WORKING PAPER

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CO_2 emissions from trucks in the European Union: An analysis of the 2021 reporting period

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SUMMARY

The Council of the European Union finalized the revision of CO_2 standards for trucks and buses in May 2024. The revised standards kept the 2025 CO_2 reduction target at 15% relative to 2019 emissions, increased the 2030 target to a reduction of 45%, and mandated new 2035 and 2040 targets of 65% and 90%, respectively. To track the performance of different truck manufacturers toward meeting those targets, the European Environment Agency publishes the certified CO_2 emissions of new trucks in the European Union. The agency recently published certified data for the third reporting period, extending from July 2021 to June 2022.

Figure ES1 summarizes the performance of the major manufacturers in the European Union, highlighting the EU average as well. Scania is the only manufacturer on track to meet its 2025 targets and remained the least-emitting manufacturer for the third reporting period. IVECO remained the highest-emitting manufacturer in the 2021 reporting period, while MAN recorded the largest improvement in CO_2 emissions between 2019 and 2021. Manufacturers are pursuing different strategies to meet their CO_2 emissions reduction targets. DAF, MAN, and Mercedes-Benz are mainly focusing on improving the emissions performance of their diesel and natural gas vehicle fleet. IVECO, Renault, Scania, and Volvo are pursuing a mixed approach with continuous improvement in their conventional vehicle performance and an increasing share of zero-emission vehicles.

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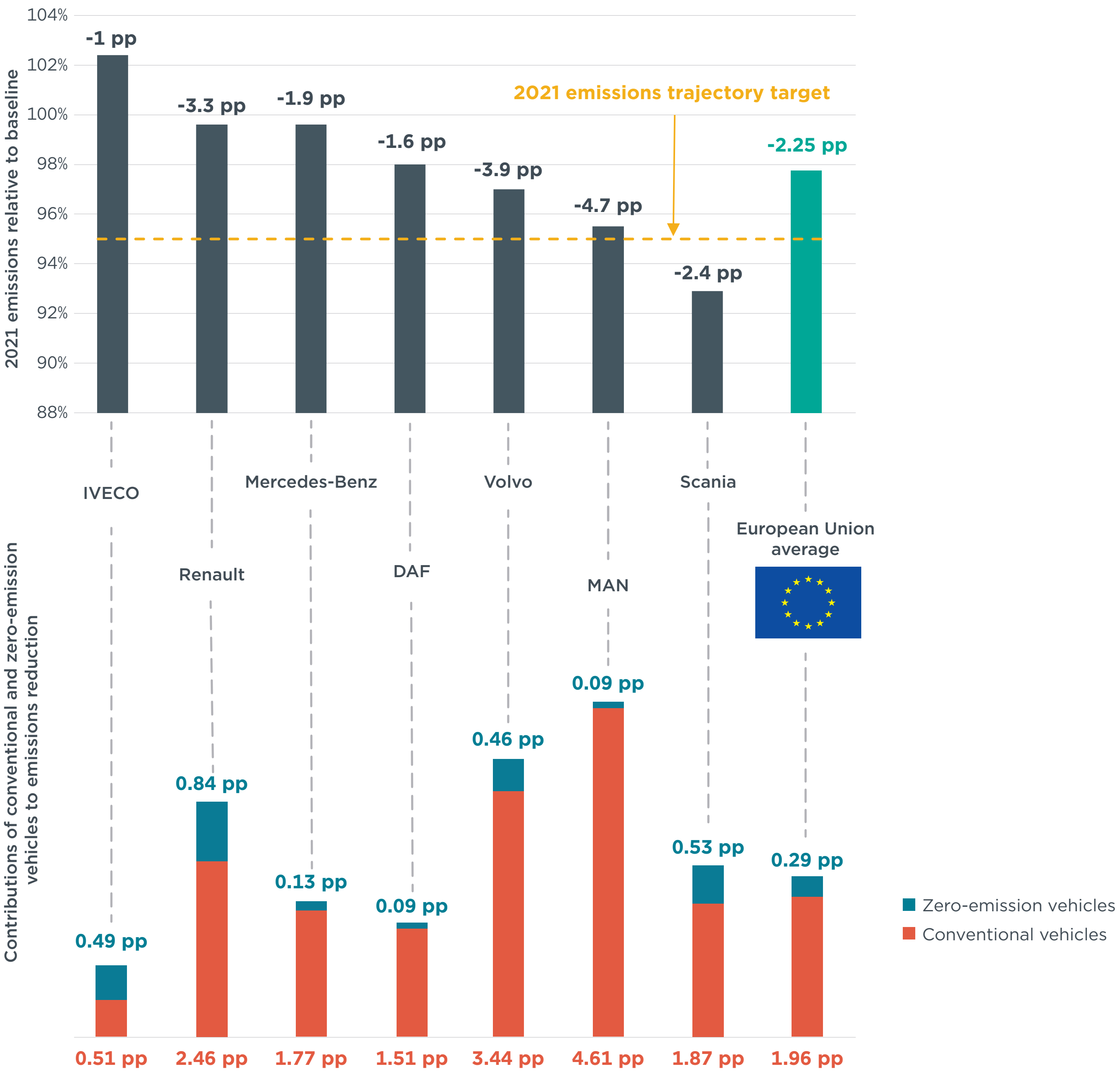
Figure ES1

CO_2 emissions of major truck manufacturers in the European Union for the 2021 reporting period, relative to the 2019 baseline, and the percentage point (pp) reduction in emissions by manufacturer since the 2019 reporting period



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INTRODUCTION

The European Union's CO_2 standards for heavy-duty vehicles (HDVs), first introduced in 2019 (Regulation (EU) 2019/1242), were recently revised and finalized by the Council of the European Union in May 2024 (Mulholland, 2024). While the 2025 targets remain unchanged at a 15% reduction in CO_2 relative to a 2019/2020 baseline, the 2030 target has been raised to a 45% reduction. The revision introduced new targets beyond 2030, mandating a 65% reduction by 2035 and a 90% reduction by 2040. The revision also extends the scope of vehicles covered in the standards, including more truck types, buses, coaches, trailers, and vocational vehicles.

