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CO_2 emissions from trucks in the European Union: An analysis of the 2020 reporting period

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Introduction

The European Union's CO_2 standards for heavy-duty vehicles (HDVs) currently require most new trucks to reduce their emissions by 15% in 2025 and 30% in 2030, compared to a 2019/2020 baseline (European Commission, 2019a).[1] To inform the regulatory process, official certification data on the CO_2 emissions of new trucks are published annually by the European Environment Agency (EEA) on behalf of the European Commission (European Commission, 2018).

We previously published an analysis of the CO_2 emissions data from the baseline period that ran from July 2019 to June 2020, along with detailed data on the market penetration of various emissions reduction technologies (Ragon & Rodriguez, 2021). In this report, we provide an update of that analysis based on the data for the reporting period that ran from July 2020 to June 2021, hereafter referred to as the 2020 reporting period as defined in regulation (EU) 2018/956 (European Commission, 2018). As with this previous report, here we track the progress of manufacturers towards their 2025 emissions reduction target, assess their performance in different technology areas, and identify each manufacturer's chosen technology pathway to comply with the standards.

Unless specified otherwise, all data presented in this paper are extracted from the publicly available certification data monitored in the 2020 reporting period according to regulation (EU) 2018/956, and were obtained from EEA's website (European Environment Agency, 2022).

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1 The baseline period was from the 1st of July 2019 through the 30th of June 2020. On February 14, 2023, the European Commission released a proposal to amend the existing CO_2 standards for Europe's heavy-duty vehicles. The proposal increases the 2030 target to 45% and introduces targets of 65% in 2035 and 90% in 2040. It also extends the scope of the standards to cover more varieties of trucks, buses, coaches, and trailers.

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Market analysis

The Certification Regulation (EU) 2017/2400 requires the monitoring and reporting of the emissions from ten VECTO groups. VECTO groups are classifications given to HDVs based on several attributes, including axle configuration, body type, and gross vehicle weight. Manufacturers producing four of these VECTO groups—4, 5, 9, and 10—were required to report on their vehicle characteristics, including energy and emissions performance from 2019. Six VECTO groups have been added in the latest release—1, 2, 3, 11, 12, and 16— and manufacturers producing these vehicles were required to report this information from 2020.[2] As such, this is the first year of data available for these latter six vehicle groups. The attributes of these ten vehicle groups are shown in Table 1.

Table 1. VECTO group characteristics

VECTO group	Axle configuration	Body type	GVWR (t)	Monitoring and reporting from
1	4x2	Rigid/Tractor	>7.5-10	Jan 2020
2	4x2	Rigid/Tractor	>10-12	Jan 2020
3	4x2	Rigid/Tractor	>12-16	Jan 2020
4	4x2	Rigid	>16	July 2019
5	4x2	Tractor	>16	July 2019
9	6x2	Rigid	all weights	July 2019
10	6x2	Tractor	all weights	July 2019
11	6x4	Rigid	all weights	July 2020
12	6x4	Tractor	all weights	July 2020
16	8x4	Rigid	all weights	July 2020

Note: GVWR is gross vehicle weight rating

Groups 4, 5, 9, and 10 are required to reduce their emissions under the CO_2 standards (European Commission, 2019), whereas the remaining groups have not yet been included in the standards.[3] Hereafter, we classify groups 4, 5, 9, and 10 under the term "regulated," and the remining vehicle classes as "unregulated."

Regulated vehicles are further split into subgroups based on their mission profile, either urban delivery (UD), regional delivery (RD), or long-haul (LH), which are described further in Table 2.

Table 2. VECTO subgroup characteristics

VECTO group	Subgroup	Cabin type	Engine power
4	UD	All	< 170 kW
	RD	Day cab	≥ 170 kW
		Sleeper cab	≥ 170 kW and < 265 kW
	LH	Sleeper cab	≥ 265 kW
5	RD	Day cab	All
		Sleeper cab	<265 kW
	LH	Sleeper cab	≥ 265 kW
9	RD	Day cab	All
	LH	Sleeper cab	All
10	RD	Day cab	All
	LH	Sleeper cab	All

2 Groups 1, 2, and 3 were required to report from January 2020, while groups 11, 12, and 16 were required to report from July 2020.

3 The proposed revision to the CO_2 standards extends the scope to include several new vehicle groups, including groups 1, 2, 3, 11, 12, and 16.

Figure 1 shows the breakdown of sales in 2019 and 2020 by these regulated and unregulated vehicle groups. In 2020, regulated vehicles were responsible for 89% of the 210,000 total reported sales of trucks (i.e., all ten VECTO groups reported), and 59% of all HDV sales (i.e., all trucks and buses). The market division of trucks has changed since 2019, most notably by a reduction in the share of 10-LH vehicles and an increase in the share of 5-LH. This change was largely driven by the United Kingdom's departure from the European Union in 2020. Group 10-LH vehicles are very common in the UK, whereas group 5-LH is more common in most other European countries. The UK was required to report emissions in 2019 but did not need to do so in 2020.

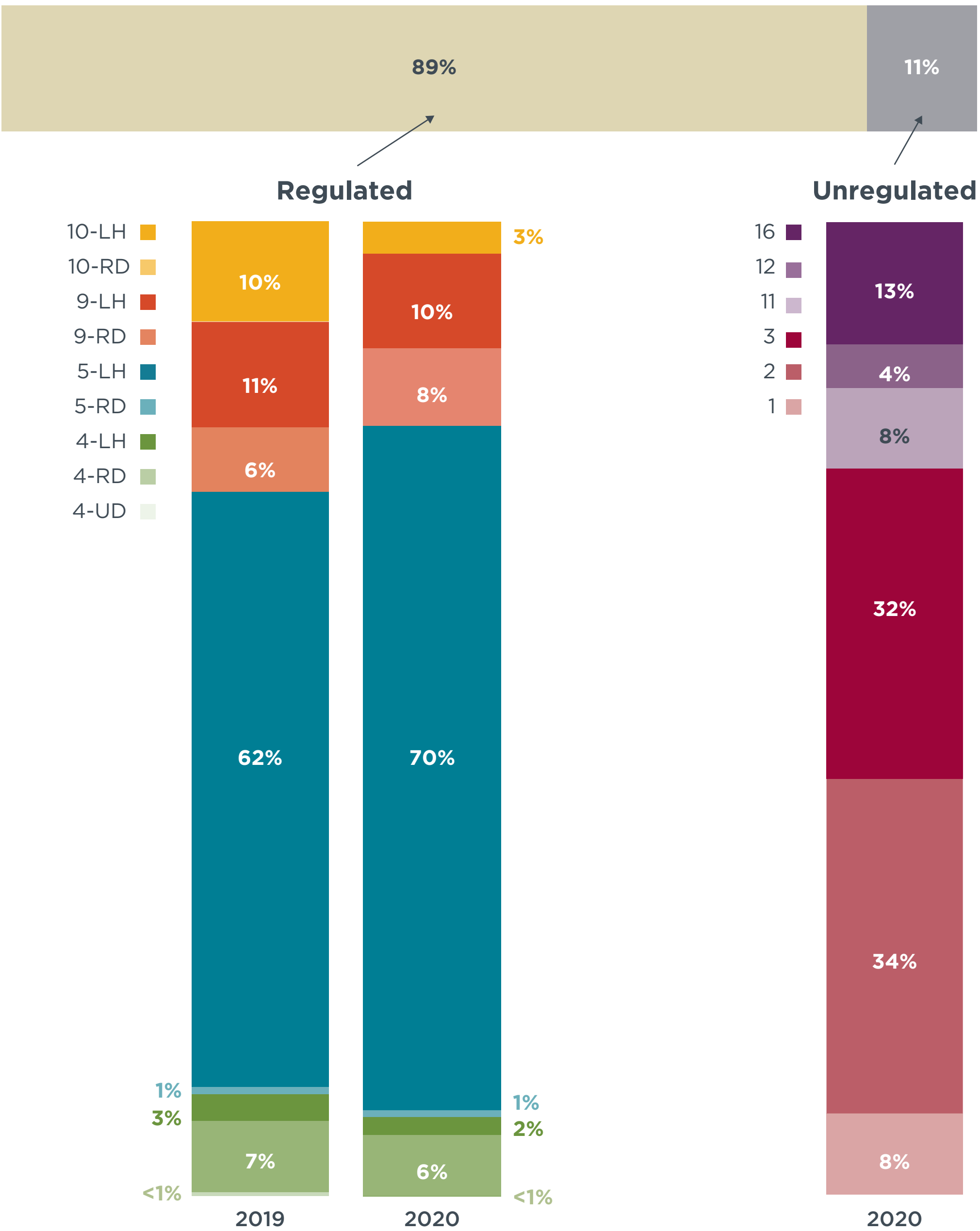

Figure 1. Vehicle sales share for regulated and unregulated vehicles.

The weighted share of use cases of these regulated and unregulated vehicles is defined under the annex to the proposal of the CO_2 standards amendment (European Commission, 2023). For example, a VECTO 5-LH truck is assumed to run 90% under a long-haul use case while the smaller VECTO category 2 truck splits its share evenly over urban and regional delivery. These weights are shown in Table 3.

Table 3. Use case weights attributed to each VECTO subgroup and total sales in the 2020 reporting period.

VECTO subgroup	Regional delivery	Long haul delivery	Urban delivery	Construction	2020 sales
1	40%	-	60%	-	2,173
2	50%	-	50%	-	8,890
3	50%	-	50%	-	8,264
4-UD	-	-	100%	-	107
4-RD	90%	10%	-	-	11,508
4-LH	10%	90%	-	-	3,322
5-RD	90%	10%	-	-	1,327
5-LH	10%	90%	-	-	129,131
9-RD	90%	10%	-	-	14,543
9-LH	10%	90%	-	-	17,900
10-RD	90%	10%	-	-	54
10-LH	10%	90%	-	-	5,905
11	50%	-	-	50%	2,148
12	70%	-	-	30%	1,163
16	-	-	-	100%	3,234
Sales weighted average	**24%**	**69%**	**5%**	**2%**	

Applying a sales-weighted average to these use case shares, long-haul operations dominate the heavy-duty vehicle market, as they did in 2019, with a 69% share. Regional delivery use cases had a sales-weighted share of 24%, driven primarily by rigid trucks groups 4 and 9. Urban delivery use cases had a sales-weighted share of 5% driven entirely by groups 1, 2, 3 and 4-UD, while construction use cases had a sales-weighted share of 2% driven by groups 11, 12, and 16.

Figure 2 shows the variation in use case shares across manufacturer sales portfolios. Across the regulated classes, DAF had the highest share of all manufacturers invested in long-haul trucks with 90% of sales. Renault had the highest share of regional delivery trucks with 21%. IVECO showed the most pronounced change in market shares relative to the 2019 reporting period, having increased its share of long-haul vehicles by 8% while reducing the share of regional vehicles by the same amount.

There has been an increase in the share of 5-LH vehicle sales across all manufacturers from 2019 to 2020. Only considering the EU-27 Member States (and excluding the 2019 UK data as they did not report in 2020), the share of 5-LH vehicles (tractor-trailers) increased by 3%, taking over shares from 9-LH and 4-LH rigid body trucks. On a manufacturer level, the greatest share increase in 5-LH vehicles was seen from IVECO (8%), MAN (4%), and DAF (3%).

Considering unregulated classes, Scania's sales in the 2020 reporting period were almost entirely centered on construction and municipal vehicle sales (groups 11, 12, and 16) while DAF, IVECO, Renault, and Mercedes-Benz sell predominantly regional and urban delivery vehicles (groups 1, 2, and 3). MAN and Volvo had a slightly more diverse portfolio across the unregulated vehicle categories.

