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Driving with cleaner engines

The evolution of diesel heavy-duty vehicles in China, 2012–2023

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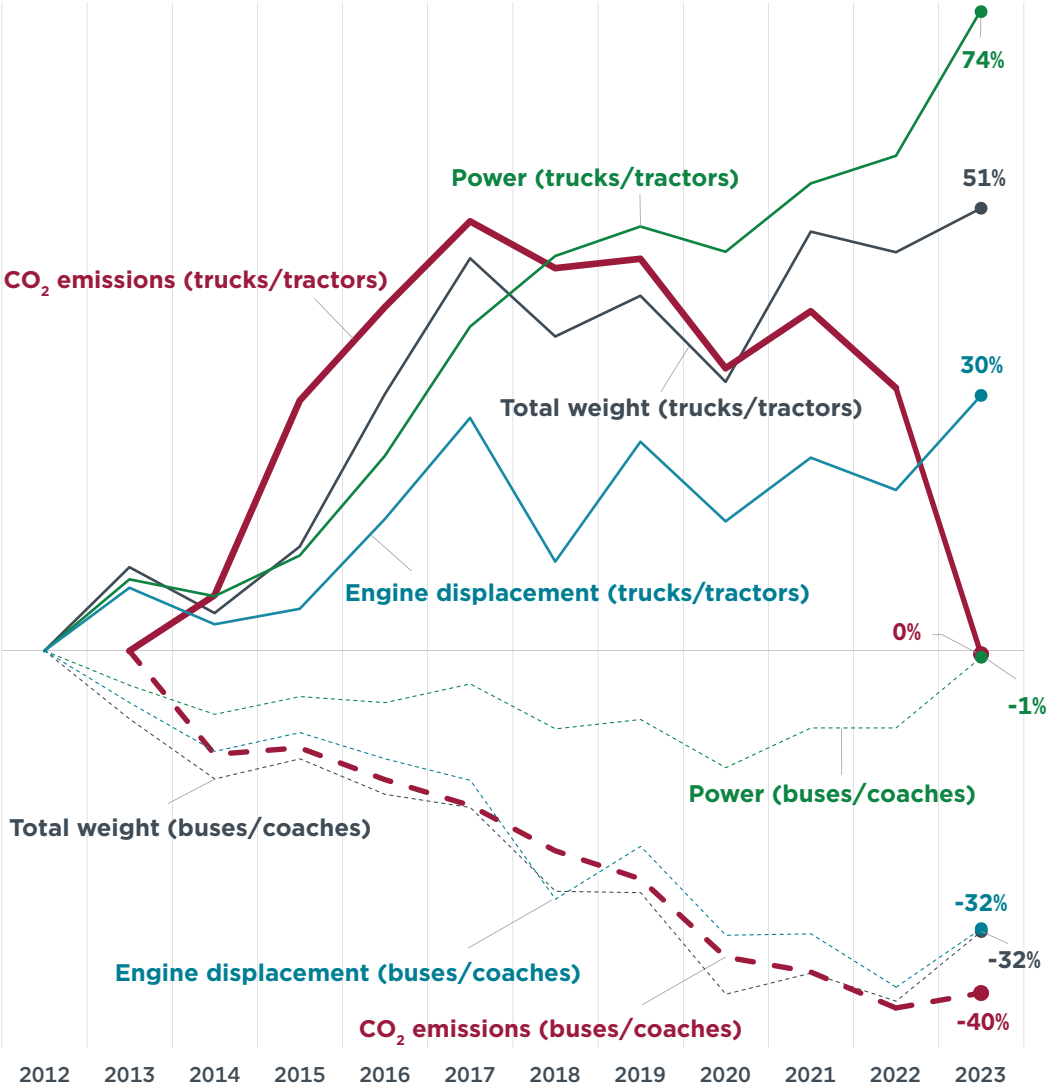
EXECUTIVE SUMMARY

China's heavy-duty vehicle (HDV) industry has witnessed profound changes, driven by advancements in vehicle technology, shifting fuel types, and environmental regulations. This report assesses trends in China's HDV market between 2012 and 2023, a critical period for technological and regulatory developments in the industry. It surveys the evolution of HDV sales by powertrain, vehicle specifications, emissions performance, and the market structure of fuel supply and transmission technologies for HDVs.

This analysis finds that diesel vehicles continue to dominate the HDV sector in China, although natural gas and battery electric vehicles have seen notable growth in market share in recent years. In terms of vehicle specifications, the HDV industry has shown a marked divergence between trucks and tractors on the one hand and buses and coaches on the other. As illustrated in Figure ES1, between 2012 and 2023, trucks and tractors saw large increases in engine power (+74%), total weight (+51%), and engine displacement (+30%), while buses and coaches saw declines in all three parameters: of 1% for engine power, 32% for total weight, and 32% for engine displacement.

Figure ES1
Evolution of diesel HDV specifications and type-approved CO_2 emissions from 2012 to 2023



Notes: Values reflect sales-weighted fleet averages. Straight trucks, dump trucks, and tractor-trailers are represented with solid lines; coaches and city buses are represented with dashed lines.

Type-approved CO_2 emissions—which are directly calculated from certified fuel consumption, the regulated metric in China's fuel economy standards for HDVs—have shown a similar divergence. Overall, buses and coaches have recorded a sustained decline in CO_2 emissions since 2013, amounting to a 40% improvement by 2023. For trucks and tractors, the road to meeting regulatory targets has been bumpier. Sales-weighted average CO_2 emissions from trucks and tractors initially increased due to lenient regulations and the exclusion of heavy truck categories—notably dump trucks, which were not regulated by fuel consumption standards until Stage 2 standards took effect for all new type-approved models in 2015. Since the introduction of Stage 3 standards in 2019, the type-approved CO_2 emissions of new trucks have fallen sharply, reaching parity with 2013 levels in 2023. This "inverted-U" pattern in Figure ES1 indicates progress on fuel consumption control by manufacturers despite growth in power, total weight, and engine displacement. The adoption of technologies such as common rail injection and exhaust gas recirculation have contributed to improved fuel efficiency among trucks.

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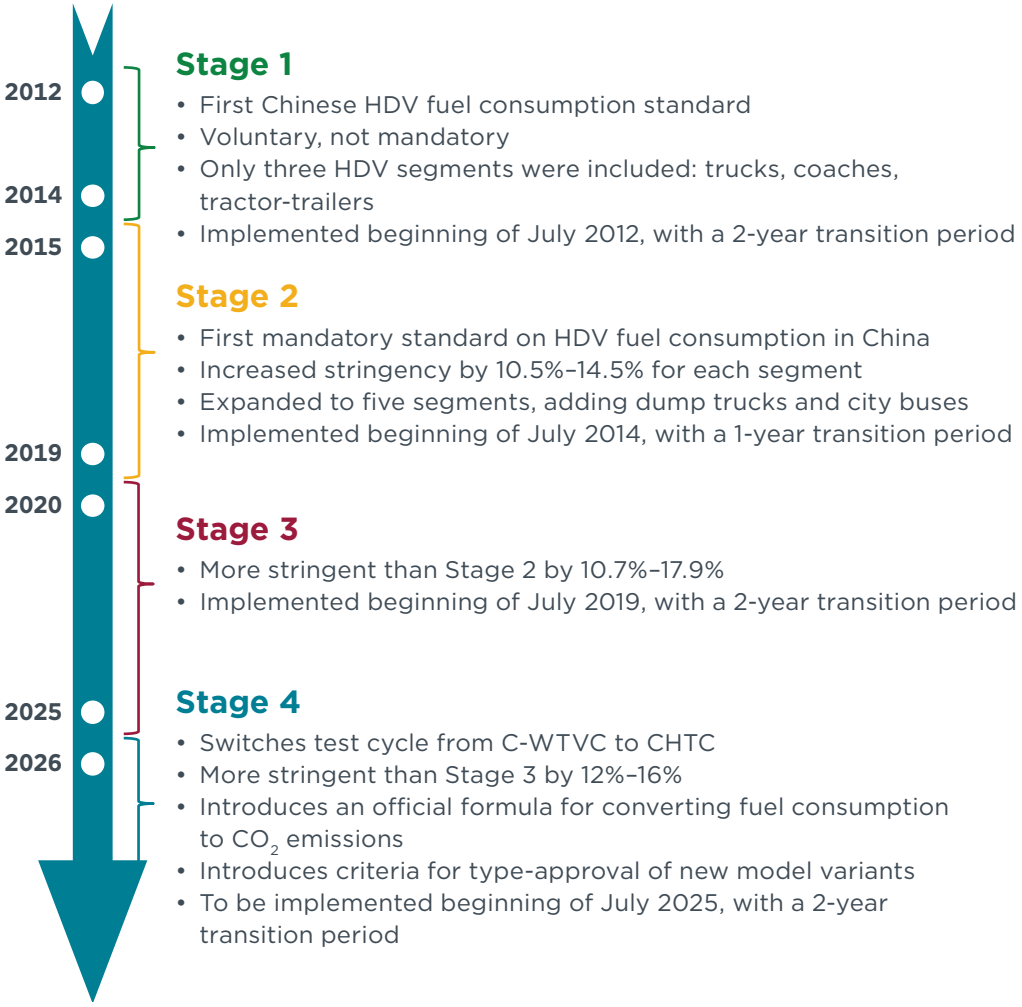
INTRODUCTION

Heavy-duty vehicles (HDVs) account for a significant portion of road transport emissions in China: As of 2022, 80% of nitrogen oxides (NO_X) and 90% of particulate matter (PM) was contributed by diesel HDVs, according to the latest annual report on environmental performance of mobile sources (Ministry of Ecology and Environment, 2023). As the world strives to meet climate goals and transition to sustainable mobility, HDVs represent a critical area of focus for policymakers, manufacturers, and environmental stakeholders.

