensors + OBM package for cars and vans and the same amount for lorries and buses. In reaching such a number, we made the following calculations: Continental, one of the largest suppliers of automotive components spent €664 million in 2019 to develop all powertrain components and sensors[224]. Assuming one quarter of this is on sensors, four main suppliers developing such sensors and systems in EU, and a development time of two years, makes a total value of €1.3 billion. We split this cost equally between CI and PI powertrains and then again equally between LD and HD applications.

Finally, we have introduced an additional cost of 800 k per OEM for the purchase of an additional SHED test for performance of evaporation relevant tests.

9.5.5. Calibration costs

Calibration refers to the engineering and testing activities required to adjust the performance of the selected emission control technology to the specifications of a particular vehicle model or engine type. This involves sizing of the emission control hardware, tuning of the combustion parameters to adjust the engine map and ECU programming to achieve OBD functionality. Calibrations are being performed by the OEMs or by independent testing centres hired by the manufacturers specifically for this task. In our approach, we do not differentiate between the two options in terms of costs.

The Euro 6/VI evaluation study came up with cost estimates for calibration costs at the different stages of Euro 6 and Euro VI. The calibration costs per vehicle or engine type were found to increase as one moved to later Euro 6 steps due to the increased number of components needed to be calibrated for emissions control. Calibration costs were found to differ between PI and CI powertrains due to the higher complexity of diesel aftertreatment compared to the well-established three way catalyst for PI. A summary of the costs at Euro 6 D/ Euro VI E are shown in Table 9-64. Calibration costs differed

[224] Continental 2019 Annual Report. Accessed March 2021.

between lead and derivative types, with lead ones being the ones first appearing in a family.

Table 9-64: Calibration costs for Euro 6/VI and projected incremental calibration costs for Euro 7.

	Euro 6d Calibration cost per type	Policy Option 1 Scenario 1	Policy Option 2 Scenario 1	Policy Option 2 Scenario 2&3	Policy Option 3 Scenario 1	Policy Option 3 Scenario 2
		Increment	Increment	Increment	Increment	Increment
	M€	M€	M€	M€	M€	M€
PI Cars and vans						
Lead	5.4	0	0.81	1.62	-1.08	-0.54
Derivative	0.675	0	0.1015	0.203	-0.135	-0.0675
CI Cars and vans						
Lead	6.1	0	0.915	1.83	-1.22	-0.61
Derivative	0.762	0	0.1145	0.229	-0.153	-0.0765
Lorries and Buses						
Lead	3.5	0	0.7	1.4	-0.7	-0.35
Derivative	0.23	0	0.0875	0.175	-0.088	-0.044

Based on the Euro 6/VI calibration costs, one can infer the calibration costs at Euro 7. We have to consider that in contrast to R&D that appear as one-off costs, calibration costs follow the vehicle over its lifetime. Moreover, we need to estimate calibration costs as incremental difference over what Euro 6/VI would be:

- For PO1, we assume calibration costs for petrol vehicles to be identical to Euro 6. We do not foresee any major new components to be introduced while limits are practically identical. Moreover, the control of emissions for the region outside of RDE is not very demanding in terms of limit values, therefore this is assumed to be covered by the same calibration procedure which currently enables AES for Euro 6 vehicles.
- PO 2 will potentially require new components for petrol vehicles, including an e-cat, an ORVR canister, and perhaps some CUC for ammonia. This will require additional calibration effort also towards decreasing impacts on energy consumption. This additional effort is considered to be 30% of what the original effort to bring in Euro 6d was. Such an increase is similar to what was assumed in the Euro 6/VI evaluation study going from pre-RDE Euro 6 to RDE, including the calibration for GPF. The additional calibration costs for CI powertrains is also considered to be 30% of Euro 6d cost, mostly for the calibration of the e-cat over an extended range of operation conditions. For heavy duty vehicles, it is basically only the limit for NOx which is substantially decreasing however together with N_2O and NH_3 control. We estimate this will require some significant effort for calibration to make sure all nitrogen species are adjusted within the required limits. This is why we have assumed 40% higher costs than Euro VI E. We assume that the calibration effort required for PO2 Sc1 would be half the effort required for the scenarios PO2 Sc2 and Sc3.
- PO 3 involves the introduction of sensors in the exhaust and fuel vapour lines. Although the technology increases the hardware and R&D costs we believe this will actually help calibration because new signals can be provided to the engine and the engine can calibrate its operation according to the input this receives

using intelligent software. We actually believe that the calibration effort in this case will be less that even what it was at Euro 6/VI by 20% in all cases in PO3 Sc1, and by 10% in PO3 Sc2.

Furthermore, we do consider that manufacturers become acquainted with the calibration of engines in the long run. As a result, we assume that the additional calibration effort over Euro 6/VI diminishes after 10 years due to the experience gained.

In terms of number of calibrations executed per year, the Euro 6/VI evaluation study also came up with an estimate of the number of lead and derivative models and engines that were annually calibrated in the EU in the 2013-2020 time frame. That analysis showed that when Euro 6 was first introduced, a large number of lead engine and model types had to be calibrated. The number of calibration numbers was stabilized as the emission standard matured in time. We can use this evidence to estimate the number of lead and derivative models and engine types at a Euro 7. This is shown in Table 9-65. We actually have assumed that the model series at Euro 7 will remain similar to what they were at Euro 6/VI. Therefore, we have estimated the ratio of number of calibrations per million of vehicles registered in the EU per year and we use this number with the number of registrations of vehicles estimated to be introduced in the Euro 7 time frame. We have actually distinguished two regions, one for the first year of introduction of the model that several lead calibrations needs to be done and one region of normal lifetime where most of the calibrations are derivative ones.

Table 9-65: Number of calibrations performed at Euro 6/VI and estimated number of calibrations per million of registrations for Euro 7.

CI Cars and vans	Euro 6/VI		Euro 7 No of calibrations/Mveh	
	First year of introduction	Maturity	First year of introduction	Maturity
PI Cars and vans				
New Registrations (Munits)	4.44	7.75		
Lead	129	43	28.9	5.6
Derivative	267	770	60.0	99.4
CI Cars and vans				
New Registrations (Munits)	6.48	5.56		
Lead	33	10	5.1	1.8
Derivative	127	290	19.5	52.2
Diesel Lorries and Buses				
New Registrations (Munits)	0.27	0.35		
Lead	11	3	40.1	8.6
Derivative	94	37	343.0	106.5

9.5.6. Type-approval costs

The type-approval costs are considered to include the following cost categories:

- costs for witnessing,
- fees to type approval authorities,

- cost for testing (certification), and
- administrative/reporting costs.

The Euro 6/VI costs that were assumed in the Evaluation Assessment of Euro 6/VI study are presented in Table 9-66:

Table 9-66: Estimation of the type approval costs of Euro 6d / VI E as assumed in the Evaluation Assessment of Euro 6/VI study.

	LDVs - Euro 6d			HDVs - Euro VI E		
	Mode-rate	Low	High	Mode-rate	Low	High
Costs for witnessing (per engine family)	17,500	15,000	20,000	17,000	8,000	15,000
Fees to type approval authorities (per type approval)	750	0	1,000	750	0	1,000
Cost for testing (certification) (per engine family)	262,000	172,000	351,000	480,000	280,000	680,000
Admin/reporting costs (per type approval)	40,000	20,000	60,000	45,000	35,000	55,000

The study on the "Potentials for Simplification of Vehicle Emission Standards", delivered in the framework of the Task 2 of the same Part B study, concluded to the following reductions in the number of type approvals and in the test and administrative cost per type approval, as presented in Table 7.1 of the respective report:

Table 9-67: Estimation of the Simplification proposals described in the report of the "Potentials for Simplification of Vehicle Emission Standards" study of Task 2.

Paragraph within the report "Potentials for Simplification of Vehicle Emission Standards"	Short description	Reduction number of type approvals	Reduction of test and administrative burden per type approval
		Reduction compared to Euro-6/VI introduction (all stages)	
5.1.1 Chapter 6	Merging 715/2007 and 595/2009 in combined new emissions regulation		0.5%
5.1.2	Scope – defining new border between LD and HD emissions legislation (TPMLM or Frontal area)	5%	
5.1.3	One date of Euro-7 introduction per category	60% - diesel cars/vans 40% - petrol cars/vans and lorries/buses	
5.1.4	Introduction TCI, reduction OBD		10%
5.1.5	Removal of ATCT test		5% - LD only
5.1.6	Removal of Idle, Opacity and Crankcase test		0.5%
5.1.8	Alignment EU and UNECE emissions regulations		small, but positive

The number of type approvals is presented in Table 9-47 to Table 9-49 for both previous and current technologies, as well as for the estimated number of type approvals for Euro 7 until 2050.

The same type approval cost reductions apply to all Policy Options Scenarios, with the exception of the Policy Option 3 where an additional reduction of 30% and 50% in the number of type approvals was assumed for Scenario 1 and Scenario 2, respectively. The costs per type approval for each Policy Option Scenario after applying the estimated reductions due to Simplification of the regulation are presented in Table 9-68.

Table 9-68: Moderate, low and high estimations for costs per type approval assumed for each Policy Option Scenario.

(Values are per type approval)	LDVs			HDVs		
	Mode-rate	Low	High	Mode-rate	Low	High
Policy Option 1 & Policy Option 2						
Costs for witnessing	2,776	3,173	2,380	3,228	2,848	1,519
Fees to type approval authorities	630	840	0	668	890	0
Cost for testing (certification) (per engine family)	41,563	55,682	27,286	91,143	129,119	53,167
Admin/reporting costs (per type approval)	33,600	50,400	16,800	40,050	48,950	31,150
Policy Option 3 (reduction by 30%)						
Costs for witnessing	1,943	2,221	1,666	2,260	1,994	1,063
Fees to type approval authorities	441	588	0	467	623	0
Cost for testing (certification) (per engine family)	29,094	38,977	19,100	63,800	90,383	37,217
Admin/reporting costs (per type approval)	23,520	35,280	11,760	28,035	34,265	21,805

9.5.7. Infrastructure costs

No costs for infrastructure are considered in any policy option. In Policy Option 3 we estimate that the infrastructure already established for OBFCM will be used, hence no incremental cost is considered.

9.6. Cost-benefit and cost-effectiveness analysis

The Cost-Benefit Analysis (CBA) model that was specifically developed to perform the retrospective assessment of the Euro 6/VI vehicle emission standards was also used for the impact assessment of the post-Euro 6 Policy Options examined in the current study. The model was modified to serve the needs of the current study, i.e. to examine the specific scenarios in each Policy Option.

The cost-benefit results show whether the societal investment associated with the environmental policy provides at least similar quantity of benefits, when both are expressed in monetary terms. A different cost-benefit assessment is performed for cars, vans, lorries and buses, while aggregated results are also examined for LDVs and HDVs.

Figure 9-19 presents schematically the block diagram of the CBA tool. The introduction of new vehicle technologies is directly related to the vehicle sales, stock, activity and energy consumption. This has on the one hand a positive impact on the total emissions levels, resulting to lower levels, i.e. to environmental benefit (ΔEmissions), and on the other hand a negative impact on the total costs (hardware, R&D, etc.), resulting to additional costs, when compared to the state-of-the-art technologies' emission levels and costs, respectively. The equivalent monetised benefit coming from the pollutants saved is calculated by multiplying the emission savings in kg with the external marginal costs in €/kg, for each of the examined pollutant. The subtraction of the total environmental monetised benefits from the total implementation costs results to the total net cost-benefit result. When the cost-benefit result is positive this would mean a net damage, while a negative cost-benefit result would mean a net benefit for the examined scenario. The cost-effectiveness analysis provides the cost per unit of mass of pollutants saved. This is derived by dividing the implementation costs over the emission savings for each pollutant.

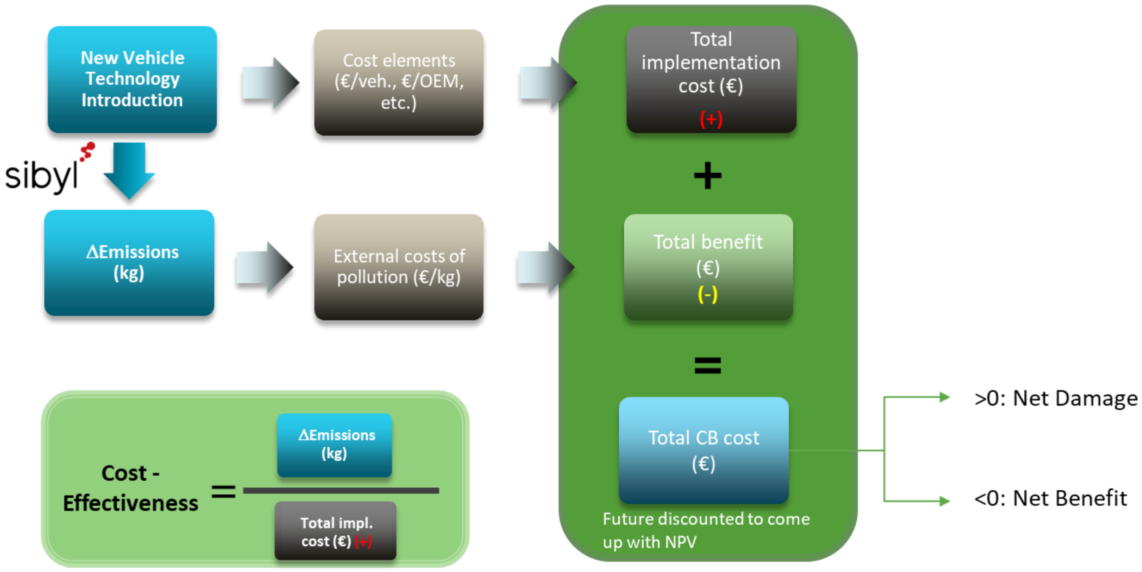


Figure 9-19: Schematical representation of the CBA model.

