BRIEFING

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An analysis on the revision of Europe's heavy-duty CO_2 standards

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INTRODUCTION

Europe's current CO_2 standards for heavy-duty vehicles (HDVs) require the emissions of most new trucks to be 15% lower by 2025 and 30% lower by 2030 compared to 2019 reporting period levels.[1] On February 14, 2023, the European Commission (EC) proposed to revise those standards.[2] The proposal would maintain the 2025 CO_2 reduction target and would raise the 2030 target to 45%, while introducing a 65% reduction target for 2035 and a 90% target for 2040. It would expand the scope of these standards to buses, coaches, trailers, and several new types of trucks. The revision also amends the compliance flexibilities of the original standards—phasing out some elements while introducing others. Finally, the proposal changes the definition of a zero-emission vehicle and the penalties for manufacturers.

Each of these amendments would impact compliance pathways for manufacturers, including technology uptake and the real emission reductions achieved. This briefing paper details the most significant proposed amendments and their implications for the heavy-duty sector's ability to achieve deep emission reductions.

1 European Commission, "Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 Setting CO2 Emission Performance Standards for New Heavy-Duty Vehicles and Amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC," *Official Journal of the European Union* L 198/202 (July 25, 2019), http://data.europa.eu/eli/reg/2019/1242/oj/eng. The 2019 reporting period of 2019 (as defined by (EU) 2018/956), runs from July 1, 2019 to June 30, 2020.

2 European Commission, "Proposal for a Regulation of the European Parliament and of the Council Amending Regulation (EU) 2019/1242 as Regards Strengthening the CO_2 Emission Performance Standards for New Heavy-Duty Vehicles and Integrating Reporting Obligations, and Repealing Regulation (EU) 2018/956," *Official Journal of the European Union*, February 14, 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A88%3AFIN.

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THE SCOPE OF THE STANDARDS

The current CO_2 standards apply to most new trucks (which were responsible for 69% of HDV CO_2 emissions in 2020[3] and 59% of HDV sales).[4] The proposed revision would extend the scope of standards to cover vehicles responsible for 91% of heavy-duty CO_2 emissions and 83% of sales. Figure 1 presents the vehicle segments covered by the current standards and the new segments covered by the proposal. Figure 2 presents the share of emissions from the unregulated vehicle types.

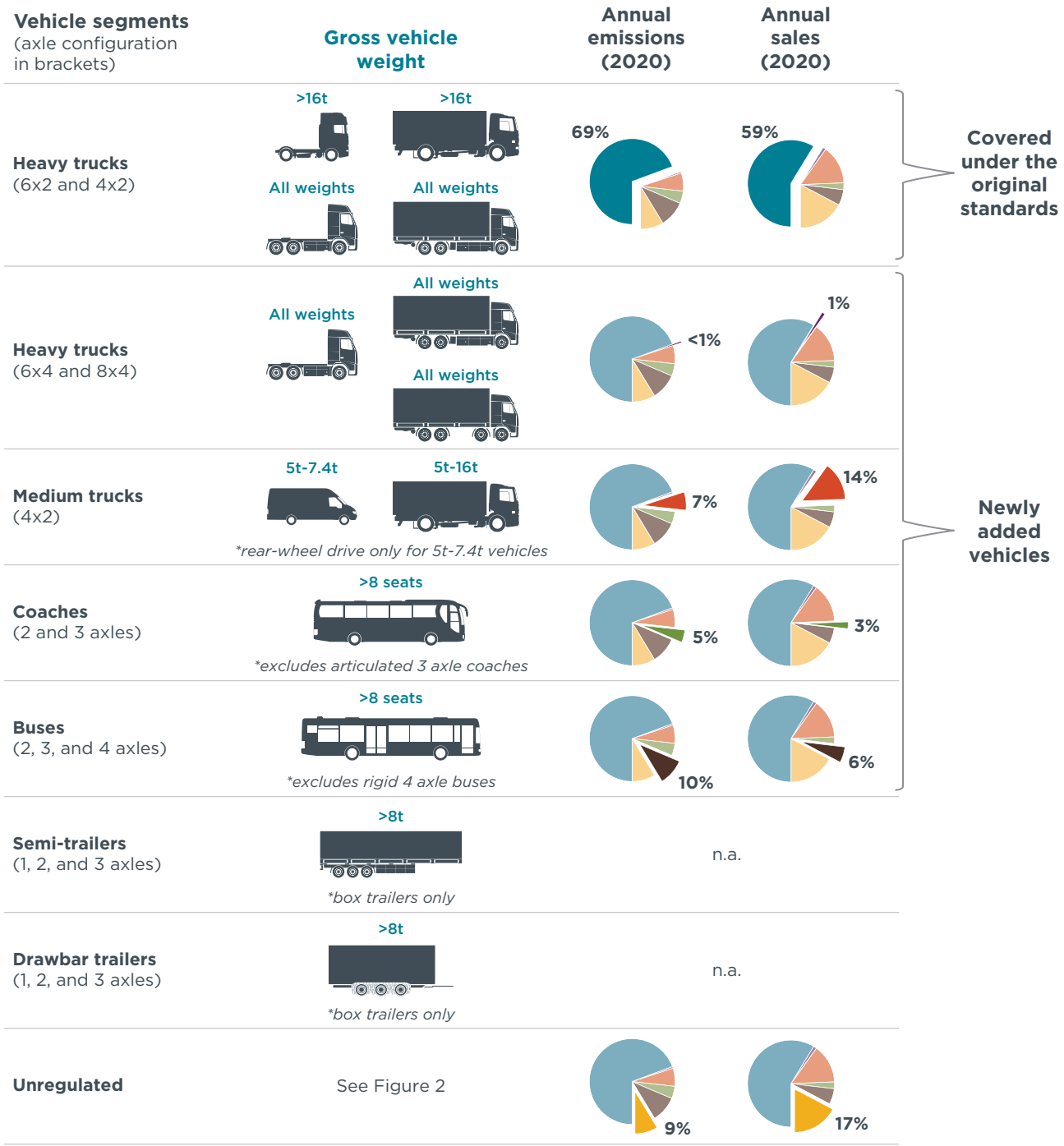

Figure 1. Scope of vehicles covered under the CO_2 standards and their annual emissions relative to all HDVs.

3 Based on modelling detailed in Eamonn Mulholland, Joshua Miller, Caleb Braun, Arijit Sen, Pierre-Louis Ragon, and Felipe Rodríguez, "The CO2 Standards Required for Trucks and Buses for Europe to Meet Its Climate Targets" (Washington, DC: ICCT, 2022), https://theicct.org/publication/hdv-co2standards-recs-mar22/.

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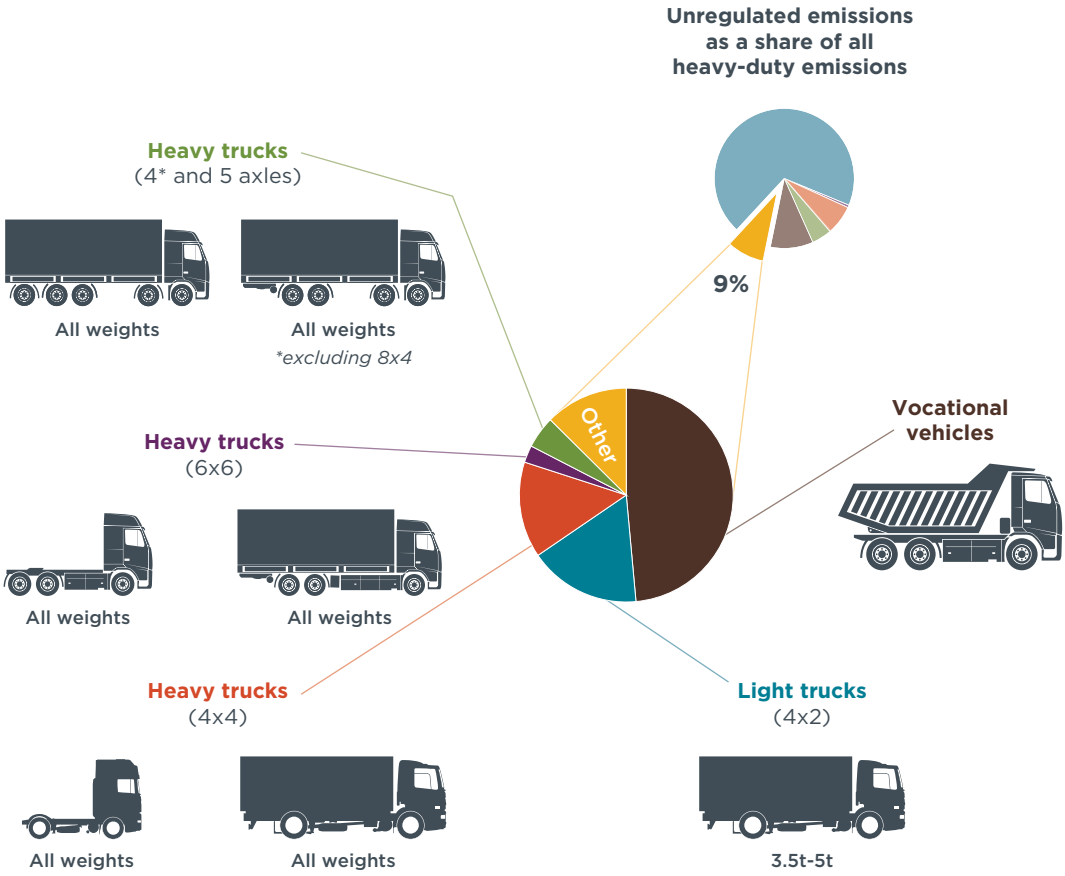

Figure 2. Unregulated vehicle types and their 2020 emissions share.

VOCATIONAL VEHICLES

Vocational vehicles are not covered by the CO_2 standards. These vehicles are broadly defined as not-for-delivery vehicles (e.g., refuse trucks, tipper trucks, and construction vehicles).[5] If a vehicle type shown in Figure 1 meets that definition, a manufacturer may report it as vocational and exclude it from standards. These vehicles that would have otherwise been covered by CO_2 standards if not reported as vocational account for approximately 4.5% of HDV emissions.[6]

The framework to extend the scope of the standards to cover vocational vehicles already exists. Vocational vehicles are the only unregulated vehicle type with requirements to monitor and report CO_2 emissions,[7] a precursor for any vehicle to be included in standards. All other unregulated vehicle types shown in Figure 2 do not meet this criterion and cannot be easily integrated into the CO_2 standards. Including vocational vehicles would increase the coverage of standards from 91% to 96% of all heavy-duty CO_2 emissions, and from 83% to 89% of all sales.

5 More specifically, a vocational vehicle is defined either as (i) HDV not intended for the delivery of goods who has a bodywork code 1, 9, 10, 15, 16, 18, 19, 20, 23, 24, 25, 26, 27, 28, 31 (definitions available in Appendix 2 of (EU) No 678/2011) or (ii) a tractor with a maximum speed not exceeding 79 km/h.

6 We assume that 1% of the currently regulated 4x2 and 6x2 trucks are vocational based on data reported to the European Environment Agency, "Monitoring of CO_2 Emissions from Heavy-Duty Vehicles," September 2, 2022, https://www.eea.europa.eu/data-and-maps/data/co2-emission-hdv. We also assume that 30–50% of 6x4 vehicles are vocational and 100% of 8x4 vehicles are vocational based on their mission profile declared in the Annex accompanying the proposal to the revision of the CO_2 standards.