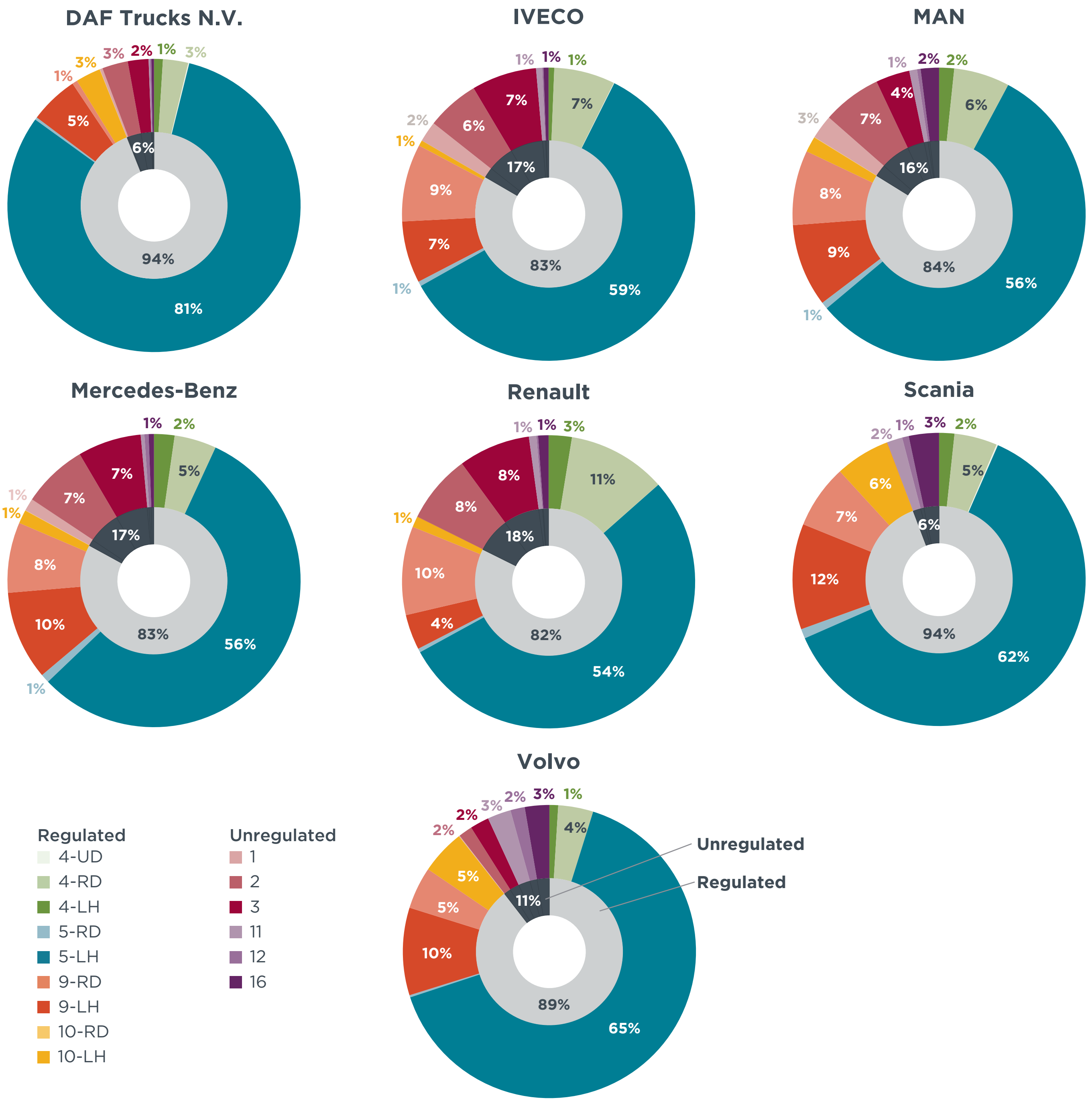

Figure 2. Vehicle sales shares by manufacturer and VECTO group in 2020.

The overall market share by manufacturers in the 2020 reporting period is shown in Figure 3. Most manufacturers held a similar share of the market with approximately 15%, with the exception of IVECO and Renault with 9%. IVECO had the single largest increase in sales share of any manufacturer in 2020 of 2.4%, while the biggest loss was felt by DAF of 1.6%.

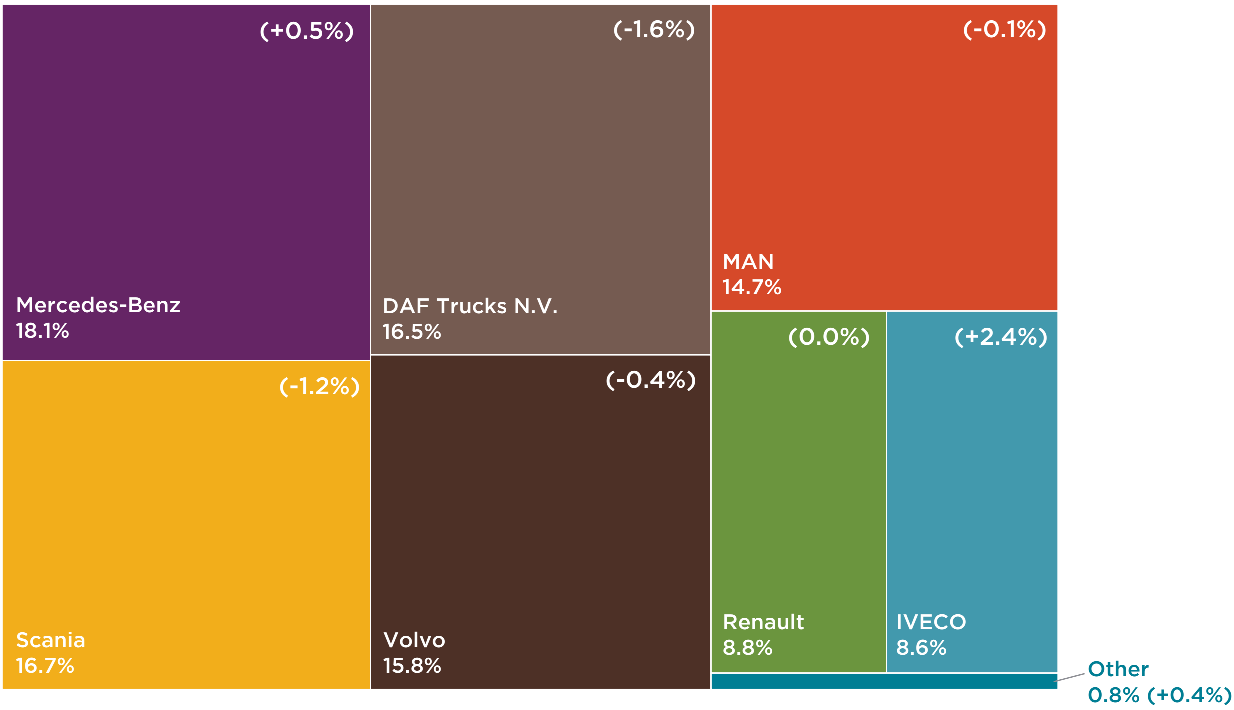

Figure 3. Vehicle sales in 2020 split by manufacturer. Percentages in brackets denote the change since 2019.

Changes in CO_2 emissions from the baseline period

To reduce the administrative burden for manufacturers, CO_2 emissions for HDVs are certified through the simulation tool, VECTO. VECTO assumes standardized test cycles and payloads intended to represent the average use-case of a vehicle to certify their emissions. A study conducted by Graz University of Technology showed good alignment between the simulated CO_2 emissions and real-world emissions of trucks, indicating that these certified values provide an insight into the average evolution of emissions when considering the fleetwide values (Fontaras, Grigoratos, Giechaskiel, & Ciuffo, 2017). Thus, the emissions presented in this section provide insight into the average use case for these vehicles, but real-world emissions will be dependent on the vehicle's specific use profile and terrain and may not perfectly align with the certified CO_2 emissions value.

Emissions from four of the nine regulated VECTO subgroups decreased between 2019 and 2020. Most importantly, emissions from the subgroup 5-LH, which were responsible for ~60% of total HDV emissions in 2020 (Mulholland et al., 2022), decreased by 1.3% from 56.6 to 55.9 gCO_2/tkm.[4] The second highest emitting class, 9-LH, responsible for ~10% of 2020 emissions, also reduced its emissions by 1.8%. While long-haul trucks decreased their emissions over this one-year period, the emissions from regional and urban delivery trucks increased by 0.5% and 0.1%, respectively.

To provide a fair metric to assess the total reduction in the European HDV fleet, the changes in emissions must be weighted by both the sales share and the mileage, payload, and weighting (MPW) factor, which is determined as the product of the vehicle's mileage and payload relative to the equivalent for the most common truck group in Europe, 5-LH.[5] When weighted by these two factors, regulated European trucks reduced their emissions from 52.51 to 51.96 gCO_2/tkm (equal to 673.4 and 665.7

4 Emissions are reported in terms of gCO_2/tonne kilometers (tkm) to account for the payload of a vehicle. If a truck carrying a payload of 5 tonnes travels 1 kilometre, it has travelled 5 tkm.

5 The MPW factor is also used in determining a manufacturer's compliance with their respective emission reduction targets.

gCO_2/km, respectively), or a decrease of 1% between 2019 to 2020. In context, the current CO_2 standards require a 15% reduction by 2025, or an average reduction of 2.5% per year.

In 2020, the manufacturers of the unregulated vehicle classes were required to monitor and report their emissions and fuel consumption for the first time. Groups 1, 2, and 3, broadly defined as smaller urban and regional delivery trucks, reported a lower level of emissions in terms of gCO_2/km and a better fuel economy in terms of l/100 km than nearly all regulated vehicles. However, these vehicles have a higher emissions level in terms of gCO_2/tkm owing to a low average reference payload.

Conversely, groups 11, 12, and 16, broadly defined as construction vehicles, are found to have lower fuel economy than all regulated vehicle groups. Fuel consumption in terms of l/100km of groups 12 and 16 were twice as high as the average regulated groups, with group 11 four times as high. These vehicles have a higher average unloaded weight compared to delivery vehicles and can be required to carry heavy loads with frequent stops and starts, whereas delivery vehicles travel more regularly at a constant speed. Even though these vehicles have a significantly higher fuel consumption than their delivery counterparts, it is representative of their demanding use profiles. Table 4 summarizes the average fuel consumption (in terms of l/100km) and CO_2 emissions (in terms of gCO_2/tonne-km and gCO_2/vehicle-km) of all VECTO groups.

Table 4. Emissions and fuel economy of all certified truck groups in 2019 and 2020.

		gCO_2/tkm		gCO_2/km		l/100km	
	Vehicle subgroup	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Regulated	4-LH	106.0	102.3	786.2	759.2	29.7	28.9
	4-RD	197.2	197.9	627.0	629.2	23.3	23.2
	4-UD	307.2	307.4	814.1	814.7	30.9	27.6
	5-LH	56.6	55.9	783.5	773.5	29.2	28.3
	5-RD	84.0	83.2	861.7	853.7	31.2	31.7
	9-LH	65.2	64.0	873.2	857.4	32.8	31.6
	9-RD	111.0	111.7	696.9	701.5	25.5	25.3
	10-LH	58.3	58.6	806.5	810.5	30.8	30.9
	10-RD	83.3	88.5	854.1	907.4	32.6	34.7
Unregulated	1		450.3		618.8		23.6
	2		364.5		678.0		25.7
	3		244.7		674.7		25.5
	11		668.8		2407.6		91.9
	12		108.6		1113.6		42.5
	16		110.3		1082.4		40.9

Figure 4 presents the distribution of emissions across all subgroups, with the reference emissions in 2019 (regulated vehicles only) and 2020 (regulated and unregulated vehicles), and the change presented where possible. Relative to 2019, the distribution of vehicle emissions for most vehicle groups have homogenized slightly. The coefficient of variation—the standard deviation of the emissions series for each vehicle within a group divided by the group's mean value—reduced across nearly all groups, meaning a narrower spread of emissions across all vehicles. The coefficient of variation did, however, marginally increase in the group with the highest sales share, 5-LH, indicating an increase in the heterogeneity of the emissions across this group.