The net-present value (NPV) is derived by allocating the net cost-benefit to the period of investigation, using a social discount rate. This rate is taken equal to 4%, as recommended by the EU's Better Regulation Guidelines (and the supporting Better Regulation Toolbox: Tool#61[225]). The time horizon of the examined period is 2050 in order to facilitate the full range of the equivalent monetised benefits coming in from the reduction in air pollution and greenhouse gases. With a discount rate of 4%, any benefit zeroes in approximately 30 years' time from the year that a Euro technology has been first introduced, eliminating any residual monetary benefits that would be neglected if the simulation horizon was earlier.

9.6.1. Uncertainty in cost-benefit calculations

In Section **Error! Reference source not found.** the method for estimating costs is presented. The estimations were based on the following sources:

- Targeted stakeholder consultation,

[225] https://ec.europa.eu/info/files/better-regulation-toolbox-61_en

- Literature studies,
- Estimations adopted in the report on the “Euro 6/VI Evaluation study”,
- Internal discussions among all relevant members of the CLOVE consortium.

The level of confidence of the cost estimates is considered as medium to high as also stated in Table 9-44. Though, the estimation of costs regarding different categories are difficult to accurately assess because these depend on market structure, size, and competition, while negotiated prices between suppliers and manufacturers are confidential. Besides, different sources (stakeholders, studies, etc.) have provided divergent inputs. In order to take uncertainty into account, our calculations include three potential cost levels (low, central, high), to reflect the total uncertainty in cost estimation.

Particularly, the estimated R&D costs range is presented in Table 9-63 for each examined scenario. The upper estimates of the R&D costs were based on the responses provided by OEMs.

The type-approval costs were based on the presented in the report on the “Euro 6/VI Evaluation study” (Table 9-66) and they were modified for the Euro 7 scenarios based on the estimations of the simplification proposals described in the report of the “Potentials for Simplification of Vehicle Emission Standards” study of Task 2 (Table 9-67). The range of the type-approval cost estimates were also based on range presented in the report on the “Euro 6/VI Evaluation study”.

The hardware costs for evaporation control in the different policy options and scenarios were presented in Table 9-58 to Table 9-61. The costs uncertainty (low/high estimate) was reflected with an uncertainty of 25% of the central value. The same uncertainty range was also assumed for the administrative evaporative costs.

No uncertainty range is considered for the rest cost categories, i.e. for hardware and for calibration costs. For hardware costs, the reason is that, as outlined in the Combined report and also earlier presented, the technology package was first determined and the emission limit was then set based on the package selected. In such a process, the hardware cost uncertainty is by definition zero as this has been preselected. For calibration, we have estimated costs as a margin over Euro 6/VI. As we are interested in relative differences over Euro 6/VI any uncertainty therefore cancels out.

The cost-benefit resulting tables presented in Section 6 of the report include these low/high cost estimates, while the central cost value is calculated as the average of the low/high estimates. The monetised environmental benefit was also calculated with an uncertainty range, based on the normal and conservative evolution of Euro 6/VI emission factors that were used, as discussed in Section 9.4.2. The central value for the environmental benefits is derived as the average of the low/high benefit values in the tables of Section 6. The final cost-benefit result is presented for the central costs and benefits values, also providing the range within the high benefit / low cost and low benefit / high cost, provided as the cost-benefit uncertainty range.

It is clarified that the uncertainty range presented corresponds to the extents of the expected uncertainty that, in statistics, this would correspond to six standard deviations.

9.7. Other direct and indirect economic, environmental and social impacts

A description of the methods utilized in the analysis of the direct and the indirect economic, environmental and social impacts is performed in this section.

9.7.1. Methodology on assessment of Environmental impacts

The total emissions are calculated based on the emission modelling methodology presented in Section 9.4. In brief, the total emissions are calculated by multiplying the number of vehicles by the annual mileage per vehicle by the estimated emission factor. This is performed for each of the combination of the following:

- For each Euro technology;
- For each vehicle category;
- For each engine/fuel technology;
- For each Policy Option and Scenarios (including the baseline);
- For each of the investigated pollutants.

The environmental benefits for each Euro 7 Policy Options / Scenario are calculated over the baseline scenario, i.e. over the scenario which assumes that no Euro 7 technology shall be introduced, and that only Euro 6/VI vehicles will be registered in the future. The evolution of the total emissions of each Euro standard along with the emission savings of the Euro 7 Policy Options / Scenarios over Euro 6/VI are illustrated for the years 2010-2050 in Sections 5.x.1 “Environmental impacts” for each Policy Option.

9.7.2. Methodology on assessment of Economic and Social impacts

Focusing on the economic and social impacts, this encompasses the following elements:

1. General macro-economic indicators, such as creation of new jobs, skills required, research and innovation etc.;
2. Competitiveness of the EU industry and internal market cohesion
3. Qualitative impacts on SMEs and consumers (incl. consumer trust).

Sources of information

In order, to assess the socio-economic impacts, the **first step** was to carefully review all the deliverables and accompanied analyses in the ecosystem of studies of CLOVE consortium related to the impact assessment of Euro 7 (see Section 1.5). This was done, in order to extract key and valuable information, based on the data/findings/conclusions in the various deliverables/reports, relevant to the Euro 7 IA. This process provided the necessary evidence which form the basis of assessment of various impacts of the Euro 7 PO.

In order, to assess the socio-economic impacts, the **second step** was to identify relevant EU IAs-SWDs published by the Commission in the past, relevant to cleaner road transport, i.e. towards reducing vehicle emissions (GHG and air pollutants) and contributing to improved air quality. This provided key insights and evidence on how past regulatory proposals and initiatives were projected to impact socially and economically, and direct comparisons and assumptions were made in the context of the proposed Euro 7 scenarios.

The **third step** was to conduct an extensive literature review to find relevant scientific and consultant studies which focus on assessing the impact of new developments regarding technology, regulations, global markets, EU environmental policy, and how they affect the key elements identified above. This includes studies funded directly from the European Commission. In particular for employment, there are several scientific and consulting studies discussing and quantifying the impact of vehicle price on labour in the automotive sector as well as the impact of innovation on labour.

The **fourth step**, particular regarding economic impacts, involved estimated the total regulatory costs. As presented in Section 9.5 in detail, these include, equipment costs (hardware costs, R&D/calibration/facilities/tooling costs), implementation costs (testing and witnessing costs, type-approval fees, administrative costs related to the implementation process).

Such costs are important inputs for assessing the socio-economic impacts, especially in the areas of:

- Affordability for consumers/social inclusion,
- Competitiveness in terms of product prices,
- Economic affordability of SME users/stakeholders

Also based on estimated regulatory costs, which are focused primarily on performance of vehicles in terms of air pollutants, comparisons are made with the associated cost linked with the CO_2 targets and zero emission vehicles.

Qualitative assessment matrices

In order to summarize the assessment of each element, certain matrices were created in order to indicate a quantifiable impact on a custom scale, regarding the introduction of the different policy options of Euro 7. In particular, this aims to:

- Identify the relevant and most important topic areas
- Provide a summarized scale of the accompanied impact.
- Assess expected trends, also based on the feedback from the stakeholder consultations.

The scaling format utilized in the assessment matrices, included both negative and positive quantification/values, as the nature of the various impacts on the different PO may have opposite effects.

Table 9-69: Legend/scale of quantification of severity of impacts for the different PO.

Positive impact	Score	No/Negative impact	Score
		No impact	0
Low	1	Low	-1
Moderate	2	Moderate	-2
High	3	High	-3

These impacts are meant to be understood as follows:

- They are all expressed on a relative scale to compare the different policy options to each other, with ‘3’ assumed to correspond to the maximum positive impact that any policy option can offer and “-3” corresponding to most of the negative impact. However, these need to be put also on an absolute scale, based on the considerations in the following bullet points.
- No impact (0) is considered when no appreciable differences in the concerned criterion (competitiveness, employment, consumer trust, etc.) is concerned.
- Low impact (1 / -1) expresses cases where the policy option brings a visible impact on the criterion considered but not to an extent that this would significantly change the area considered at any important manner. For example, in employment that would in total correspond to less than 1% of jobs concerned.
- Moderate impact (2 / -2) expresses cases where the policy option will have a clear effect that can clearly be felt but not one of a size that can completely change the criterion concerned. For example, in case of competitiveness, this would not be able to lead to fundamentally change the position of the EU industry compared to its competitors. In terms of employment, this could mean an up to 3% impact on positions in the sector concerned.
- High impact (3 / -3) is assigned to cases where the policy option is expected to have an impact of the extent that this could fundamentally change the current conditions with regard to the criterion concerned. For example, for competitiveness this would mean a significant advantage (correspondingly, disadvantage) over competitors, for skills this would mean the need to change the skills of the majority of the personnel in the area concerned, and for employment this could mean impacts beyond 3% (negative or positive).

10. Annex II: Input from targeted stakeholder consultation

In this annex, we present the charts developed in the analysis of the 2nd targeted stakeholder consultation for the impact assessment of post-Euro 6/VI vehicle emission standards. The raw data of all stakeholder responses and follow-up interviews are provided in an excel file format.

10.1. 2nd targeted stakeholder consultation survey

A survey/ online questionnaire was formulated for stakeholders to provide their input.

10.2. Summary of responses

Table 9-70: Overview of received responses and interviews, per stakeholder group

Stakeholder category	Sector	Survey Responses	Interviews
Industry/business sector	Vehicle manufacturers (OEMs)	16	2
	Equipment/component suppliers, fuel industry	17	6
	Industry/business associations	12	3
Member States and national authorities	Public authorities/administrations (e.g. ministries)	7	1
	Type approval authorities / Technical services	9	1
Civil society and research institutions	Non-governmental organisations (NGO)	2	1
	Consumer organisations	2	0
	Academic or research institution	2	0
TOTAL Number of responses/interviews		**67**[226]	**14**

[226] One stakeholder (equipment/component supplier) provided two separate submissions, which were identical. Hence only their latest submission was used for the chart analysis in the following sections (meaning the total responses are 66 for the analysis), to avoid a duplication effect.

Table 9-71: Detailed list of stakeholders who participated in the 2nd targeted stakeholder consultation.

(anonimised participants)

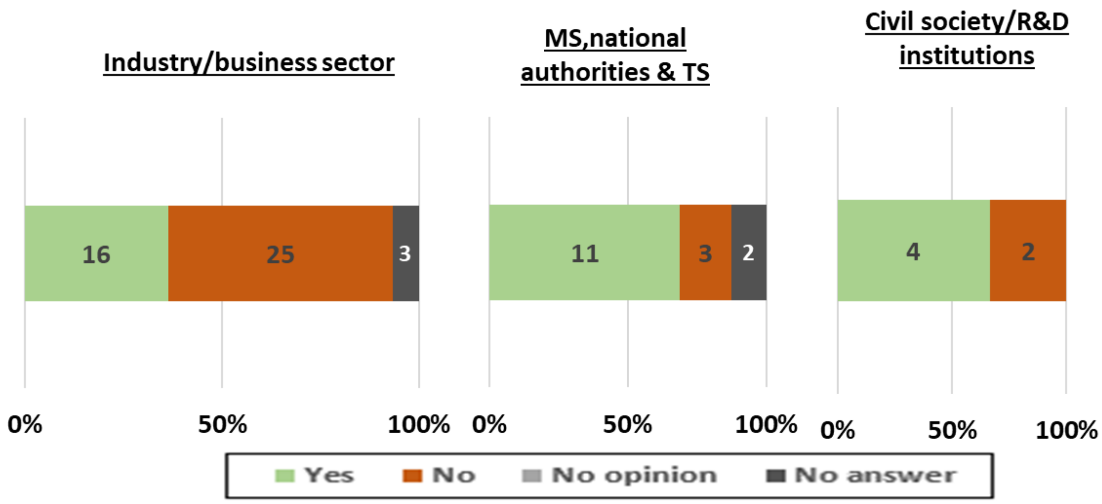
Classification of organisation	Sector	Scale of view	Country of residence	Form of contribution	Number of participants
Academic or research institution	Research	Individual business	France	Survey	1
	Research	Individual business	Germany	Survey	1
Non-governmental organisation	Public health	European association	Belgium	Survey	1
	Research	Individual business	United Kingdom	Survey, Interview	1
Consumer organisation	Consumers	International organisation	Belgium	Survey	1
	Consumers	European organisation	Belgium	Survey	1
Equipment/component supplier	Automotive parts	Individual business	Belgium	Survey	1
	Automotive parts	Individual business	United Kingdom	Survey	1
	Automotive parts	Individual business	Belgium	Survey, Interview	2
	Automotive parts	Individual business	Czech Republic	Survey	1
	Test equipment	Individual business	France	Survey, Interview	1
	Automotive parts	Individual business	United States	Survey, Interview	1
	Test equipment	Individual business	Germany	Survey	1
	Automotive parts	Individual business	Germany	Survey	3
	Automotive parts	Individual business	France	Survey, Interview	2
	Automotive parts	Individual business	France	Survey	2
Fuel industry	Fuel/feedstock	Individual business	United Kingdom	Survey	1
Industry/ business association	Vehicle manufacture	Global association	Belgium	Survey	2
	Automotive parts	European association	Belgium	Survey, Interview	2
	Public transport	German association	Germany	Survey	1
	Vehicle testing	Global association	Belgium	Survey	1
	Automotive parts	German association	Germany	Survey	1
	Vehicle manufacture	Global association	Germany	Survey	1
	Automotive parts	Global association	United States	Survey, Interview	1
	Fuel/feedstock, Vehicle manufacture	European association	Belgium	Survey	2
	Vehicle trade	National association	United Kingdom	Survey	1
Vehicle OEM	Vehicle manufacture	Individual business	Germany	Survey, Interview	2