7 In accordance with: EC, "Regulation (EU) 2022/1379 of the European Parliamant and of the Council of 5 July 2022 Amending Regulation (EU) 2017/2400 as Regards the Determination of the CO2 Emissions and Fuel Consumption of Medium and Heavy Lorries and Heavy Buses and to Introduce Electric Vehicles and Other New Technologies," *Official Journal of the European Union* L 212/1 (2022), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R1379&qid=1664295468190&from=en.

Some vocational vehicle types, such as refuse trucks, are already well poised for electrification, owing to their predictable routes, low mileages, and overnight depot storage. Several zero-emission vocational vehicles are already commercially available in Europe. Table 1 lists these vehicles.

Table 1. List of zero-emission vocational vehicles commercially available in Europe.

Manufacturer	Model	Axle configuration	Vocational type	Fuel Type	Battery size (kWh)	Fuel cell power (kW)	Zero-emission range (km)
BYD	EYT 4x2	4x2	Yard Tractor	BEV	217		
Eforce	EF26 KSF	6x4	Refuse collection	BEV	170-340		450
FAUN	Bluepower Garbage Collection	6x4	Refuse collection	FCEV	85	90	300–400
FRAMO	FRAMO Construction Industry	8x4	Concrete mixer	BEV			300
FRAMO	Municipal economy	6x4	Refuse collection	BEV			140
Hyzon	Econic Refuse Truck	6x4	Refuse collection	FCEV	55	110	200
Quantron	QHB Q-Heavy	6x4	Refuse collection	BEV	200/280		200
Renault	D Wide ZE	6x4	Refuse collection	BEV	200		180
Volvo	FMX electric heavy-duty truck	8x4	Concrete mixer	BEV	360		

BEV: battery electric vehicles; FCEV: fuel cell electric vehicle

RISKS OF EXCLUDING CERTAIN VEHICLE TYPES FROM THE SCOPE OF THE STANDARDS

Excluding vocational vehicles opens a potential loophole in the CO_2 standards. A manufacturer could produce a vehicle which meets the criteria to be registered as vocational (a flatbed truck, for example). After registration, the vehicle could lawfully be modified allowing it to be operated as a delivery vehicle (by fixing a box body to a flatbed truck, for example). This, in effect, provides a mechanism for a vehicle to avoid being covered by the CO_2 standards.

HDVs registered with a gross vehicle weight (GVW) of less than 5 tons are also exempt from the standards. While a manufacturer is constrained by the weights and dimensions directive[8] in the maximum GVW they can set, they have flexibility in certifying vehicles as lower than this maximum. A manufacturer could thus lower the weight of a vehicle to bring its GVW below this limit and exempt it from the standards. Vehicles with a high GVW are desirable to fleet operators, because they can transport a greater quantity of goods. A manufacturer that reports a vehicle to have a lower GVW than permitted may benefit from avoiding coverage by the CO_2 standards but risks a loss in competitiveness. In 2022, approximately 5,000 vehicles (1.5% of all HDV sales in 2022) that would be regulated by the CO_2 standards proposal had a GVW within 1 ton of the 5 ton threshold under which they would be unregulated (see Figure 3). Vehicles with a GVW below 5 tons are not easily integrated into the CO_2 standards as they are not required to report their emissions by the certification regulation.[9]

8 Council of the European Union, "Council Directive 96/53/EC of 25 July 1996 Laying down for Certain Road Vehicles Circulating within the Community the Maximum Authorized Dimensions in National and International Traffic and the Maximum Authorized Weights in International Traffic," *Official Journal of the European Union* L 235 (September 17, 1996): 59–75.

9 European Commission, "Regulation (EU) 2022/1379 of the European Parliament and of the Council of 5 July 2022 Amending Regulation (EU) 2017/2400 as Regards the Determination of the CO2 Emissions and Fuel Consumption of Medium and Heavy Lorries and Heavy Buses and to Introduce Electric Vehicles and Other New Technologies."

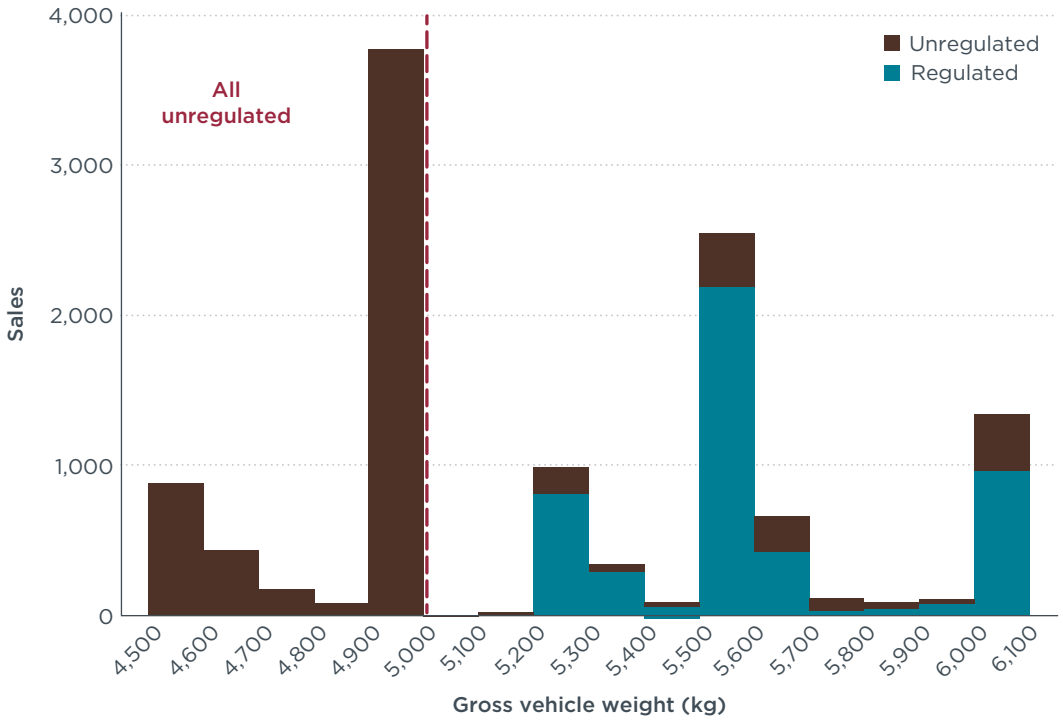

Figure 3. Histogram of gross vehicle weight in bins of 100 kg by sales in 2022. Only a small subset of weights are shown here to highlight the number of vehicles that are close to the 5,000 kg GVW threshold, under which all vehicles are unregulated. Most HDVs have a GVW higher than the values shown here.

PROPOSED NEW TARGETS

The average targets introduced by the revision are a 45% reduction by 2030, a 65% reduction by 2035, and a 90% reduction by 2040. These are averaged targets over trucks, coaches, and buses, but not trailers. The specific targets for each vehicle type differ from the average targets, as shown in Figure 4. The proposed revision to the standards does not explicitly detail how these average targets are determined from the specific targets, but we describe our understanding of their calculation (based on communications with the EC) in the Appendix.

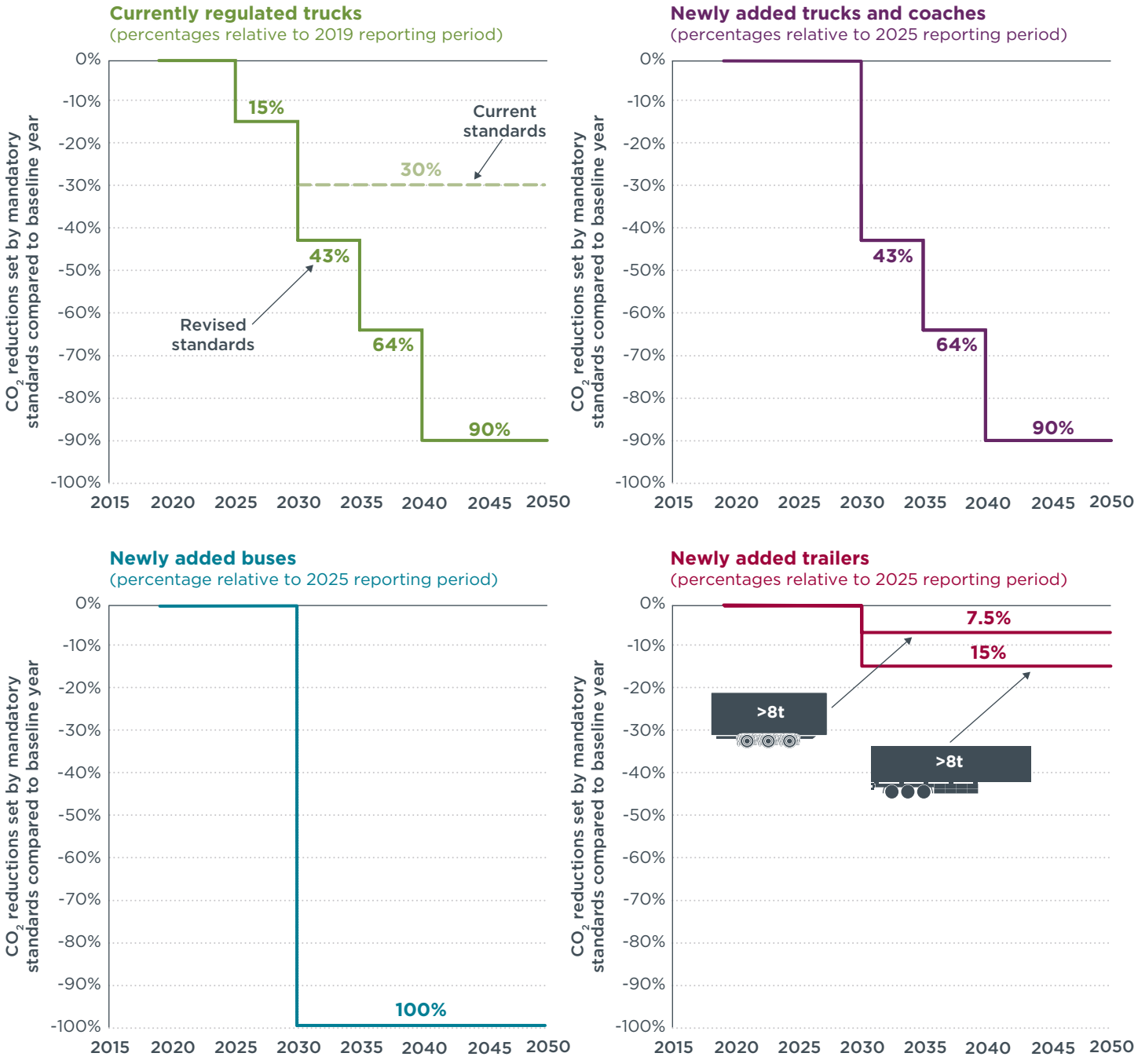

Figure 4. Specific targets for HDVs relative to their reporting period (the 2019 reporting period ran from July 2019 to June 2020; the 2025 reporting period will run from July 2025 to June 2026).

The specific targets are applied to bins of vehicles. Every bin covers multiple vehicle types based on their characteristics, also known as VECTO groups. These bins and their targets are outlined in Table 2.

Table 2. Vehicle bins defined in the Annex of the CO_2 revision, their corresponding VECTO group, vehicle characteristics, and their reduction targets by year.