The CO_2 emissions of newly registered trucks are officially certified, and the European Environment Agency (EEA) publishes the certification data annually. We previously analyzed the certified CO_2 emissions data for the 2019 (Ragon & Rodríguez, 2021) and 2020 (Mulholland et al., 2024) reporting periods. This report examines the 2021 reporting period data from July 2021 through June 2022 and analyzes the progress of truck manufacturers toward their 2025 CO_2 reduction targets. We highlight manufacturers' decarbonization strategies and retrospectively assess their performance across different technology areas.

Unless otherwise specified, all data presented in this report are sourced from the publicly available certification data from the 2021 reporting period—as directed by Regulation (EU) 2024/1610—and were retrieved from the EEA website (European Environment Agency, 2024).

MARKET ANALYSIS

The European Commission requires manufacturers to report the CO_2 emissions for 10 classifications of trucks using simulation software known as the Vehicle Energy Consumption calculation TOol (VECTO). The use of this software is mandatory under Certification Regulation (EU) 2017/2400. Trucks are assigned to different VECTO groups based on their technical specifications, such as the axle type, body type, and gross vehicle weight rating. Table 1 presents a summary of the main attributes of each VECTO group. For VECTO Groups 4, 5, 9, and 10, truck manufacturers were obliged to report their trucks' emissions performance since 2019. For all remaining groups, reporting was required as of 2020.

Table 1
Main attributes of VECTO groups

VECTO group	Axle configuration	Body type	Gross vehicle weight rating	Monitoring and reporting from
1	4x2	Rigid/Tractor	7.5–10 t	January 2020
2	4x2	Rigid/Tractor	10–12 t	January 2020
3	4x2	Rigid/Tractor	12–16 t	January 2020
4	4x2	Rigid	> 16 t	July 2019
5	4x2	Tractor	> 16 t	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

Under the original CO_2 regulations, only vehicles belonging to Groups 4, 5, 9, and 10 were required to reduce their emissions, with 2025 being the first target year (Regulation (EU) 2019/1242). In this report, those groups are referred to as *originally regulated groups*. The remaining groups are included in the recent standards revision of May 2024, with 2030 being the first target year. Those are referred to as *newly regulated groups*. The originally regulated groups are further subcategorized based on their mission profiles, as shown in Table 2, considering the truck cabin type, engine power, and mission profile.

Table 2

Subgroups of the originally regulated VECTO groups

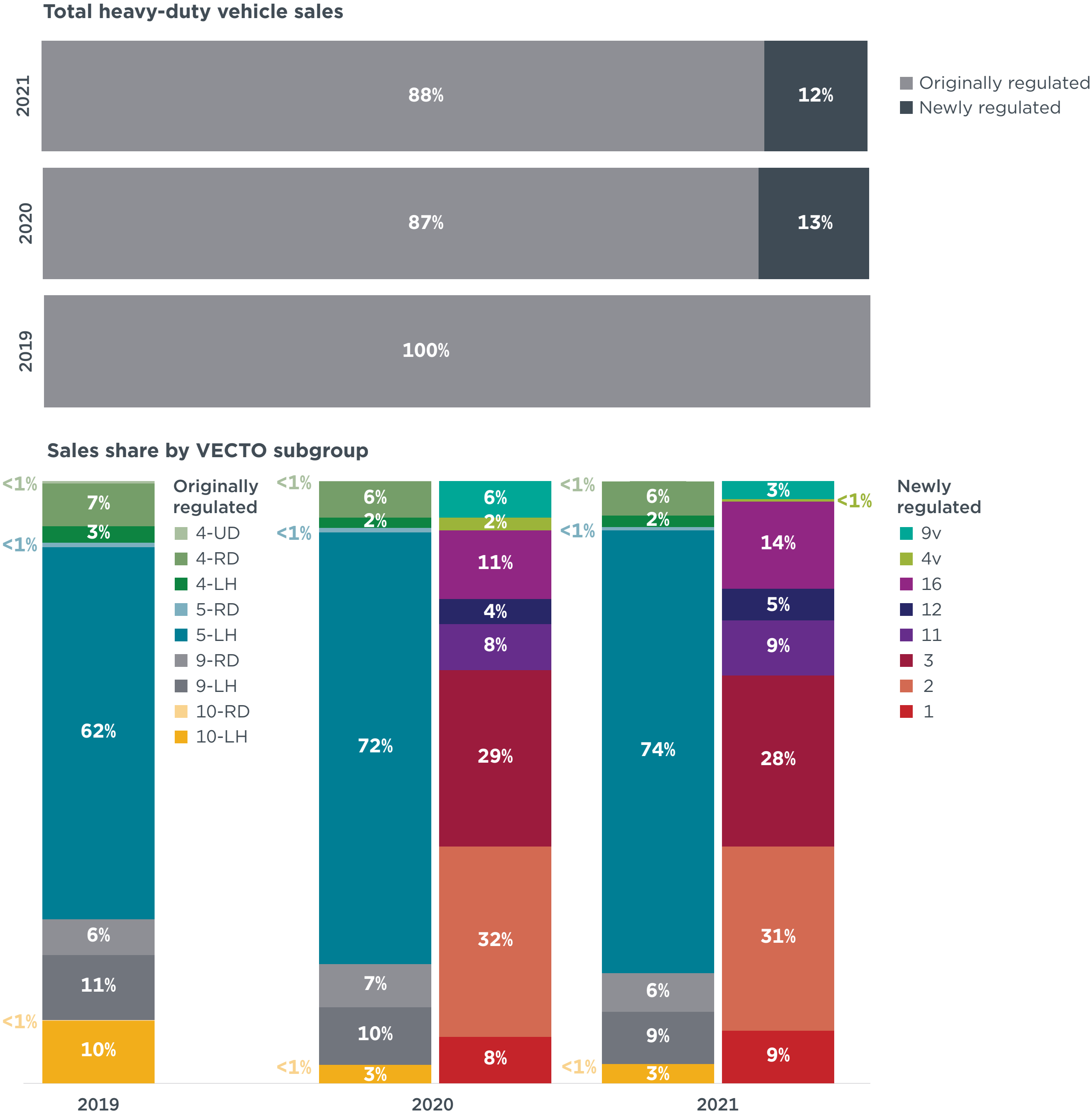
VECTO group	Subgroup	Cabin type	Engine power
4	UD	All	< 170 kW
	RD	Day cab	≥ 170 kW
		Sleeper cab	≥ 170 kW and < 265 kW
	LH	Sleeper cab	≥ 265 kW
	v	All	All
5	RD	Day cab	All
		Sleeper cab	< 265 kW
	LH	Sleeper cab	≥ 265 kW
	v	All	All
9	RD	Day cab	All
	LH	Sleeper cab	All
	v	All	All
10	RD	Day cab	All
	LH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