	Vehicle manufacture	Individual business	Netherlands	Survey	1
	Vehicle manufacture	Individual business	United Kingdom	Survey	1
	Vehicle manufacture	Individual business	Italy	Survey	1
	Vehicle manufacture	Individual business	Non EU	Survey	4
	Vehicle manufacture	Individual business	Austria	Survey	1
	Vehicle manufacture	Individual business	France	Survey	1
	Vehicle manufacture	Individual business	Sweden	Survey	3
	Vehicle manufacture	Individual business	Germany	Survey	2
Public authority/ public administration (e.g. ministry/ department/ agency)	Public authority	Member State	Denmark	Survey	1
	Public authority	Member State	Germany	Survey	2
	Public authority	Member State	Spain	Survey	1
	Public authority	Member State	Sweden	Survey	1
	Public authority	Member State	Netherlands	Survey	1
	Public authority	Member State	Netherlands	Survey, Interview	1
Technical services	Technical inspection (PTI)	Individual business	Belgium	Survey	1
	Vehicle testing	Individual business	Poland	Survey	1
	Vehicle testing	Individual business	Germany	Survey	3
	Vehicle testing	Individual business	Spain	Survey	1
	Vehicle testing	Individual business	France	Survey, Interview	1
Type-approval authority	Vehicle testing	Member State	Luxembourg	Survey	1
	Vehicle testing	Member State	Spain	Survey	1

10.3. Content of new vehicle emission standards

1. In EU Regulations, the terms “zero- and low-emission vehicles“ are defined in relation to CO_2 emissions.

Do you think the definition should be extended to include pollutant emissions (Figure 9-20):



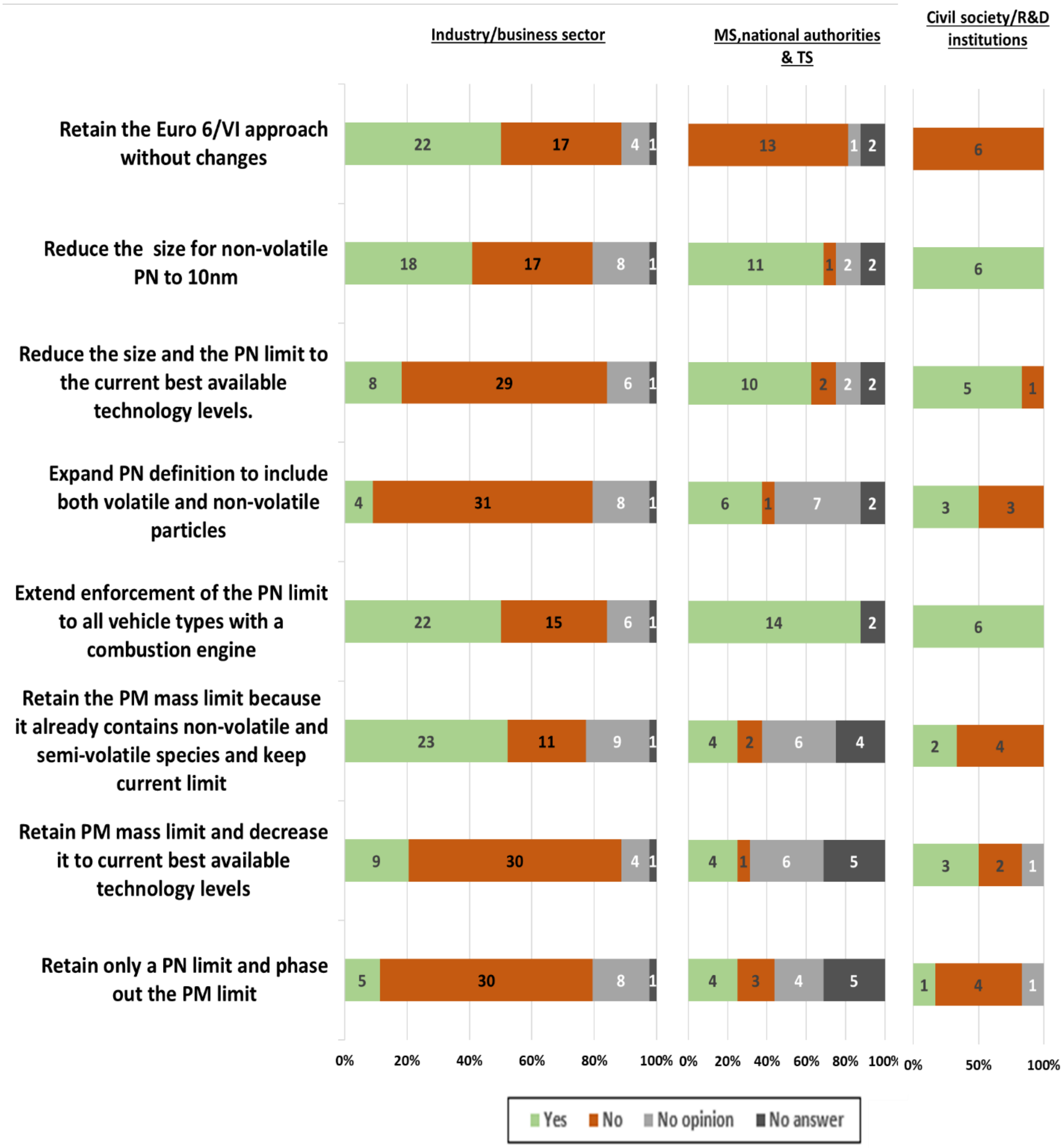
2. How significant would you rate the contribution of the following technical choices in designing the post Euro 6/VI emission standard?

2.1 For cars and vans; Real driving emissions (RDE) (Figure 9-21):

2.2 For lorries and buses; in-service conformity (ISC) (Figure 9-22):

3. PM and PN exhaust limits refer to particulate matter mass and particle number, respectively. Currently, PN measurement refers to non-volatile particles with a size down to 23 nm. PM comprises non-volatile, semi-volatile and some volatile species adsorbed on the surface of the particle and the sampling filter.

Given this, do you think that post-Euro 6/VI legislation should (Figure 9-23):

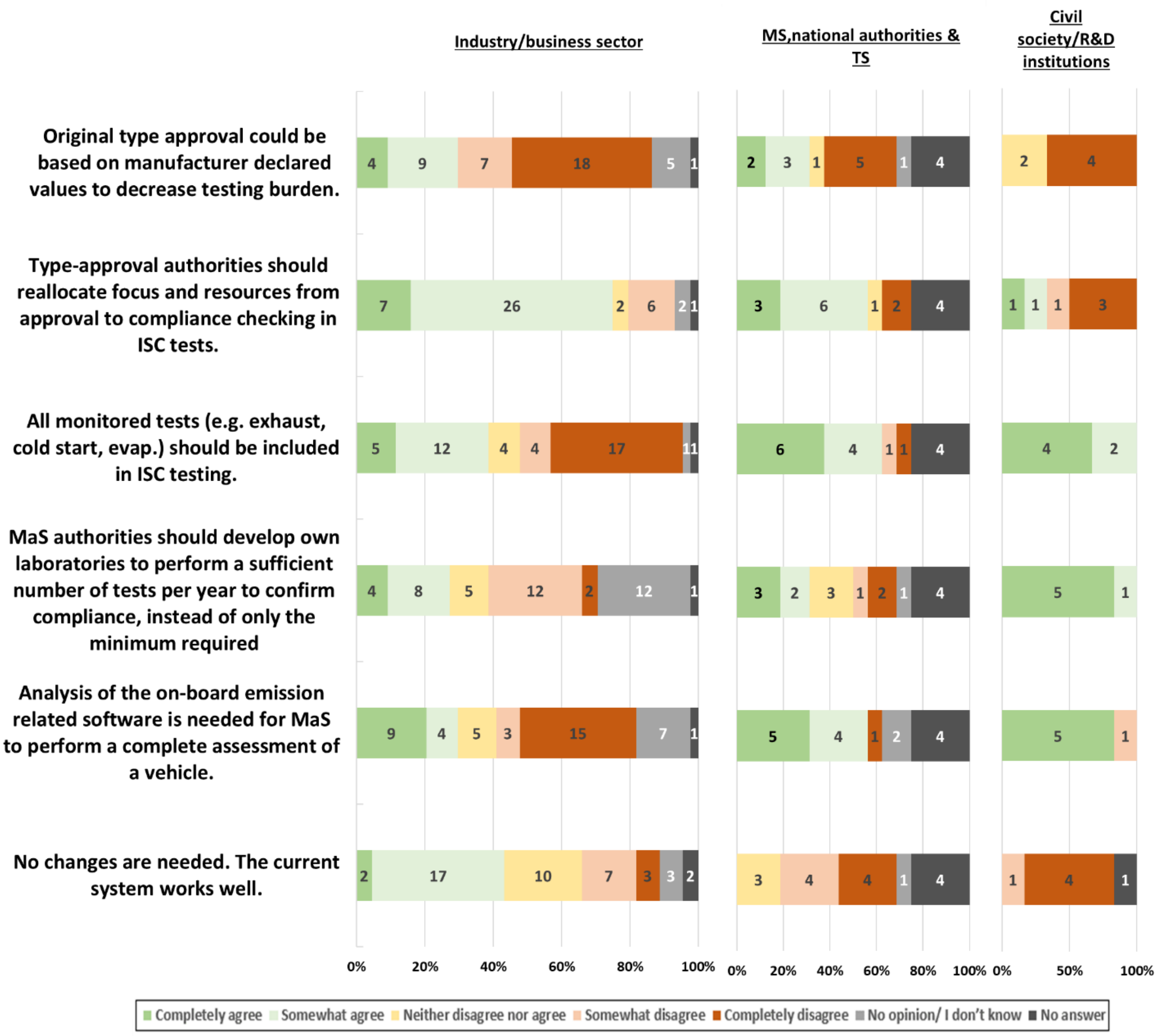


4. In Euro 6/VI, NOx is the only N-species in vehicle exhaust emissions that is regulated (along with NH3 limit for heavy-duty diesel engines).

For post-Euro 6/VI standards, please indicate the extent to which you agree with the following statements (Figure 9-24):

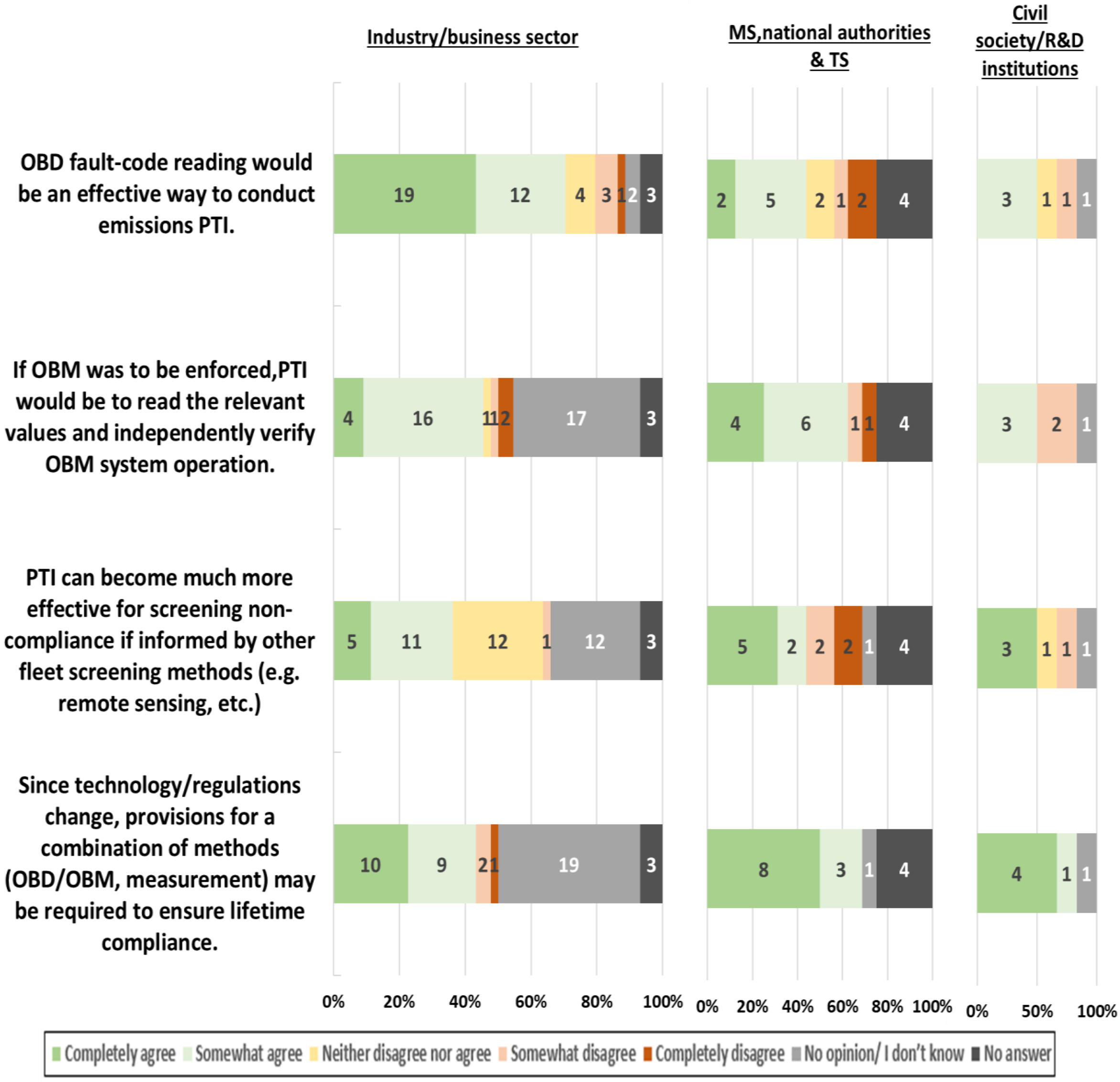
5. Further to new vehicles type approval (TA), in-service conformity (ISC) and market surveillance (MaS) are part of the Euro 6/VI and TA Regulation to make sure vehicles comply with their designed environmental performance in actual use.