	Vehicle bins	VECTO group	Gross vehicle weight (t)	Axle configuration	2025	2030	2035	2040
Currently regulated trucks	Heavy lorries >16 t with a 4x2 or 6x2 axle configuration	4-UD, 4-RD, 4-LH, 5-RD, 5-LH, 9-RD, 9-LH, 10-RD, 10-LH	>16	4x2, 6x2	15%	43%	64%	90%
Newly added trucks and coaches	Medium lorries	53, 54	>5 - ≤7.4	4x2 (rear wheel drive only)	0%	43%	64%	90%
	Heavy lorries > 7.4t and ≤ 16 t	1s, 1, 2, 3	>7.4 - ≤16	4x2	0%	43%	64%	90%
	Heavy lorries with special axle configuration	11, 12, 16	All weights	6x4, 8x4	0%	43%	64%	90%
	Completed coaches	32-C2, 32-C3, 32-DD, 34-C2, 34-C3, 34-DD	>3.5	2- and 3-axles	0%	43%	64%	90%
	Primary coaches		>3.5	2- and 3-axles	0%	43%	64%	90%
Newly added trailers	Semi-trailers	Many groups: specifically all groups up to 3 axles in Table 1, 4, and all groups in Table 6 of (EU) 2022/1362.	>8	1-, 2-, and 3-axles	0%	15%	15%	15%
	Drawbar trailers		>8	1-, 2-, and 3-axles	0%	7.5%	7.5%	7.5%
Newly added buses	Urban heavy buses	31-LF, 31-L1, 31-DD, 31-LF, 33-L1, 33-DD, 35-FE, 39-FE, 31-L2, 33-L2	>3.5	2-, 3-, and 4-axles	0%	100%	100%	100%

Note: A primary coach is the chassis and powertrain of the vehicle, while the completed coach also includes the bodywork. Coaches and buses are more frequently handled by multiple manufacturers, some who manage the primary stage and others who manage the completed stage which is why the distinction is made here.

In general, every manufacturer is required to reduce the average emissions of all vehicles falling under each VECTO group by the target in their respective bins. Compliance is measured on a fleet-wide basis, allowing manufacturers to overachieve in a certain VECTO group and underachieve in another. Compliance is also measured separately for passenger vehicles (i.e., buses and coaches) and freight vehicles (i.e., trucks and trailers), so it is not possible for manufacturers to rely on low emitting buses to offset high emitting trucks.

In the proposal, all newly added truck and coach bins follow the same targets, as outlined in Figure 4. However, the proposal includes a framework for differentiated targets. For example, a less stringent target could be applied to heavier lorries with a special axle configuration, while a more stringent target could be concurrently applied to medium lorries.

THE PROPOSED NEW REFERENCE PERIOD

The targets for newly added vehicles (see Figure 1) will be based on emissions monitored over the 2025 reporting period. For currently regulated vehicles, the reference period remains based on the 2019 reporting period.

It would be in the interest of manufacturers to create high baseline emissions in new reference period, as it would ease the effort required to meet their targets. To avoid this, the EC released an implementing regulation in 2020 to verify data reported in the baseline period and apply corrective measures, as necessary, whereby the input values provided by manufacturers into the simulation tool VECTO (which calculates

vehicle emissions) are crosschecked against those provided by the Member States.[10] In effect, this means the EC will monitor data reported in 2025, as it did in 2019, to ensure reported CO_2 emissions have not been artificially inflated.

THE PROPOSED TARGET FOR CITY BUSES

City buses have a proposed target of a 100% reduction for 2030 onward. While there are some limited exceptions to this target (discussed later), it effectively means all new city bus registrations are required to be zero-emission from 2030 onward.

City buses already have a high share of zero-emission vehicles (see Figure 5). The share increased from 9% in 2021 to 18% in 2022.[11] Ongoing investments from several legacy manufacturers alongside new entrants into the market have increased the availability of zero-emission buses in Europe. Notably, several Chinese manufacturers that focus solely on zero-emission vehicles have begun to get a foothold in the European market in recent years. In 2022, Yutong sold the largest number of zero-emission buses of any manufacturer (10% share of all zero-emission buses) followed by BYD (also a 10% share). To secure the supply for net-zero technologies within the European Union, the revision to the CO_2 standards stipulates authorities must award public contracts based on this criteria[12] with a weighting of 15%–40%. The remainder of the weighting is given to the best price-value ratio.

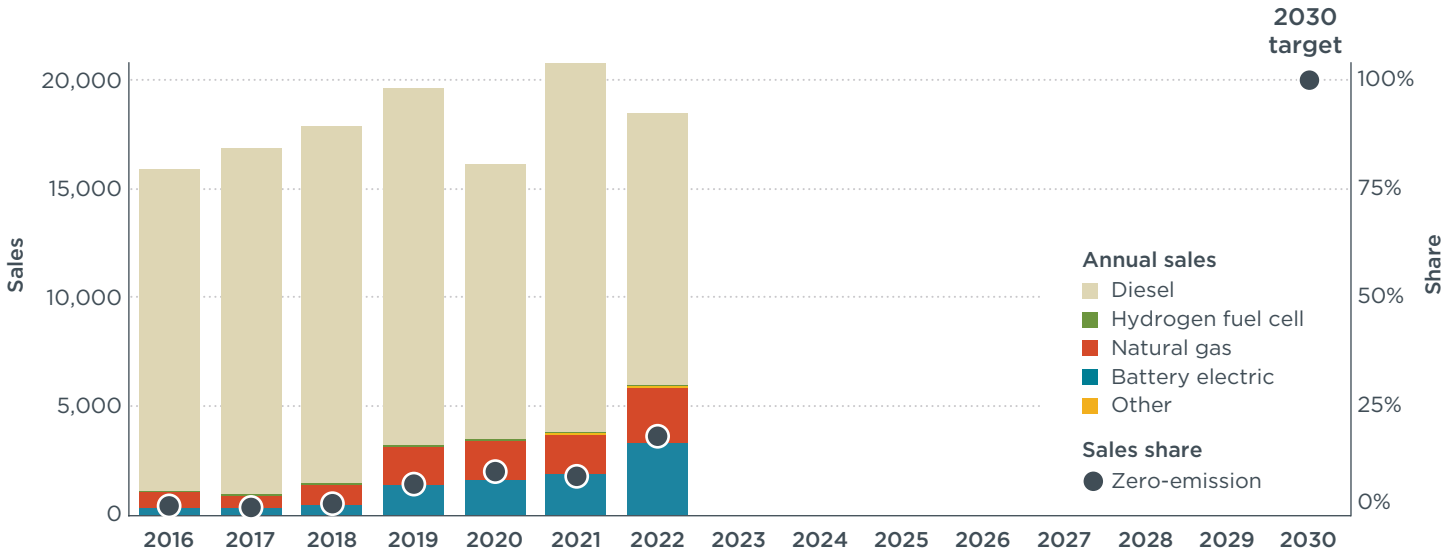

Figure 5. Sales (bars, left axis) and shares (crosses, right axis) of city buses in Europe by fuel type and year between 2016 and 2022.

PROJECTED EMISSIONS REDUCTIONS

The proposed regulation would avoid 1.8 billion tons of CO_2 through 2050. By 2050, annual emissions are projected to be 159 million tons of CO_2 lower than 2020, or a 64% reduction relative to 1990, as shown in Figure 6. To arrive at these projections, we apply the targets outlined in the proposal to the same modeling framework as described

10 European Commission, "Commission Implementing Regulation (EU) 2020/1079 of 20 July 2020 on the Verification and Correction of Data Referred to in Regulation (EU) 2018/956 on the Monitoring and Reporting of CO_2 Emissions from and Fuel Consumption of New Heavy-Duty Vehicles," *Official Journal of the European Union* L 235/1 (July 20, 2020), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R1079&from=EN.

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12 The security of supply is based, in part, on the proportion of products or tenders originating in third countries, the introduction by third countries of restrictive or distortive measures, and the availability of essential spare parts for the functioning of the equipment.

by a previous ICCT analysis.[13] All buses, coaches, and medium trucks experience a decarbonization of 86% over the 30-year period, while heavy trucks reduce emissions by 68%.[14]

We also modeled the impact of two scenarios considered by the Impact Assessment accompanying the proposal, *Target Level Medium* (TL_Med) and *Target Level High* (TL_High). TL_Med proposed targets of 40% in 2030, 60% in 2035, and 80% in 2040. TL_High proposed targets of 50% in 2030, 70% in 2035, and 100% in 2040. A lower zero-emission target of 80% for buses by 2030 was also considered in the Impact Assessment, which we integrate with the TL_Med scenario. There were no additional trailer targets proposed, so there is no variation in these targets across all scenarios.

Under TL_Med, an annual emission reduction of 52% is achieved in 2050 relative to 1990, and an additional 301 million cumulative tons of CO_2 would be emitted over the 2020-2050 period relative to the proposal, or a 17% increase over the 1.8 billion tons avoided in the proposal. Under TL_High, the annual emissions reduction relative to 1990 increases to 79% by 2050, and there would be a reduction in cumulative emissions of 373 million tons relative to the proposal, or a 20% additional reduction compared to the 1.8 billion tons avoided in the proposal.

In contrast, the EC has proposed the target for all transport to be reduced by 90% by 2050, relative to 1990.[15] Our previous assessment showed that a 98% reduction is necessary from the heavy-duty sector to contribute its equitable share towards this target.[16]

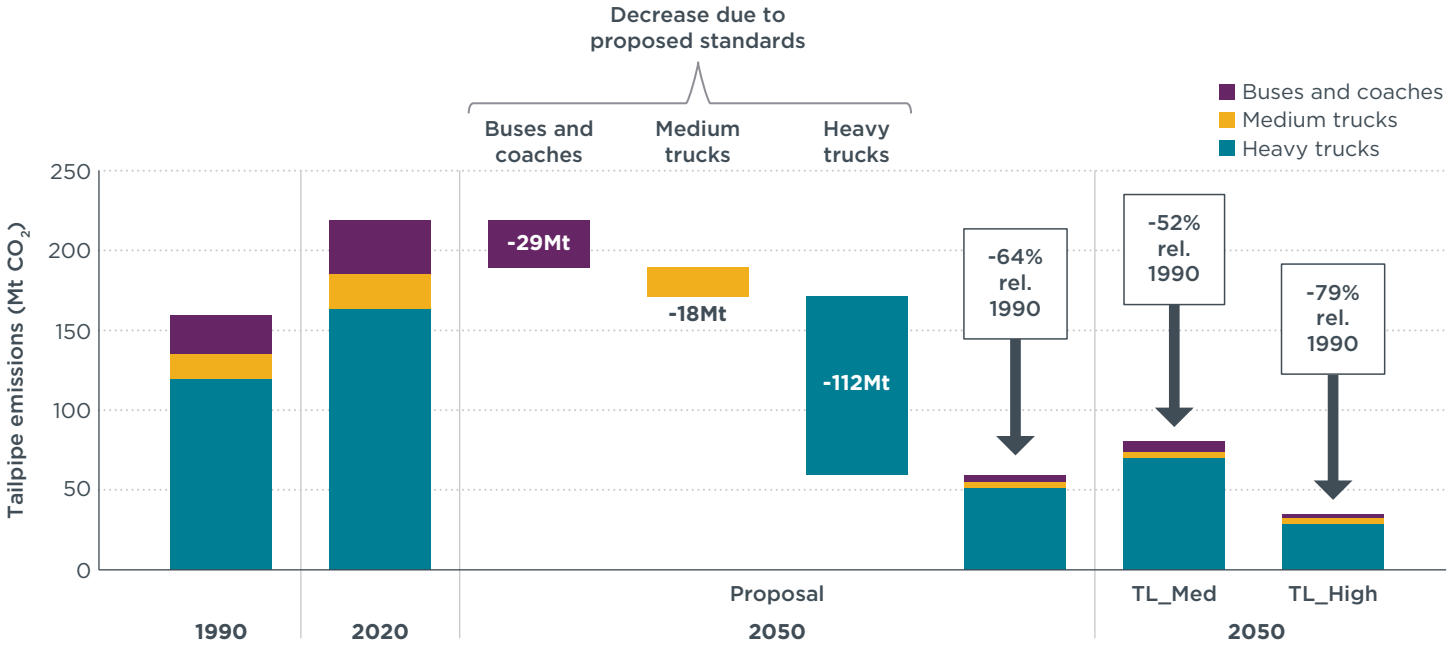

Figure 6. Projections of annual emissions under the proposed revision to the CO_2 standards; reductions due to the TL_Med and the TL_High scenarios outlined in the accompanying Impact Assessment are shown on the right-hand side.