Over the last decade, China's HDV industry has witnessed profound changes in vehicle technology and fuel types, driven in part by increasingly stringent environmental regulations. China does not have any direct, enforceable regulations for curbing CO_2 emissions from HDVs; instead, CO_2 emissions are regulated indirectly through HDV fuel consumption standards. Since the first standards were introduced in 2012, they have been updated twice (in 2014 and 2019) and are to be updated again in mid-2025 (Figure 1). Past updates have gradually decreased the upper limit of fuel consumption for HDVs by segment and gross vehicle weight class. In Stage 2 and Stage 3, the fuel efficiency was improved by 10.5%–14.5% and 10.7%–17.9%, respectively (Mao et al., 2023).

Figure 1
Evolution of China's fuel consumption standards for heavy-duty vehicles



Source: Liu and Mao (2024)

This report analyzes major trends in China's HDV industry from 2012 to 2023—a period marked by significant regulatory development and technological advancement in the HDV industry. It examines the evolution of HDV sales by powertrain, changes in vehicle specifications, patterns in type-approved CO_2 emissions, and trends in fuel supply and transmission technologies for HDVs. This work builds upon previous ICCT analyses of China's fuel consumption standards (Mao et al., 2021; Mao & Rodrigues, 2022).

DEFINITION, SCOPE, AND SEGMENTATION OF HDVS

This report analyzes type-approval information for HDVs sold between 2012 and 2023. The data sources are from the Ministry of Industry and Information Technology's *On-Road Motor Vehicle Manufacturers and Product Catalogs* (2018). Additionally, the analysis incorporates multiple re-aggregated datasets from third-party data providers.

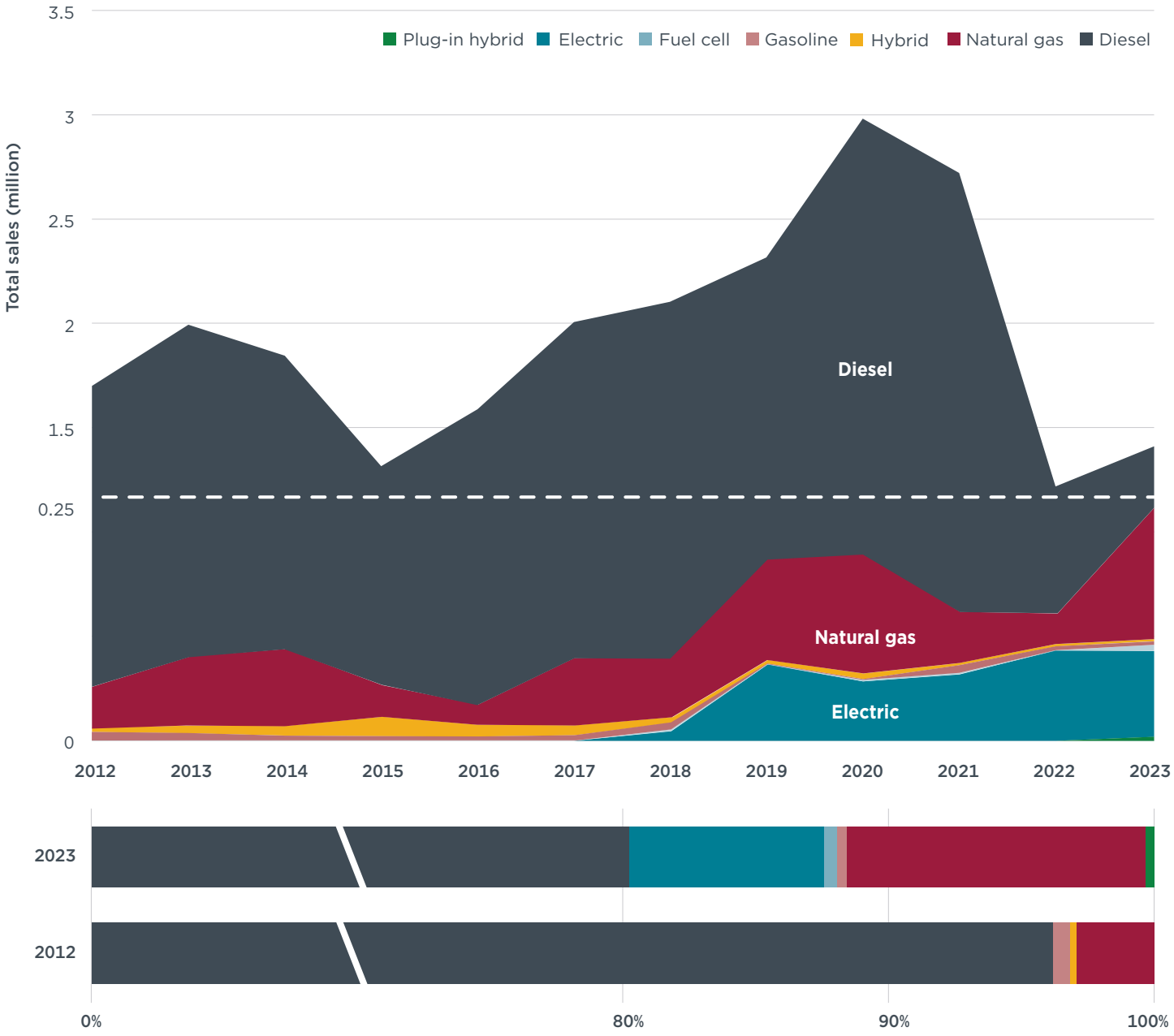
This study examines the five HDV categories covered under China's fuel consumption standards: straight trucks, dump trucks, tractor-trailers, city buses, and coaches (Table 1). All diesel vehicle models with a gross vehicle weight (GVW) above 3,500 kg were analyzed; for tractor-trailers, the gross combination weight (GCW) rather than the GVW was used, consistent with the way these vehicles are regulated in the fuel consumption standards. Under the standards, each segment of HDVs must meet fuel efficiency targets on the basis of type-approved fuel consumption for individual models. Models are grouped by GVW or GCW, such that vehicles of the same category within a certain weight range are regulated by the same fuel consumption standard. For instance, straight trucks with a GVW between 3.5 and 4.5 tonnes are covered by the same limit. The appendix presents segmentation, weight range, and fuel consumption limits for each vehicle category.

Table 1
Vehicle categories assessed in this study

	**Straight trucks**, including medium (GVW of 3.5–12 tonnes) and heavy (GVW of 12 or more tonnes) models
	**Dump trucks**
	**Tractor-trailers**
	**City buses**
	**Coaches**

SALES

Figure 2
Sales mix of HDVs in China, 2012–2023



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Apart from a drop in sales in 2015 due to an economic recession, China's diesel HDV market saw a decade-long boom before the COVID-19 pandemic, rising from 1.6 million new vehicles sold in 2012 to a peak of 2.9 million sold in 2020. Sales plummeted in 2020–2022 and have been slow to rebound amid declining demand from the construction and manufacturing industries (Figure 2) (Herlt et al., 2024).

Diesel has long been the leading powertrain among HDVs in China, though its market dominance has waned in the past decade. Such vehicles accounted for 96% of the HDV market in 2012, declining to 80% in 2023.

Conversely, natural gas and battery electric vehicles saw growth over this period. About 60,000 new compressed natural gas (CNG)/liquefied natural gas (LNG)-powered HDVs were sold in 2023, making up 7.7% of total HDV sales. The adoption of CNG/LNG-powered HDVs reflects both government efforts to promote natural gas as an alternative clean energy as well as operators taking advantage of the lower cost of gas relative to diesel in recent years (Howe & Verma, 2024). The uptake of electric HDVs also has risen in recent years, with battery electric trucks and buses reaching a 7.3% market share in 2023.

VEHICLE SPECIFICATIONS

From 2012 to 2023, the average curb weight of most HDV categories remained relatively constant, fluctuating within a 10% variance (Figure 3). However, the curb weight of heavy straight trucks fell sharply between 2016 and 2018 due to a 2016 regulatory update by China's Ministry of Transport (MOT) limiting new straight trucks with two axles and a GVW between 16 and 20 tonnes to a GVW of no more than 18 tonnes. In response, manufacturers reduced the curb weight of heavy straight trucks to accommodate as much payload as possible.

As shown in Figure 4, all HDV categories saw increases in engine power between 2012 and 2023, with more rapid growth of 41% (+18 kW) among medium straight trucks, 39% (+103 kW) among tractor-trailers, and 33% (+71 kW) among dump trucks. Heavy straight trucks ended with a 4% (+6 kW) increase over the period, as the MOT regulation noted above resulted in a steep drop in engine power between 2017 and 2018.