Please indicate the extent to which you agree with the following statements with respect to making ISC and MaS more effective (Figure 9-25):



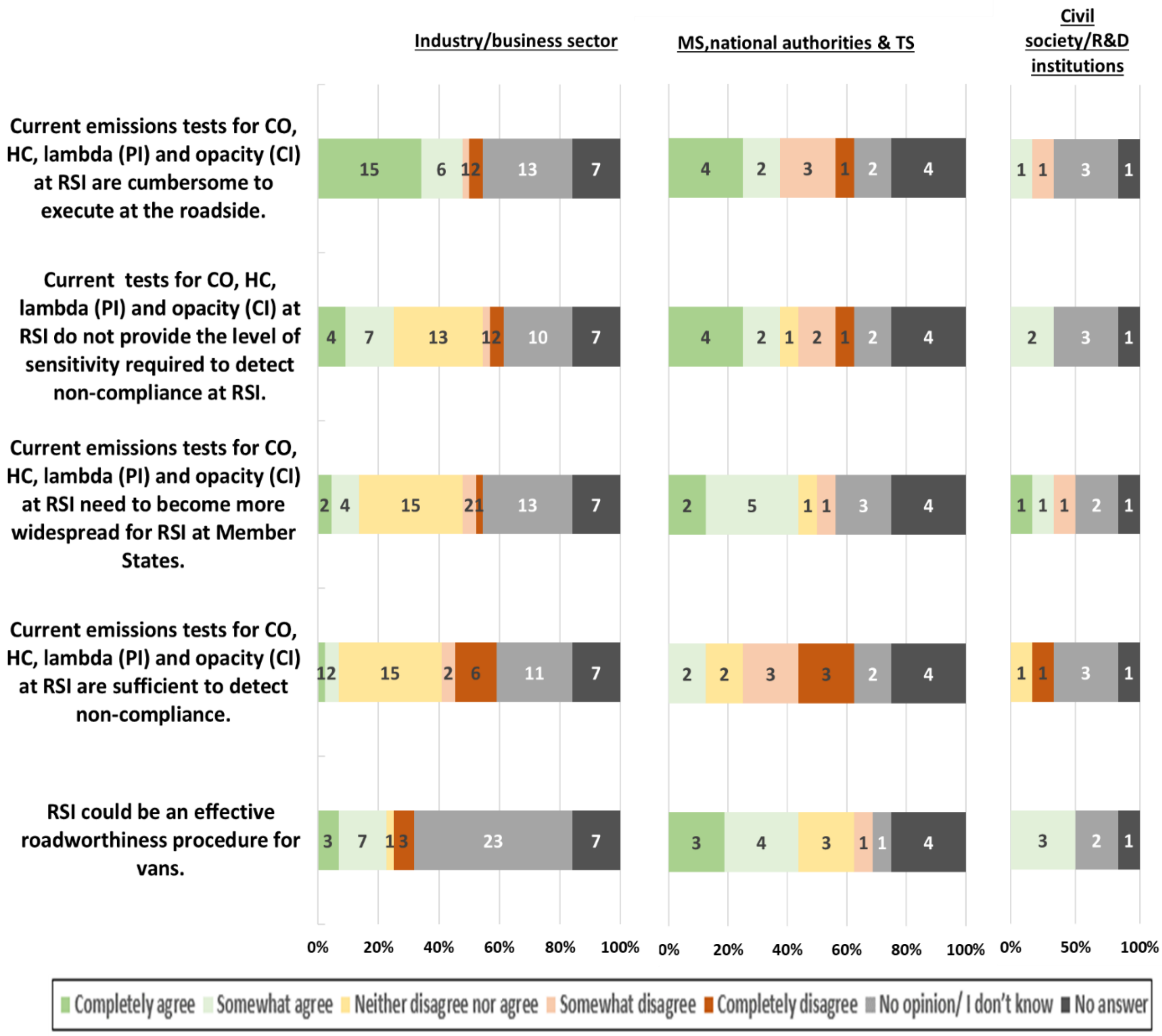
6. The purpose of periodic technical inspection (PTI) is to ensure the roadworthiness of vehicles during their lifetime. A minimum number of testing requirements needs to be followed in each Member State.

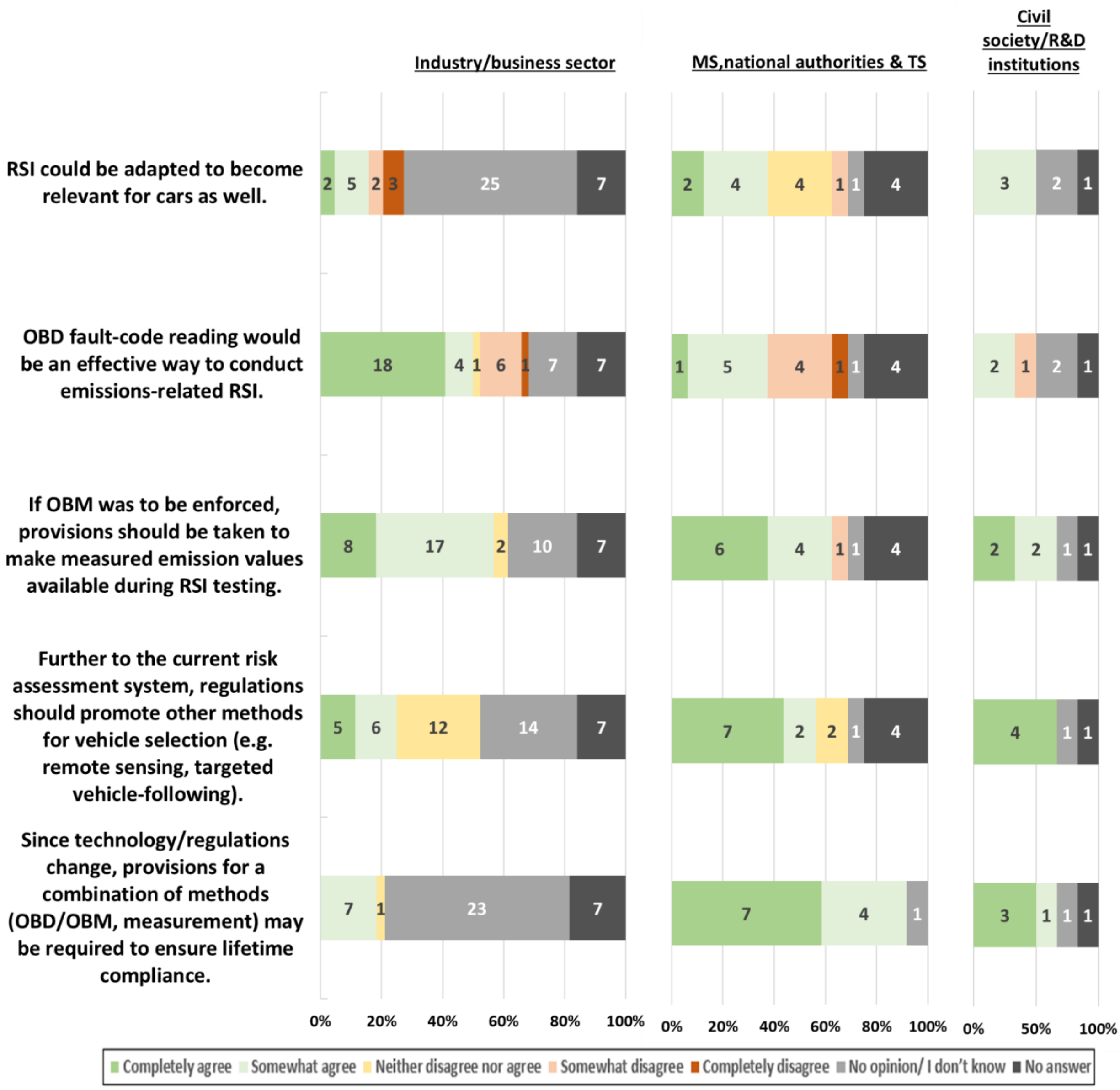
Please indicate the extent to which you agree with the following statements regarding emission-related aspects of PTI (Figure 9-26):


Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
OBD fault-code reading would be an effective way to conduct emissions PTI.
If OBM was to be enforced,PTI would be to read the relevant values and independently verify OBM system operation.
PTI can become much more effective for screening non-compliance if informed by other fleet screening methods (e.g. remote sensing, etc.)
Since technology/regulations change, provisions for a combination of methods (OBD/OBM, measurement) may be required to ensure lifetime compliance.
0%
20%
40%
60%
80%
100%
50%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
No opinion/ I don't know
No answer

7. The purpose of technical roadside inspection (RSI) currently is to complement PTI to ensure the roadworthiness of commercial vehicles. A minimum number of testing requirements needs to be followed in each Member State.

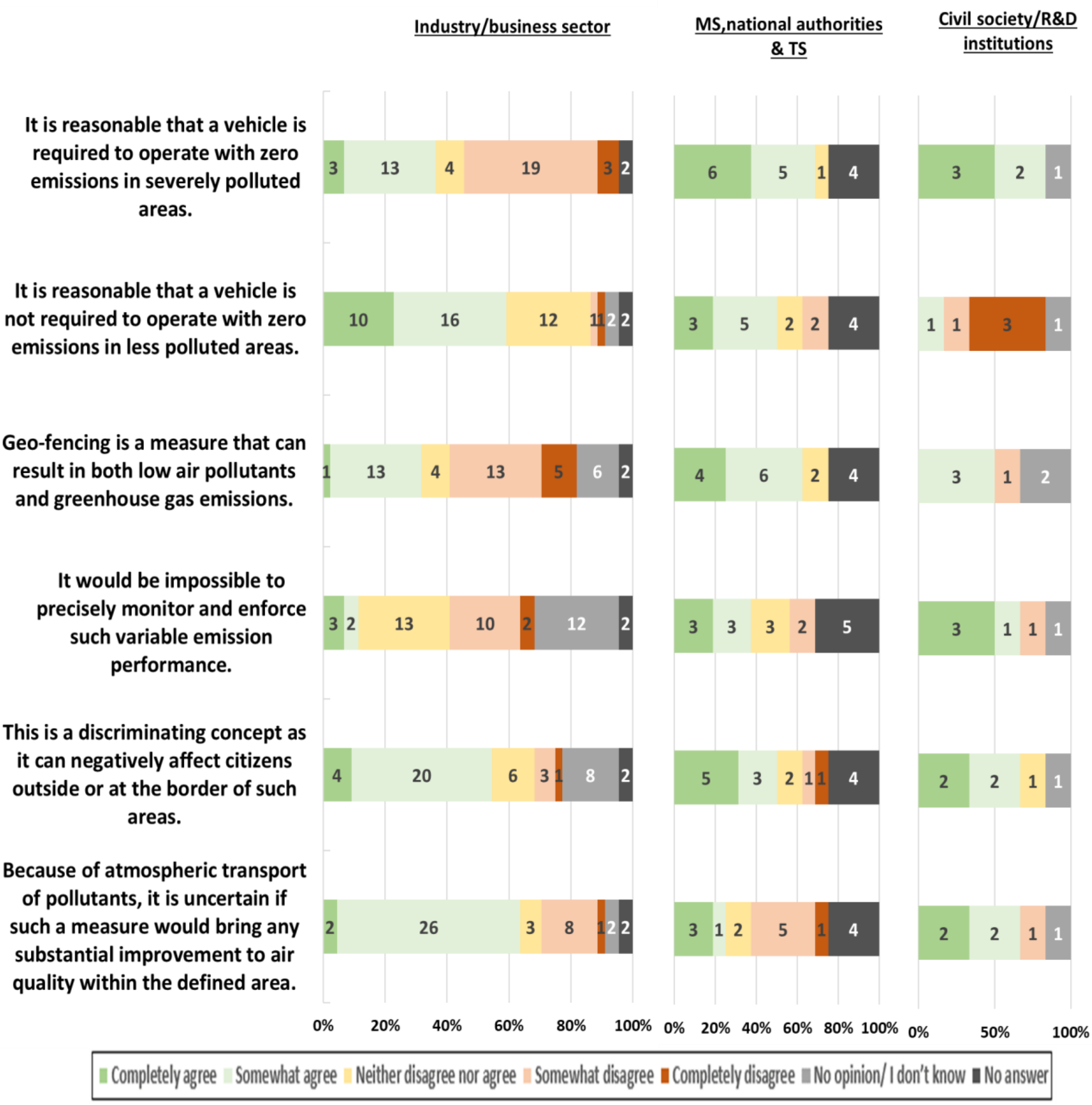
Please indicate the extent to which you agree with the following statements regarding emission-related aspects of RSI (Figure 9-27):




Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
RSI could be adapted to become relevant for cars as well.
OBD fault-code reading would be an effective way to conduct emissions-related RSI.
If OBM was to be enforced, provisions should be taken to make measured emission values available during RSI testing.
Further to the current risk assessment system, regulations should promote other methods for vehicle selection (e.g. remote sensing, targeted vehicle-following).
Since technology/regulations change, provisions for a combination of methods (OBD/OBM, measurement) may be required to ensure lifetime compliance.
0% 20% 40% 60% 80% 100%
0% 50% 100%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
No opinion/ I don't know
No answer