13 Mulholland, Miller, Braun, Sen, Ragon, and Rodríguez,, "The CO_2 Standards Required for Trucks and Buses for Europe to Meet Its Climate Targets."

14 Medium trucks are defined here as vehicles with a GVW between 5–16 t. Heavy trucks have a GVW more than 16 t.

15 European Commission, "EU Sustainable and Smart Mobility Strategy," 2020, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12438-Sustainable-and-Smart-Mobility-Strategy.

16 "The CO_2 Standards Required for Trucks and Buses for Europe to Meet Its Climate Targets."

The total stock of zero-emission trucks and buses projected under the proposal is outlined in Figure 7. We assume these values to represent battery-electric vehicles only and deal with the potential role of hydrogen fueled vehicles in a later section.

Under the proposal, there will be a stock of 675,000 zero-emission HDVs on the road by 2030; roughly two thirds of these would be trucks and the remaining third buses. Under the Sustainable and Smart Mobility Strategy launched by the EC, the target for 80,000 zero-emission trucks was set for 2030, of which is significantly exceeded with the proposed standards.[17] The stock of zero-emission trucks is expected to rise quickly from 2030 onwards, as technical limits in the improvement of the internal combustion engine are reached[18] requiring an accelerated uptake of zero-emissions vehicles to comply with the standards. This zero-emission stock of trucks reaches nearly 3 million vehicles in 2040 and 6 million in 2050.

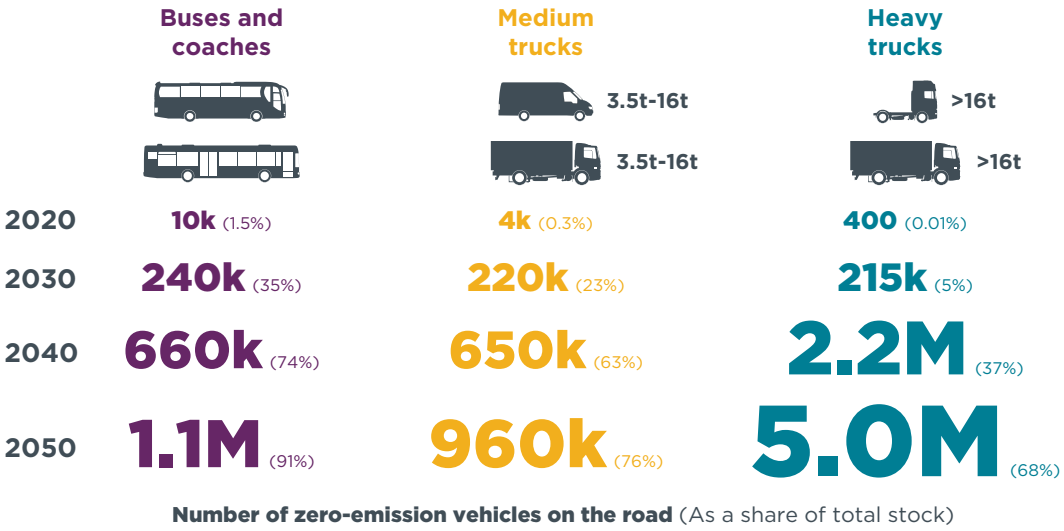

Figure 7. Projected stock of zero-emission trucks and buses under the proposed revision to the CO_2 standards.

The corresponding sales share is presented in Figure 8. These are the shares of zero-emission trucks and buses required to comply with the standards assuming a consistent annual efficiency improvement to the internal combustion engine of 3% until the technical efficiency limit of the combustion engine is reached. Under this assumption, by 2030, truck manufacturers would require a share of at least 28% zero-emission vehicles to comply with CO_2 targets. By 2040, to comply with standards, a zero-emission share of 78% by 2040 is required by trucks, and 95% for buses and coaches combined.

In contrast, most major manufacturers have committed to increase their sales share of zero-emission vehicles to 35%–60% by 2030.[19] More recently, engagements between Europe's leading heavy-duty manufacturer with the German Federal Ministry of Transport and Digital Infrastructure indicated that by 2030 they expect zero-emission trucks will have a share of 60% across Europe.[20]

17 European Comission, "EU Sustainable and Smart Mobility Strategy."

18 These technical limits vary by truck type and are detailed in Hussein Basma and Felipe Rodríguez, "The European Heavy-Duty Vehicle Market until 2040: Analysis of Decarbonization Pathways," (Berlin: ICCT, 2023), https://theicct.org/publication/hdv-europe-decarb-costs-jan23/.

19 These 2030 targets include a zero-emission sales share target from Daimler Trucks of between 50%–60%, Renault Trucks have a target of 35%, Scania and Volvo Trucks of 50%, and MAN have a 40% target for long-haul trucks and 60% for regional delivery trucks. The sources of these commitments can be found in Table 2 of "The CO_2 Standards Required for Trucks and Buses for Europe to Meet Its Climate Targets."

20 NOW GmbH, "Marketentwicklung Klimafreundlicher Technologien Im Schweren Strassen Güterverkehr" (Berlin, 2023), https://www.klimafreundliche-nutzfahrzeuge.de/marktentwicklung-klimafreundlicher-technologien-im-schweren-strassengueterverkehr/.

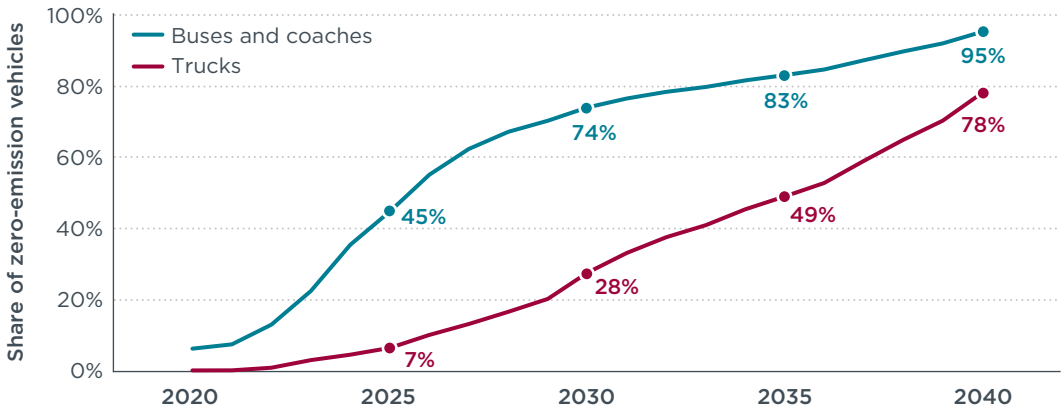

Figure 8. Sales share of zero-emission trucks, buses, and coaches in 2020 through 2040 to comply with the proposed revision to the CO_2 standards.

COMPLIANCE

Compliance is measured for every manufacturer on a fleet-wide basis; once for freight vehicles (i.e., trucks and trailers), and once for passenger vehicles (i.e., buses and coaches).

This means that a manufacturer will have one overall target for their trucks and trailers,[21] and a second for their buses and coaches. As such, manufacturers will not be able to compensate for non-compliant freight vehicles with over-compliant passenger vehicles, or vice versa. They could, however, overachieve with their target for coaches to compensate for underachieving the 100% reduction target for buses. They could also compensate for a high emitting truck group by producing a low-emitting different group.

These two compliance pathways avoid an unfair competitive advantage for larger manufacturers. The top seven major manufacturers of trucks in Europe are responsible for more than 97% of all truck sales; most of these manufacturers also produce buses (see Figure 9).[22] The market for buses is more segregated, with many more medium-sized manufacturers than the truck market. A single compliance requirement for freight and passenger vehicles would offer additional flexibility to larger manufacturers that produce both trucks and buses, allowing them to share the burden over both passenger and freight vehicle types. Such a flexibility would not be available to manufacturers that only produce passenger vehicles. Enabling two separate requirements prevents larger manufactures from gaining a competitive advantage over medium sized manufacturers that only produce buses and would not benefit from the same flexibility.

21 No manufacturers produce both trucks and trailers. However, if a manufacturer produced both, its compliance, in theory, would be based on both the performance of trucks and trailers.

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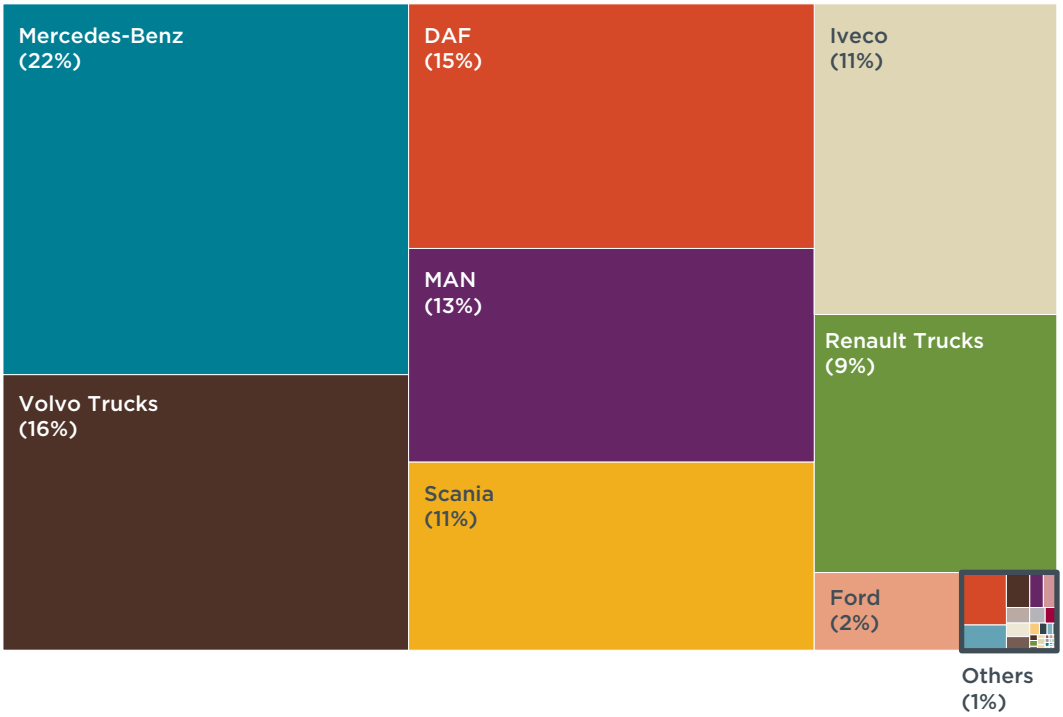
Truck manufacturers by sales in 2022