Notes: UD is urban delivery, RD is regional delivery, LH is long-haul, and v is vocational. Vocational vehicles were not included in the originally regulated VECTO groups and are therefore part of the newly regulated VECTO groups.

Figure 1 shows the breakdown of sales in the 2019, 2020, and 2021 reporting periods by the originally regulated and newly regulated truck groups. Originally regulated truck groups accounted for 88% of the newly registered trucks in the 2021 reporting period, consistent with the 2020 reporting period market composition. The sales shares of every group and subgroup in the 2021 data is highly consistent with the 2020 data. Within the originally regulated groups, the sales share of Subgroup 5-LH increased by 2 percentage points (pp). Within the newly regulated groups, the sales shares of Group 16 increased by 3 pp, while the sales share fell 1 pp for Groups 2 and 3.

Figure 1

Sales shares for originally and newly regulated heavy-duty vehicles



Notes: The European Environment Agency did not report data on the newly regulated subgroups for the 2019 reporting period. Within the newly regulated groups, there were no registrations reported for the 5v and 10v subgroups.

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Different vehicle subgroups are assigned different use cases, defined by the European Commission under the annex to the amended CO_2 standards (Regulation (EU) 2024/1610). Those use cases, also called mission profiles, include regional delivery, long-haul, urban delivery, and construction. One subgroup can be assigned multiple mission profiles, with each mission profile assigned a weight, as shown in Table 3. When applying a sales-weighted average to these mission profiles across all vehicle subgroups, long-haul trucking accounted for 70% of the weighted average sales in

2021, primarily driven by subgroups 5-LH and 9-LH. Relative to 2020, there was no significant change in the sales shares of the different mission profiles.

Table 3

Weights attributed to each VECTO subgroup by use case and total sales in the 2021 reporting period

VECTO subgroup	Regional delivery	Long haul	Urban delivery	Construction	Sales		
					2019[a]	2020	2021
1	40%		60%			2,170	2,455
2	50%		50%			8,877	8,648
3	50%		50%			8,221	8,013
4-UD			100%		672	94	72
4-RD	90%	10%			12,038	10,824	11,221
4-LH	10%	90%			4,653	3,224	3,810
5-RD	90%	10%			1,267	1,318	1,031
5-LH	10%	90%			105,452	130,259	146,010
9-RD	90%	10%			10,077	13,068	12,639
9-LH	10%	90%			18,428	17,296	17,179
10-RD	90%	10%			165	48	45
10-LH	10%	90%			17,743	5,583	6,345
11	50%			50%		2,157	2,589
12	70%			30%		1,167	1,479
16				100%		3,199	4,085
2019 weighted average	21%	78.6%	0.4%	0%			
2020 weighted average	24%	69%	5%	2%			
2021 weighted average	23%	70%	4%	3%			