Figure 5 provides the average emissions performance for each subgroup by manufacturer in 2019 and 2020. IVECO was the highest emitting of all reporting manufacturers and Scania the lowest. Specifically, IVECO had the worst performing average emissions for every regulated subgroup except for 4-UD, which accounted for just 0.4% of regulated vehicle sales in 2020. Of the unregulated vehicles, IVECO was also the worst performer for medium trucks 1, 2, and 3. They performed slightly better for in the municipal and construction classes 12 and 16, however these vehicles only make up a small share of their vehicle sales.

Scania was the best performer in seven of the nine subgroups, except for 4-UD and 9-RD. Most notably, Scania performed well above average in class 5-LH, with their emissions 5% lower than the overall subgroup average. In the unregulated vehicles, Scania did not perform as well and remained around the average for classes 11, 12, and 16, which make up the majority of their unregulated sales. Scania's superior performance in group 5-LH was found to largely derive from their significantly lower reported coefficient of air drag compared to its competitors (Ragon & Rodriguez, 2021). However, this does not necessarily translate across for municipal and construction trucks where air drag performance may play a lesser role in emissions reduction relative to engine performance.

Lastly, all manufacturers lowered their emissions in the largest vehicle segment, 5-LH, with MAN making the most significant improvement over 2019 (3.0% improvement), followed by Volvo (2.3% improvement). Scania had one of the lowest improvements in this area (0.7%), second only to IVECO (0.6%)

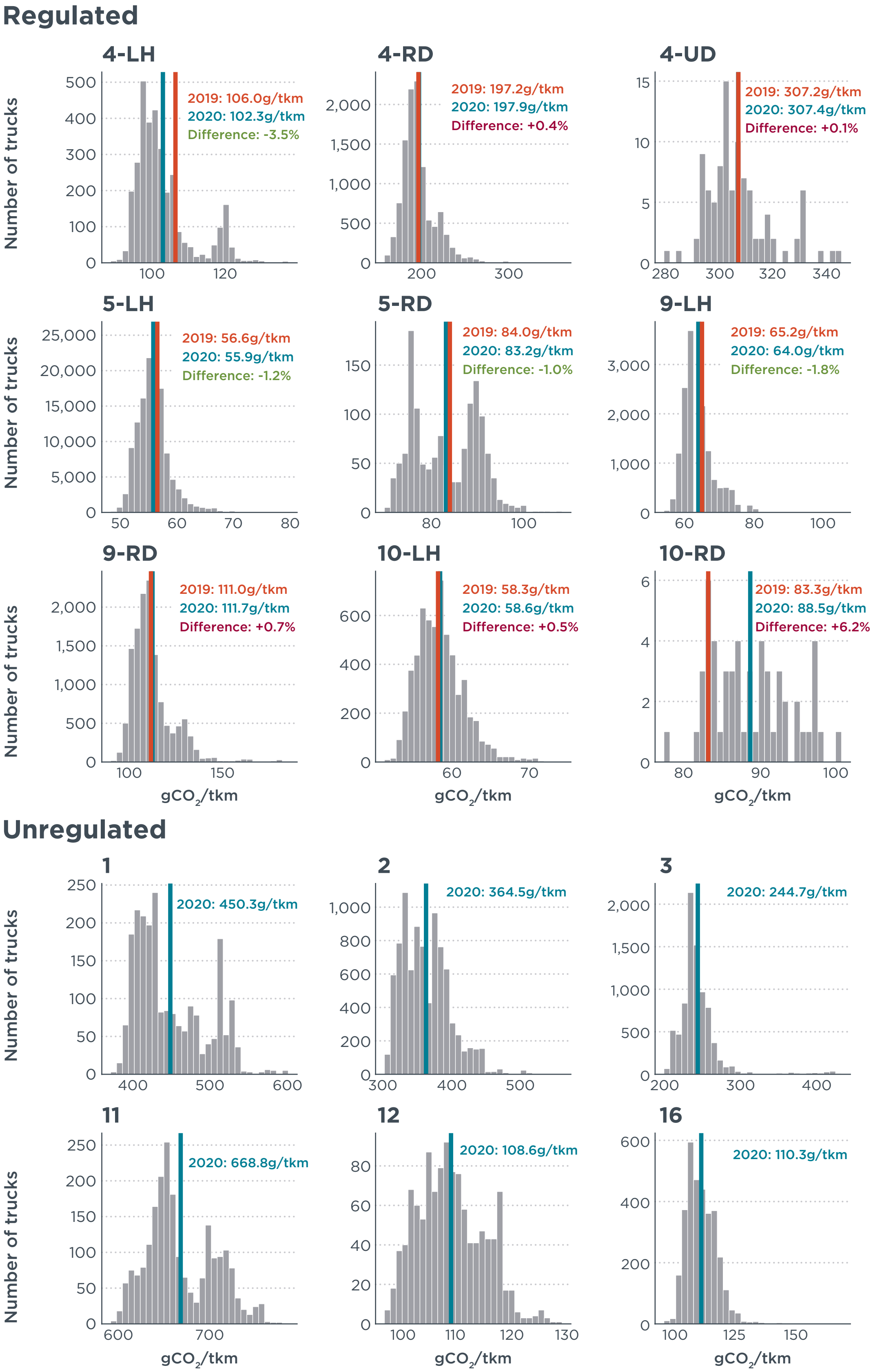

Figure 4. Distribution of CO_2 emissions for each subgroup. The orange and blue lines denote to overall average emissions in 2019 and 2020.

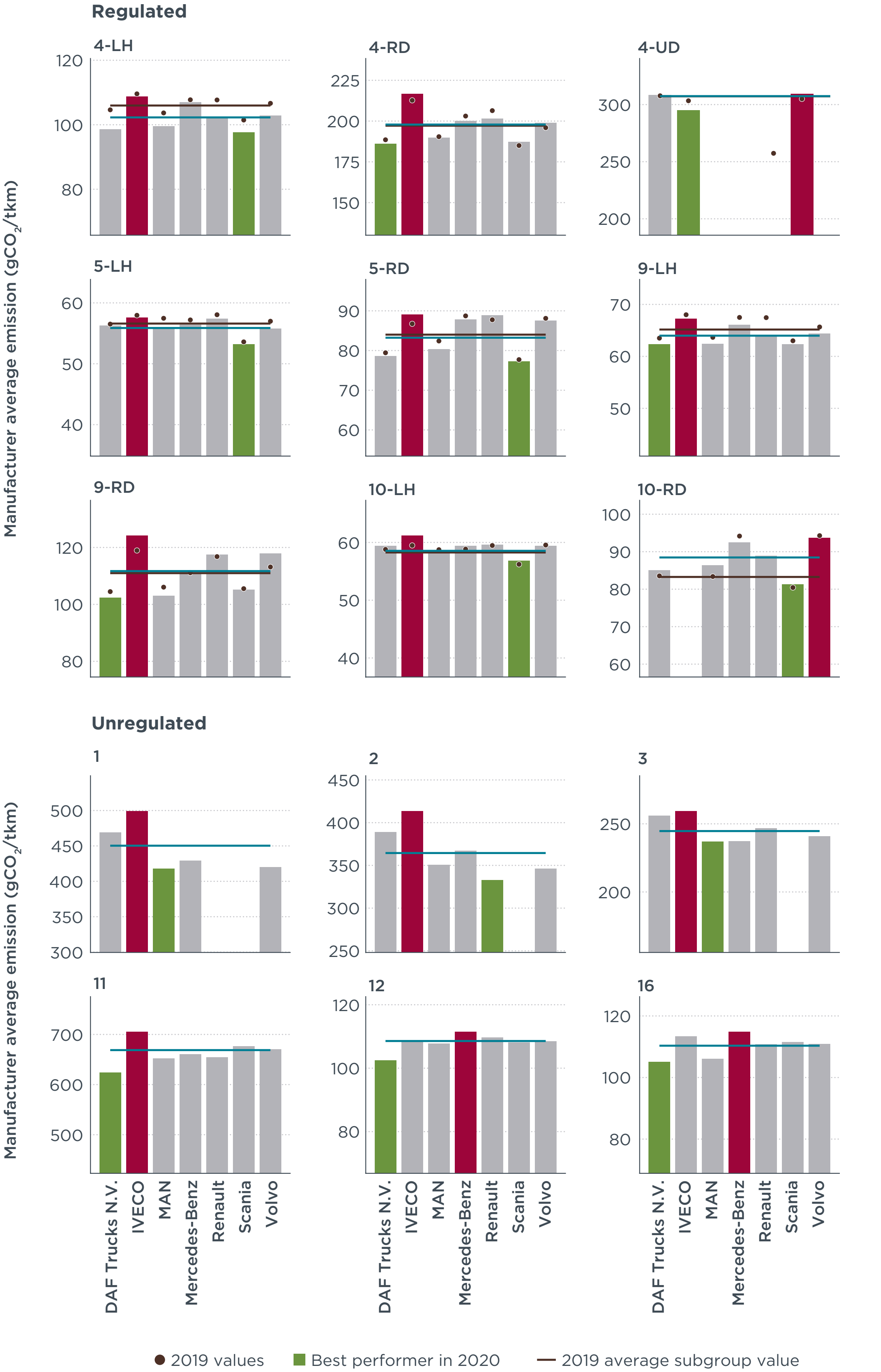

Figure 5. Average emissions by subgroup for each manufacturer in 2020. Note, the y-axis does not start at zero.

Manufacturer progress towards the 2025 target

Every year, the European Commission calculates two main metrics for each manufacturer to determine emission performance: their fleet average specific CO_2 emissions, and their CO_2 emissions reduction trajectory.

The fleet average specific CO_2 emissions for each manufacturer are calculated as the sum product of ***each manufacturer's average emissions of each subgroup***, the manufacturer's sales share of each subgroup, and the mileage, payload, and weighting (MPW) factor. The resulting value can be reduced by a maximum of 3% through an additional incentive known as the zero- and low-emissions vehicles factor.

The reduction trajectory for each manufacturer is calculated as the sum product of the ***common reference emissions*** across all manufacturers of each subgroup in the baseline (shown in Table 4), the manufacturer's sales share of each subgroup, and the MPW. The reduction trajectory line is thus different for every manufacturer based on their sales share. If a manufacturer's fleet average specific CO_2 emissions fall below the reduction trajectory, they receive credits. Manufacturers will not accrue debts if they fall above the reduction trajectory until 2025.

Figure 6 presents the fleet average specific CO_2 emissions in relative terms to the reduction trajectory to make it comparable across manufacturers. If a manufacturer's value falls below the yellow line, they are on track to meet their 2025 target and earn credits. If it falls above it, they are not on track.