Figure 3
Curb weight

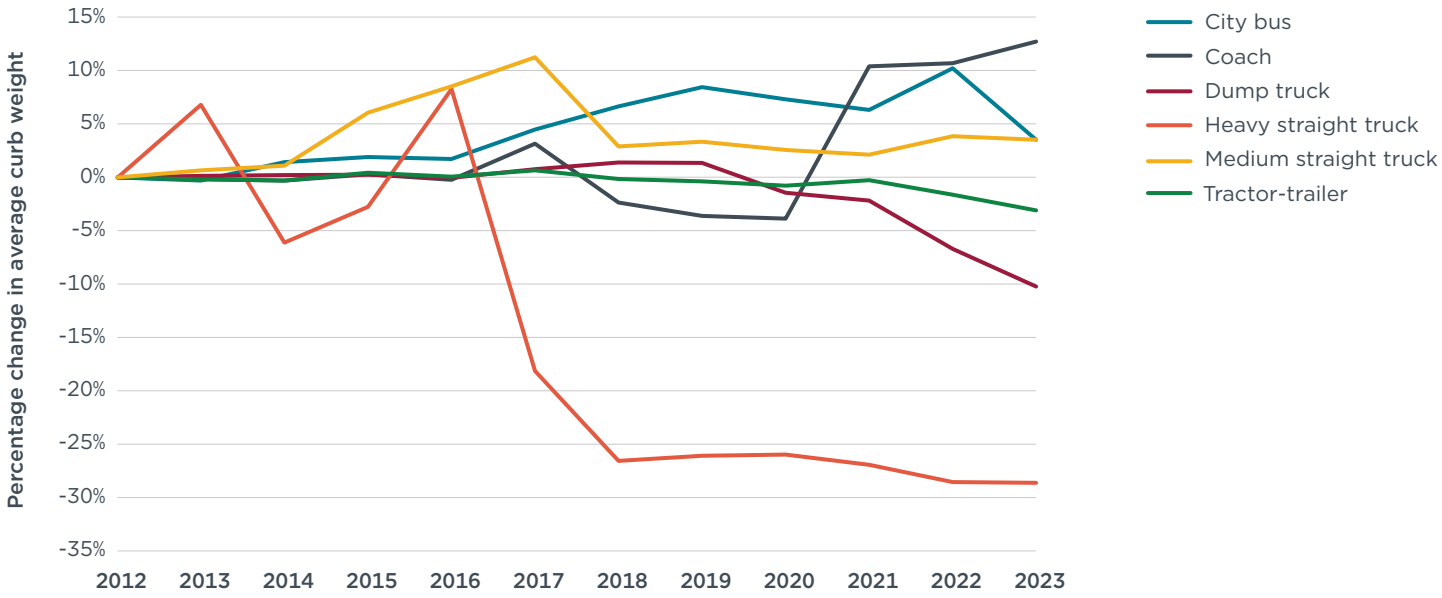
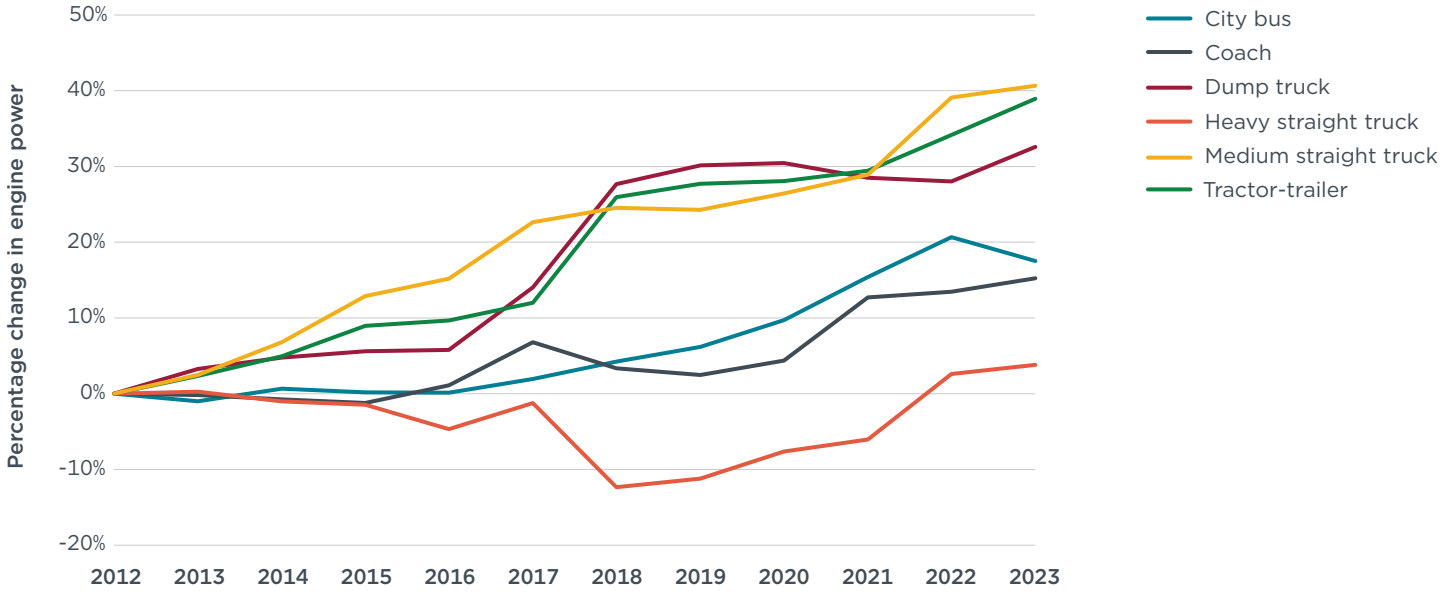


Figure 4
Engine power



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From 2012 to 2023, average engine displacement—the total volume of cylinders in an engine, a key measure of power output—declined for city buses and coaches (Figure 5). Heavy and medium straight trucks also saw a downward trend of engine displacement due to smaller curb weight and size. Tractor-trailers and dump trucks, however, experienced a moderate increase in this specification.

Power density, or the power output generated per liter of engine displacement, rose across all vehicle categories over the same period. City buses saw the greatest change in power density from 2012 to 2013, of 64% (+16.7 kW/L). In contrast, tractor-trailers, the heaviest category examined, saw the smallest increase, of 19% (+4.8 kW/L) (Figure 6).

Figure 5
Engine displacement

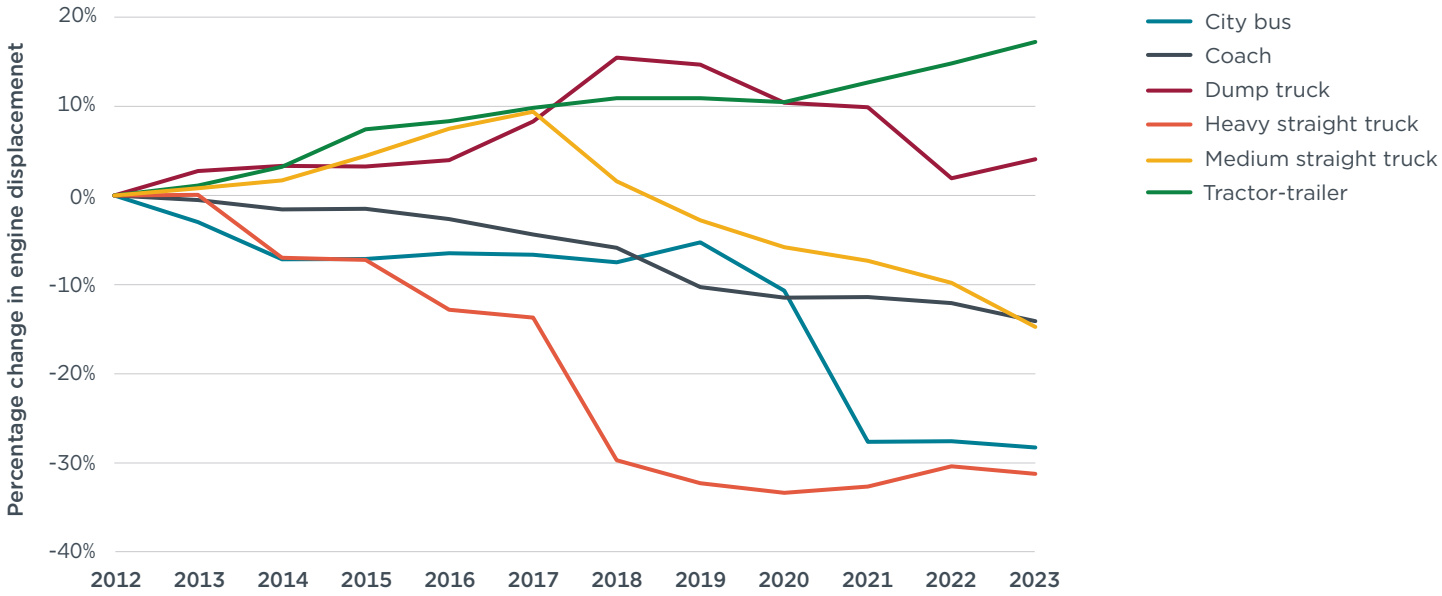

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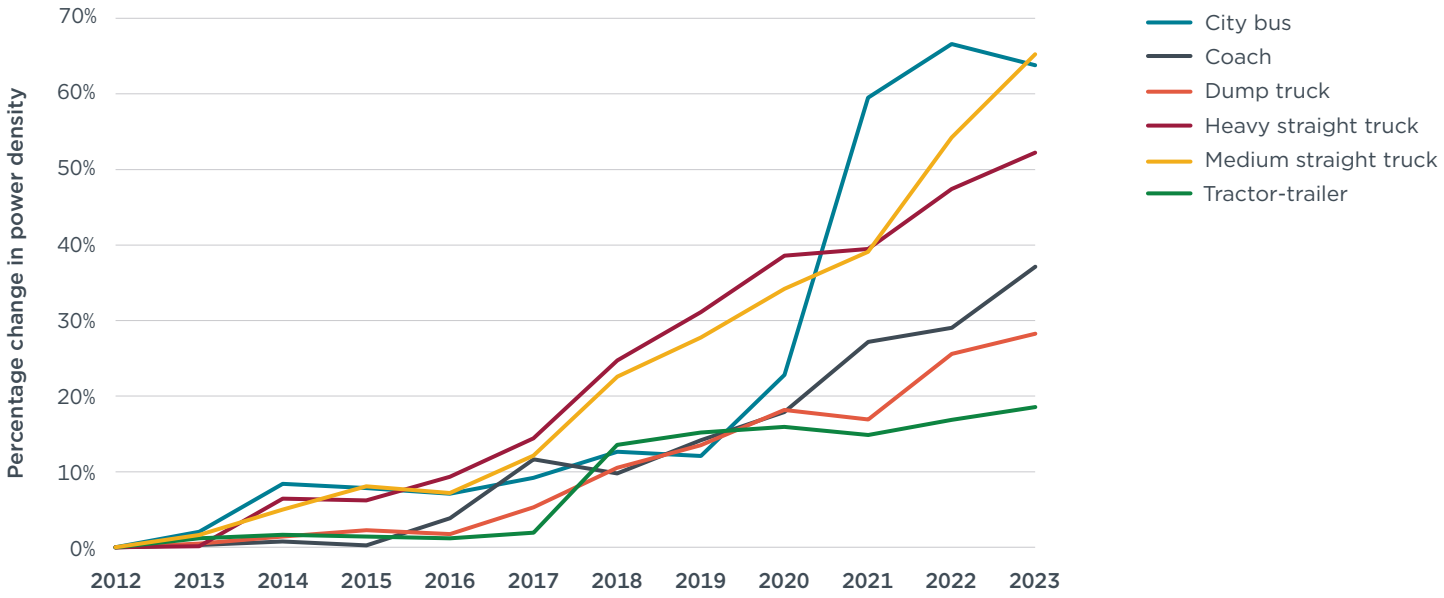
Figure 6
Power density