Bus manufacturers by sales in 2022

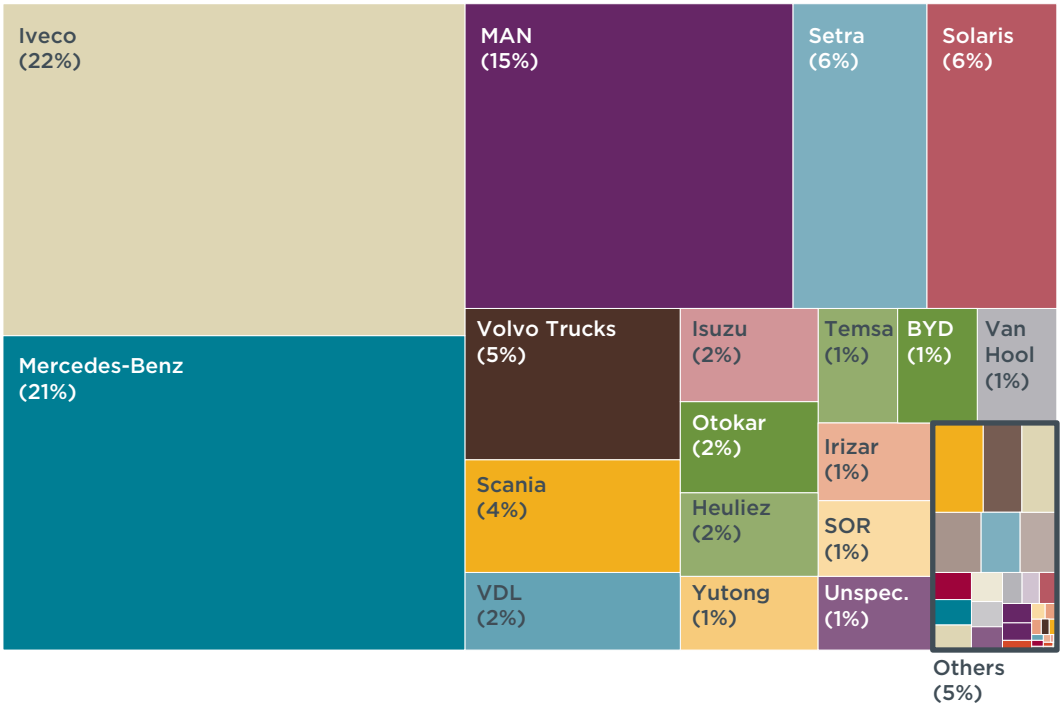


Figure 9. Market share of buses and trucks by 2022 sales in the EU27; only sales of vehicle groups covered under the CO_2 standards proposal are included here.

EXEMPTIONS

To reduce the burden for small and medium enterprises, the proposed CO_2 standards would allow manufacturers that produce fewer than 100 vehicles in a reporting period to be exempt from complying with the standards. If a manufacturer sells fewer than 100 vehicles but is connected to another manufacturer (e.g., if they are owned by the same parent company), and their combined sales are more than 100 vehicles, they will

not receive this exemption.[23] Manufacturers with fewer than 100 sales may still opt to be included in the CO_2 standards, which may be beneficial for zero-emission vehicle manufacturers which want to be included in the vehicle trading system discussed later.

The heavy-duty market is very consolidated, meaning a small number of manufacturers are responsible for a large number of sales. The top seven manufacturers were responsible for 89% of all HDV sales in 2022.[24] In the same year, 50 heavy-duty manufacturers produced fewer than 100 vehicles, but had cumulative sales of 884 vehicles, or 0.3% of the total HDV sales. As such, this exclusion has a very small bearing on the efficacy of the CO_2 standards. The manufacturers that would be excluded by this exemption clause based on 2022 sales are shown in Figure 10.

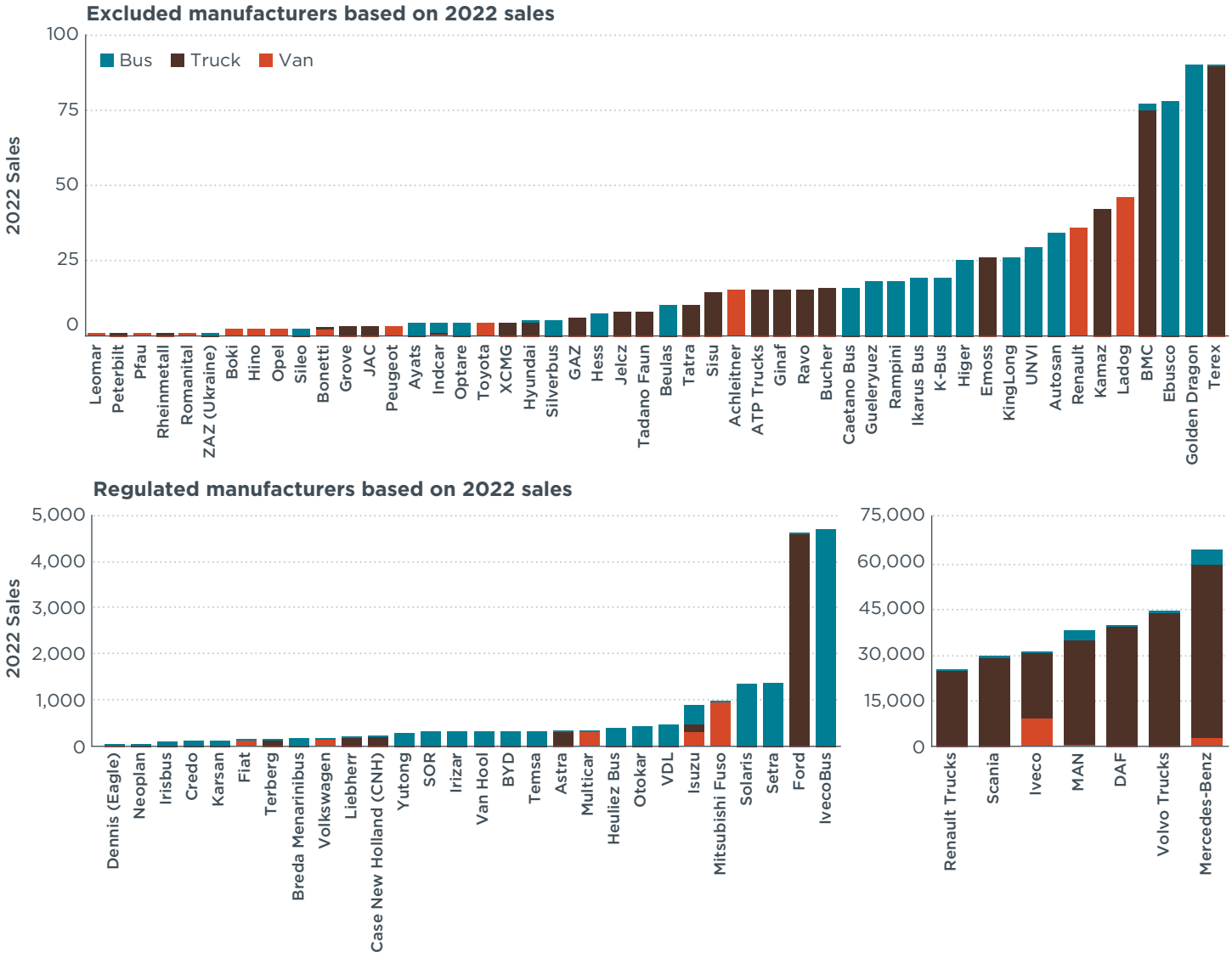


Figure 10. Manufacturers that would be exempted from the CO_2 standards based on sales from 2022 broken down by vehicle type; manufacturers on the top would be automatically exempt from the standards, while those shown on the bottom would be included.

An exemption is also allowed for Member States regarding the 100% target for buses. The purpose is to allow for a limited share of buses to remain exempt if it can be proven that a zero-emission vehicle is unable to fulfill the same role as would be undertaken

23 In 2022, only two manufacturers met this criterion, Neoplan from TRATON and Dennis (Eagle) from Terberg.

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by a conventional vehicle due to the climate or terrain. This limit is yet to be defined and will be done in the future through a delegated act published by the EC. As such, it is difficult to identify the bearing this exemption will have on the standards, as it will depend on the technicalities of the subsequent delegated act.

THE CREDIT AND DEBT SYSTEM

A credit and debt system has been in effect since the inception of the CO_2 standards. It rewards credits to manufacturers who reduce their emissions below an emissions trajectory line, defined as the straight line connecting two targets (e.g., 15% in 2025 and 43% in 2030). These credits can then be used to offset any future debts. Debts can be earned from 2025 onwards for currently regulated vehicles, and from 2030 for newly regulated vehicles. These debts are earned if a manufacturer has not reduced their emissions below the specific target once the target year is reached. For example, if a manufacturer has not reduced their truck emissions below 43% by 2030, they will earn debts for every year they remain above 43%.

The original credit and debt system had two phases, one which ran from 2019 to 2024, and the second from 2024 to 2029. Credits under the first phase could (and still can) only be used to offset debts earned in the year 2025. From 2026 onwards, the credits earned in the first phase are no longer valid. The first phase has remained unchanged in the proposal.

Under the second phase, debts can be earned from 2026 and accumulate each year for which a manufacturer remains above their target in 2025. Credits can be used to offset these debts, and any debts which have not been cleared from 2029 face a penalty.

Under the proposal, the first phase remains the same but the second phase has been extended to 2039. By doing so, the revision of the regulation gives a longer life to credits in the second phase—up to 15 years, as credits earned in 2025 can be used until 2040. In comparison, the credit system under the greenhouse gas standards for HDVs in the United States sets a credit life of 5 years.[25]

All debts must be cleared, i.e., offset by credits, in the reporting periods for the years 2029, 2034, and 2039. If a manufacturer has insufficient credits to offset all their debts in any one of these years, they must pay a penalty, as discussed later. Newly added vehicles cannot earn debts between 2025 and 2030, but they can earn credits. This follows the same system for currently regulated trucks which can only earn credits from 2019 onward, but cannot earn debts until 2025.

The new credit and debt system is shown in Figure 11. Trailers can also earn credits and debts following a similar approach, which we omit from this figure.

25 Environmental Protection Agency and Department of Transport, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles— Phase 2 Final Rule," October 25, 2016, 2, https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf.