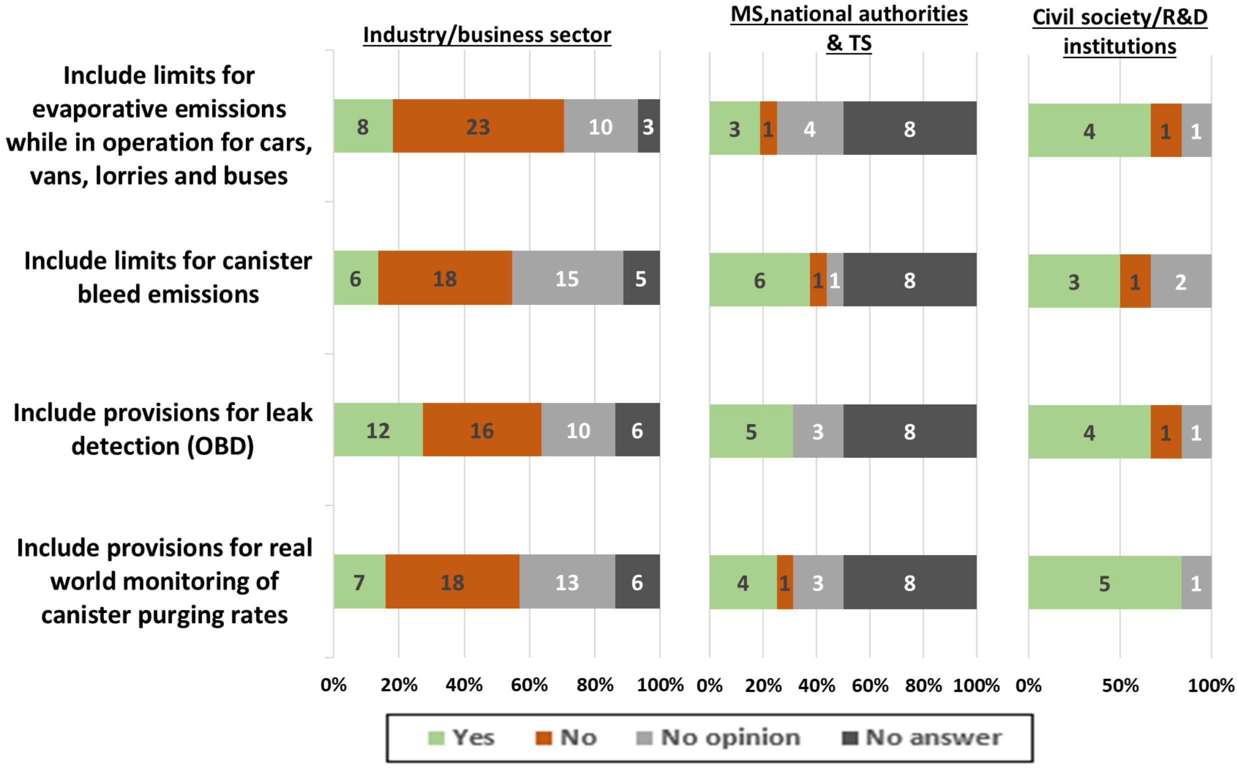
8. Introducing the concept of geo-fencing may be considered in order to bring about air quality benefits in severely polluted areas (e.g. city centres). In this case, vehicles would automatically shift to zero emissions performance when entering defined areas and return to their usual performance on leaving.

Please indicate the extent to which you agree with the following statements (Figure 9-28):

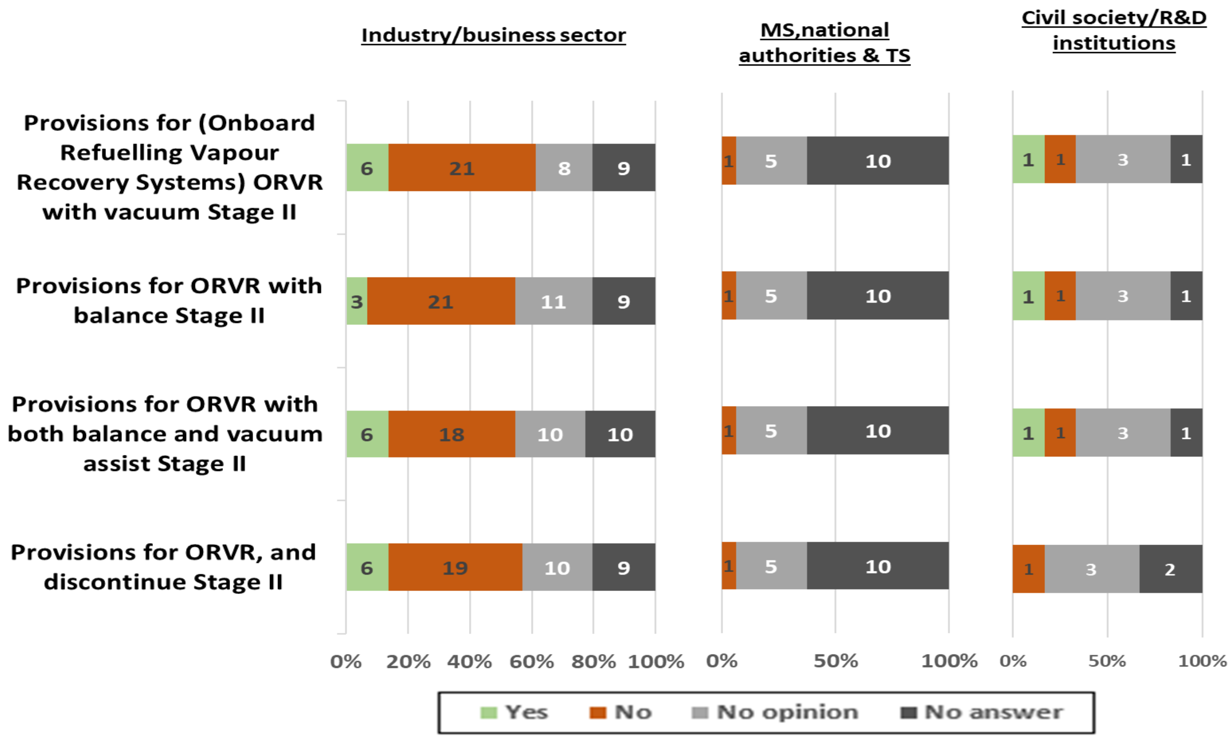


Evaporative emissions

9. While parked and in operation*:* Do you think post-Euro 6/VI vehicle emission standards should (Figure 9-29):



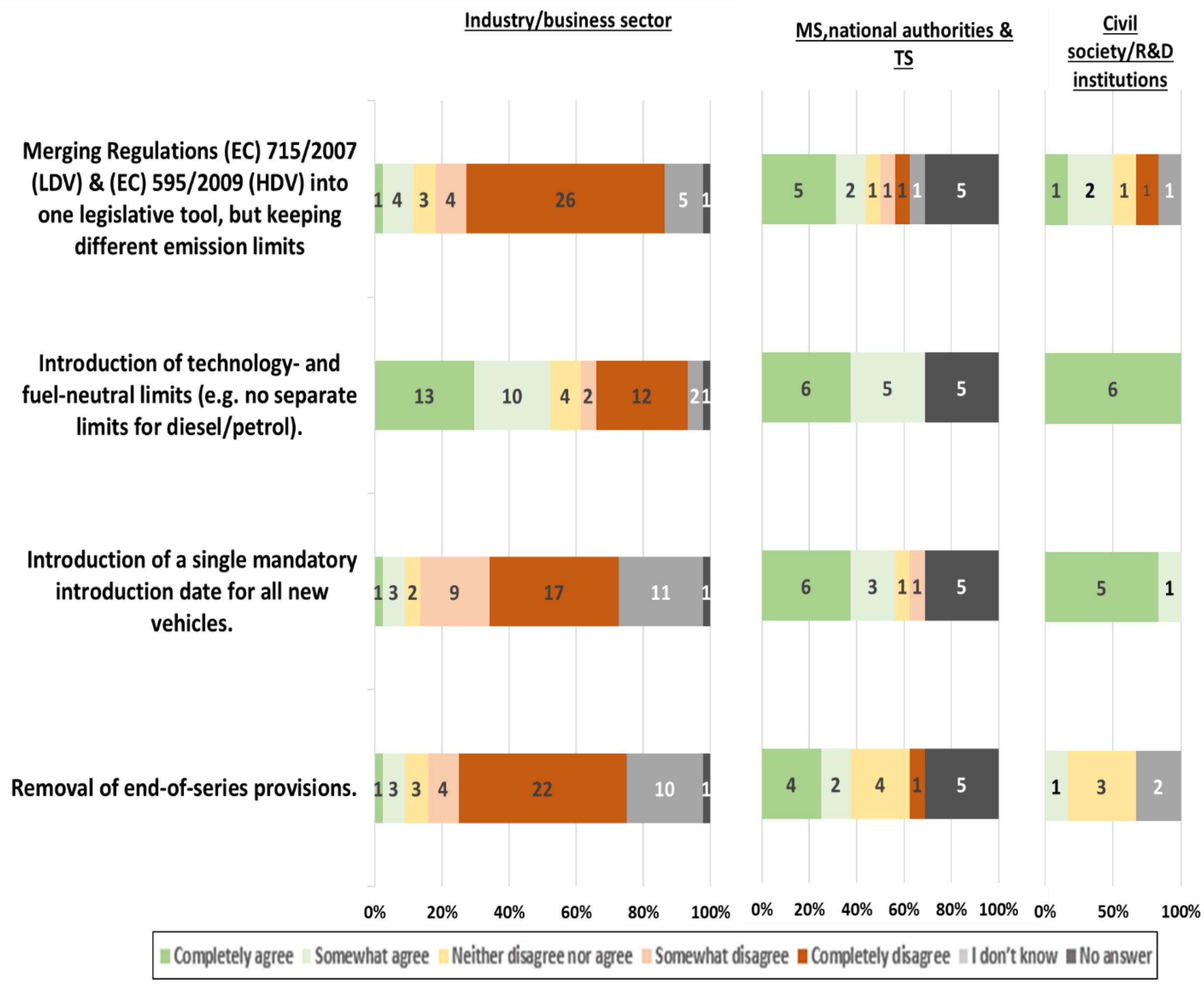
10. While refuelling: In your view, should post-Euro 6/VI vehicle emission standards including the following (Figure 9-30):

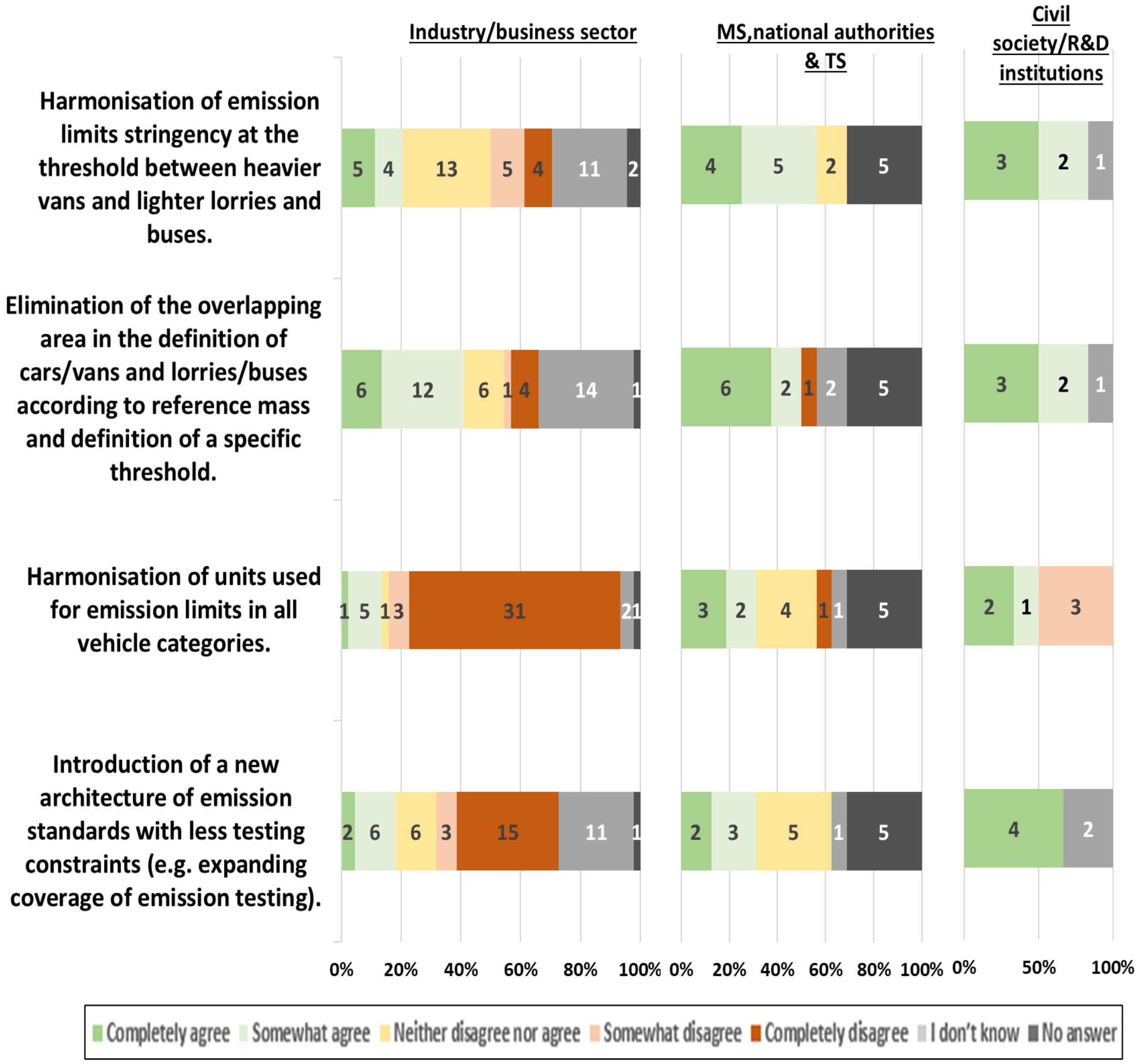


10.4. Simplification of vehicle emission standards architecture

11. Simplification through alignment: The following proposals are aimed at improving the alignment of the legislation for all vehicle categories and thus contributing to the simplification of the legislation.