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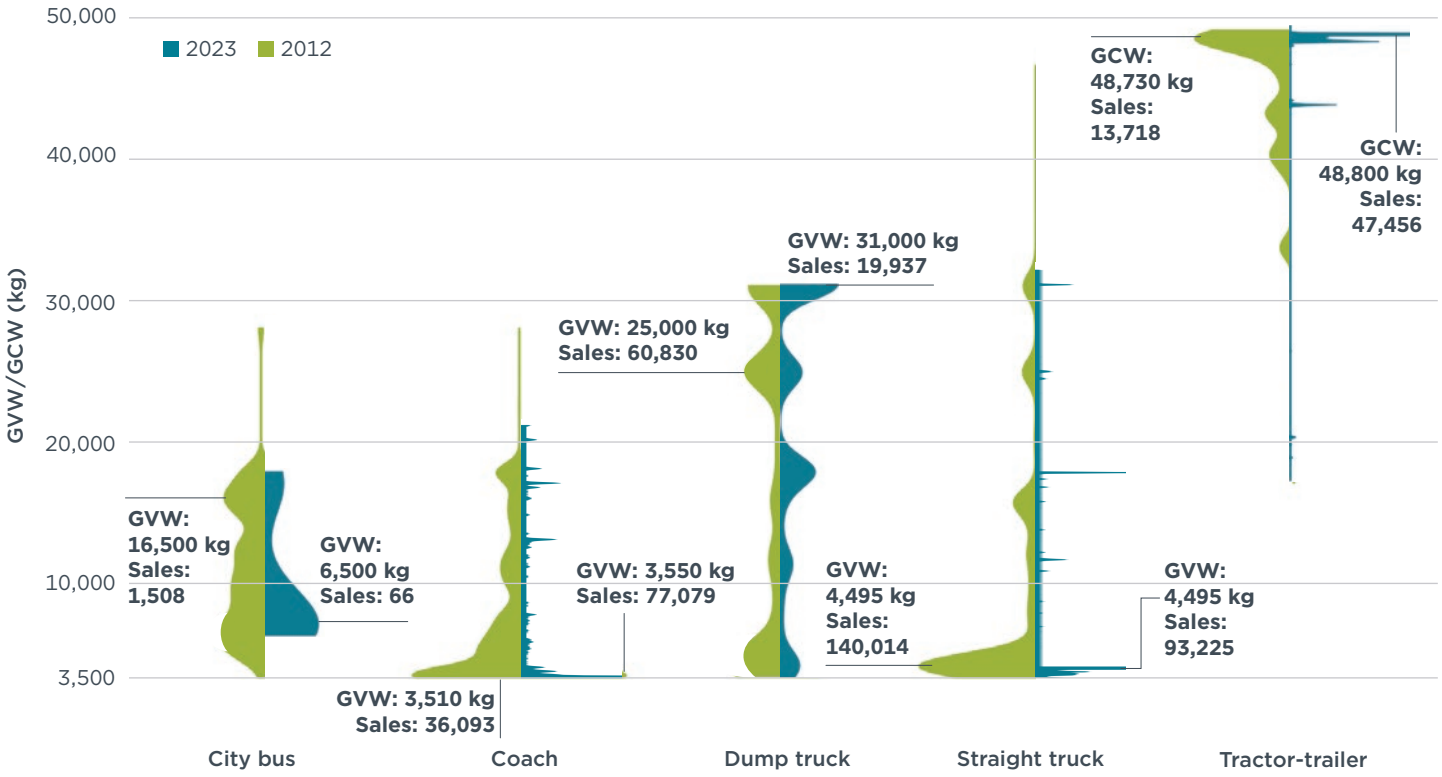
In 2023, relative to 2012, coaches, straight trucks, and tractor-trailers were more intensively grouped around particular weight thresholds (e.g., 3,500 kg for coaches, 4,500 kg for straight trucks, and 49,000 kg for tractor-trailers) (Figure 7). This reflects shifts in vehicle applications as well as the impacts of regulatory measures, as manufacturers have sought to maximize the payload capacity of their vehicles by designing them around the upper limit of regulatory GVW classes, a market tendency also known as vehicle enlargement.

Certain sales trends by GVW stand out. Heavier coaches have become less popular as fewer large coaches have been required for long distance travel due a boom of high-speed trains and increased flight coverage. From 2012 to 2023, passenger turnover ramped up in the high-speed rail industry, from 1.9 billion to 2.7 billion people, and almost doubled in the airline industry, from 320 million to 610 million people. Meanwhile, medium straight trucks below 4,500 kg have grown in popularity since 2020, after a 2017 MOT decision to waive work permit requirements for trucks under this weight threshold. For tractor-trailers, which are mostly responsible for long-haul delivery, models with a total weight of 48,800 kg were most popular in 2023. This follows the MOT's introduction in 2018 of a hard cap of 49,000 kg on the total weight of trucks used for freight purposes, which limits the maximum GCW for tractor-trailers with 6 axles, the typical configuration of the heaviest class of tractor-trailers in China.

Figure 7

Sales of each vehicle category by GVW (and GCW for tractor-trailers), 2012 and 2023



TYPE-APPROVED CO_2 EMISSIONS

For each vehicle category, CO_2 emission trends are assessed by GVW/GCW class: In Stage 3, there are 8 classes for tractor-trailers, 11 for dump trucks, 11 for straight trucks, and 12 for city buses and coaches. Vehicles of the same category and GVW class are held to the same maximum fuel consumption limit, such that the regulation can be visualized as a "staircase" by year.

In this study, we convert fuel consumption from diesel in L/100 km to CO_2 emissions in g/km. For each category, we then present CO_2 emission trends for all GVW classes and compare emissions with regulatory limits for the class with the highest sales in 2023, which are described in Table 2.[1]

Table 2
Selected vehicle segments and GVW classes for CO_2 emissions analysis

Vehicle categories	GVW/GCW (kg)
Tractor-trailer	46,000–49,000
Medium straight truck	3,500–4,500
Heavy straight truck	16,000–20,000
Dump truck	25,000–31,000
Coach	3,500–4,500

As mentioned above, China has a per-vehicle fuel consumption regulation for new models. The first such regulation, Stage 1, was enacted in 2012 and set limits for coaches, straight trucks, and tractor-trailers. An updated regulation, Stage 2, came into effect in 2014 and extended limits to dump trucks and city buses. Stage 3 came into effect in 2021 and imposed more stringent requirements on fuel consumption for all vehicle categories. Stage 4 standards will take effect in July 2025 and will tighten fuel consumption limits by approximately 12%–16% compared with Stage 3, depending on the vehicle type.

Amid these regulatory efforts, CO_2 emissions from diesel vehicles in China have generally declined over the past decade. Figures 8–16 illustrate the fuel consumption and CO_2 emissions of diesel HDVs from 2012 to 2023.

1 City buses were not selected for analysis because of the high electrification rate in this segment.

TRACTOR-TRAILERS

The historical CO_2 emission trends of the three best-selling GCW classes are shown in Figure 8. The introduction of Stage 1 standards did not initially drive down gross CO_2 emissions from tractors, as the limit was set considerably above the type-approved fuel consumption of these vehicles. The most significant reductions came with the adoption of Stage 3 standards: As illustrated in Figure 9, the best-selling tractor-trailer class in 2023 (with a GCW of 46,000–49,000 kg) recorded a decrease in average CO_2 emissions from 1,139.3 g/km in 2021 to 1,024.1 g/km in 2023, a 10.1% improvement. As of 2023, 0.6% of tractor-trailers in this class met the Stage 4 standards.

Figure 8

Sales-weighted CO_2 emissions of tractor-trailers, highlighting the three best-selling GCW classes