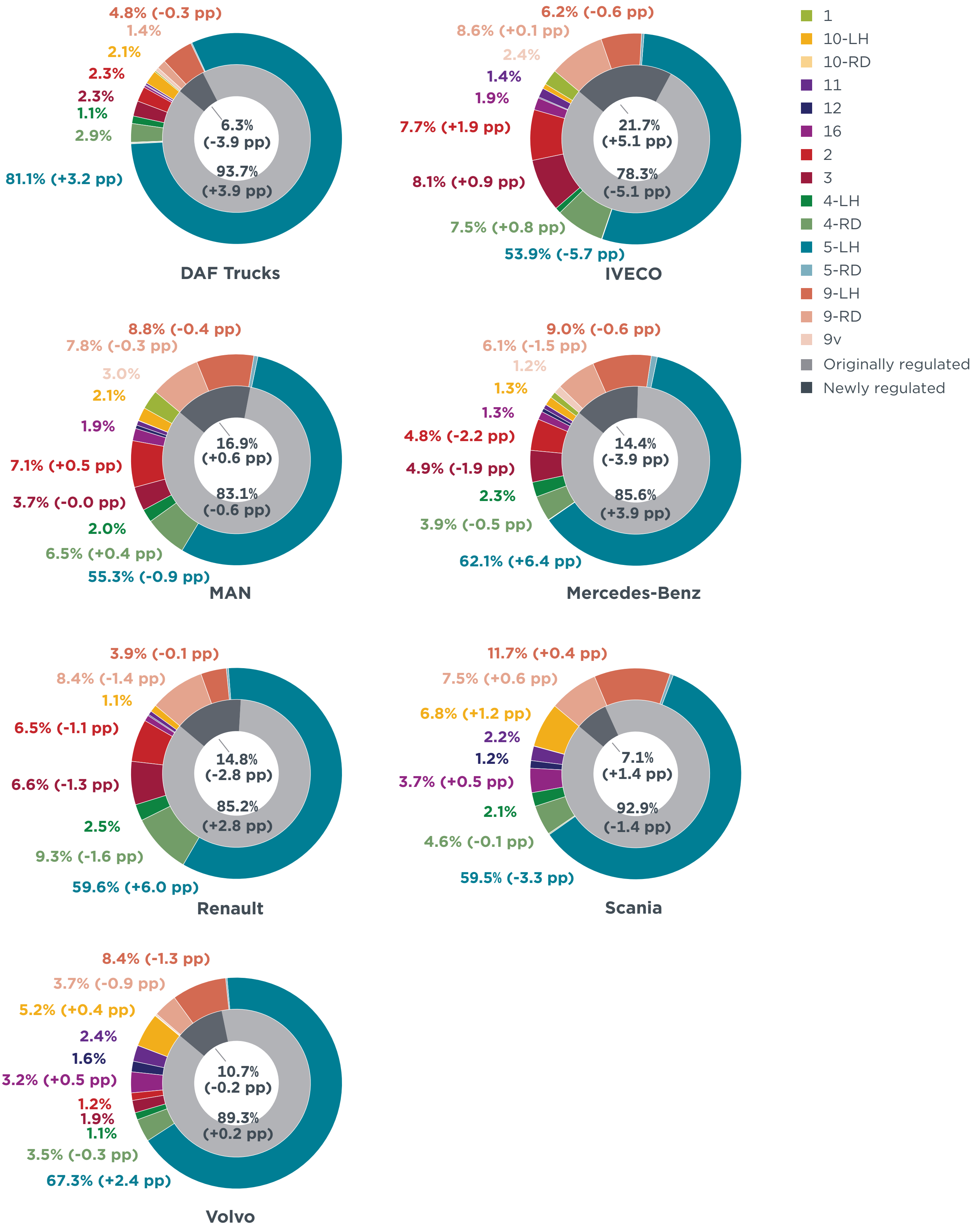
[a] The 2019 reporting period did not include data on the newly regulated truck groups. The 2019 data included the United Kingdom.

Note: Red cells indicate a decrease in sales or weighted average while green cells indicate an increase in sales or weighted average.

Truck manufacturers' sales shares differ for several VECTO groups and subgroups, and their fleet composition affects their weighted-average CO_2 emissions. Figure 2 presents the vehicle sales share by manufacturer and VECTO group in 2021, and the percentage point change relative to 2020. Focusing on Subgroup 5-LH, 81.1% of DAF's fleet consists of vehicles in this subgroup. This is the highest share of all manufacturers invested in Subgroup 5-LH, which also saw a 3.2 pp increase relative to 2020. Mercedes-Benz showed the highest year-to-year sales share increase for this subgroup, exceeding 6 pp. IVECO recorded the biggest reduction at 5.7 pp relative to 2020.

Figure 2

Share of trucks sold by VECTO subgroup for each manufacturer in 2021



Notes: The percentage point (pp) change relative to 2020 is reported between parentheses for VECTO groups with shares greater than 3%. Data labels are not shown for VECTO groups with shares lower than 1%.

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CHANGES IN CO_2 EMISSIONS FROM THE BASELINE PERIOD

Truck manufacturers certify the CO_2 emissions of their HDVs using VECTO, considering standardized mission profiles and payloads. Table 4 summarizes the CO_2 emissions of all certified VECTO groups—expressed in grams of CO_2 per tonne-kilometer (g CO_2/tkm)—for the 2019, 2020, and 2021 reporting periods. Data on the subgroups' fuel consumption in liters per 100 km is documented in Table A1 in the Appendix.

Starting with the originally regulated trucks, VECTO Subgroup 5-LH—which holds the largest share of vehicle registrations—recorded a continuous reduction in CO_2 emissions, from 56.6 g CO_2/tkm in 2019, to 55.9 g CO_2/tkm in 2020, and 55.5 g CO_2/tkm in 2021. This corresponds to a 0.97% annual average reduction in CO_2 emissions and a total reduction of 1.94% in 2021 relative to the 2019 baseline period. VECTO Subgroup 9-LH is the second-largest group regarding registrations share. This subgroup's 2021 average CO_2 emissions were 62.9 g CO_2/tkm, recording around a 3.53% reduction relative to the 2019 baseline period, or a 1.77% annual reduction. In contrast, Subgroups 4-RD and 9-RD—each representing a considerable 6% of the 2021 sales shares and a 4% share of total emissions—recorded higher emissions for the second year in a row relative to the 2019 reporting period. However, their 2020–2021 year-to-year CO_2 emissions slightly declined.

The average total CO_2 reductions of the originally regulated trucks in the European HDV fleet is calculated by considering the VECTO groups' and subgroups' corresponding sales shares along with a mileage and payload weighting factor, referred to as MPW. With this weighting taken into account, the 2021 fleet-average CO_2 emissions were 52.1 g CO_2/tkm, representing a 1.13% reduction relative to the 2019 reporting period. This corresponds to a 0.56% annual average reduction in CO_2 emissions, which is less than the 2.5% annual reduction needed to reach the 15% CO_2 reduction target by 2025.

The emissions of newly regulated trucks were only reported as of 2020. Group 1 showed a 3.3% increase in CO_2 emissions in 2021 relative to 2020. Except for VECTO Group 11, all other newly regulated trucks did not record any considerable CO_2 reductions between 2020 and 2021.