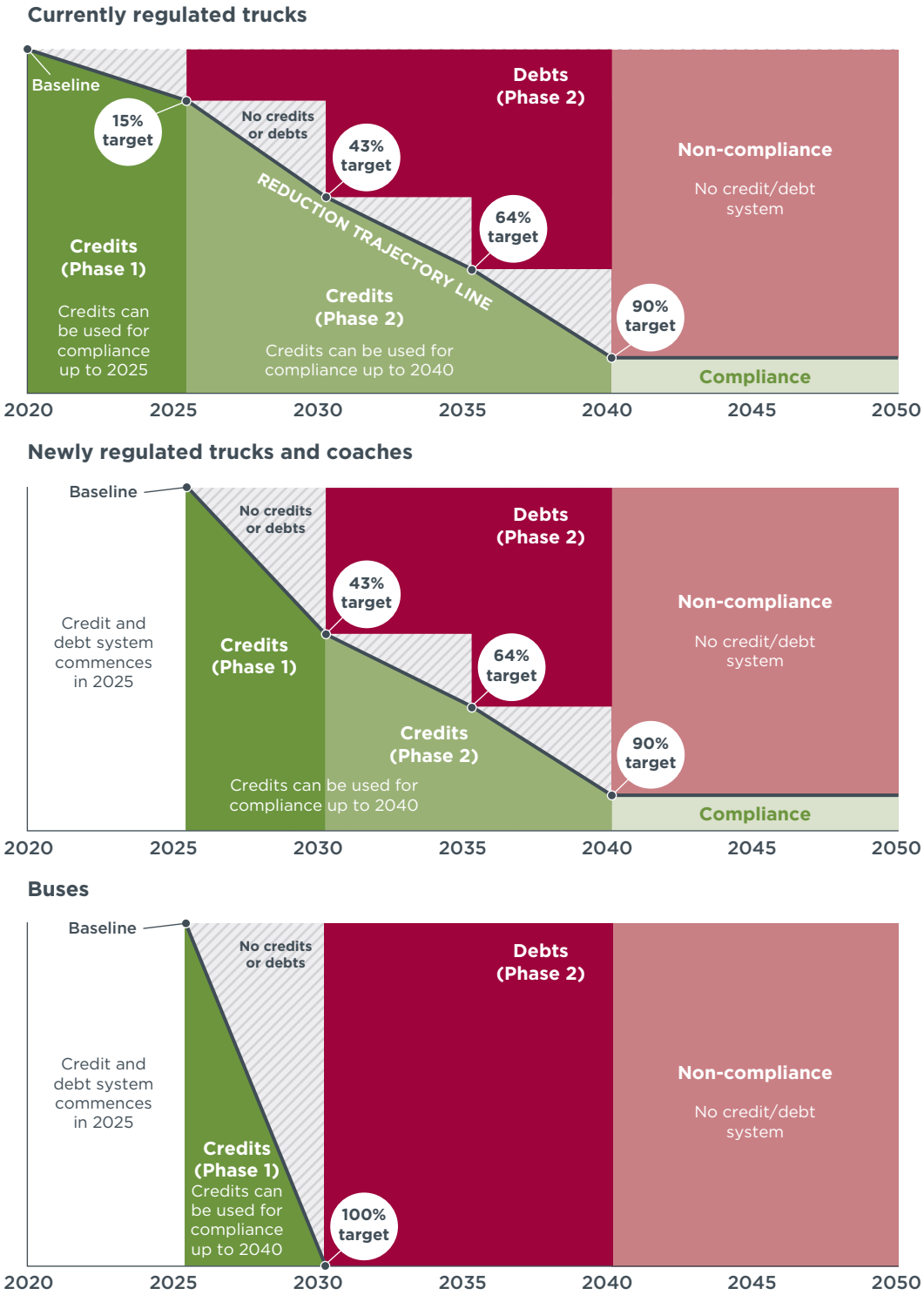

Figure 11. The proposed credit and debt system; these figures represent the system whereby a manufacturer would earn credits and debts if they only sold the vehicles in the heading. However, in reality, the system would be a combination of the charts (e.g., most bus manufacturers also sell coaches so their credit and debt system would be a combination of the bottom two charts, dependent on their sales share of each vehicle).

THE IMPLICATIONS OF A LONG CREDIT LIFE

Under the proposal, any credits earned from 2025 onward can be used through 2040. A long credit life may risk undermining the efficacy of the standards and could delay the deployment of zero-emission technologies. A credit system is intended to provide manufacturers flexibility in their production timelines which is not reflected in the long life granted under the proposal. A shorter credit life maintains consistency in the pace of the transition that private sector investors need to justify their investments in the transition away from fossil-based infrastructure.

Further, if a target is easily achieved in the early stages of the standard with zero-emission production exceeding the established targets driven by market forces rather than regulation, a significant number of early credits may be achieved and banked for use in the later stages of the standards.

This issue is particularly evident in the bus market. The share of zero-emission buses is already high in Europe (18% in 2022).[26] This share will likely continue to increase through 2025 at which point these vehicles will become regulated. At such a high zero-emission market share, manufacturers will generate a high volume of credits immediately in 2025 which can be used until 2040.[27] By contrast, currently regulated trucks can only use credits they earn under the current phase until 2025 but for no longer.

Figure 12 illustrates the credits and debts earned by a manufacturer that only produces buses.[28] Consider a manufacturer with a zero-emission sales share equal to the European average until 2022. Linearly extrapolating this share arrives a 90% value in 2030, which we hold constant through 2039. This share falls below the 100% target, and thus the manufacturer would earn debts between 2030 and 2039. In 2034 and in 2039, this manufacturer is required to clear all of their debts. The credits earned in the period 2025–2029 are more than sufficient to cover all of these accumulated debts. As such, a manufacturer following the average European market of zero-emission bus shares could produce conventional buses for a decade after a 100% reduction target is set.

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27 The calculation of the average specific CO_2 emissions of buses is different than that of trucks and buses in that it is based on both the zero-emission shares in a given year and on the reference emissions of buses in 2025 (which is also influenced by the shares of ZEVs), while the reduction trajectory line is only based on the reference emissions. As such, even if all manufacturers have the same high share of zero-emission sales in 2025, the double counting of the zero-emission sales shares in the calculation of the average specific CO_2 emissions means that every manufacturer's average fleet emissions would exceed the reduction trajectory line.

28 We assume that the manufacturer only produces VECTO group 31 (the most common bus type sold in Europe) which has an emissions of 1,341 gCO_2/km. We also assume that the manufacturer has annual sales of 1,000 vehicles.

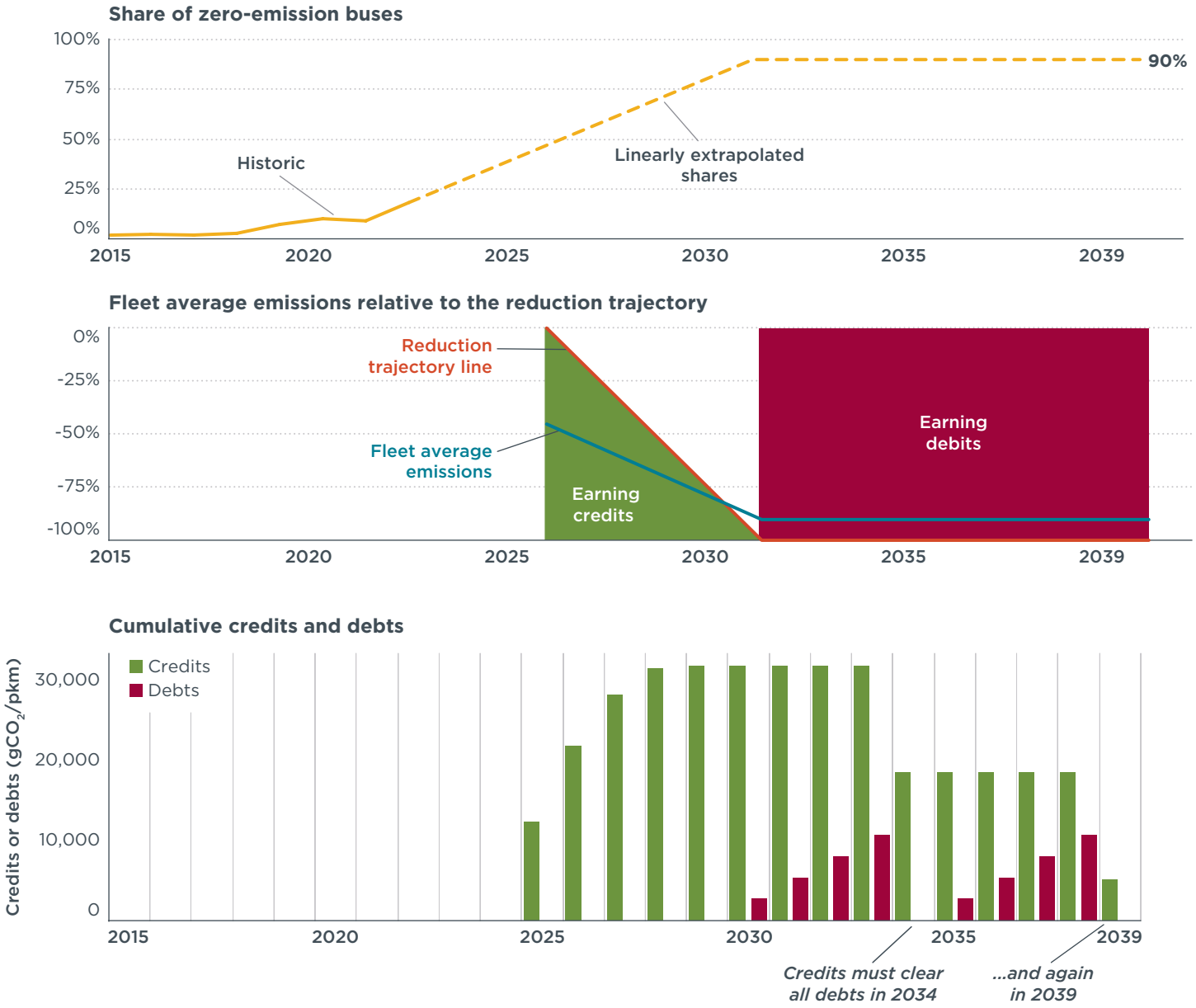

Figure 12. Illustrative example of a manufacturer who has the average zero-emission sales share of zero-emission buses, extrapolated to a 90% share in 2030 and held constant. The top chart shows the assumed sales share of zero-emission buses, the middle plot shows their fleet average emissions relative to the reduction trajectory line, and the bottom plot shows the accumulated credits and debts earned through 2039.

Establishing a shorter credit life, such as that in the U.S. Phase 2 GHG heavy-duty standards,[29] may alleviate this risk by allowing credits to have a rolling 5-year life where, for example a credit earned in 2027 can be used until 2032, and a 2028 credit can be used until 2033. Alternatively, credits could be set to zero in the year after when the debts must be cleared (i.e., 2030 and 2035) mimicking the approach for the current phase of the credit and debt system, that is all credits earned between 2019 and 2024 can only be used in 2025.

29 Environmental Protection Agency and Department of Transport, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles— Phase 2 Final Rule," 2.

VEHICLE TRADING

Vehicle trading is a new mechanism introduced by the proposal. It allows a manufacturer to report another entity's vehicle as their own to comply with their CO_2 target under the proposal. Different rules apply for conventional vehicles and zero-emission vehicles.

For conventional vehicles, connected manufacturers (e.g., manufacturers who share a parent company) can transfer an unlimited number of vehicles between them. Figure 13 highlights the manufacturers this would apply to. This flexibility shares the burden of compliance across all entities covered by a parent manufacturer and, in theory, a manufacturer could trade all of their vehicles to a connected entity, effectively allowing them to pool their emissions with another. Non-connected manufacturers are unable to trade conventional vehicles.