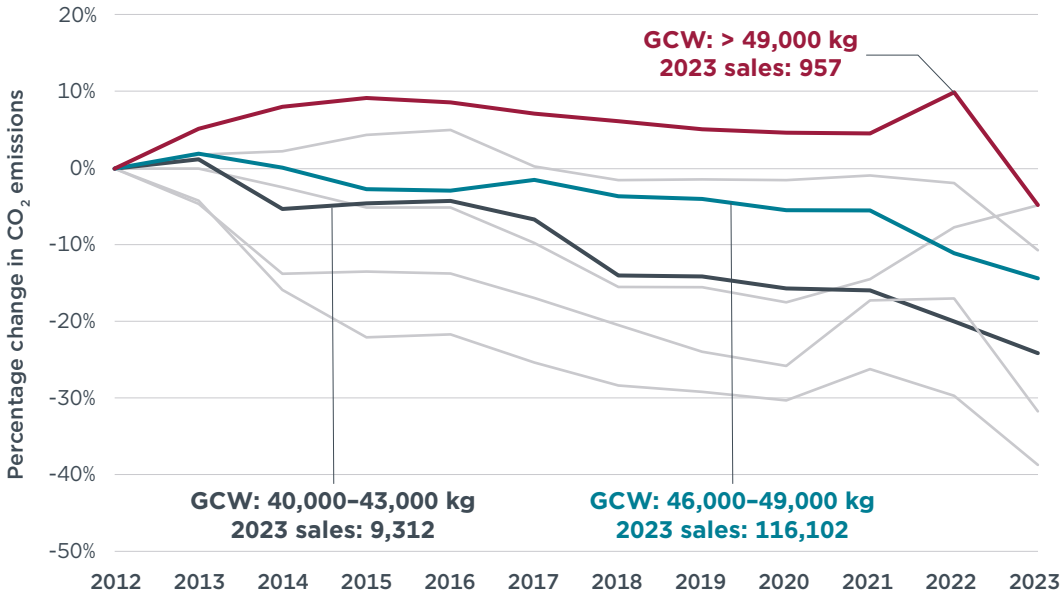
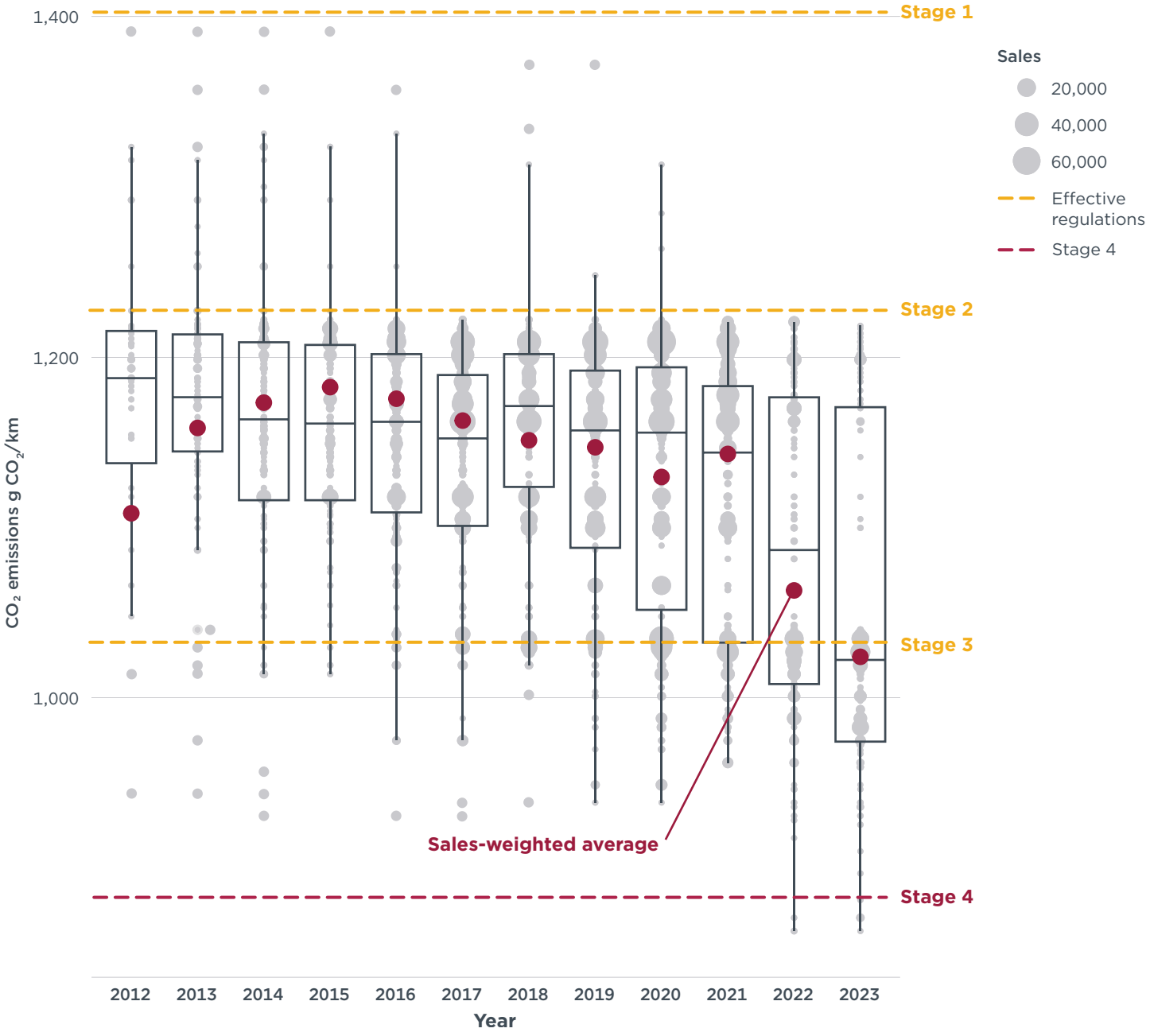


Figure 9

Sales-weighted CO_2 emission compliance for tractor-trailers of the best-selling GCW class (46,000–49,000 kg), converted from fuel consumption data



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MEDIUM AND HEAVY STRAIGHT TRUCKS

Among medium straight trucks, Stage 1 limits were too high to bring about a decrease in CO_2 emissions. For the best-selling GVW class in 2023 (3,500–4,500 kg), Stage 3 standards were intended to bring down average CO_2 emissions by 11.5% from Stage 2 (Figure 10). Average CO_2 emissions fell by an additional 2.5% in 2023, compared with 2021. As of 2023, approximately 22.9% of medium straight trucks of the most popular GVW class already met Stage 4 limits (Figure 11).

Figure 10

Sales-weighted CO_2 emissions of straight trucks, highlighting the three best-selling GVW classes

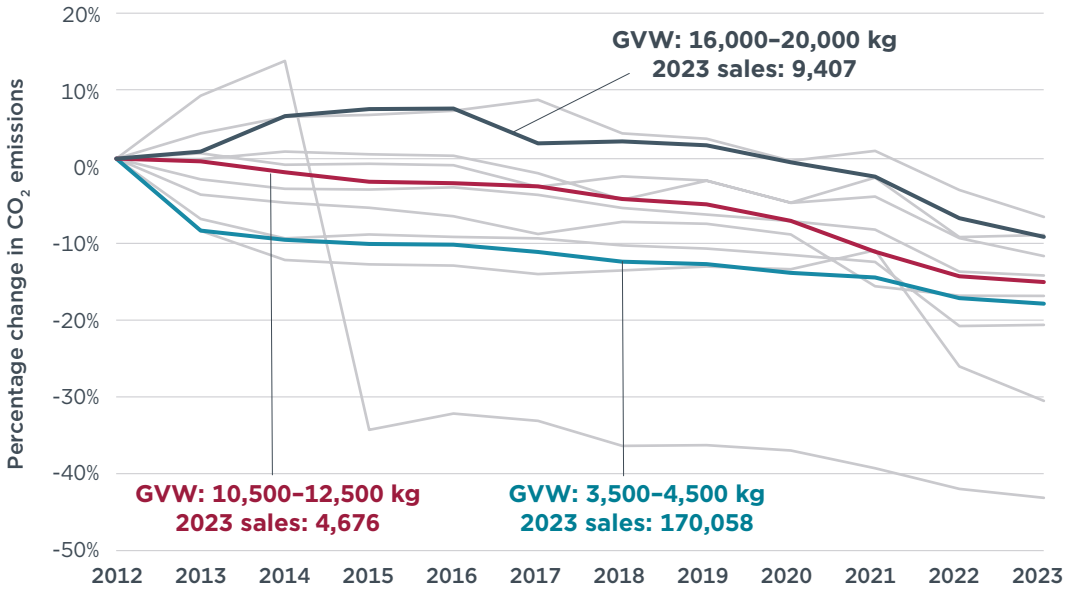

Figure 11

Sales-weighted CO_2 emission compliance for medium straight trucks of the best-selling GVW class in 2023 (3,500–4,500 kg), converted from fuel consumption data

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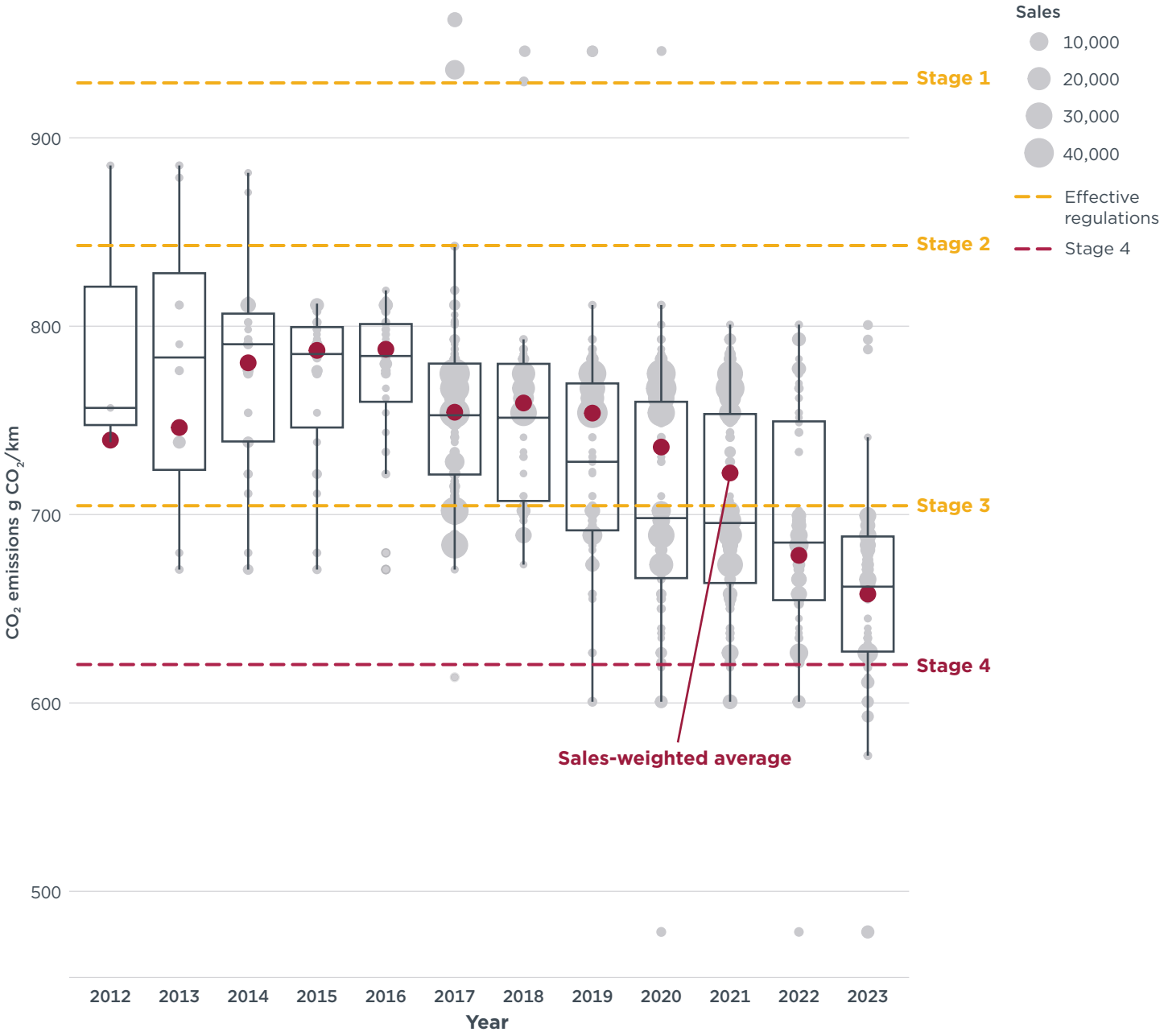
As with medium trucks, heavy truck emissions were largely unaffected by Stage 1 standards, which were set well above average emissions. Gross fuel consumption declined with the adoption of more stringent fuel consumption standards (Figure 12). Stage 3 drove down the average CO_2 emission in the best-selling GVW class (16,000–20,000 kg) by 5.1% in 2023, compared with 2021. As of 2023, 5.4% of straight truck models and 5.5% of heavy trucks sold already met the stricter Stage 4 criteria.