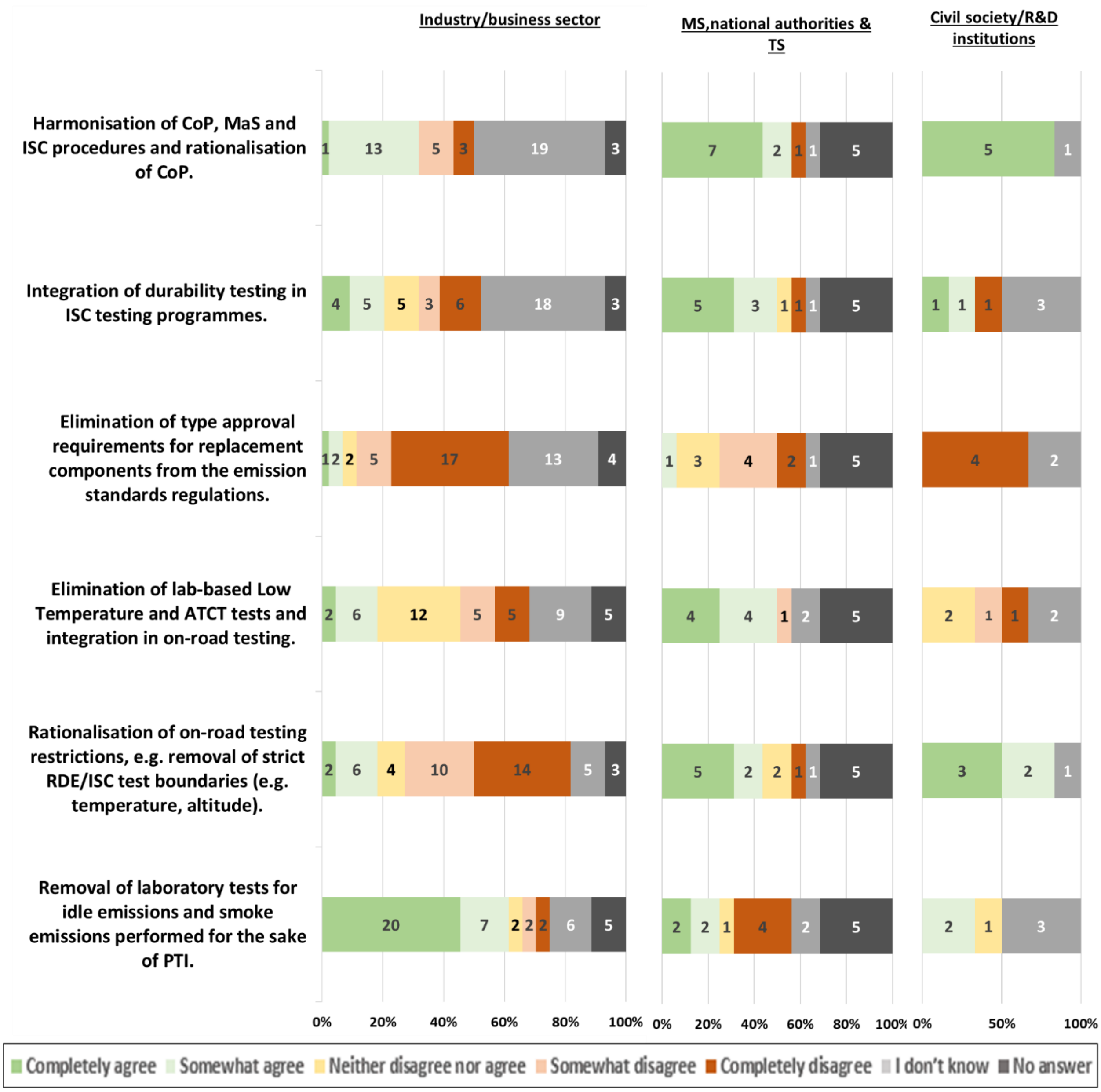
To what extent do you agree or disagree that the following proposals may contribute to simplification of the legislation (Figure 9-31):

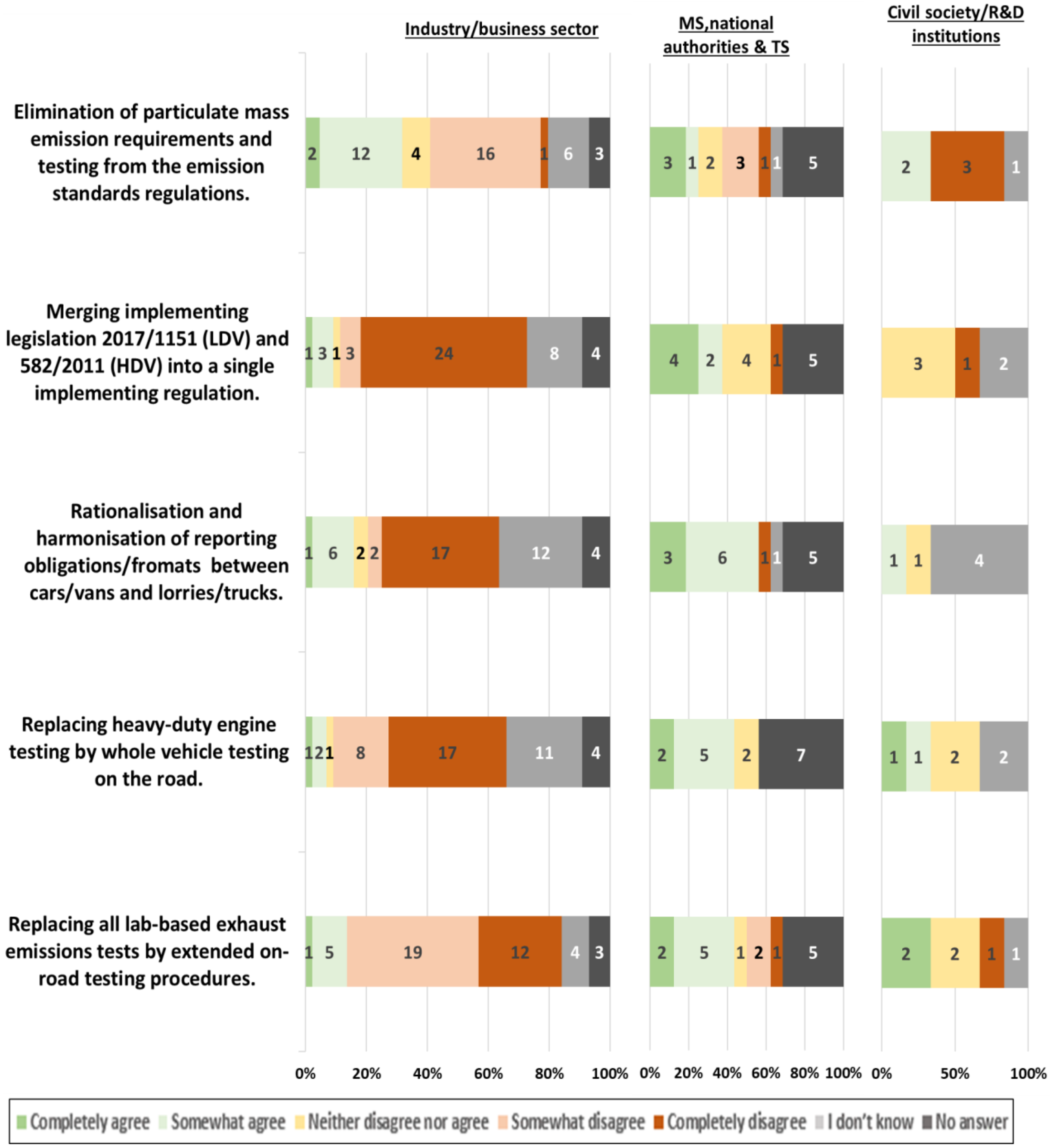



Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
Harmonisation of emission limits stringency at the threshold between heavier vans and lighter lorries and buses.
Elimination of the overlapping area in the definition of cars/vans and lorries/buses according to reference mass and definition of a specific threshold.
Harmonisation of units used for emission limits in all vehicle categories.
Introduction of a new architecture of emission standards with less testing constraints (e.g. expanding coverage of emission testing).
0% 20% 40% 60% 80% 100%
0% 50% 100%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
I don't know
No answer

12. Simplification by rationalisation of tests: The following proposals are aimed at the rationalisation of emissions testing and thus contributing to the simplification of the legislation, while keeping the ambition of its environmental goals.

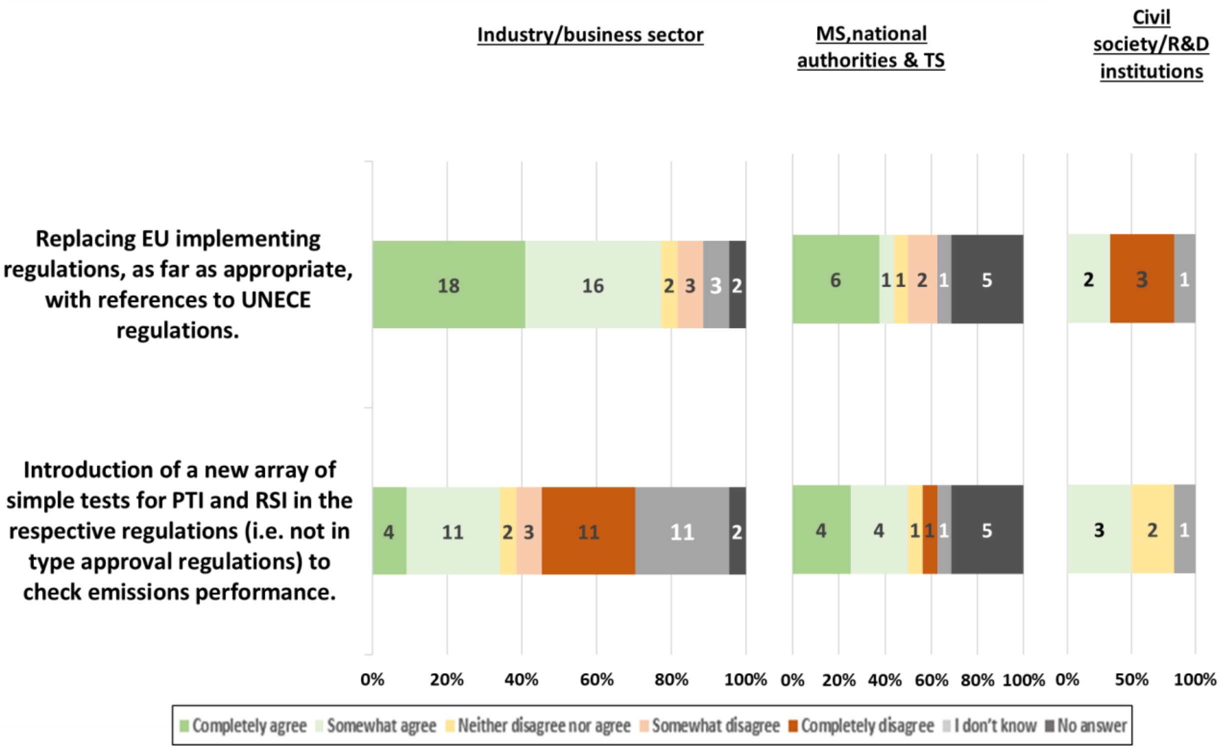
To what extent do you agree or disagree that the following proposals may contribute to simplification of the legislation (Figure 9-32)?




Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
Elimination of particulate mass emission requirements and testing from the emission standards regulations.
Merging implementing legislation 2017/1151 (LDV) and 582/2011 (HDV) into a single implementing regulation.
Rationalisation and harmonisation of reporting obligations/fromats between cars/vans and lorries/trucks.
Replacing heavy-duty engine testing by whole vehicle testing on the road.
Replacing all lab-based exhaust emissions tests by extended on-road testing procedures.
0% 20% 40% 60% 80% 100%
0% 20% 40% 60% 80% 100%
0% 50% 100%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
I don't know
No answer

13. Simplification by improved external consistency: The following proposals are aimed at improving the external consistency of the emission standards legislation (with UNECE, CO_2 standards, Roadworthiness) and thus contributing to the simplification of the legislation.

To what extent do you agree or disagree that the following proposals may contribute to simplification of the legislation (Figure 9-33)?



10.5. Technology choices to decrease vehicle emissions

Overall, there was limited input, especially on costs, coming mainly from the industry. Many industry stakeholders stated that it was difficult to provide:

Specific information on max potential of emission reduction and associated technology without first having defined the testing conditions and other requirements (durability, operation area, etc.)

Quantitative data for measurement range and costs of OBM system and without first having defined specific requirements and targets (e.g. operating frequency, monitoring strategy, accuracy, durability)

That said, certain stakeholders did provide limited information on technology packages that can potentially reduce pollutant emission levels, but under established testing conditions/procedures such as RDE and WLTP/WHTC testing, as dictated by current EU regulations (also the US FTP cycle). A synopsis of such technologies is presented in Table 9-72.