Table 4

Emissions of all certified truck groups in the 2019, 2020, and 2021 reporting periods

	Vehicle subgroup	CO_2 emissions (g CO_2/tkm) 2019	2020	2021	Annual change	2019 to 2021 change
Originally regulated groups	4-LH	106.0	102.3	98.4	−3.59%	−7.17%
	4-RD	197.2	197.9	197.6	0.10%	0.20%
	4-UD	307.2	307.4	306.8	−0.07%	−0.13%
	5-LH	56.6	55.9	55.5	−0.97%	−1.94%
	5-RD	84.0	83.2	83.9	−0.06%	−0.12%
	9-LH	65.2	64.0	62.9	−1.77%	−3.53%
	9-RD	111.0	111.7	111.2	0.09%	0.18%
	10-LH	58.3	58.6	57.9	−0.35%	−0.69%
	10-RD	83.3	88.5	79.0	−2.58%	−5.16%
Newly regulated groups	4v	626	625.1	645.9	1.60%	3.2%
	9v	403.9	396.1	413.1	1.15%	2.3%
	1	Not reported	416.62	430.27	3.28%	
	2		268.04	267.79	-0.09%	
	3		208.13	208.76	0.30%	
	11		157.02	154.89	-1.36%	
	12		104.44	103.50	-0.90%	
	16		110.34	110.32	-0.02%	

Note: Red cells imply a year-to-year increase in emissions while green cells imply a year-to-year decrease in emissions.

Figure 3 shows the relative contribution of each truck subgroup to the total CO_2 emissions in the 2019, 2020, and 2021 reporting periods. Subgroup 5-LH accounted for close to 73% of fleet emissions in 2021—a result of the subgroup's high sales volumes, payload, and annual mileage—making it the highest emitting subgroup. Subgroup 9-LH, with a total emissions share of 9% in 2021, was the second-highest emitting subgroup.

Figure 3
Share of weighted CO_2 emissions from heavy-duty vehicles by VECTO group in the 2019, 2020, and 2021 reporting periods