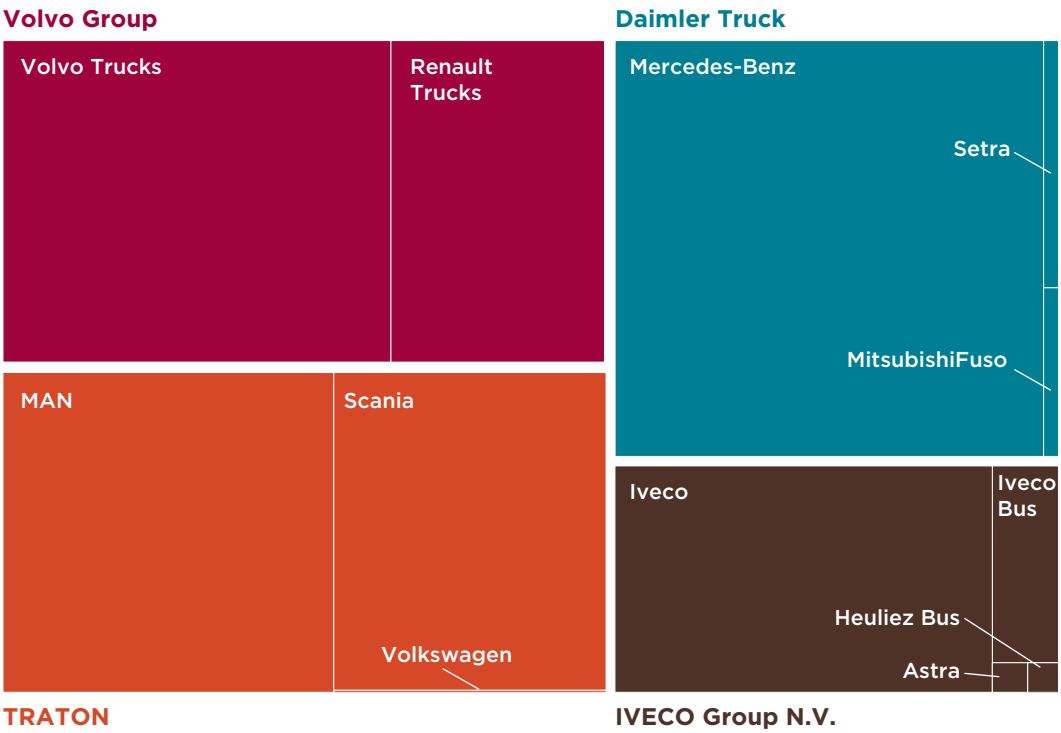

Figure 13. HDV manufacturers that share a parent company; manufacturers of the same color have the option to trade all vehicles under the new proposal (square size corresponds to the manufacturer's sales in 2022)

For zero-emission vehicles, all manufacturers have the flexibility to trade vehicles, limited up to 5% of the receiver's sales volume in any given reporting period. This can provide a new revenue stream for smaller manufacturers who focus exclusively on zero-emission vehicles.

Figure 14 shows manufacturers that only sold ZEVs in 2022. These manufacturers are already in compliance with the standards and can thus trade all their vehicles with conventional manufacturers to earn additional revenue.

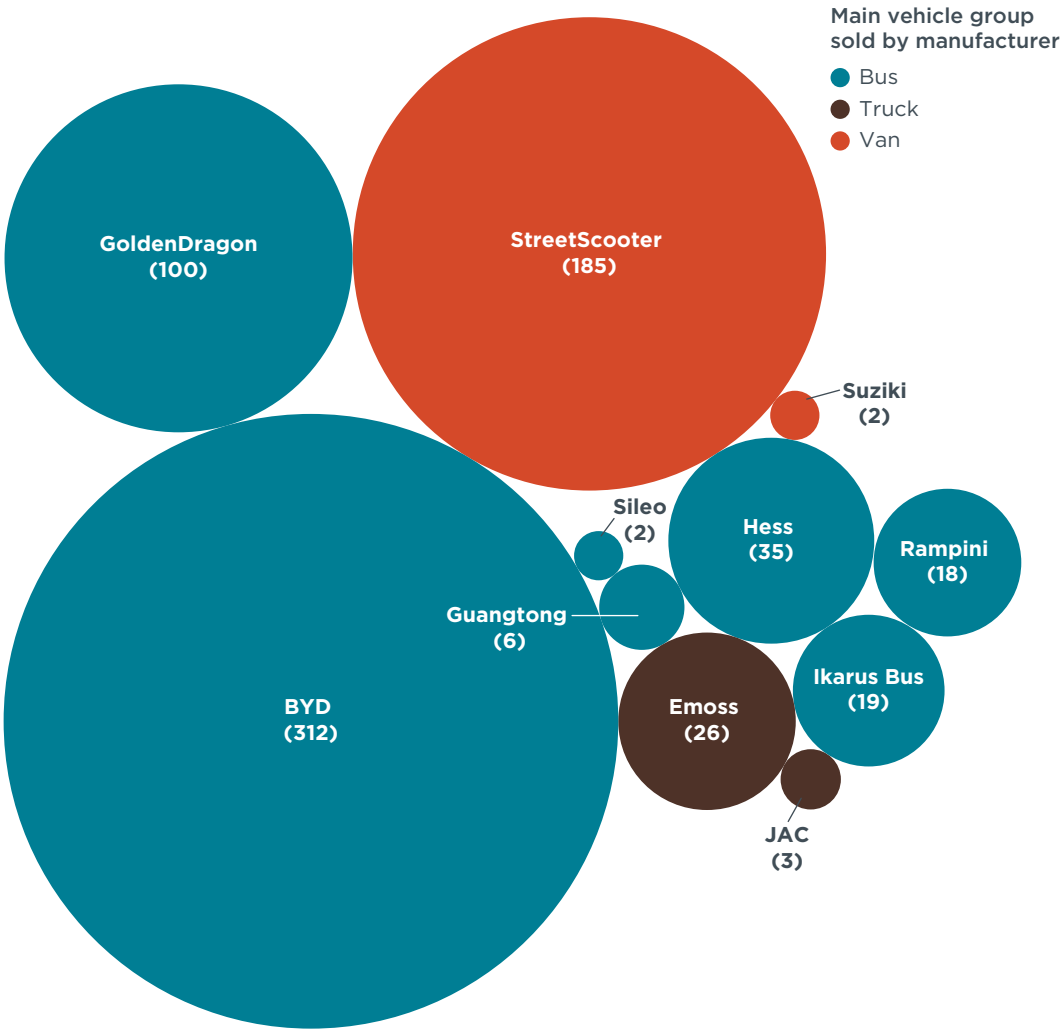

Figure 14. Vehicle sales by manufacturers that only produce ZEVs. Total sales in 2022 are in brackets. Note StreetScooter's vehicles have a GVW of less than 5 tons and are thus excluded from the standards.

PROPOSED DEFINITION FOR ZERO-EMISSION VEHICLES

ZERO-EMISSION TRUCKS AND BUSES

The definition of a zero-emission HDV is proposed to change. The original definition allowed for a vehicle with emissions of less than 1 gCO_2/kWh (equal to roughly 0.2% of a standard tractor trailer's emissions[30]) to be classified as zero-emission. This threshold has been increased to:

- 5 gCO_2/tkm for trucks (about 9% of a standard tractor trailer's emissions[31]),
- 5 gCO_2/pkm for buses and coaches (about 25% of a standard bus's emissions, or 30% of a coach's[32])

30 Based on the emissions measured over the average engine in 2020 over the World Harmonised Steady Cycle. Data available from: European Environment Agency, "Monitoring of CO2 Emissions from Heavy-Duty Vehicles."

31 European Environment Agency.

32 Atiquzzaman Khan Ankur, Stefan Kraus, Thomas Grube, Rui Castro, and Detlef Stolten, "A Versatile Model for Estimating the Fuel Consumption of a Wide Range of Transport Modes," *Energies* 15, no. 6 (January 2022): 2232, https://doi.org/10.3390/en15062232.

The original threshold of 1gCO_2/kWh enabled the categorization of monofuel hydrogen combustion engines as zero emissions. While the combustion of pure hydrogen does not directly produce CO_2, it does produce nitrogen oxides. These must be handled by an emissions control system that can produce minute emissions of CO_2.

The increase in the threshold makes allowance for dual-fuel combustion engines operating with a mix of hydrogen and diesel. The most promising dual-fuel engine technology, called high-pressure direct injection (HPDI), requires a diesel fuel pilot injection to initiate the ignition process. In effect, this would mean any truck with CO_2 emissions equal to up to 9% of the emissions of a standard tractor trailer or 25%–30% of a standard bus or coach could be classified as zero-emission.

To quantify the potential implication of this allowance, Figure 15 presents the range of emissions that may ensue through accelerated adoption of hydrogen internal combustion engines powered by a dual-fuel HPDI engine. It shows the emissions projection for the Proposal scenario, the TL_Med scenario, and the TL_High scenario from the impact assessment (described earlier), with the lower bounds assuming only zero-emission vehicles (that is, battery-electric vehicles or hydrogen fuel cell vehicles) are used, and the upper bound assuming dual-fuel HPDI hydrogen combustion engines are used for all zero-emission vehicles with a GVW over 16 t. This analysis is carried out assuming a threshold of (i) 5gCO_2/tkm, (ii) 1gCO_2/tkm, and (iii) 1gCO_2/kWh.

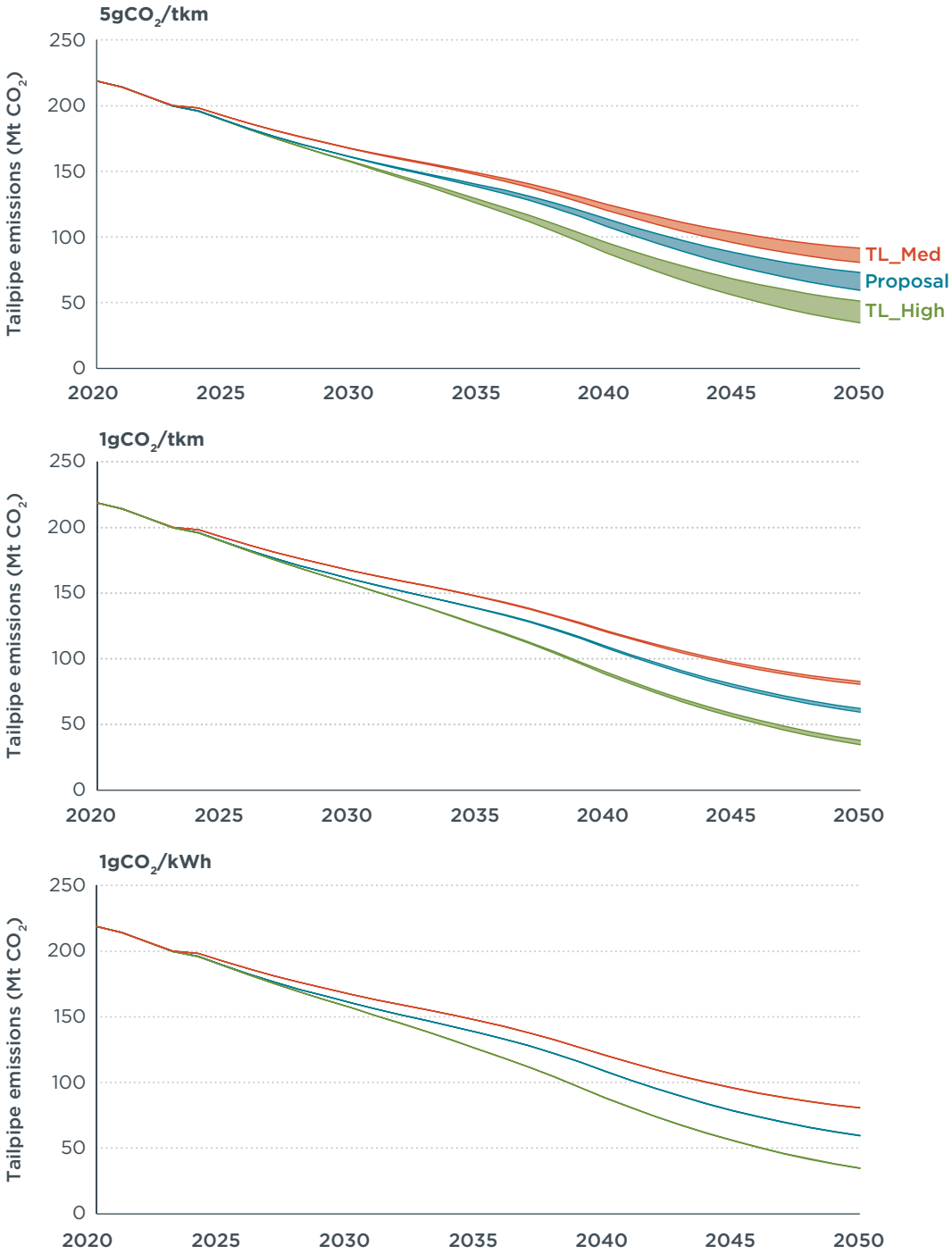

Figure 15. Range of emission projections for the heavy-duty vehicle sector under the proposal, the medium and the high ambition scenarios under a variety of thresholds for the definition of ZEVs. The upper bound of the range assumes all ZEVs above 16 tons of GVW are powered by a dual-fuel HPDI hydrogen combustion engine; the lower bound assumes these vehicles are powered by battery electric or hydrogen fuel cell vehicles.