Table 9-72. Summary of technology trends to achieve lower pollutant emissions, according to questionnaire responses

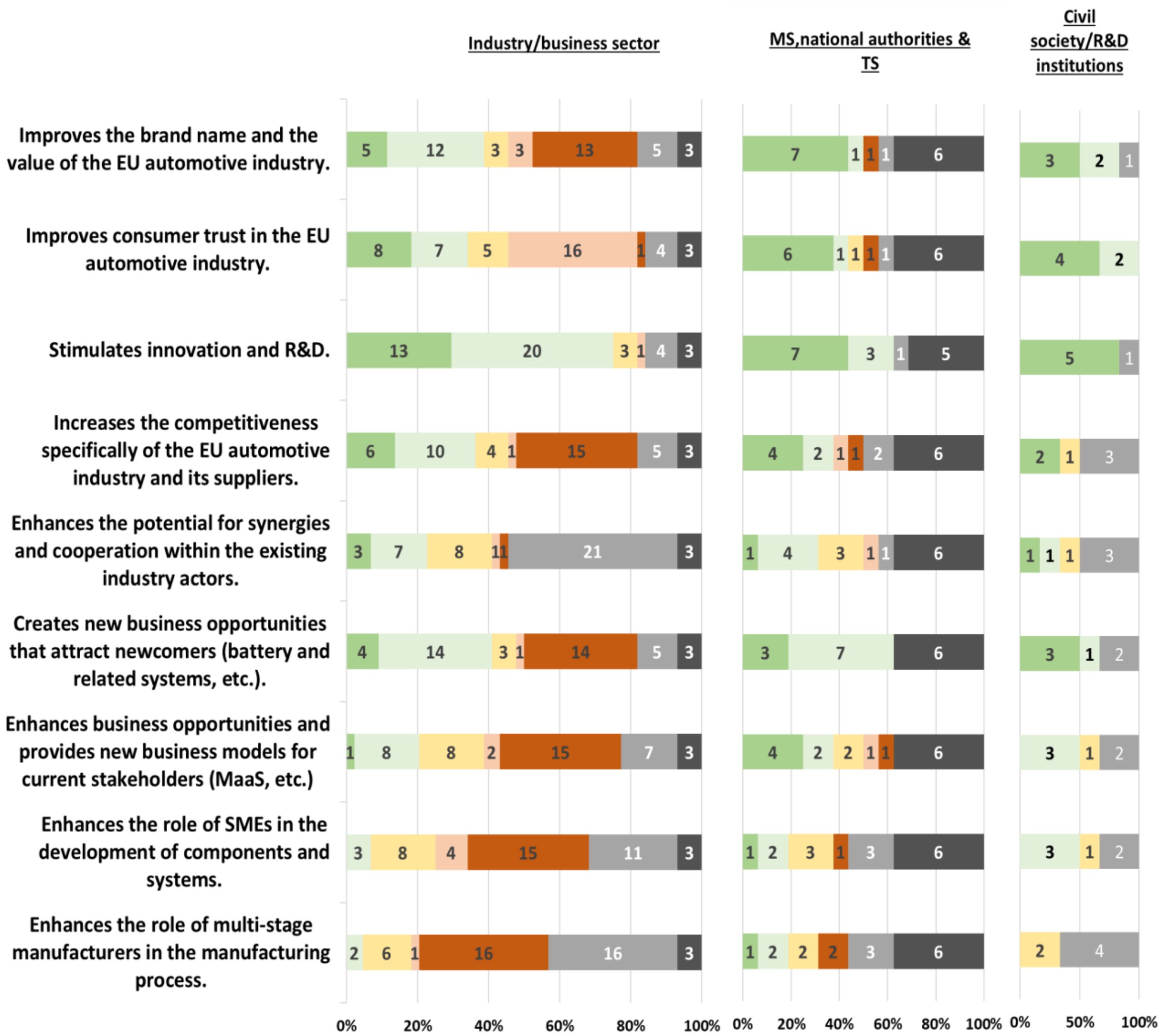
Cars/Vans		Lorries/Buses	
Gasoline	**Diesel**	**Diesel**	**NG/Other**
• larger TWC • EHC • close-coupled TWC + GPF • underfloor TWC • underfloor ASC • underfloor passive SCR • (GDI) engine optimisation • accurate lambda control • (mild) hybridization	• Close-coupled DOC/LNT + SCRF + SCR • underfloor SCR + ASC • twin urea injection • EHC • thermal management • control with sensors • (mild) hybridization	• Twin urea injection • double SCR • close-coupled (DOC + SCR/ASC) + underfloor (DOC + DPF + SCR + ASC) • HP EGR • Variable Geometry Turbo (VGT) • EHC on DOC or SCR • NH_3 sensor	no input

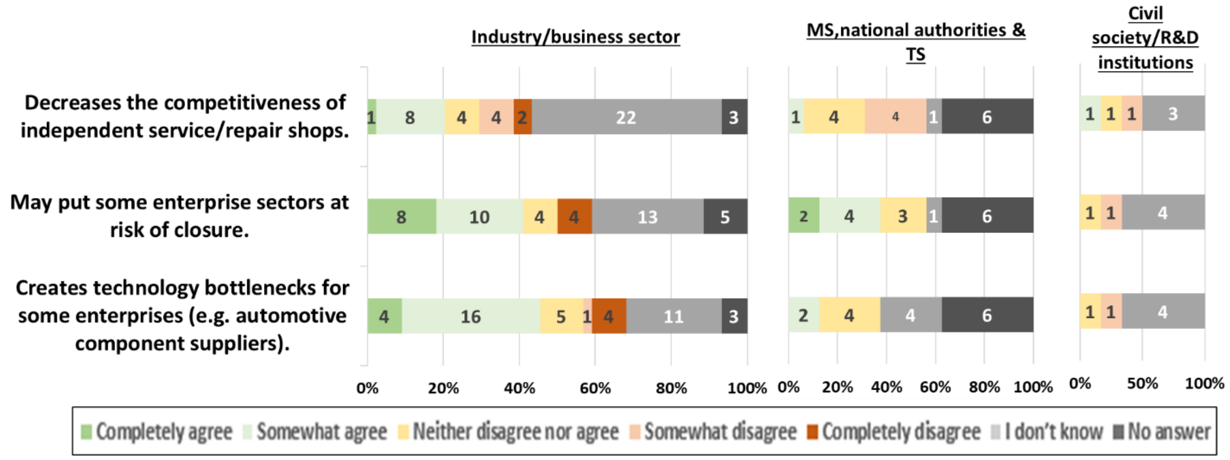
ASC	Ammonia Slip Catalyst
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EHC	Electrically-assisted Heated Catalyst
HP EGR	High Pressure Exhaust Gas Recirculation
LNT	Lean NOx Trap
OC	Oxidation Catalyst
SCR	Selective Catalytic Reduction
SCRF	SCR with a soot Filter
TWC	Three Way Catalyst

10.6. Other impacts of new vehicle emission standards

Business and industry

14. Please indicate to what extent you agree or disagree with the following statement(s) relating to how stricter post-Euro 6/VI vehicle emission standards may affect the relevant EU industry (Figure 9-34):

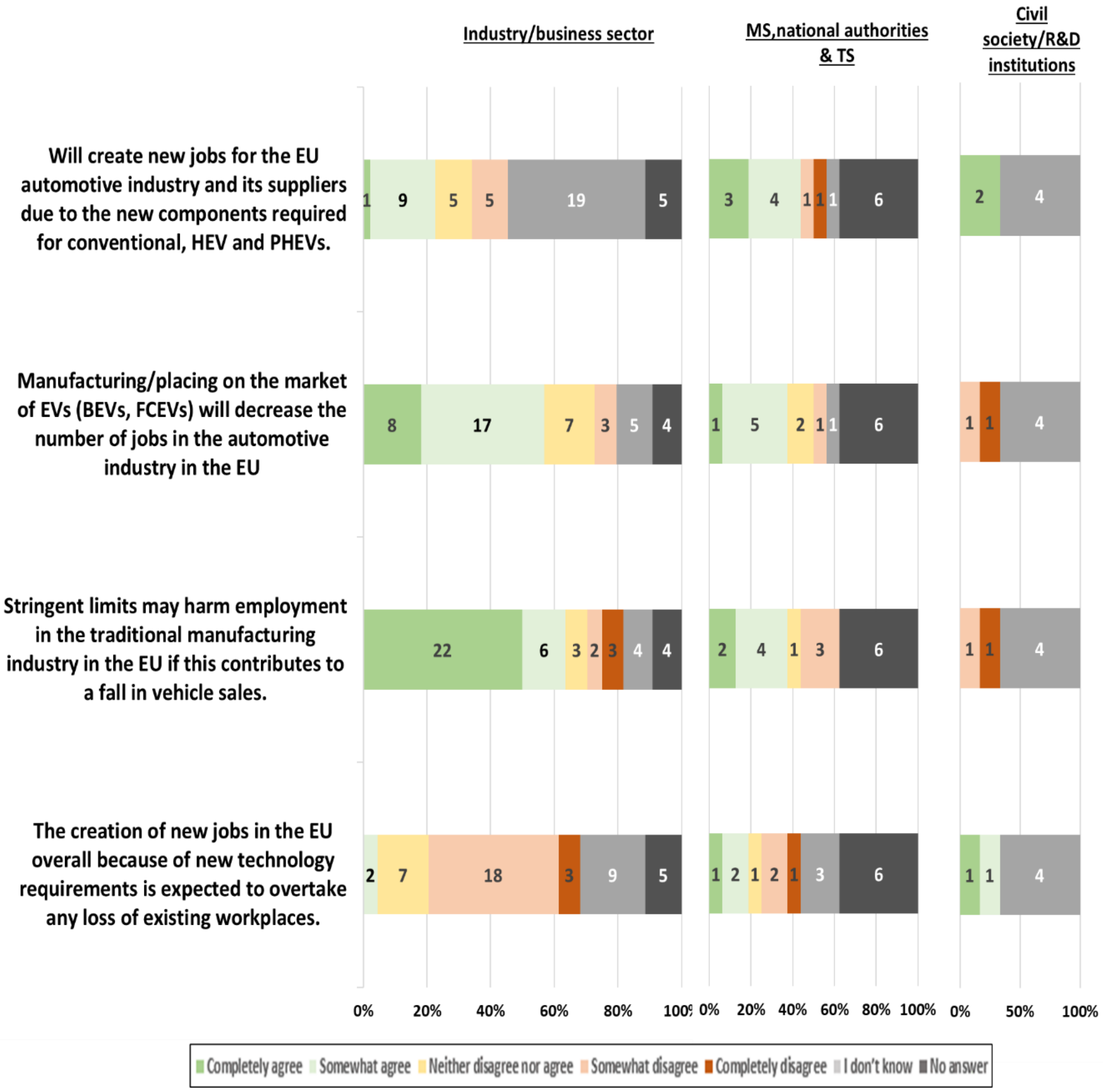


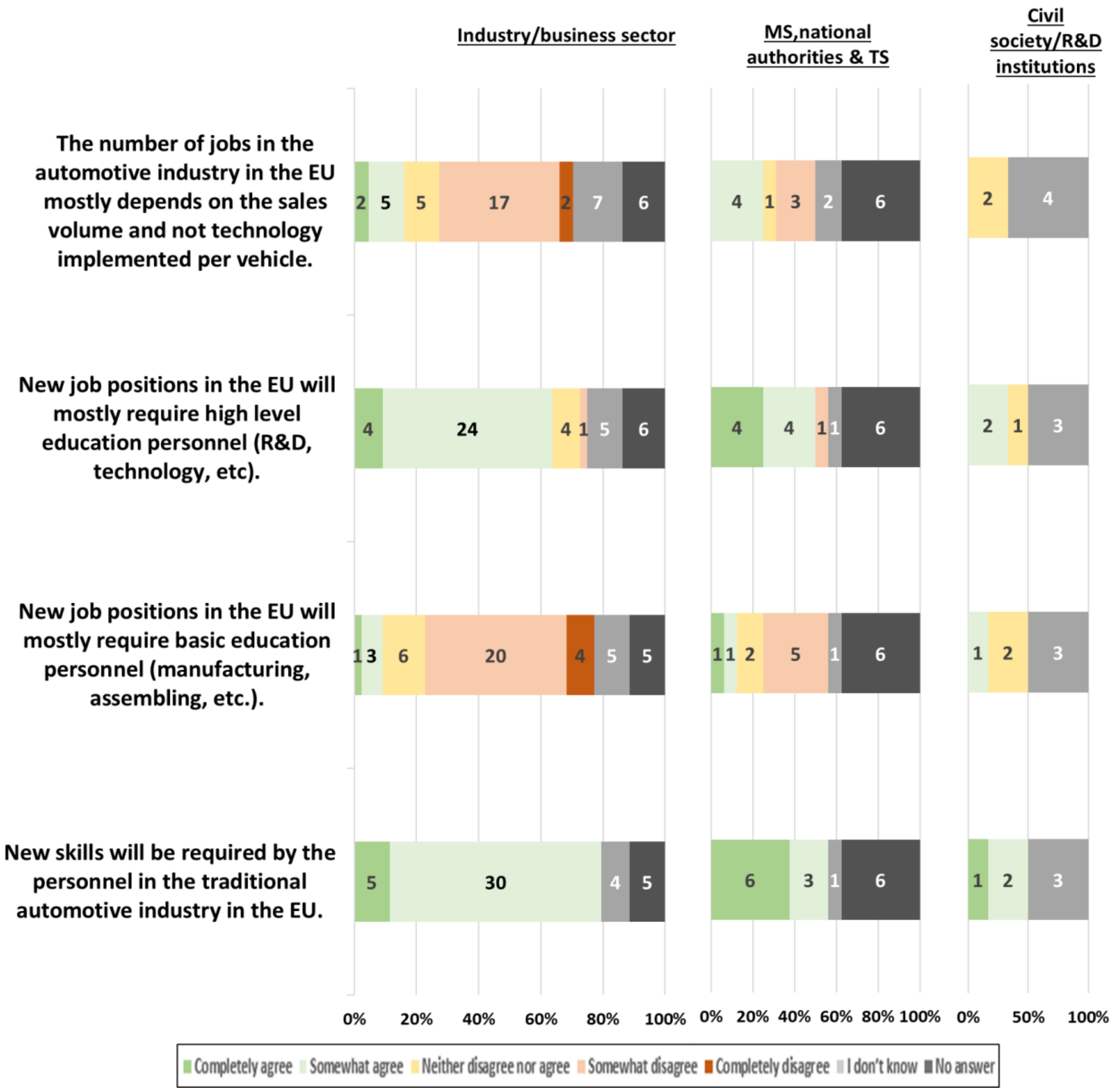


Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
Decreases the competitiveness of independent service/repair shops.
May put some enterprise sectors at risk of closure.
Creates technology bottlenecks for some enterprises (e.g. automotive component suppliers).
1 8 4 4 2 22 3
1 4 4 1 6
1 1 1 3
8 10 4 4 13 5
2 4 3 1 6
1 1 4
4 16 5 1 4 11 3
2 4 4 6
1 1 4
0% 20% 40% 60% 80% 100%
0% 20% 40% 60% 80% 100%
0% 50% 100%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
I don't know
No answer