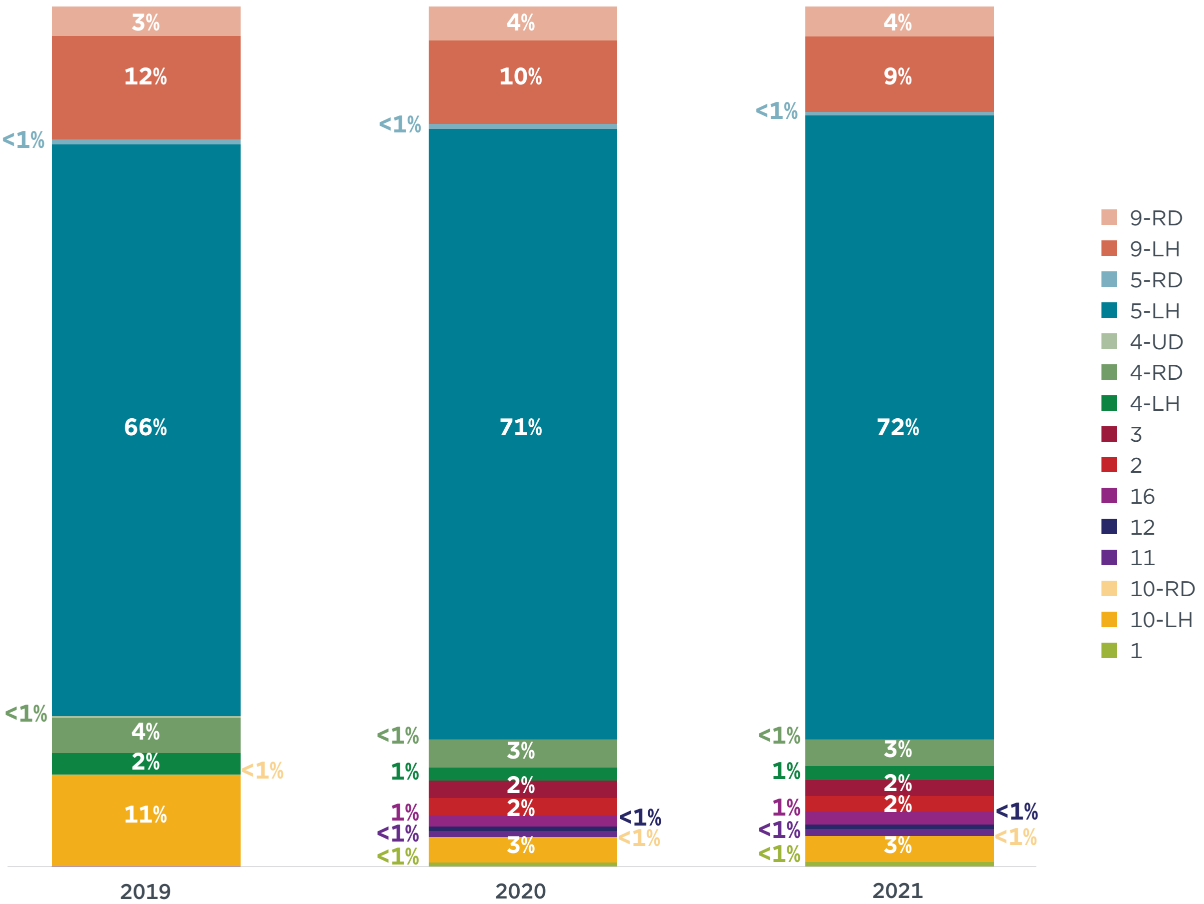

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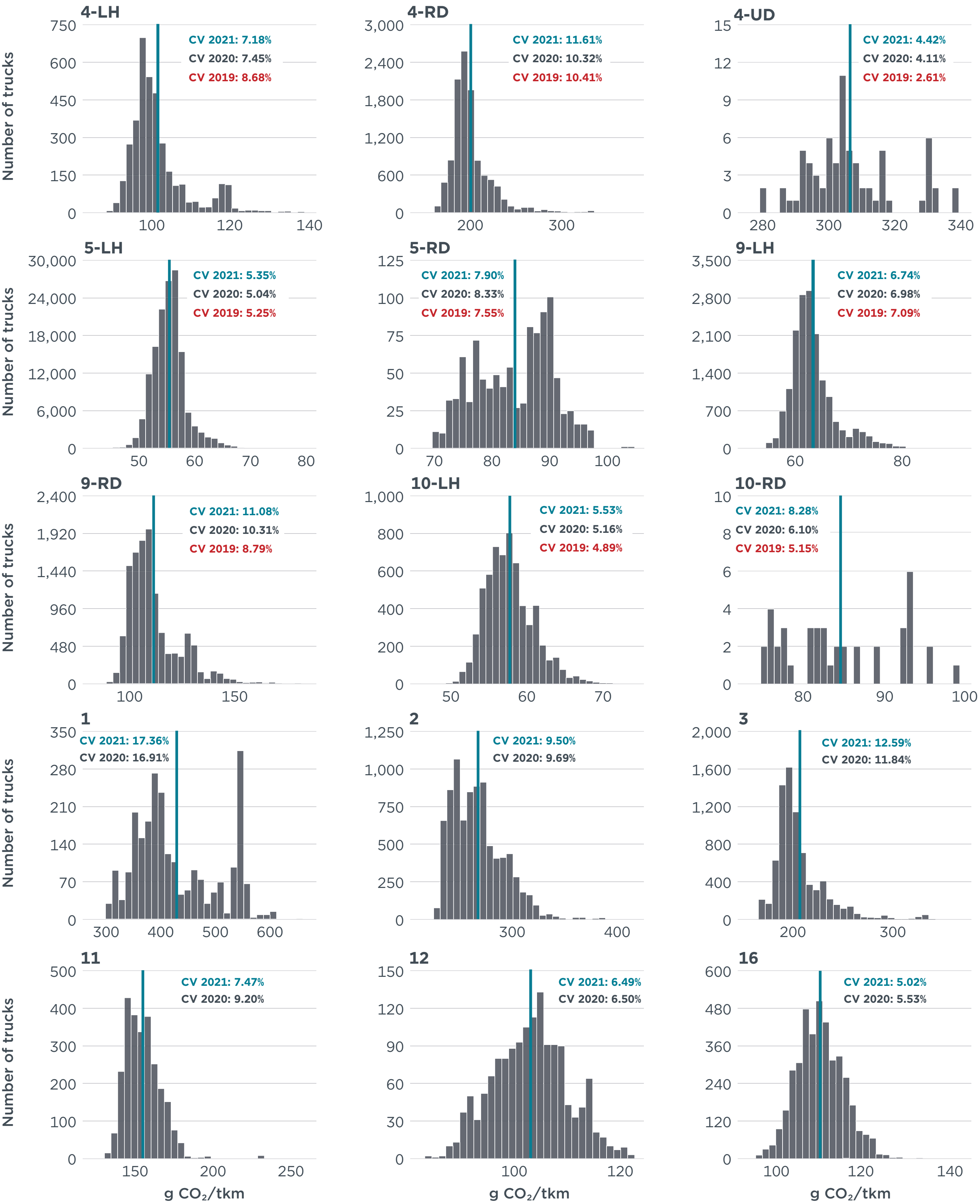
Figure 4 details the emissions distribution for the 2021 reporting period for all certified subgroups, highlighting each subgroup's average. The distribution provides insights into the level of homogeneity of each subgroup's CO_2 emissions, considering different truck manufacturers. This is reflected in the coefficient of variation (CV), which shows the percentage of variation from the mean emissions for trucks in that subgroup. The CV is shown in the figure for each subgroup for 2019 (whenever possible), 2020, and 2021. For most subgroups with significant sales shares, the CV shows minor changes.

Figure 4

Distribution of CO_2 emissions and coefficient of variation (CV) by subgroup for the 2021 reporting period



Notes: Blue lines represent the overall average emissions for 2021. Scales of the horizontal and vertical axes are not synchronized for all subplots. Zero-emission vehicles have been excluded to prevent distortion of the distribution.