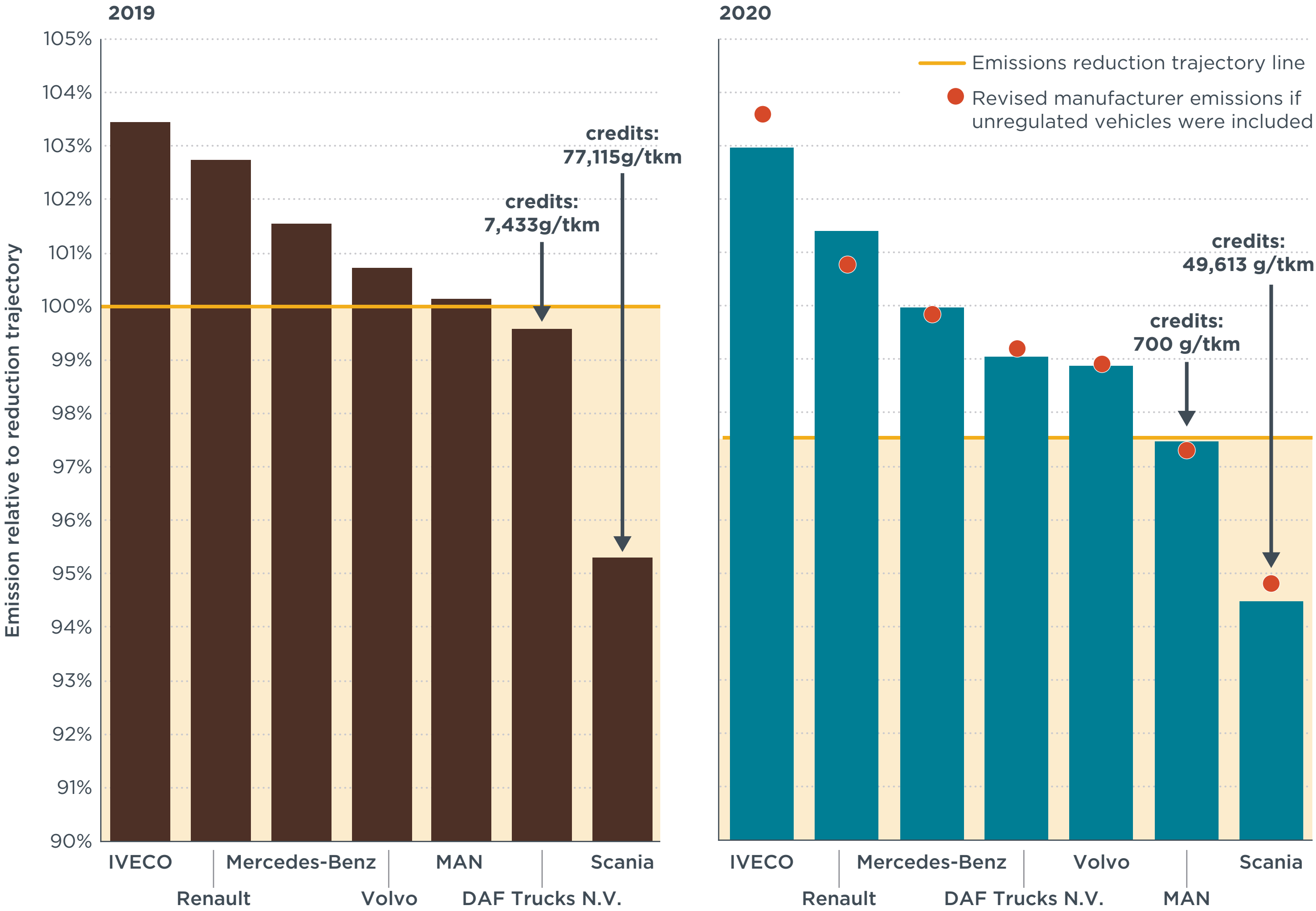

Figure 6. Fleet average specific CO_2 emissions relative to the reduction trajectory for each major manufacturer in 2019 and 2020.

Table 5 provides a numerical summary of manufactures' performance towards their reduction targets. The reduction trajectory starts at 100% in 2019 and decreases by 2.5% every year until 2025 when it reaches a value of 85% (i.e., for the 15% target).

The values for every manufacturer show the difference between their specific fleet average CO_2 emissions and their specific reduction trajectory. For a manufacturer to be considered on track to meet their emissions targets, this value should be less than or equal to the value in the reduction trajectory row. Scania and DAF were on track in 2019 to meet their target, but in 2020 DAF reduced their emissions by very little and are now not on track in 2020. MAN was not on track in 2019 but reduced their emissions considerably in 2020 and are now on track.

Table 5. Fleet average specific CO_2 emissions relative to the reduction trajectory for each major manufacturer in 2019 and 2020.

	2019	2020	Cumulative credits (gCO_2/tkm)
Reduction trajectory	**100%**	**97.5%**	
IVECO	103.4%	102.9%	
Renault	102.9%	101.4%	
Mercedes Benz	101.5%	99.9%	
Volvo	100.9%	99.0%	
MAN	100.2%	97.5%	700
DAF Trucks N.V.	99.6%	99.0%	7,433
Scania	95.3%	94.5%	126,766

Note: Values above the reduction trajectory are highlighted in red and signify manufacturers are not on track to meet the 2025 target. Values below are highlighted in green and signify they are on track and are rewarded with credits.

MAN showed the greatest improvement of all manufacturers by achieving a 2.7% reduction over 2019 values, bringing them below the reduction trajectory and earning credits amounting to 700 gCO_2/tkm. Sizeable reductions of between 1.5% and 2% were also evident from Volvo, Mercedes-Benz, and Renault. The highest emitting manufacturer, IVECO, showed the lowest level of improvement of 0.5%.

Despite achieving a relatively low improvement in 2020, Scania remains by far the lowest emitting manufacturer, largely due to their superior air drag performance. Scania earned credits amounting to 49,613 gCO_2/tkm in 2020, and, adding to their previously earned credits in 2019, hold 126,766 gCO_2/tkm worth of credits. Considering the penalty for non-compliance equates to €4,250/tkm in 2025, these credits have a value of nearly €540 million.

The proposed revision to the CO_2 standards extends the scope of the regulation to cover additional classes, including groups 1, 2, 3, 11, 12, and 16. We considered how extending the standards to include these vehicles would affect each manufacturer by factoring in the emissions from each unregulated subgroup (see Figure 6).

The extension would have little effect on manufacturers with low shares of unregulated vehicles, such as DAF and Volvo. Manufacturers with a higher share of vehicles in groups 1, 2, and 3, such as MAN, would be less affected than those with higher shares of 11, 12, and 16, due to the formers' relatively low MPW. One exception is IVECO, who has a relatively high share of groups 1, 2, and 3, but whose emissions are significantly above the average of all others. For IVECO, extending the standards to these unregulated groups would increase the gap between the fleet average specific CO_2 emissions and the reduction trajectory by 0.5%. Scania's emissions would also rise by 0.5% through the addition of these unregulated vehicle, owing to their higher share of 11, 12, and 16 vehicles. Scania has an above average level of emissions from these vehicles relative to other manufacturers.

Alternative fueled vehicles

Natural Gas

Diesel powertrains comprised 96% of all certified vehicles in the 2020 reporting period. Natural gas made up the vast majority of the remaining 4%, with 0.01% ethanol fueled and 0.02% zero-emission trucks sales reported. Focusing on natural gas, IVECO and Scania were the largest players, selling 5,220 and 2,237 respective vehicles in total and cumulatively accounting for 94% of all natural gas sales. The remaining 6% sales share was made up by Renault (3%), Mercedes-Benz (2%), and Volvo (1%). Figure 7 presents the breakdown of sales by subgroup by share and actual sales.

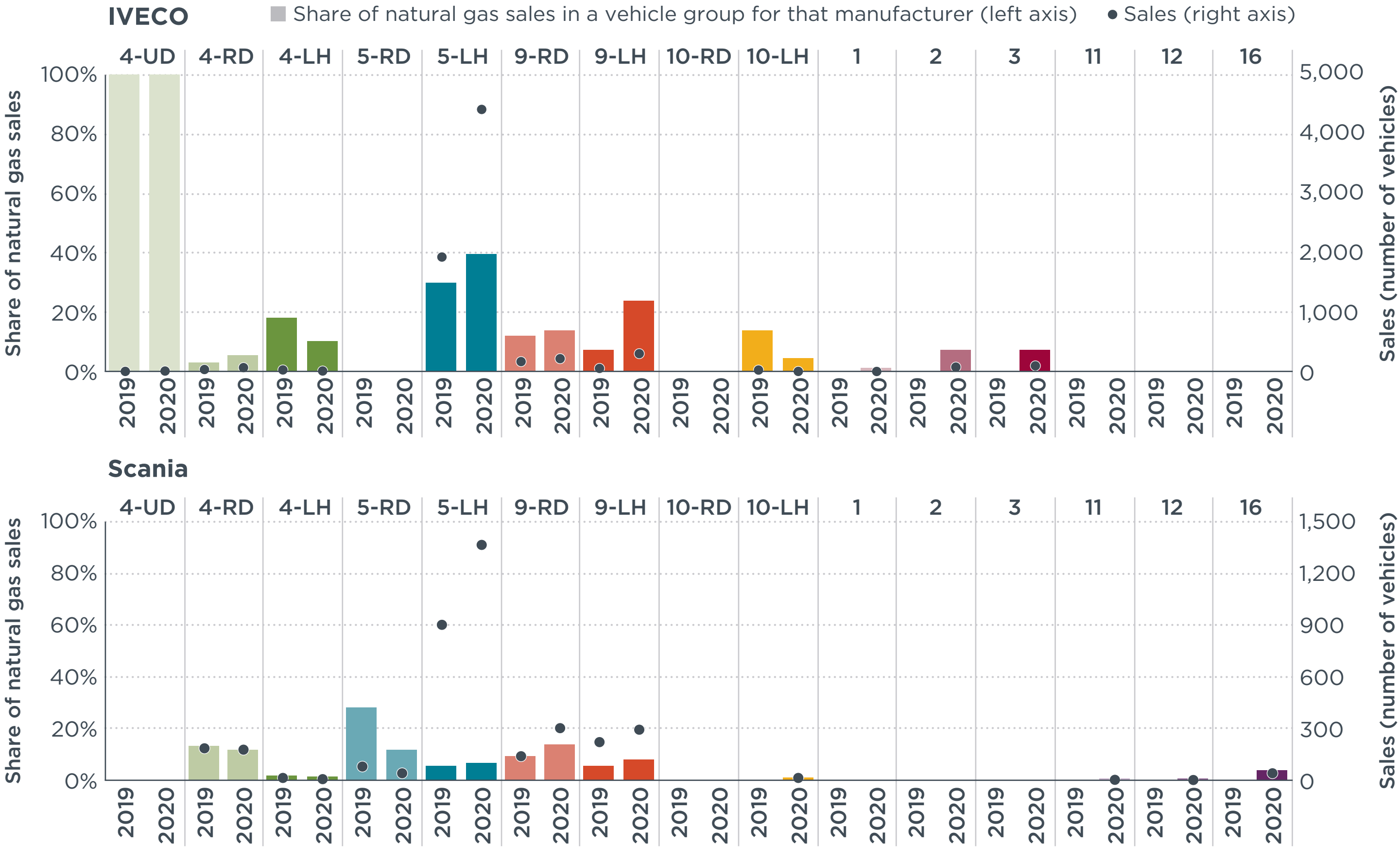

Figure 7. Shares of natural gas sales (left axis) and total sales (right axis) across all subgroups for the top two reporting manufacturers. The sales share is specific to each manufacturer, and not sales over all manufacturers.

Sales of natural gas trucks nearly doubled over the 2019 and 2020 reporting periods. Scania increased its sales of natural gas vehicle by 45%, whereas diesel sales only increased by 4%. IVECO increased natural gas sales by 131% compared to a 65% increase for diesel. In both cases, the increase was driven mostly by long-haul applications in subgroups 5-LH and 9-LH.