Employment

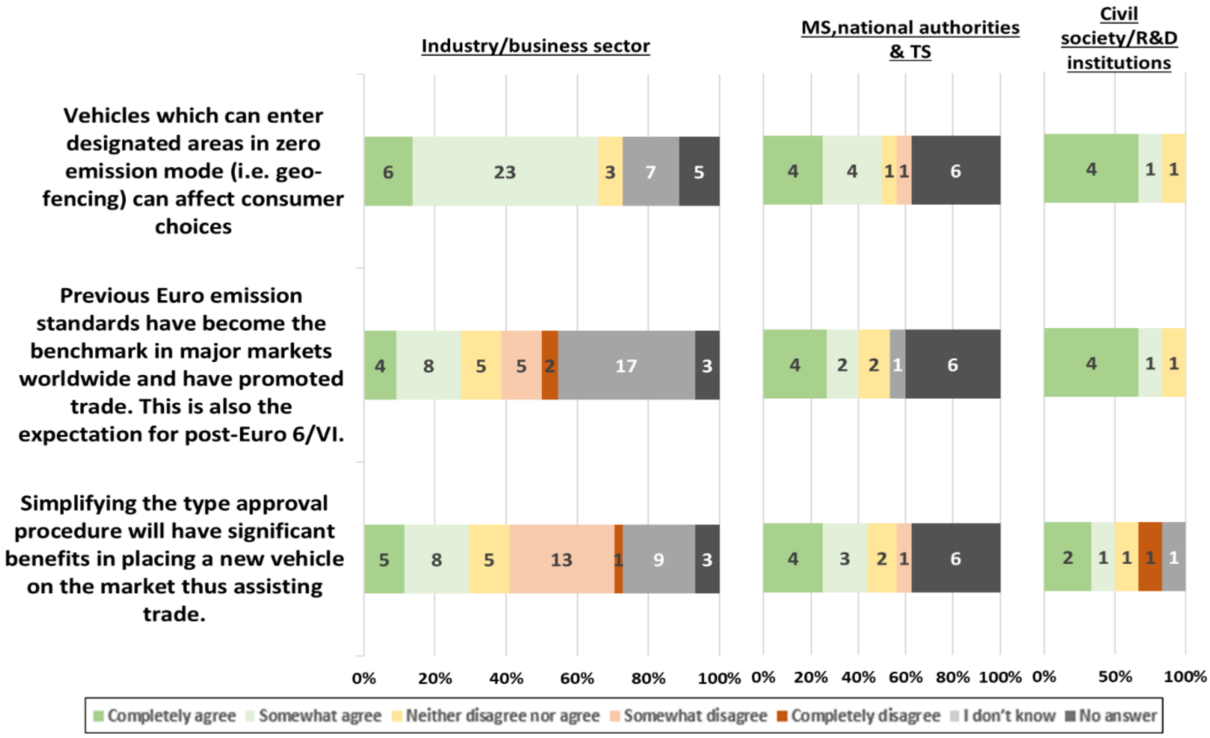
15. To what extent do you agree or disagree with the following statements relating to how employment in the EU may be affected by the introduction of a post-Euro 6/VI step in emission standards (Figure 9-35):




Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
The number of jobs in the automotive industry in the EU mostly depends on the sales volume and not technology implemented per vehicle.
New job positions in the EU will mostly require high level education personnel (R&D, technology, etc).
New job positions in the EU will mostly require basic education personnel (manufacturing, assembling, etc.).
New skills will be required by the personnel in the traditional automotive industry in the EU.
0% 20% 40% 60% 80% 100%
0% 20% 40% 60% 80% 100%
0% 50% 100%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
I don't know
No answer

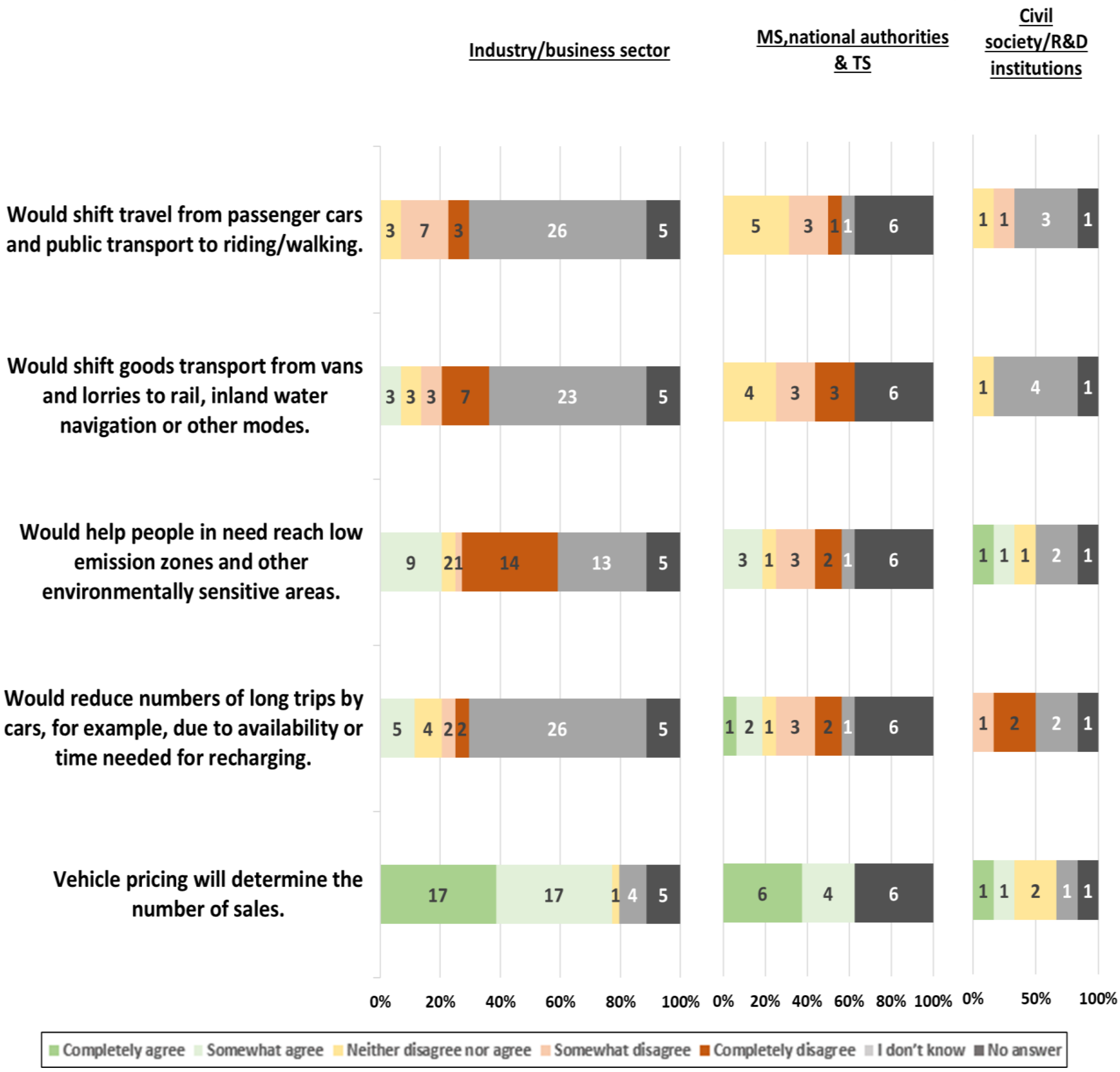
Trade and market

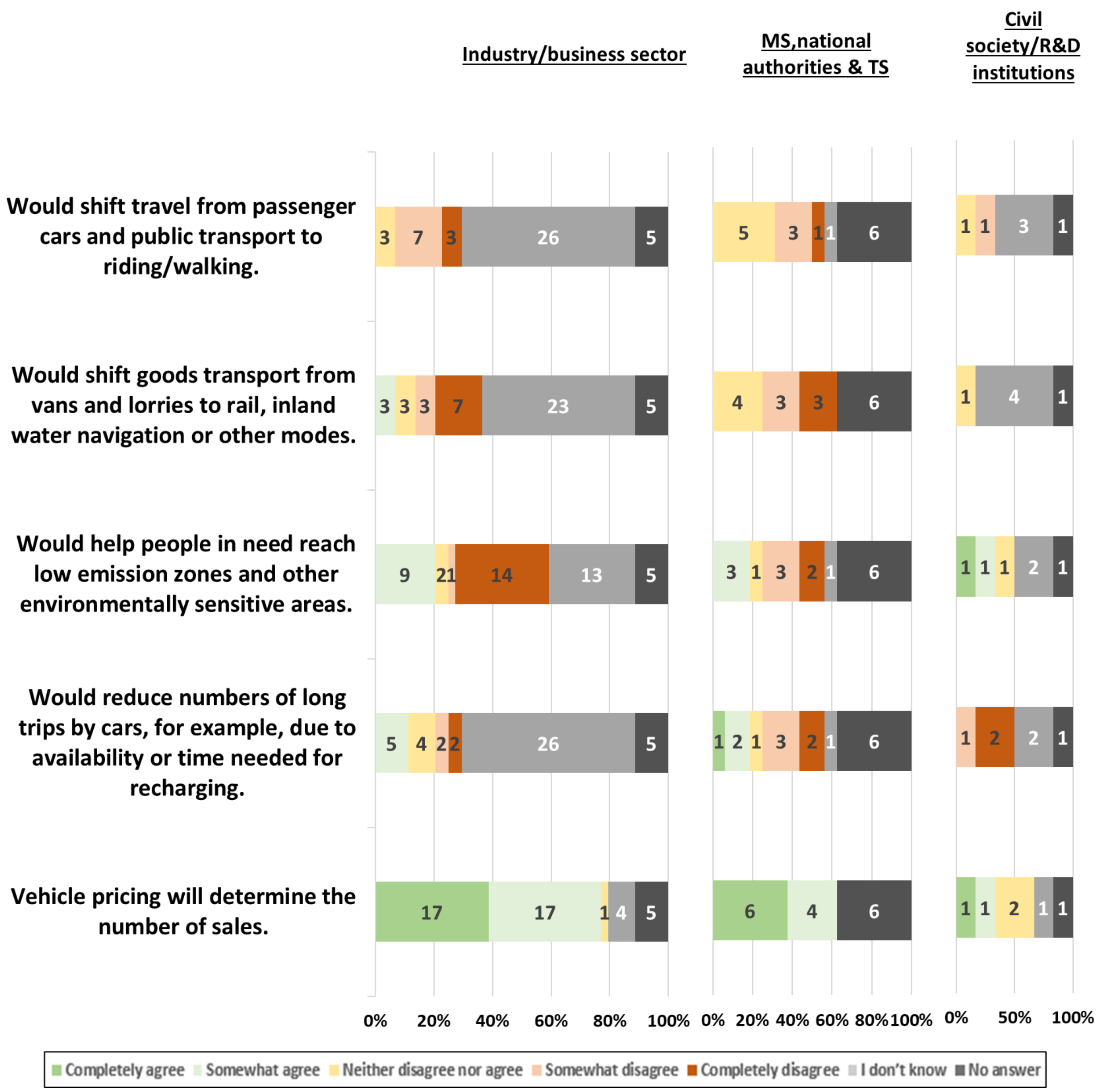
16. To what extent do you agree or disagree with the following statements relating to how employment in the EU may be affected by the introduction of a post-Euro 6/VI step in emission standards (Figure 9-36):


Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
Vehicles which can enter designated areas in zero emission mode (i.e. geo-fencing) can affect consumer choices
Previous Euro emission standards have become the benchmark in major markets worldwide and have promoted trade. This is also the expectation for post-Euro 6/VI.
Simplifying the type approval procedure will have significant benefits in placing a new vehicle on the market thus assisting trade.
6 23 3 7 5
4 4 1 1 6
4 1 1
4 8 5 5 2 17 3
4 2 2 1 6
4 1 1
5 8 5 13 1 9 3
4 3 2 1 6
2 1 1 1 1
0% 20% 40% 60% 80% 100%
0% 20% 40% 60% 80% 100%
0% 50% 100%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
I don't know
No answer

10.7. Expected Fleet and Activity Impacts of New Vehicle Emission Standards

17. Please indicate to what extent you agree or disagree with the following statements regarding the wide introduction in the market of clean(er) vehicles (Figure 9-37):




Industry/business sector
MS,national authorities & TS
Civil society/R&D institutions
Would shift travel from passenger cars and public transport to riding/walking.
Would shift goods transport from vans and lorries to rail, inland water navigation or other modes.
Would help people in need reach low emission zones and other environmentally sensitive areas.
Would reduce numbers of long trips by cars, for example, due to availability or time needed for recharging.
Vehicle pricing will determine the number of sales.
0%
20%
40%
60%
80%
100%
50%
Completely agree
Somewhat agree
Neither disagree nor agree
Somewhat disagree
Completely disagree
I don't know
No answer

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