Figure 12

Sales-weighted CO_2 emission compliance for heavy straight trucks of the best-selling GVW class in 2023 (16,000–20,000 kg), converted from fuel consumption data



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DUMP TRUCKS

Dump trucks saw general improvement on fuel consumption due to the introduction of Stage 2 and Stage 3 standards. In 2023, the average fuel consumption of the top-selling GVW class (25,000–31,000 kg) was 39.5 L/100 km, an 8.5% improvement from 2021 (Figure 13). As of 2023, approximately 14.3% of dump trucks in this class already met the Stage 4 standards (Figure 14).

Figure 13

Sales-weighted CO_2 emissions of dump trucks, highlighting the three best-selling GVW classes

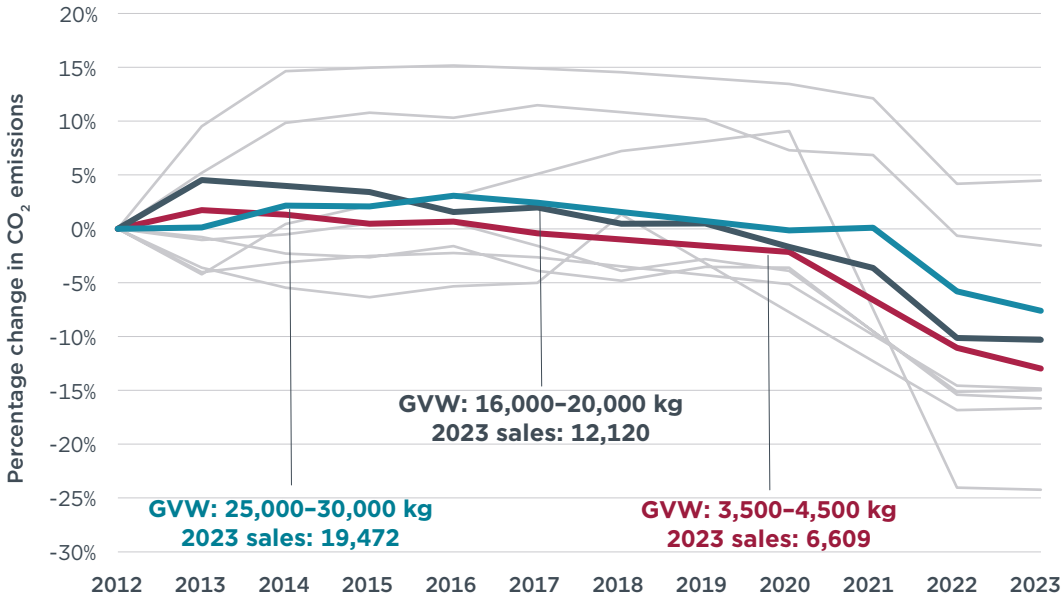

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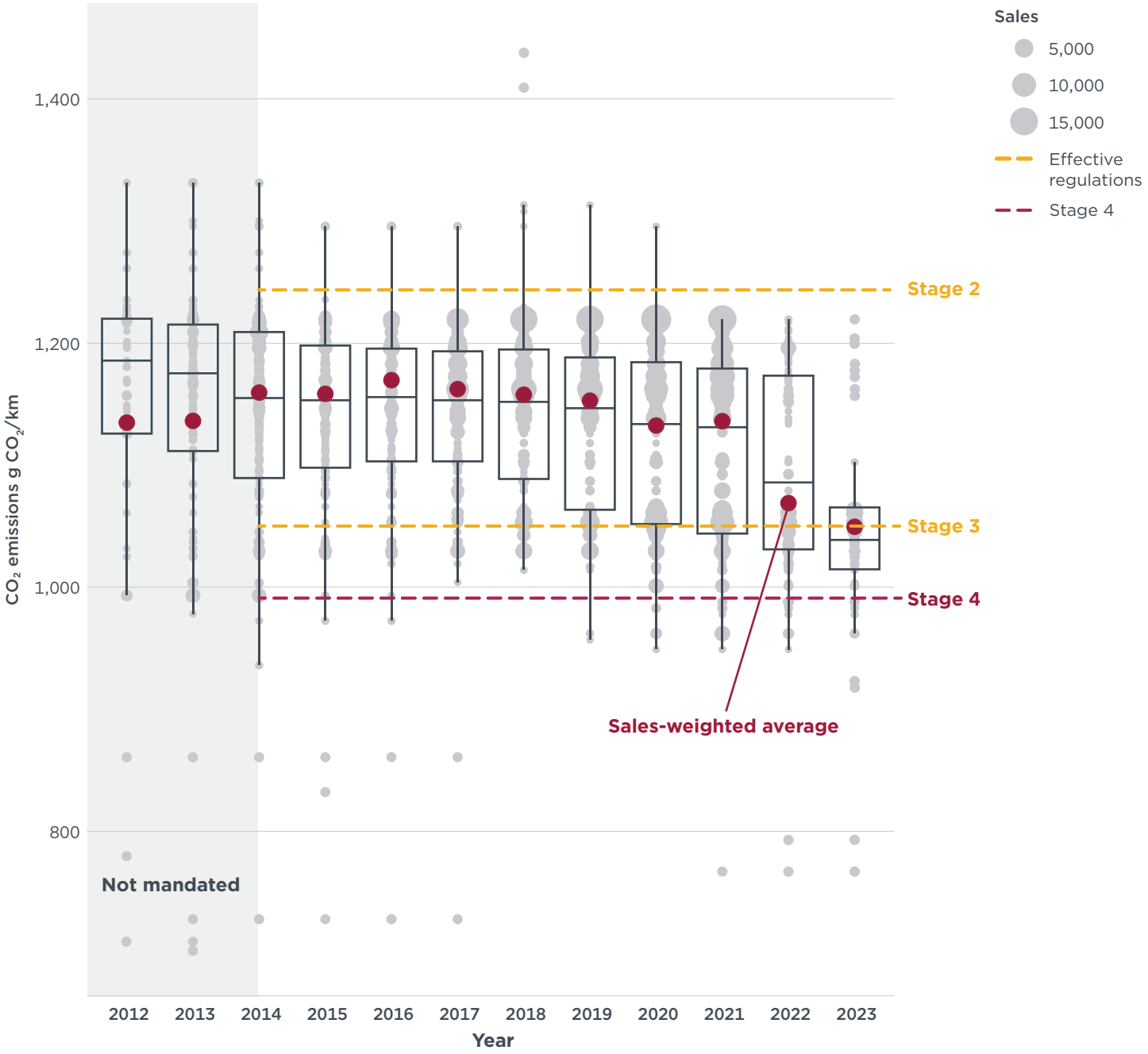
Figure 14

Sales-weighted CO_2 emission compliance for dump trucks of the best-selling GVW class in 2023 (25,000–31,000 kg), converted from fuel consumption data



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COACHES

The fuel efficiency of coaches has likewise improved due to increasingly stringent fuel consumption standards over the last decade. Stage 3 drove down the average fuel consumption of the best-selling class (3,500–4,500 kg) by 4.6% in 2023, compared with 2021 (Figure 15). As of 2023, approximately 1.4% of coaches in this class already met Stage 4 standards (Figure 16).

Figure 15

Sales-weighted CO_2 emissions of coaches, highlighting the three best-selling GVW classes