The average emissions of most IVECO's subgroups were lower as a result to their adoption of natural gas. The difference was most apparent for IVECO's long-haul vehicle subgroups, where the average emissions (in terms of gCO_2/tkm) of 5-LH and 9-LH trucks would have been 2% higher in 2020 if there were no natural gas vehicles registered. For vehicle subgroup 4-LH, the equivalent value would have been 1% of a difference, and 0.01% for 10-LH. The benefits for Scania were less apparent, where the absence of natural gas registrations in 5-LH trucks would have resulted in average emissions being 0.22% higher relative to the actual reported values. Emissions for both 4-RD and 9-LH would have both been lower by 0.3% if natural gas vehicles were omitted.

The bulk of natural gas truck sales were registered in countries with the overall highest sales shares in Europe. Germany, Italy, Poland, France, and Spain were responsible for nearly 80% of natural gas sales and 66% of total certified HDV sales. Only a small number of Member States had natural gas shares which exceeded the European wide average: Bulgaria (9.5% share across all certified vehicles), Latvia (7.5%), and Italy (6.4%).

A number of dual-fuel vehicles, which run on a combination of natural gas and diesel, were reported exclusively by Volvo (1,132 vehicles in 2020, up from 842 in 2019) The version of VECTO used to perform these simulations was not capable of running it for these alternative powertrains, and thus no information is available on their emissions.

Zero- and low-emission vehicles

Zero-emission vehicles can be split into two categories: certified vehicles reported by manufacturers and uncertified vehicles reported by Member States. While manufacturers are only required to report the registration of certified vehicles, regulation (EU) 2018/956 stipulates that Member States are required to report all sales of heavy-duty vehicles. Data reported by Member States do not provide significant detail on the vehicle type, energy consumption, or emissions, unlike manufacturers, who are required to do so for certified vehicles. However, Member State data does provide insight into the fuel type used and, as such, on the number of zero-emission vehicles.

Manufacturer reported vehicles (top of Figure 8) can be split into the specific VECTO groups, but Member State reported vehicles (bottom of Figure 8) only specify whether the vehicle is an N2 truck (3.5 t < GVW < 12 t) or an N3 truck (GVW > 12 t).

Focusing on the seven main manufacturers of HDVs, 116 zero-emission trucks were reported in the 2020 reporting period, representing a five-fold increase from 2019. Of these sales, 51 fell under the certified vehicle groups reported by manufacturers, while 65 were uncertified vehicles reported by Member States.

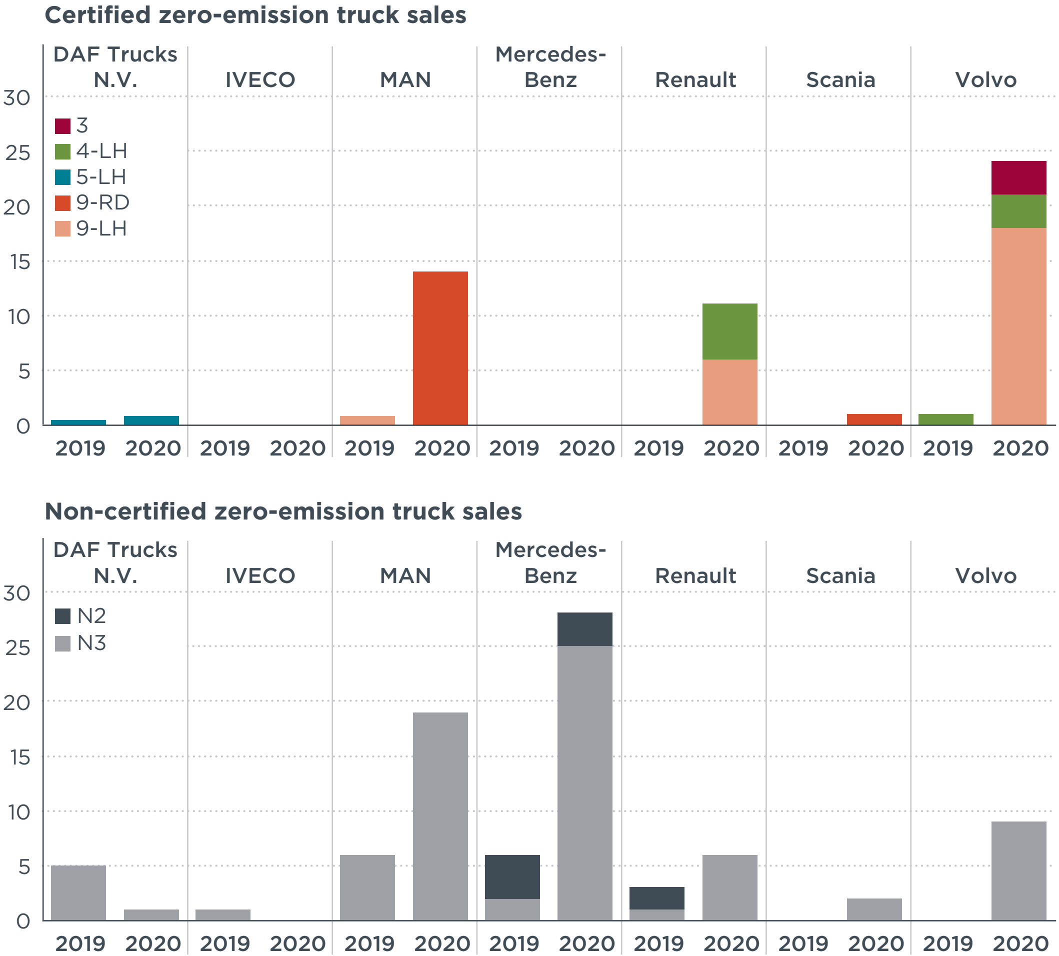

Figure 8. Sales of zero-emission vehicles by vehicle type and manufacturer in 2019 and 2020.

MAN, Mercedes Benz, and Volvo were responsible for the majority of zero-emission truck sales. The most popular zero-emission model sold in 2020 was the Volvo FE, a rigid 4x2 truck, with 18 sales. The majority of regulated zero-emission sales were concentrated in the Netherlands (27%), Sweden (25%), Germany (14%), and France (10%). Only 11 zero-emission tractor-trailers were reported in 2020, two of which were produced by DAF and the remainder by the Dutch manufacturer Emoss. The vehicles registered by Emoss were originally reported as diesel-fueled vehicles manufacturerd by DAF but retrofitted by Emoss to become an electric vehicle and registered with the Member States as such.

Beyond these seven main manufacturers, an additional 1,179 zero-emission trucks were reported in 2020, the vast majority of which were medium-duty trucks produced by StreetScooter, formerly owned by Deutsche Post DHL in Germany.

Slight discrepancies exist between the reported number of zero-emission vehicles with other sources of registration. For the 2020 calendar year (which differs from the reporting period of 2020 discussed so far in this section), zero-emission truck sales registered according to IHS Global SA were 30% higher than those reported by the EEA database.[6] Specifically, there were double the number of heavy-duty trucks (90 instead of 44 as reported by the EEA), and 25% more medium-duty trucks (946 compared to the EEA's 757).[7]

6 Supplied by IHS Markit; Copyright © IHS Markit, 2023.

7 The majority of these zero-emission medium-duty trucks were manufacturerd by vehicles outside of the seven major manufacturers shown in Figure 8, hence the difference in the values reported.

Very few hybrid electric trucks were reported (29 in 2020, up from 18 in 2019), and all were reported exclusively by Scania. Of these hybrid vehicles, only one was reported as plug-in electric hybrid.

The ZLEV factor

Sales of zero- and low- emission vehicles (ZLEV) contribute towards a manufacturer's CO_2 target in two ways. First, it lowers a manufacturer's fleet average specific CO_2 emissions due to the emission reductions a ZLEV brings over its fossil fueled counterpart. Second, it allows for a flexibility known as the ZLEV factor which can reduce a manufacturer's target by up to 3%. Until 2025, the ZLEV factor is calculated for each manufacturer using the following formula:

$$\text{ZLEV Factor} = \frac{V}{V_{conv} + ZLEV_{in} + ZEV_{out}}$$

Where V represents the total number of sales of regulated trucks in a specific year, V_{conv} represents the sales of conventional regulated trucks, $ZLEV_{in}$ represents the sales of zero- and low-emission regulated trucks, and ZEV_{out} represents the sales of unregulated zero-emission trucks. Every zero-emission truck sold is double counted in the calculation of both $ZLEV_{in}$ (for regulated vehicles) and ZEV_{out} (for unregulated vehicles). Every low-emission truck within the regulated classes, i.e., a vehicle with an emission level less than 50% of its subgroup's average, receives a weighting between one and two towards ZEV_{in} dependent on its emissions. No low-emission trucks were reported in 2020. The ZLEV factor is applied to the manufacturer's fleet average specific CO_2 emissions and is capped at a minimum value of 0.97.

The lowest ZLEV factor was calculated by MAN of 0.9984, followed closely by Volvo (0.9985) and Renault (0.9986). The ZLEV factor for each manufacturer is presented in Table 6.

Table 6. ZLEV factor for each manufacturer in 2019 and 2020.

	DAF Trucks N.V.	IVECO	MAN	Mercedes Benz	Renault	Scania	Volvo
2019	0.9996	1.0000	0.9995	0.9996	0.9996	1.0000	1.0000
2020	1.0000	1.0000	0.9983	0.9990	0.9986	0.9998	0.9985

Vocational vehicles

A vocational vehicle is defined either as (i) an HDV not intended for the delivery of goods who has a bodywork corresponding to the types presented in the Appendix, or (ii) a tractor with a maximum speed not exceeding 79 km/h (European Commission, 2019b). Examples of vocational vehicles are fire engines, garbage collectors, or construction vehicles, such as a truck with an inbuilt concrete mixer. The onus lies on the manufacturer to identify a vehicle as vocational.

Vocational vehicles are exempt from the CO_2 standards, but manufacturers are still required to monitor and report their emissions. Unlike their delivery truck counterparts, their emissions are recorded over the construction and municipal mission profiles. Approximately 2,300 vocational vehicles were recorded in the 2020 reporting period (1.2% of the stock of regulated vehicles), down from 2,700 in 2019 (1.6%).

All vocational vehicles reported in 2020 were recorded by three manufacturers: DAF, Mercedes-Benz, and Volvo. No unregulated vehicles were classified as vocational, however based on their reference mission profiles, it is likely that many registrations of vehicle groups 11, 12, and 16 could be classified as vocational. Only groups 4 and 9 (that is, rigid body trucks with 4x2 or 6x2 axle configuration) were recorded as vocational. Group 9-RD was the most popular vocational vehicle (56% of vocational sales), followed by 4-RD (21%) and 9-LH (19%).

Table 7. Sale of vocational vehicles in 2019 and 2020 for reporting manufacturers.

Manufacturer	Reporting period	Vocational vehicles	Share of all manufacturer's vehicles
DAF Trucks N.V.	2019	1544	4.75%
	2020	1562	4.92%
Mercedes Benz	2019	1092	3.51%
	2020	657	1.19%
Volvo	2019	66	0.24%
	2020	68	0.24%

Comparison to officially reported values

Every year, the European Commission publishes an implementing decision indicating official fleet average specific CO_2 emissions, the CO_2 emission reduction trajectory, the ZLEV factor, and the number of emission credits per manufacturer based on the monitoring and reporting data. Table 8 summarizes the official values reported this year compared to those calculated from our own analysis.[8]

Table 8. Comparison of official CO_2 values, ZLEV factors, and credits to own estimated values for the 2020 reporting period.