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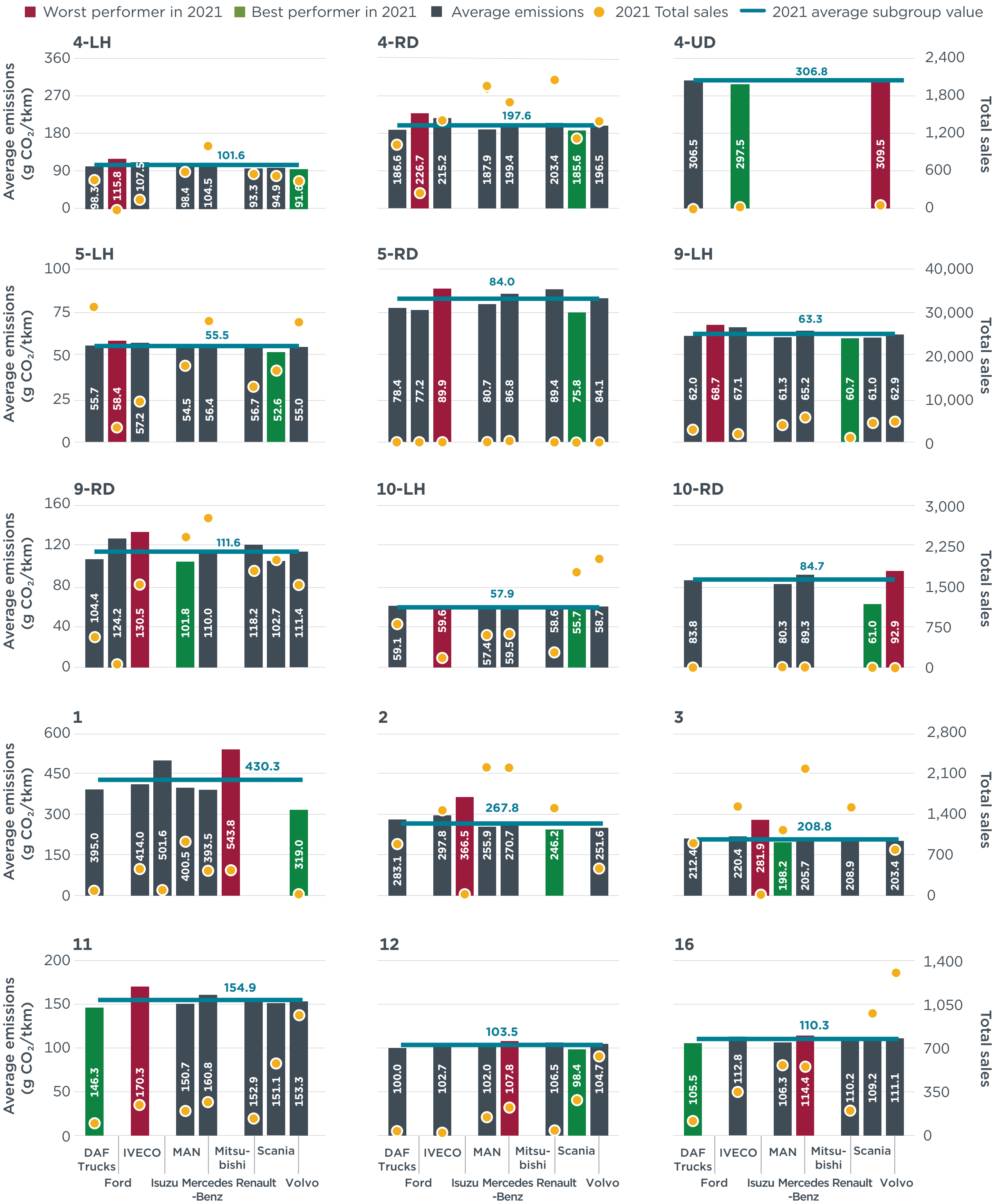
Figure 5 presents the average emissions performance for the top 10 manufacturers by sales in 2021 across the different VECTO subgroups. Starting with the originally regulated trucks, Scania was the best-performing manufacturer in five of the nine subgroups, including Subgroup 5-LH. Scania recorded average CO_2 emissions of 52.6 g CO_2/tkm for Subgroup 5-LH, 5.2% lower than the subgroup average. For Subgroup 9-LH, Renault recorded the best emissions performance, followed closely by Scania and DAF. IVECO and MAN performed the best in Subgroups 4-UD and 9-RD, respectively.

Looking at the worst-performing manufacturers, IVECO recorded the highest CO_2 emissions across seven of the nine originally regulated subgroups. Focusing on the top subgroups by sales, 5-LH and 9-LH, IVECO recorded 57.2 g CO_2/tkm and 67.1 g CO_2/tkm, 3.1% and 6.7% above the subgroup average, respectively. In addition, notably for subgroup 9-RD, IVECO reported 17.4% higher emissions than the subgroup average.

Regarding newly regulated trucks, Subgroups 2 and 3 had the highest sales volume and emissions share. Renault was the best performer in Subgroup 2 and MAN was the best performer in Subgroup 3. In contrast, IVECO recorded the worst performance in these subgroups if Isuzu—which had negligible sales in Subgroups 2 and 3—is not considered. DAF was the best performer for Subgroups 11 and 16, while IVECO and Mercedes-Benz performed the worst in Subgroups 12 and 16, respectively.

Figure 5

Average emissions by subgroup for each manufacturer in 2021



Note: Scales for emissions and sales are synchronized within each row but not across all subgroups.

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MANUFACTURER PROGRESS TOWARD THE 2025 TARGET

In addition to CO_2 emissions performance, the European Commission calculates each manufacturer's CO_2 emissions-reduction trajectory. 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 (presented in Table 4), the manufacturer's sales share of each subgroup, and the mileage and payload weighting factor (MPW). In this case, each manufacturer will have a different trajectory line and different emissions targets in g CO_2/tkm, depending on the sales shares of different subgroups. Manufacturers that reduce their fleet-average CO_2 emissions below their trajectory lines in a given year accumulate credits that can be banked for use in future years. Starting in 2025, manufacturers with fleet-average emissions above their targets must begin borrowing emission credits from future years, thus accumulating a debt.

Figure 6 presents each manufacturer's fleet-average specific CO_2 emissions relative to their individual baselines and reduction trajectories; this makes the data comparable across manufacturers.[1] The reduction trajectory starts at 100% of the 2019 baseline calculated for each manufacturer. Manufacturers must reduce emissions by 15% from the baseline to meet the 2025 target. According to the trajectory timeline, emissions must be reduced by 2.5% annually. However, five of the seven manufacturers reported emissions above their baselines in 2019, meaning they must reduce emissions more than 2.5% annually to meet the 2025 target. As of the 2021 reporting period, only Scania is on track to meet the 2025 target, accumulating credits for the third reporting period in a row. Table 5 summarizes manufacturers' performance on meeting reduction targets between the 2019 and 2021 reporting periods.

1 Specific emissions are CO_2 emissions in grams per tonne-kilometer, calculated for each vehicle produced by a manufacturer and for each manufacturer's fleet average.