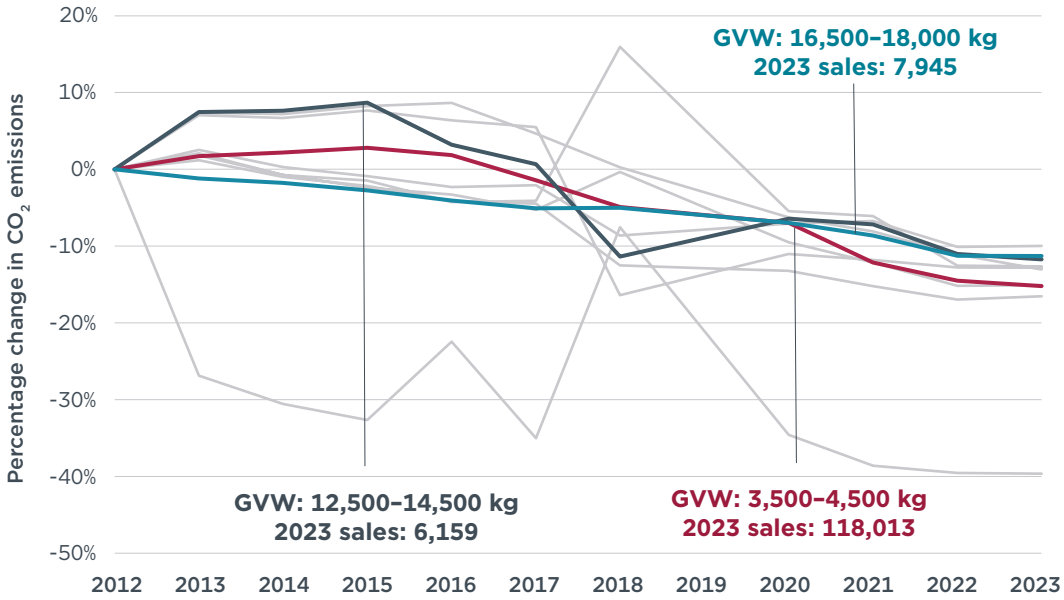

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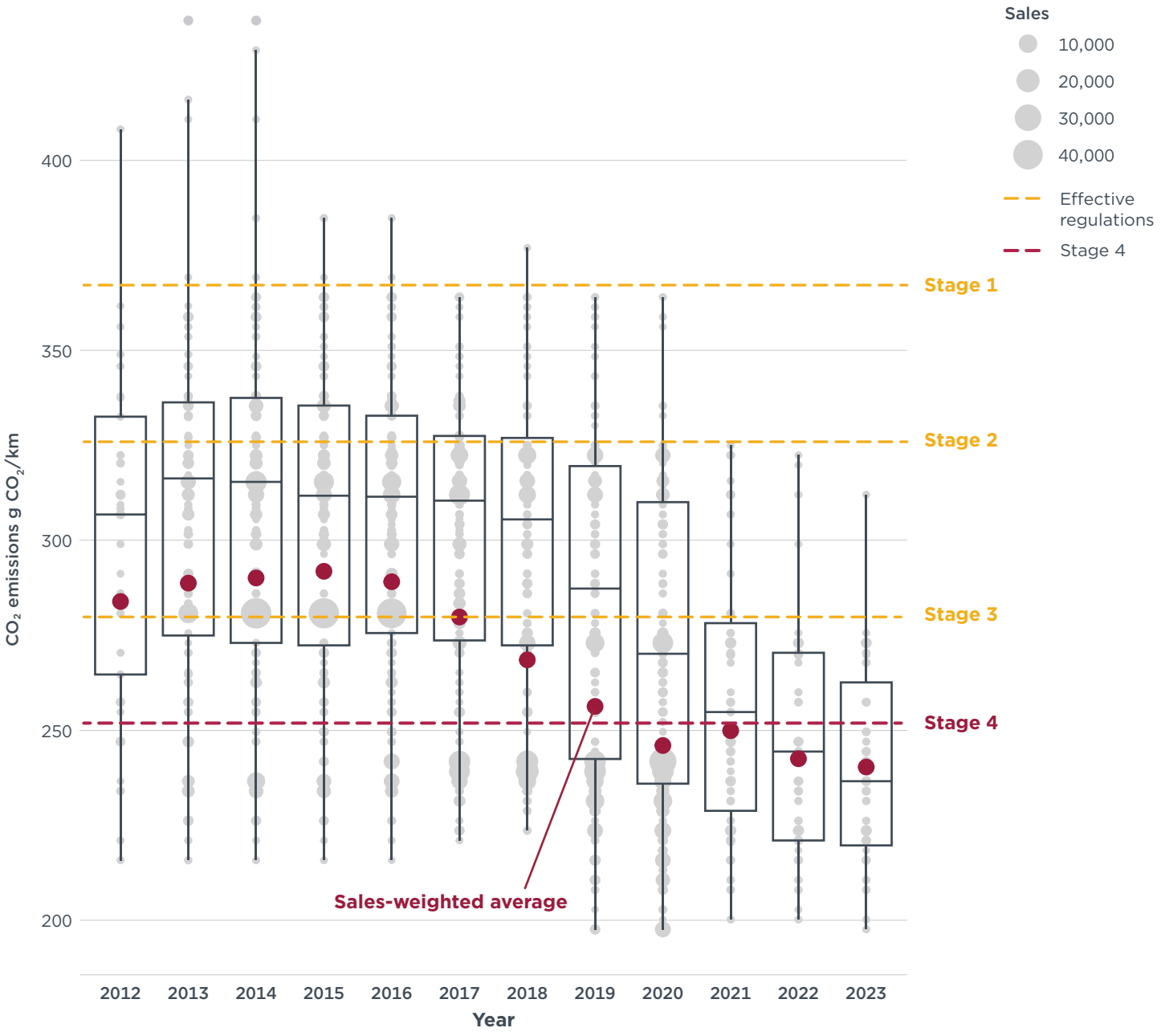
Figure 16

Sales-weighted CO_2 emission compliance for coaches of the best-selling GVW class (3,500–4,500 kg), converted from fuel consumption data



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EFFICIENCY AND EMISSION CONTROL TECHNOLOGY

Figure 17 illustrates the evolution of the market structure of fuel supply technologies for HDVs. Among the major trends between 2012 and 2023 was the application of common rail fuel injection, whereby fuel is stored at high pressure in a single rail and injected into each cylinder independently. This allows for more precise control of fuel delivery for improved performance and fuel efficiency and can therefore reduce pollutant emissions. Common rail was adopted with the China III emission standards, which took in effect in 2008, and took about a decade to be fully adopted by heavy-duty vehicles.

In 2023, almost all diesel HDVs in China were equipped with common rail systems, regardless of engine displacement or size.

Figure 17

Market structure of fuel supply technology, by engine displacement (ED)

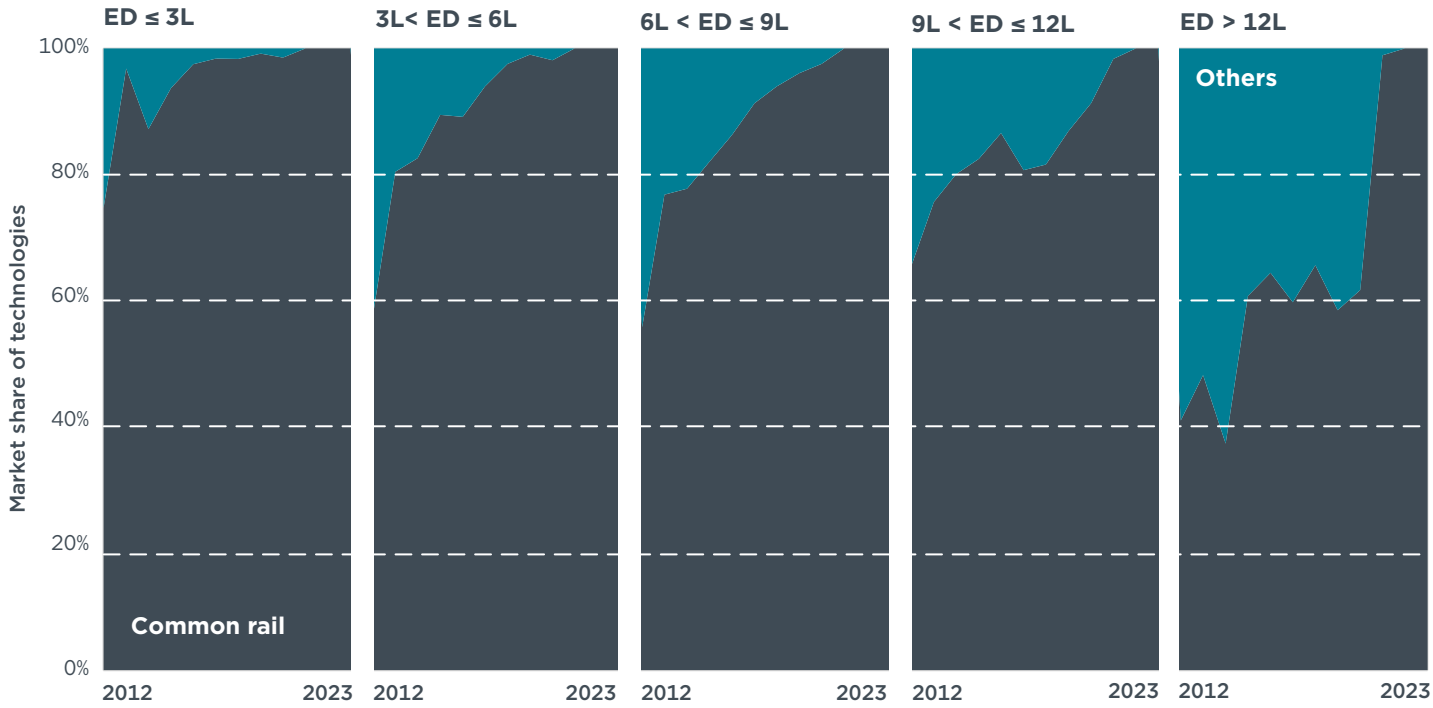

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Figure 18 shows the market shares of mainstream transmission techniques. In general, manual transmission (MT) is still dominating the heavy-duty truck industry, with over 80% and up to 95% of the market share for each engine displacement cluster between 2012 and 2023.

For heavier trucks, especially those with engine displacement over 12 L, automatic transmission (AT) and automated manual transmission (AMT) saw fluctuation, ending with a cumulative market share of approximately 30%. This shift of market structure toward these alternative transmission systems is mostly attributable to demand from customers for an easier and more comfortable driving experience (Detroit Diesel Corporation, 2017). Continuously variable transmission (CVT) was used in some light and medium trucks until 2017 but was subsequently phased out of the configuration table of trucks and tractors due to its incompatibility with the high torque demands and durability requirements of most HDVs.