	Variable	DAF Trucks N.V.	MAN	Mercedes Benz	Renault	Scania	Volvo
ICCT	Reduction trajectory	54.21	50.83	51.35	48.67	51.86	52.79
(EU) 2022/2336	Reduction trajectory	54.21	50.83	51.35	48.67	51.86	52.79
ICCT	Average specific CO_2 emissions	55.06	50.81	52.64	50.61	50.24	53.53
(EU) 2022/2336	Average specific CO_2 emissions	55.05	50.79	52.65	50.61	50.23	53.53
ICCT	ZLEV factor	1	0.998	0.999	0.999	1	0.999
(EU) 2022/2336	ZLEV factor	1	0.998	0.999	0.998	1	0.999
ICCT	Credits		700			49,613	
(EU) 2022/2336	Credits		1,011			49,534	

In general, the values from our analysis show good alignment with the official values published related to the 2020 reporting period. Virtually no difference is found in the calculation of the reduction trajectory, the emissions under which a manufacturer receives credits. No difference is apparent from the calculation of the ZLEV factor, with the exception of Renault. Some slight discrepancies are found in the calculation of the average specific CO_2 emission values, most notably for MAN, for which we calculated 700 credits compared to the official value of 1,011.

It's possible this discrepancy results from the ZLEV factor. Rounded to three decimal places, we calculated a ZLEV factor of 0.998, equal to the officially published values. Modifying our calculation of MAN's ZLEV factor by 0.04% would align the average specific CO_2 emissions calculation, as well as the number of credits, while still providing a rounded ZLEV factor of 0.998. The calculation of the ZLEV factor can be difficult

8 We do not include IVECO in this comparison. We consider IVECO as a single entity, while the implementing decision reports this data for Iveco Magirus-AG and IVECO SPA, so our calculations would not be comparable.

to assess, due to the ZEV_{out} factor (described in the previous section), which is partly reliant on data from the type-approval authorities of each Member State where entries are not always complete. As more vehicle types are covered under the certification regulation, entries of zero emission vehicles may become more certain.

Technology analysis

Reductions in CO_2 tailpipe emissions may result from improvements in engine efficiency (such as engine friction reduction, combustion optimization, and fuel switching) and road load reduction (such as aerodynamic improvements and low-rolling resistance tires).

The relative contribution towards the emissions reduction from these technologies is dependent on the vehicle's mission profile. For example, vehicles with a higher average operating speed, such as long-haul tractor trailers, benefit more from improvements in aerodynamics as this is proportional to the square of the vehicle's speed. Municipal and construction trucks with a lower operating speed benefit proportionately less from aerodynamic improvements. This section summarizes the changes in fleet technology over the 2019 and 2020 reporting periods to determine the underlying causes of the changes in fleet emissions.

Engine efficiency

The average efficiency of engines, determined through a dynamometer test for type-approval, improved across regulated vehicle groups by an average of 0.5% between the 2019 and 2020 reporting periods. The average of nearly all subgroups improved their engine efficiency over this period, with the exception of vehicle subgroups 10-RD and 4-UD, of which both had sales in the reporting period of 2020 of less than 100 vehicles. Excluding these two subgroups, the highest improvement was seen in subgroup 4-LH (2% improvement) and the lowest was in 4-RD (0.31% improvement).

Figure 9 presents the changes in average efficiency over the World Harmonized Transient Cycle (WHTC) for each manufacturer and fuel type, calculated through applying lower heating values for diesel and natural gas of 42.7 MJ/kg of fuel and 45.1 MJ/kg of fuel, respectively. We benchmark these changes against the average changes in engine displacement over the same period. Increasing the displacement of an engine increases its ability to create power at the expense of higher fuel consumption, indicating a relationship between the metric of engine displacement and average engine efficiency.

Figure 9. Changes in average engine efficiency over WHTC relative to changes in displacement over the reporting periods 2019 and 2020.

Manufacturers improved their average engine efficiency across nearly all subgroups between 2019 and 2020, despite concurrent increases in engine displacement. The most significant improvements were evident for Vovlo (1.4% improvement) and Scania (0.9%), while the average across all manufacturers and subgroups was 0.5%. Scania's improvements were exclusively achieved by their diesel engines, with no significant improvements on their natural gas engines.

The average efficiency improvement of IVECO's natural gas engines was particularly noticeable, increasing by up to 25% over the one-year period. In the vehicle subgroup 5-LH, which is responsible for the vast majority of their natural gas sales, the average improvement was 10%, owing largely to a reduction in the sales of their MY 2026 Stralis, which predominantly used an engine with an efficiency of 31%, and increasing the sales of the Stralis NP, with a more efficient engine of 35%. Little changes were evident in IVECO's diesel internal combustion engines.

Figure 10 shows the distribution of engine efficiency over the WHTC across all manufacturers and subgroups. IVECO continued to have the lowest average operating engine efficiency across all their trucks, at 38.4% in the 2020 reporting period. This is partly driven by IVECO's higher market share of natural gas truck sales relative to its counterparts. Natural gas had a significantly lower performance with an efficiency range of 27%–38%, compared to diesel with a range of 36%–43%. MAN had the most efficient average engine performance at 42.4%.

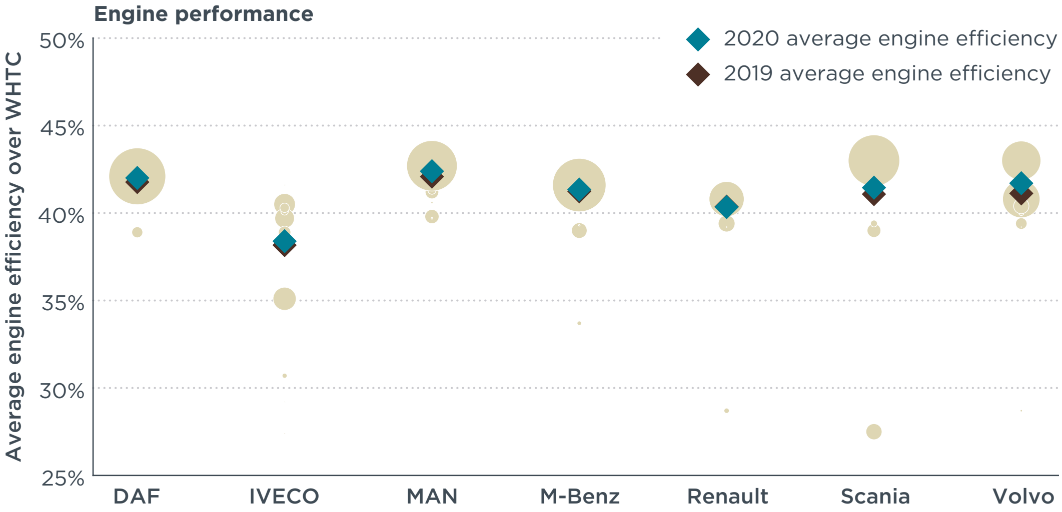

Figure 10. Reported average engine efficiency over WHTC. The size of the bubbles represents the number of sales in each class in 2020..

Figure 11 presents the average engine efficiency distribution of all regulated engines sold in 2019 and 2020. In both years, the most efficient engines on the market had a maximum efficiency of 43% over the WHTC. This one-year period saw a shift in less efficient engines towards this upper tier of 43%, indicating that more manufactures are starting to utilize the best-in-class technology available. MAN had the most efficient engine, the 12.4 liter D2676, mostly used in its TGX model, with an efficiency of 43%.

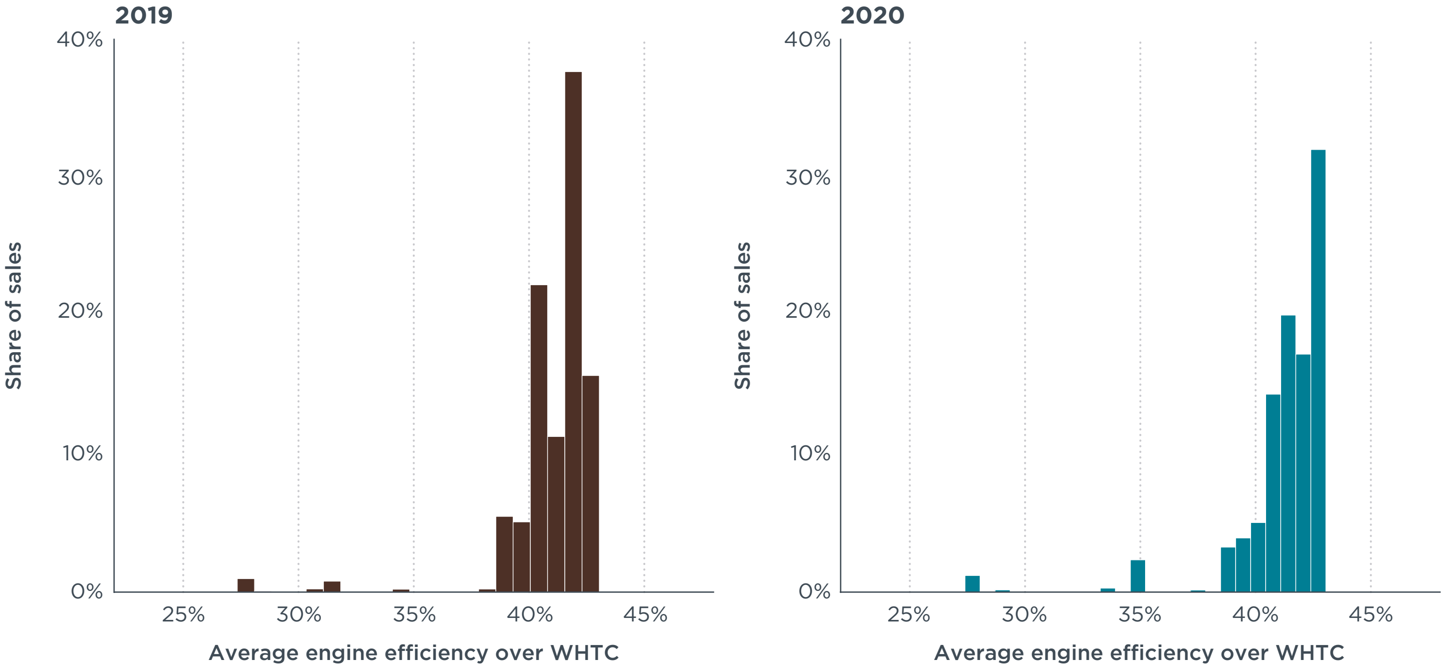

Figure 11. Distribution of average engine efficiency over WHTC for regulated vehicles in 2019 and 2020.

Road load technologies

Aerodynamics

Aerodynamic drag represents a critical contributor to vehicle efficiency. The aerodynamic drag is proportional to the square of the vehicle speed, making it a particularly important contributor towards overall vehicle efficiency for trucks operating most frequently under a long-haul cycle. A lower drag area—defined as the product of the drag coefficient and the frontal area (CdA)—is desirable as it requires a lower power level to overcome the opposing force. The CdA can be improved through measures to the vehicle's cab, such as by reducing the gap between the tractor and the trailer, or by applying measures to the vehicle's trailer, such as adding side skirts or boat tails (Rodríguez, 2018). In the certification procedure, the VECTO simulation software assumes a basic tractor trailer without any aerodynamic measures requiring any improvements in the vehicle's CdA be achieved through alterations to the cab. A certification regulation for trailers was introduced in 2022 requiring trailer manufacturers to declare their emissions from 2024 onward when powered by a standard motorized tractor (European Commission, 2022).

The drag area is reported using a range of values, from A1 (CdA of 0–3 m^2) to A24 (CdA of 8.77–9.21 m^2).[9] We use the midpoint of each reported value's range in this section. Figure 12 shows the breakdown of the coefficient of drag for each major manufacturer in 2020, with the overall annual averages represented by the diamonds.