Scenarios with a higher level of zero emission vehicles experience the greatest potential risk. In the extreme case of a high deployment of dual-fuel HPDI hydrogen combustion engines in the TL_High scenario, an additional 170 million tons of CO_2 would be emitted through 2050, arriving at a similar level of annual emissions in 2050 as the Proposal scenario if only battery electric or hydrogen fuel cell vehicles were used to comply with the standards. The proposed definition risks an increase of 130 million cumulative tons of CO_2 under the proposed targets and an additional 100 million tons under the TL_Med scenario applying the same assumptions.

Revising the definition back to 1gCO_2/tkm reduces the uncertainty to 25 million tons of CO_2 in the proposal, and a threshold of 1gCO_2/kWh reduces this further to 3 million tons of CO_2. Revising the emissions to 1gCO2/tkm is the simplest regulatory approach, allowing for both mono-fuel and efficient dual-fuel hydrogen combustion engines to be categorized as zero emissions.

ZERO-EMISSION TRAILERS

A trailer is defined as a zero-emission vehicle if it is either equipped with a non-internal combustion engine device that actively supports its propulsion, or if it is equipped with an internal combustion engine with emissions below 5 gCO_2/kWh. No conditions are specified for the non-internal combustion engine device, meaning a battery pack of any size that assists in the propulsion of a trailer allows the manufacturer to report their trailer as zero-emission.

Despite the name, a zero-emission trailer will still be certified with emissions. The Annex to the proposal states that only heavy-duty motor vehicles that are reported as zero-emission will be certified as having no emissions. According to the main text of the proposal, a trailer is not defined as a heavy-duty *motor* vehicle and as a result its emissions are not affected. Battery powered trailers assist in a trailer reducing its emissions contribution to the tractor-trailer combination, as it provides a zero-emission method of supporting propulsion of the vehicle combination. However the current version of VECTO does not yet have the functionality to account for such reductions in the certification procedure.

While not receiving any certified emission reduction from the classification, a trailer defined as a zero-emission vehicle may receive other benefits. It provides a mechanism through which trailer manufacturers can trade their vehicles, (non-connected manufacturers may only trade zero-emission vehicles). Zero-emission trailers may also benefit from a more favourable emissions class for the purposes of the road tax paid under the Eurovignette. An upcoming amendment to the weights and dimensions directive may grant an additional weight allowance to zero-emission vehicles,[33] from which zero-emission trailers may benefit from under this new definition.

THE ZERO- AND LOW-EMISSION VEHICLE FACTOR

An incentive mechanism introduced in the original standards, known as the zero- and low-emission vehicle (ZLEV) factor, allows manufacturers to artificially reduce their reported emissions by up to 3% if they produce a sufficient number of ZLEVs. Under the current standards, the ZLEV factor contribution continues for all reporting periods indefinitely. Two changes have been made to the ZLEV factor in this revision.

First, and most significantly, the incentive will be phased out from 2030 onward. The text of the proposal cites that this is due to the existing ambitions of major manufacturers which goes significantly beyond the maximum benefit available from the ZLEV factor. Most major manufacturers have committed to increase their sales share of ZEVs to 35%–60% by 2030. In contrast, the maximum benefit of the ZLEV factor is achieved at a zero-emission sales share of 5%.[34]

Second, between 2025 and 2030, two calculations are applied to freight vehicles to determine a manufacturer's fleet average emissions; one which applies the ZLEV factor and one which does not. The former is used only in the calculation of debts accrued,

33 Planned for release on 11 July, 2023.

34 Only applicable in the years 2025–2029, otherwise known as the benchmark phase. In 2019–2024, the super credit phase applies where a lower share is needed to earn the maximum benefit of the standards.

while the latter for the calculation of credits. In other words, the ZLEV factor can only help a manufacturer earn credits until 2025 but can help them avoid debts until 2030.

Considering the already high ambitions of manufacturers to increase their share of ZEVs, the phase-out of the ZLEV factor will avoid an unnecessary dilution of the standards by up to 3%.

The equations used to determine the ZLEV factor in the Annex accompanying the proposal currently stipulate that zero-emission buses will count towards this factor. This is in direct conflict with the main text of the proposal which states that only vehicles of category N (i.e., trucks) should count. Communications from the European Commission to Member States has confirmed that buses are not intended to be included, and as such the Annex should be updated accordingly.

PENALTIES

The penalties for non-compliance have been reduced in the proposed revision of the standards. In the current standards, from 2025, a penalty is to be applied of €4,250 per vehicle per gCO_2/tkm exceeded. This penalty was set to increase to €6,800 in 2030. In the the proposal, the latter of these has been removed, with the penalty of €4,250 applying for the whole period.

For a truck manufacturer that produces 40,000 vehicles (approximately the average across the seven major truck manufacturers in 2022)[35] and misses their reduction target in 2025 and 2030 by 1%, that would equate to a fine of €90 million and €150 million respectively. Under the revision, the fine for missing their target by 1% in any year where a penalty is applicable after 2025 would remain at €90 million.

The change in penalties is not discussed or justified in the impact assessment accompanying the proposal. In principle, a higher penalty for non-compliance provides stronger incentives for manufacturers to deploy the technologies required to comply with the standards.

CONCLUSIONS

To be adopted, the proposal will require agreement from both the European Parliament and the Council of the European Union, both of which can propose their own amendments. While the proposal greatly increases emissions reductions over the current standards, several key areas may yet be amended to maximize the CO_2 reduction benefits of the regulation:

Targets: The proposal introduces the world's most stringent heavy-duty CO_2 standards for a major market, but falls short of the reductions necessary to comply with Europe's binding climate neutrality target for 2050. We project that the proposed standards will reduce the total HDV emissions by 64% by 2050 relative to 1990. Increasing the targets to align with the Impact Assessment's high ambition scenario[36] would increase this emission reductions to 79%. In contrast, the EC intends for an overall 90% reduction in transport emissions by 2050.

Scope: The coverage of the current standards regulates 69% of annual HDV emissions. The revision extends this coverage to 91%. Vocational vehicles are excluded from the scope and represent 4.5% of heavy-duty emissions. The legal and technical framework for their integration with the CO_2 standards already exists.

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36 The high ambition scenario proposes targets of 50% in 2030, 70% in 2035, and 100% in 2040.

Credit and debt system: The credit and debt system introduces a flexibility for manufacturers to overachieve their target to earn credits which can later be used to offset debts earned from under compliance. Such a flexibility is a common mechanism in CO_2 standards worldwide and can be a useful tool in compliance. However, the revision grants ample flexibility by increasing the credit life from 5 years to 15 years. Such a long credit life risks the integrity of the standards, particularly for buses. Buses are rapidly electrifying, and manufacturers are on track to start earning a significant number of credits from 2025 as a result. The resulting credits earned will allow them to avoid a 100% reduction in 2030 for several years.

Zero-emission truck definition: A zero-emission truck will be allowed to emit up to 5gCO_2/tkm, the equivalent of 9% of the emissions of a standard conventional tractor trailer. This allowance is allows for dual-fuel engines running on a mix of hydrogen and diesel to be categorized as zero-emissions. This definition provides a new compliance pathway for manufacturers, but at the same time, may diminish the standards' CO_2 benefits. Revising the allowance back to its original value of 1gCO_2/kWh is the simplest regulatory approach, allowing for monofuel hydrogen combustion engines to be categorized as zero emissions, while ensuring that the real contribution of dual-fuel engines to reductions in CO_2 emissions are properly accounted for.

Penalties: The cost of non-compliance has been reduced for 2030 onwards. It was previously set to increase to €6,800 per gCO_2/tkm per vehicle in 2030 but has been revised to €4,250 under the proposal. A manufacturer that misses their target by 1% in 2025 will face the same penalty if they miss it in 2030 onwards, whereas it was previously set to increase by 60%. This lowers the incentive for manufactures to comply with their targets.

APPENDIX – CALCULATION OF THE AVERAGE TARGETS

The average targets (i.e., 45%, 65%, and 90%) are calculated by considering the overall CO_2 emission reduction achieved (in terms of tonnes of CO_2) by applying the specific targets to new vehicles.[37] This calculation requires input on the sales of new vehicles, their payload, mileage, and specific CO_2 emissions of the vehicle. The calculation of the global targets can be represented by the following equation:

$$Average\ Target_Y = \frac{\Sigma_{veh}\left(\frac{gCO_2}{tkm}\right)_{veh,Y} \times payload_{veh,Y} \times mileage_{veh,Y} \times sales_{veh,Y} \times (1 - Specific\ Target_{veh})}{\Sigma_{veh}\left(\frac{gCO_2}{tkm}\right)_{veh,2019} \times payload_{veh,2019} \times mileage_{veh,2019} \times sales_{veh,2019}} - 1$$

Where:

Y is the target year (i.e., 2030, 2035, or 2040).

Veh is the vehicle type, also known as VECTO group, as defined by the certification regulation (EU) 2017/2400. For this calculation, it only applies to regulated trucks, buses, and coaches (but not trailers).

payload is the vehicle's reference payload in tonnes, specified in Annex I of the revision to the CO_2 regulation.

mileage is the vehicle's reference annual mileage (in km), specified in Annex I of the revision to the CO_2 regulation.

sales is the total annual sales of the vehicle type.

Specific Target is the target in the target year (e.g., 43% in 2030).

gCO_2/tkm is the vehicle's specific emissions.

The payloads and mileages are declared in Annex I of the proposal,[38] and the specific CO_2 emissions for most vehicle type are available from the publicly available database to the European Environment Agency. However, a number of these variables have no official values, including the sales and specific emissions of some unregulated vehicles (notably from buses and coaches), and determining the average targets requires assuming values for these variables. The European Commission has relied on the PRIMES model to generate these global targets, a proprietary model for which these assumptions are not publicly available.

37 There is no clear definition of how the global targets are calculated in the legal text of the revision to the standards. The explanation we offer here is based off our understanding of communications with the EC.

38 European Commission, "Annexes to the Proposal for a Regulation of the European Parliament and of the Council Amending Regulation (EU) 2019/1242 as Regards Strengthening the CO_2 Emission Performance Standards for New Heavy-Duty Vehicles and Integrating Reporting Obligations, and Repealing Regulation (EU) 2018/956," *Official Journal of the European Union*, February 14, 2023, https://climate.ec.europa.eu/system/files/2023-02/policytransporthdv20230214annexesen0.pdf.