Figure 18
Market structure of transmission technology, by ED

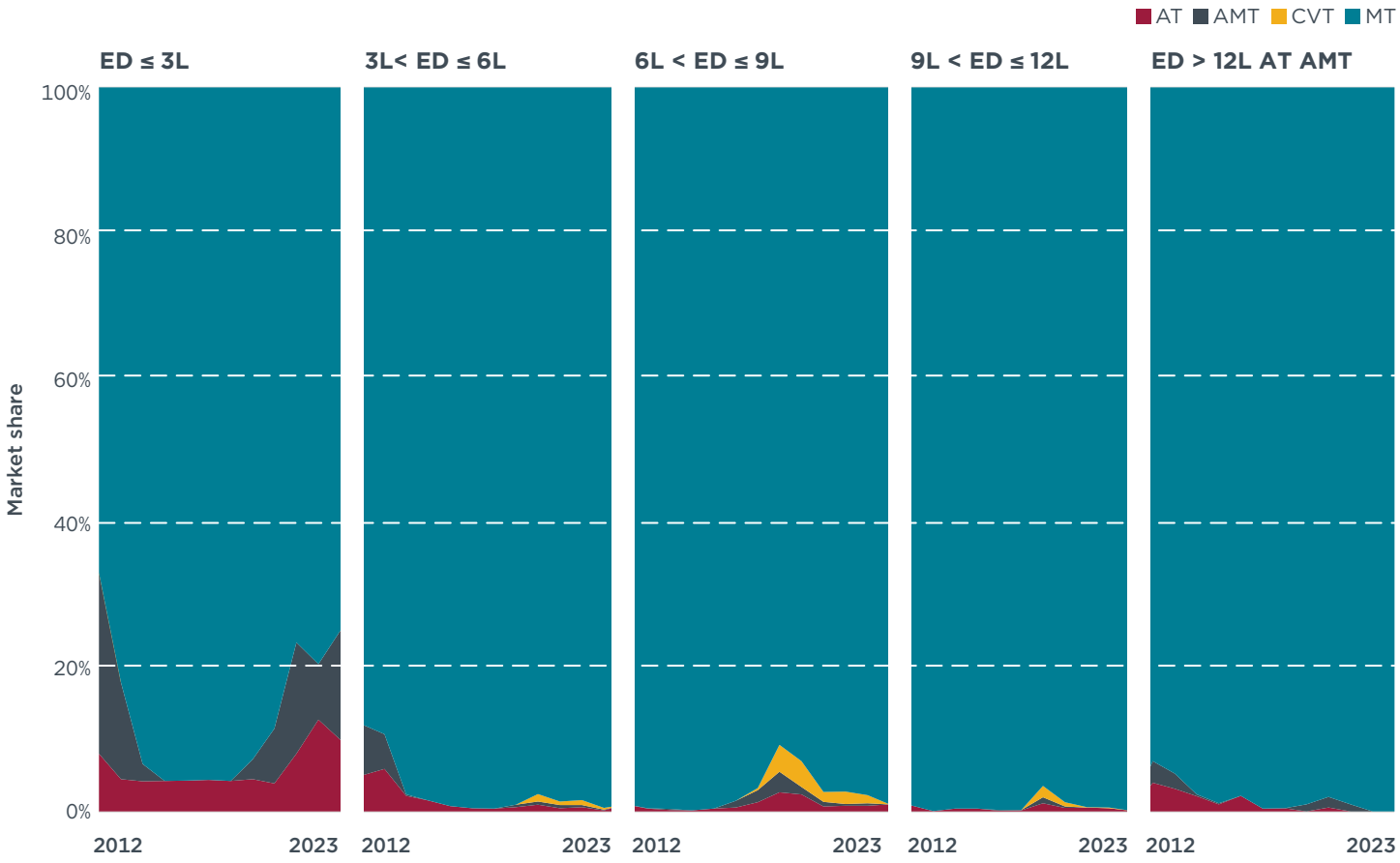

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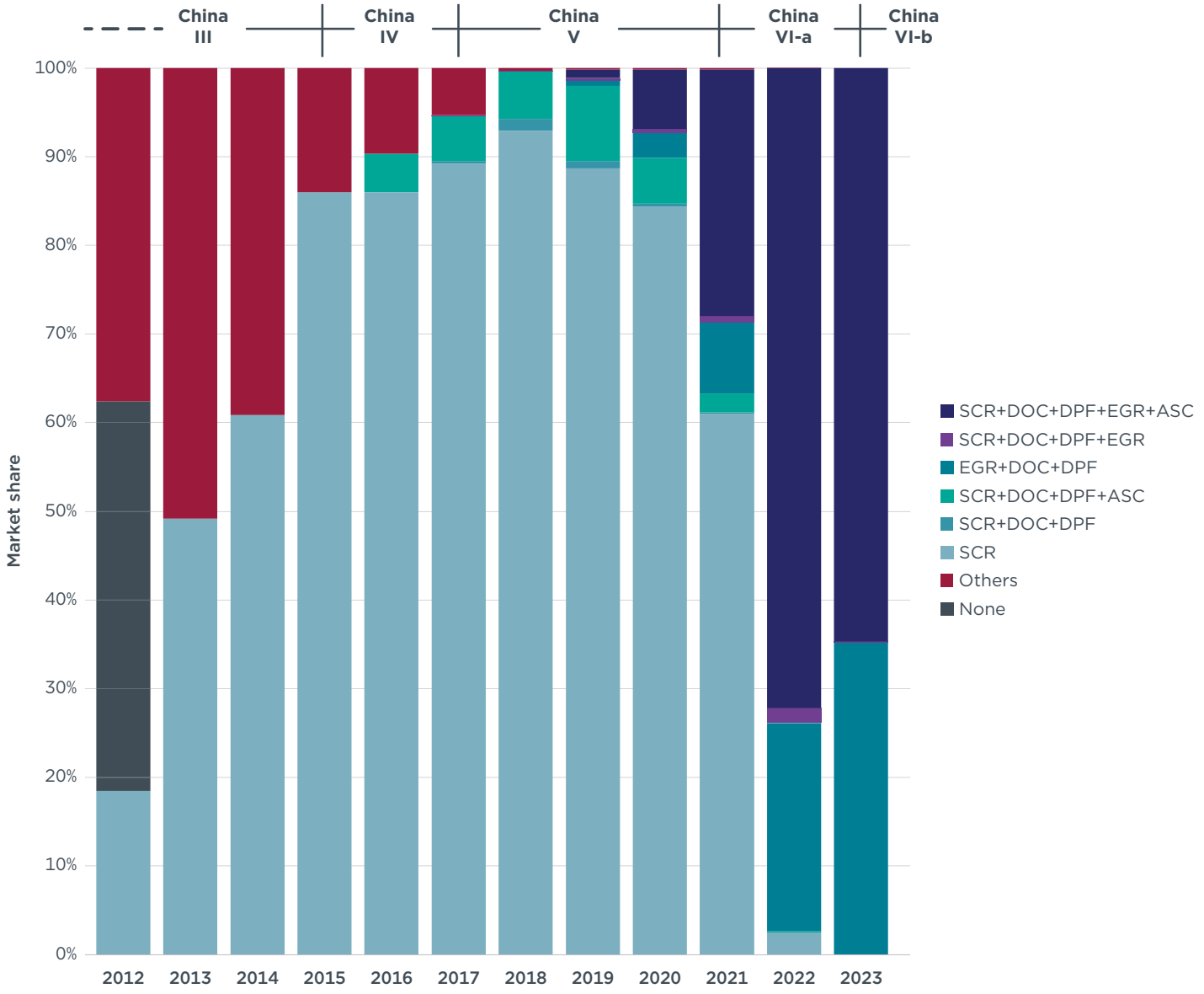
Figure 19 shows the year-by-year market evolution of aftertreatment technologies, which control emissions from the tailpipe. The evolution of emission control technology has tracked the development of pipeline emission standards for HDVs: China IV (which took effect in 2015), China V (2017), China VI-a (2021), and China VI-b (2023).

Selective catalytic reduction (SCR) systems have been the dominant technology since China III; after China V, they reached a 100% adoption rate. Exhaust gas recirculation (EGR), which is used to reduce engine-out NO_x emissions, was introduced to meet China V requirements and gradually rolled out until it achieved about 70% market share with China VI. Diesel particulate filter (DPF) technology, which is a device designed to remove soot and particulate matter from exhaust gases, grew in market share from less than 10% under China V to 100% after China VI, which made this technology a requirement in all emission control packages.

Since China VI, emission control systems have converged toward similar technical approaches, with the only difference being the presence or absence of EGR. Systems without EGR require higher NO_x conversion efficiencies. In 2023, the two most popular technology combinations split the market of diesel HDVs: Diesel Oxidation Catalyst (DOC)+DPF+SCR+Ammonia Slip Catalyst (ASC) (35%) and EGR+DOC+DPF+SCR+ASC (65%).

Figure 19

Market structure of aftertreatment technology



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APPENDIX

Table A1

Segmentation, GVW/GCW, and diesel consumption limits

	GVW class (tonnes)	Fuel consumption limits (L/100km)		GVW class (tonnes)	Fuel consumption limits (L/100km)		GCW class (tonnes)	Fuel consumption limits (L/100km)
Straight truck	3.5–4.5	11.5	Dump truck	3.5–4.5	13.0	Tractor-trailer	3.5–18	28.0
	4.5–5.5	12.2		4.5–5.5	13.5		18–27	30.5
	5.5–7	13.8		5.5–7	15.0		27–35	32.0
	7–8.5	16.3		7–8.5	17.5		35–40	34.0
	8.5–10.5	18.3		8.5–10.5	19.5		40–43	35.5
	10.5–12.5	21.3		10.5–12.5	22.0		43–46	38.0
	12.5–16	24.0		12.5–16	25.0		46–49	40.0
	16–20	27.0		16–20	29.5		>49	40.5
	20–25	32.5		20–25	37.5			
	25–31	37.5		25–31	41.0			
	>31	38.5		>31	41.5			
Coach	3.5–4.5	10.6	City bus	3.5–4.5	11.5			
	4.5–5.5	11.5		4.5–5.5	13.0			
	5.5–7	13.3		5.5–7	14.7			
	7–8.5	14.5		7–8.5	16.7			
	8.5–10.5	16.0		8.5–10.5	19.4			
	10.5–12.5	17.7		10.5–12.5	22.3			
	12.5–14.5	19.1		12.5–14.5	25.5			
	14.5–16.5	20.1		14.5–16.5	28.0			
	16.5–18	21.3		16.5–18	31.0			
	18–22	22.3		18–22	34.5			
	22–25	24.0		22–25	38.5			
	>25	25.0		>25	41.5			

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