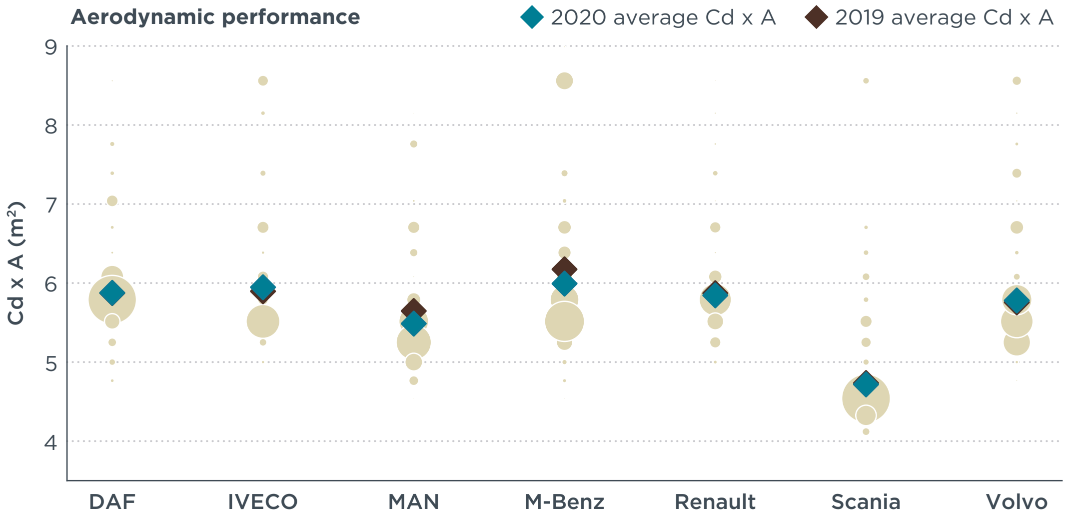

Figure 12. Reported air drag values by manufacturer. The size of the bubbles represents the number of sales in each class.

Scania continued to have a superior air drag performance relative to its competitors. In 2020, it had an average CdA value of 4.72, 19% lower than the average for all manufacturers of 5.82. Scania's overall performance remained largely unchanged in 2020 relative to 2019, with a slight improvement of 0.4%, while MAN and Mercedes-Benz showed an improvement in overall CdA of 3%. Despite this improvement, Mercedes-Benz retains the worst overall average CdA, as it did in 2019, with a value of 5.99.

The CdA value can either be input as a standard default value or can be measured by the manufacturer and input as a specific value. The default values are conservatively high—for example, the default CdA for vehicle subgroup 5-LH is 8.56 m^2 while the average of the measured values for manufacturers was 5.46 m^2 in 2019. Most

9 The ranges of each reported values can be found in Part C of annex I of the Monitoring and Reporting regulation (EU) 2018/956.

manufacturers opt to measure the specific CdA of all their vehicles. Only IVECO and Mercedes-Benz use the default values for some of their vehicles. Mercedes-Benz increased the share of vehicles for which they use measured values from 86.3% to 90.6% between 2019 and 2020, which contributed in part to their reduction in CdA. IVECO reduced their share of measured values from slightly less than 100% to 93.1% across the same period despite measuring a much more favorable CdA for the same vehicle subgroups in 2019.

Figure 13 presents the distribution of CdA values across all regulated vehicles for all manufacturers in 2019 and 2020. There was a slight shift from vehicles registered with a CdA of A19 (average CdA of 7.0 m²) and A16 (average CdA of 6.1 m²) towards A15 (5.8 m²).

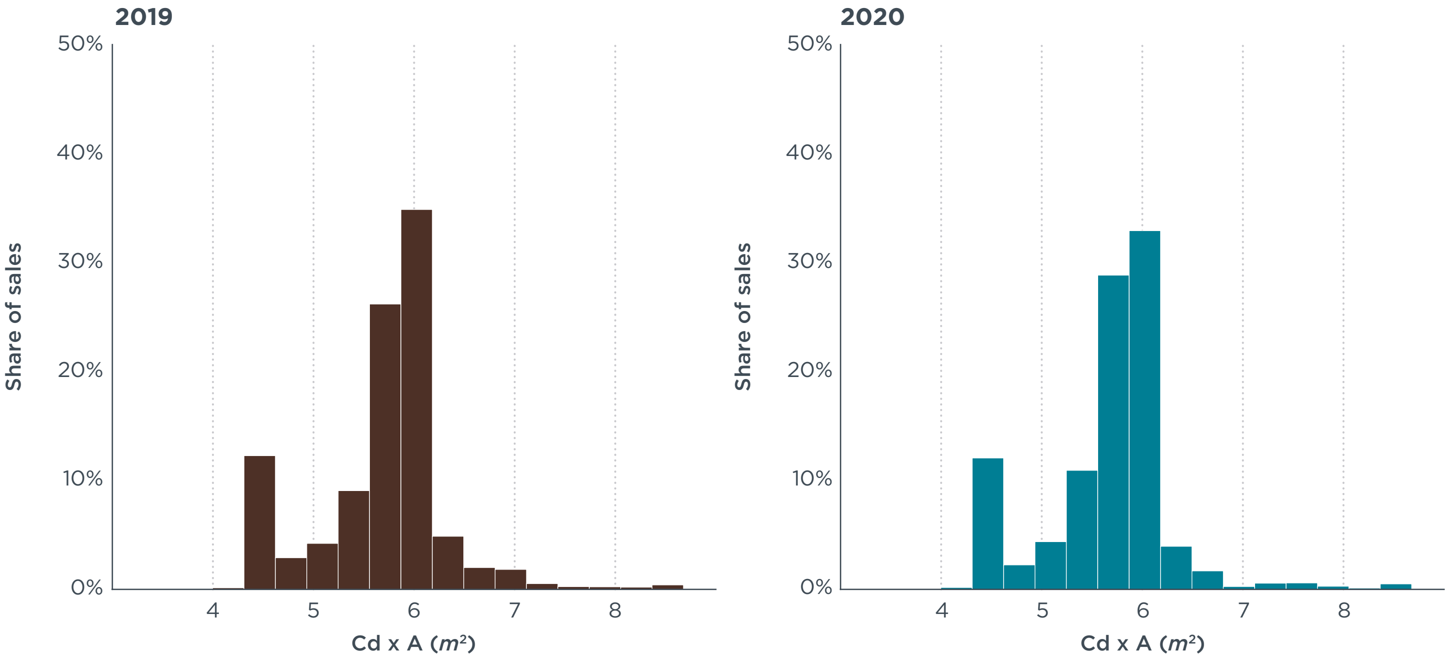

Figure 13. Distribution of the coefficient of drag for regulated vehicles in 2019 and 2020.

The average CdA for all subgroups is presented in Table 9. On average, the CdA across all subgroups improved by 1.2%. The newly added group 1 showed the lowest average of all subgroups, with a CdA of 4.99 m², largely owing to the relatively smaller frontal area of these vehicles relative to the other certified vehicles. The highest reporting average remained as group 10-RD, largely due to a much higher share of default CdA values being applied, increasing from 2% of sales in 2019 to 25% in 2020. However, sales of 10-RD are very low, at less than 100 vehicles per year. The municipal and construction trucks in groups 12 and 16 showed an above average CdA relative to the most popular regional and delivery trucks—again, potentially due to having a higher share of default values at 8% compared to an average of 3% for all vehicles in 2020. These vehicles have a lower average operating speed than their long-haul and regional delivery counterparts, resulting in a lower effect on overall emissions.

Table 9. Coefficient of drag by vehicle subgroup in 2019 and 2020.

	Vehicle Subgroup	Cd x A (m^2)		
		2019	2020	Change
Regulated	4-LH	5.59	5.53	-1.0%
	4-RD	5.60	5.69	1.7%
	4-UD	5.32	5.34	0.5%
	5-LH	5.68	5.62	-1.1%
	5-RD	7.17	7.08	-1.3%
	9-LH	5.50	5.51	0.1%
	9-RD	5.83	5.78	-0.9%
	10-LH	5.71	5.65	-1.0%
	10-RD	7.36	8.03	9.1%
Unregulated	1		4.99	
	2		5.08	
	3		5.42	
	11		5.56	
	12		6.54	
	16		7.32	

Curb mass and tire rolling resistance

The heavier a truck is, the more energy is required to overcome its rolling resistance. Light weighting a vehicle through material substitution can improve overall vehicle efficiency, most notably when applied to the chassis frame and the body of the vehicle. In the most popular and highest emitting truck class, there has been negligible change in the curb weight (i.e., the weight of the unloaded vehicle). The greatest variation was found in the subgroup 10-LH, which increased in mass by 3.4% between 2019 and 2020, potentially driven by the distortion in the market due to the exit of the UK from the EU, which had one of the most popular markets for the vehicles. The introduction of the unregulated vehicles brings with it the lightest (groups 1, 2, and 3) as well as the heaviest (11, 12, and 16) vehicles to the certification procedure. The former had a reported curb mass between 3.8 and 5.1 tonnes, while the latter had reported between 9.5 and 10.5 tonnes. By comparison, subgroup 5-LH had an average curb mass of 7.8 tonnes in 2020.

A greater degree of change is evident from the rolling resistance coefficients (RRC), a measure of the force resisting a tire's rotation due to the normal force applied to it. On average, the RRC reduced by 3% across regulated vehicles. Most notably, all manufacturers reduced their rolling resistance coefficient in groups 4-LH (4.5% reduction) and 9-LH (3.4% reduction), which make up a combined 10% of vehicle sales. The rolling resistance coefficient of 5-LH decreased by 2.1%. The unregulated vehicles report a higher-than-average rolling resistance coefficient relative to their regulated counterparts, with values ranging from 6.1 to 6.6, while regulated vehicles reported a variation of 5.3–6.0.[10] Across both curb mass and rolling resistance coefficients, there is no significant disparity across manufacturers, particularly for the most popular and highest emitting trucks classes.

10 The RRC are unitless, defined as the drag force divided by the weight. We represent it here in terms of kg/t.

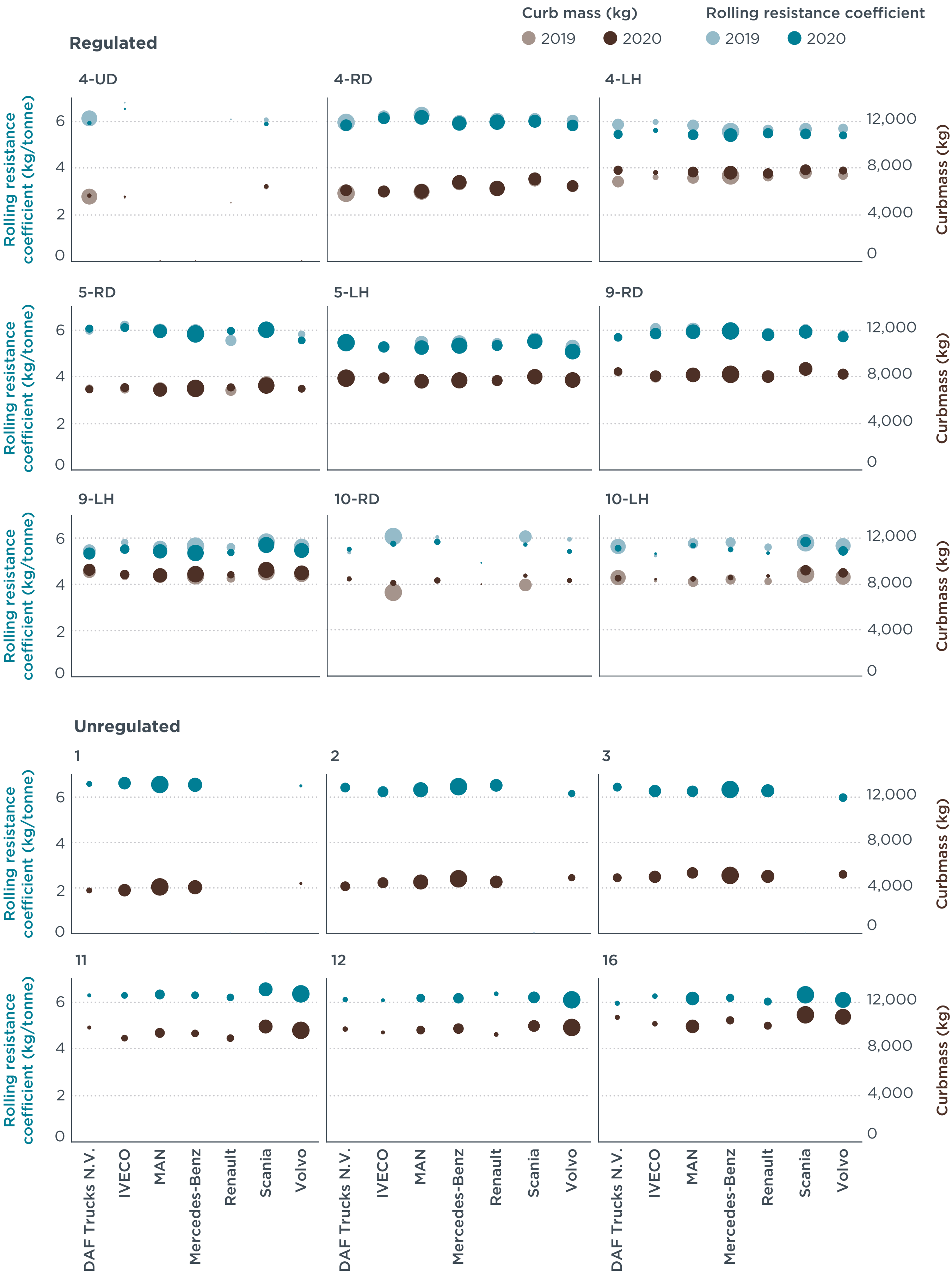

Figure 14. Reported curb masses and rolling resistance coefficients manufacturer and vehicle subgroup. The size of the bubbles represents the number of sales in each class.

CO_2 emission reduction technologies

As part of the certification process, manufacturers are obliged to report a range of Advanced-Driver Assistance Systems (ADAS) technologies which include eco roll, where a truck calculates when it may save energy by going down a gradient in neutral, and predictive cruise control, which uses satellite data to predict the optimum driving strategy for the upcoming road segment. These technologies provide CO_2 savings for manufacturers, which is measured using a predefined model in VECTO.

Manufacturers may voluntarily report other CO_2 saving technologies, although these have no benefit on the certified CO_2 values. Such technologies include an active front grill, which can open and close to lower air drag, and pulse and glide technology, which alternates between running the engine at a higher load than necessary and then coasting to lower speed to improve efficiency.

The share of these technologies is shown in Figure 13. The share of trucks with eco roll increased from 42% in 2019 to 63% in 2020, and pulse and predictive cruise control increased from 28% to 47%. For both technologies, the increase was driven by DAF, Renault, and Volvo. No significant change was evident in all other manufacturers. Only Scania reported neither predictive cruise control nor eco roll in its trucks.

Little change was evident in the voluntary CO_2 saving technologies. As with the 2019 reporting period, only Mercedes-Benz reported an active front grill and pulse and glide in its trucks in 2020.

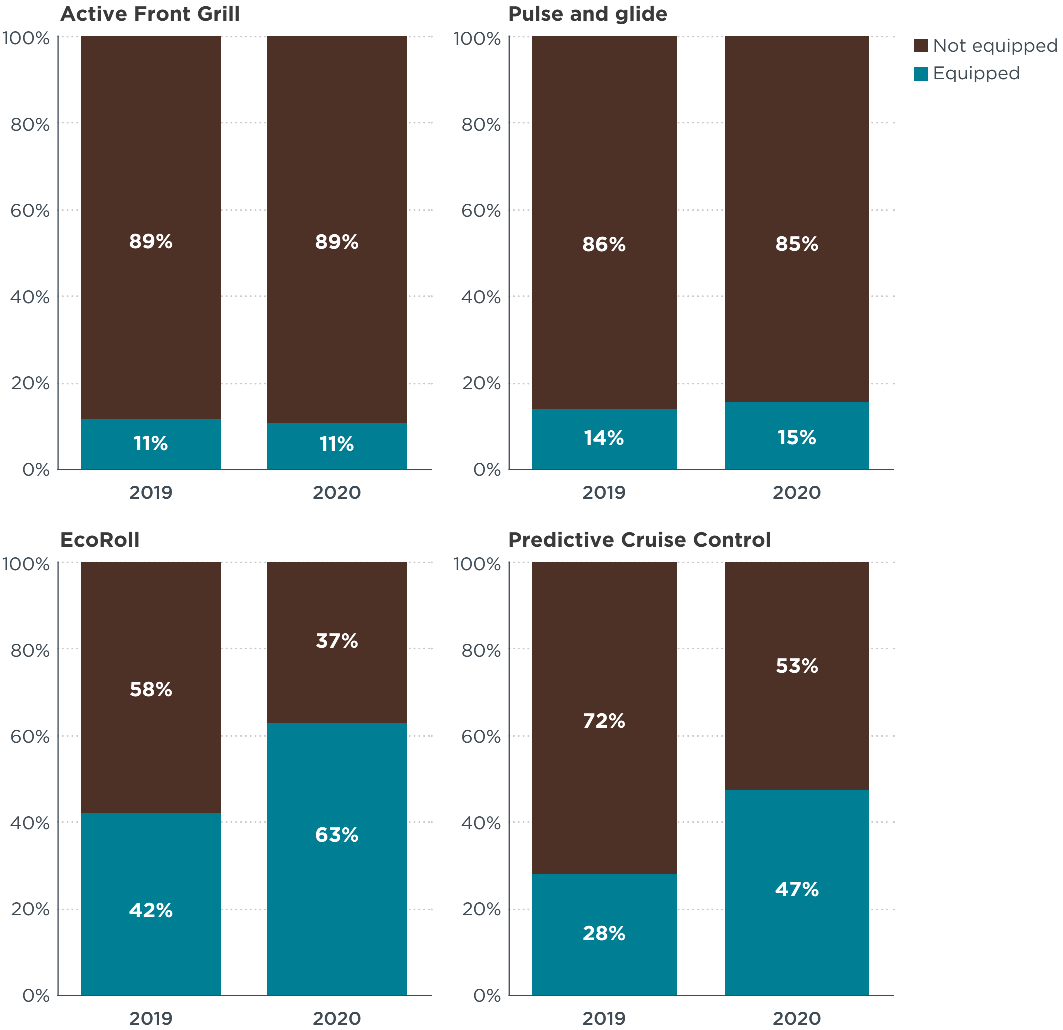

Figure 15. Share of CO_2 reduction technologies in 2019 and 2020 across all manufacturers.

Conclusions

The release of the monitoring and reporting data for 2020 has provided the second year of detailed energy and emissions information for trucks in Europe. The 2020 data provided information pertaining to medium duty trucks with a gross vehicle weight between 7.5 t and 16 t, as well as municipal and construction trucks. This addition means that detailed information on the energy consumption and emissions from roughly three quarters of all heavy-duty truck sales is now available annually.

The following main conclusions can be drawn from this latest release:

» **Average fleet emissions have decreased by 1% between 2019 and 2020, although an average of 2.5% is needed to comply with CO_2 targets.** The average fleet specific emissions of trucks covered by the CO_2 standards decreased from 52.5 gCO_2/tkm to 52.0 gCO_2/tkm over this one-year period. Because an average annual reduction of 2.5% is required to be on track to achieve the 2025 target set by the CO_2 standards, most manufacturers are currently not on track to achieve the target.

» **Scania remained the lowest emitting manufacturer, IVECO was the highest emitting, and MAN showed the best improvement.** Scania's emissions in 2020 were 5.5% below its baseline level. Their high performance, largely due to their superior air drag performance, brought their cumulative total of credits to 126,766 g/tkm, which is worth €540 million based on the cost of penalties due to non-compliance. IVECO was 3.4% above its baseline emissions. MAN showed the greatest improvement of any single manufacturer, achieving a reduction of 2.7%, driven by improvements in both aerodynamics and average engine efficiency.

» **Improvements were observed in engine efficiency, aerodynamics, and tire operability between 2019 and 2020.** The efficiency of engines improved across regulated vehicle groups by an average of 0.5%. The average coefficient of aerodynamic drag improved by 1.2%, and the average tire rolling resistance coefficient reduced by 3%. The curb weight of vehicles increased marginally by 0.3%.

» **Substantial variability around vehicle CO_2 emission values persists**. The spread of CO_2 emissions between the 5th and 95th percentile of vehicle group 5-LH, a 4x2 tractor trailer responsible for over half of heavy-duty vehicle emissions in the EU, reduced slightly from 18.8% in 2019 to 17.5% in 2020. This suggests that manufacturers are in the process of applying best practice to lower the emissions of their fleet, yet there is still ample technology potential available to manufacturers to further improve their vehicles' performance.

» **The latest dataset provided insights into the performance of municipal, construction and medium delivery trucks**. Data for medium freight trucks, with a gross vehicle weight between 7.5 and 16 tonnes, was reported for the first time in 2020 and reported a fuel economy range of 23.6–25.5 l/100km. Municipal and construction trucks, which were also added in 2020, reported a fuel-economy range of 40.9–91.9 l/100km.

» **The sale of zero-emission trucks remains low.** In 2020, Europe's seven major truck manufacturers, who are responsible for 99% of the EU's truck sales, reported 116 zero-emission trucks. An additional 1,200 were reported by other manufacturers, the majority of which were medium-duty trucks. For tractor-trailers, which make up the majority of the EU's HDV CO_2 emissions share, only 11 zero-emission trucks were reported.

The proposed revision to the HDV CO_2 standards extends the scope of the standards to the currently unregulated trucks we have reported on here, along with additional vehicle classes such as lighter trucks, buses, coaches, and trailers which are required to report their emissions from 2024 onward. The proposed increased target of 45% in 2030 and the introduced targets of 65% in 2035 and 90% in 2040 will require significant increases in investment towards zero-emission technologies beyond what we have summarized in this report. However, such a scale up is necessary for the EU to comply with its long-term climate targets.

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Appendix: Definition of vocational vehicles

Table 10. Bodywork definitions for vocational vehicles.

Bodywork code	Bodywork	
02	Drop-side	Nonvocational
03	Box body	
04	Conditioned body with insulated walls and equipment to maintain the interior temperature	
05	Conditioned body with insulated walls but without equipment to maintain the interior temperature	
06	Curtain-sided	
07	Swap body (interchangeable superstructure)	
08	Container carrier	
11	Tank	
12	Tank intended for transport of dangerous goods	
13	Livestock carrier	
14	Vehicle transporter	
17	Timber	
21	Boat carrier	
22	Glider carrier	
29	Low floor trailer	
30	Glazing transporter	
99	Bodywork that is not included in the present list	
01	Flat bed	Vocational
09	Vehicles fitted with hook lift	
10	Tipper	
15	Concrete mixer	
16	Concrete pump vehicle	
18	Refuse collection vehicle	
19	Street sweeper, cleansing and drain clearing	
20	Compressor	
23	Vehicles for retail or display purposes	
24	Recovery vehicle	
25	Ladder vehicle	
26	Crane lorry (other than a mobile crane as defined in Section 5 of Part A of Annex II)	
27	Aerial work platform vehicle	
28	Digger derrick vehicle	
31	Fire engine	