Figure 6

Fleet-average specific CO_2 emissions relative to the reduction trajectory for each major manufacturer in 2019, 2020, and 2021

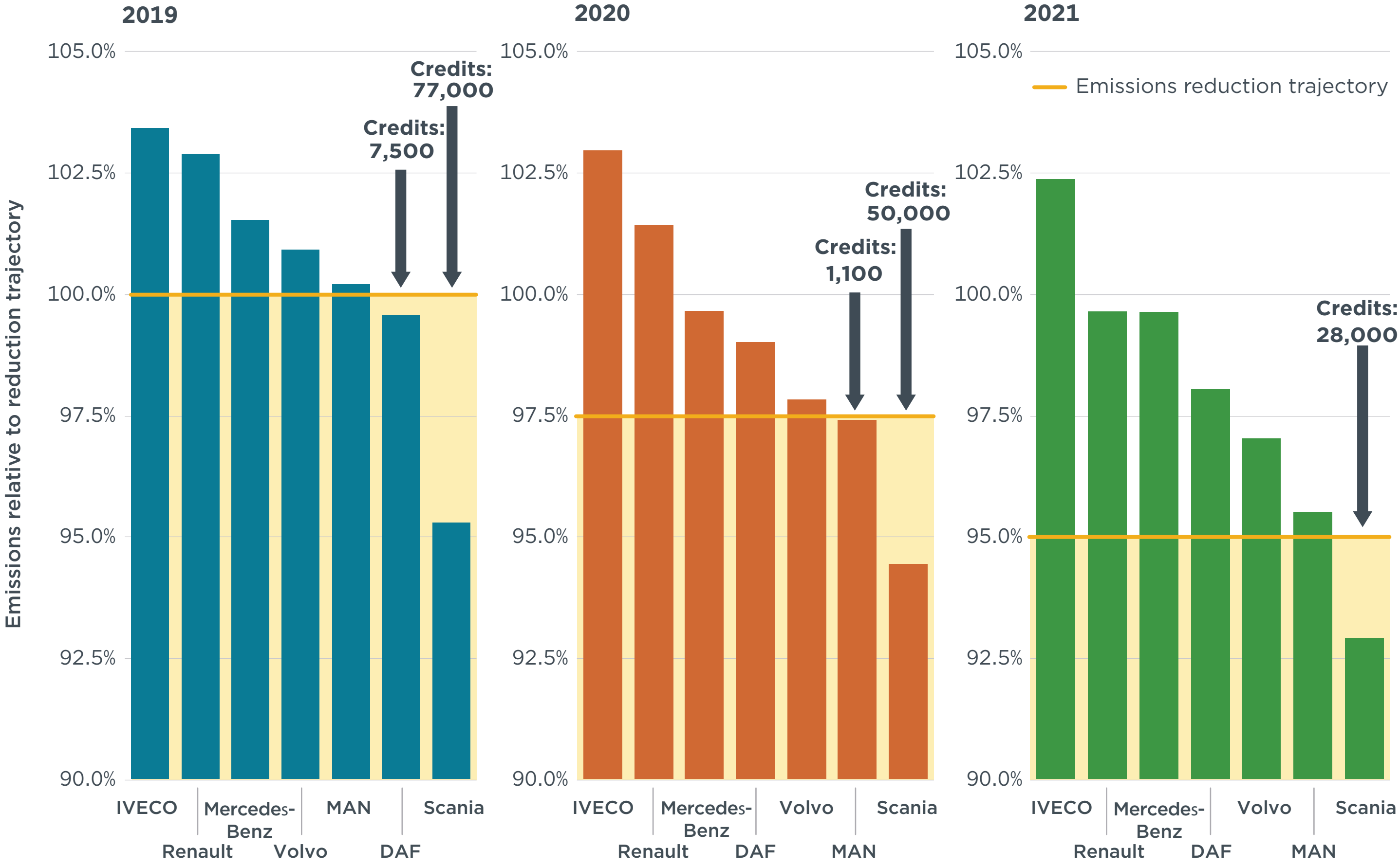

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Table 5

Fleet-average specific CO_2 emissions relative to the reduction trajectory for each major manufacturer in the 2019, 2020, and 2021 reporting periods

Reduction trajectory	2019	2020	2021	Cumulative credits (g CO_2/tkm)
	100%	97.50%	95.00%	
IVECO	103.40%	102.90%	102.40%	
Renault	102.90%	101.40%	99.60%	
Mercedes-Benz	101.50%	99.90%	99.60%	
Volvo	100.90%	98.80%	97.00%	
MAN	100.20%	97.40%	95.50%	1,106
DAF	99.60%	99.00%	98.00%	7,540
Scania	95.30%	94.50%	92.90%	154,331

Note: Values above the emissions-reduction trajectory are highlighted in red, indicating manufacturers are not on track to meet the 2025 target. Values below the emissions reduction trajectory are highlighted in green, which signifies they are on track and have been rewarded credits.

While DAF was on track to meet its targets in 2019, progress slowed in 2020 and 2021. As of the 2021 reporting period, DAF is 3% above its reduction target; emissions were reduced by 1.6% relative to the 2019 baseline period. MAN was also on track in 2020 to meet its targets, but by 2021 MAN was 0.5% above the reduction target. However, MAN recorded the highest CO_2 reduction relative to the 2019 baseline period at 4.7%, followed by Volvo at 3.9% and Renault at 3.3%. IVECO reduced its CO_2 emissions by 1% from 2019 to 2021, putting the company 7.4% above its reduction trajectory, the highest among all considered manufacturers in this analysis.

Scania, already the lowest emitter in 2019, further reduced emissions by 2.4 pp to 92.9% in 2021, successfully meeting the target and solidifying its position as the least-emitting manufacturer for the third year in a row. This achievement resulted in cumulative credits totaling 154,331 g CO_2/tkm or the equivalent of €656 million.

ALTERNATIVE FUEL VEHICLES

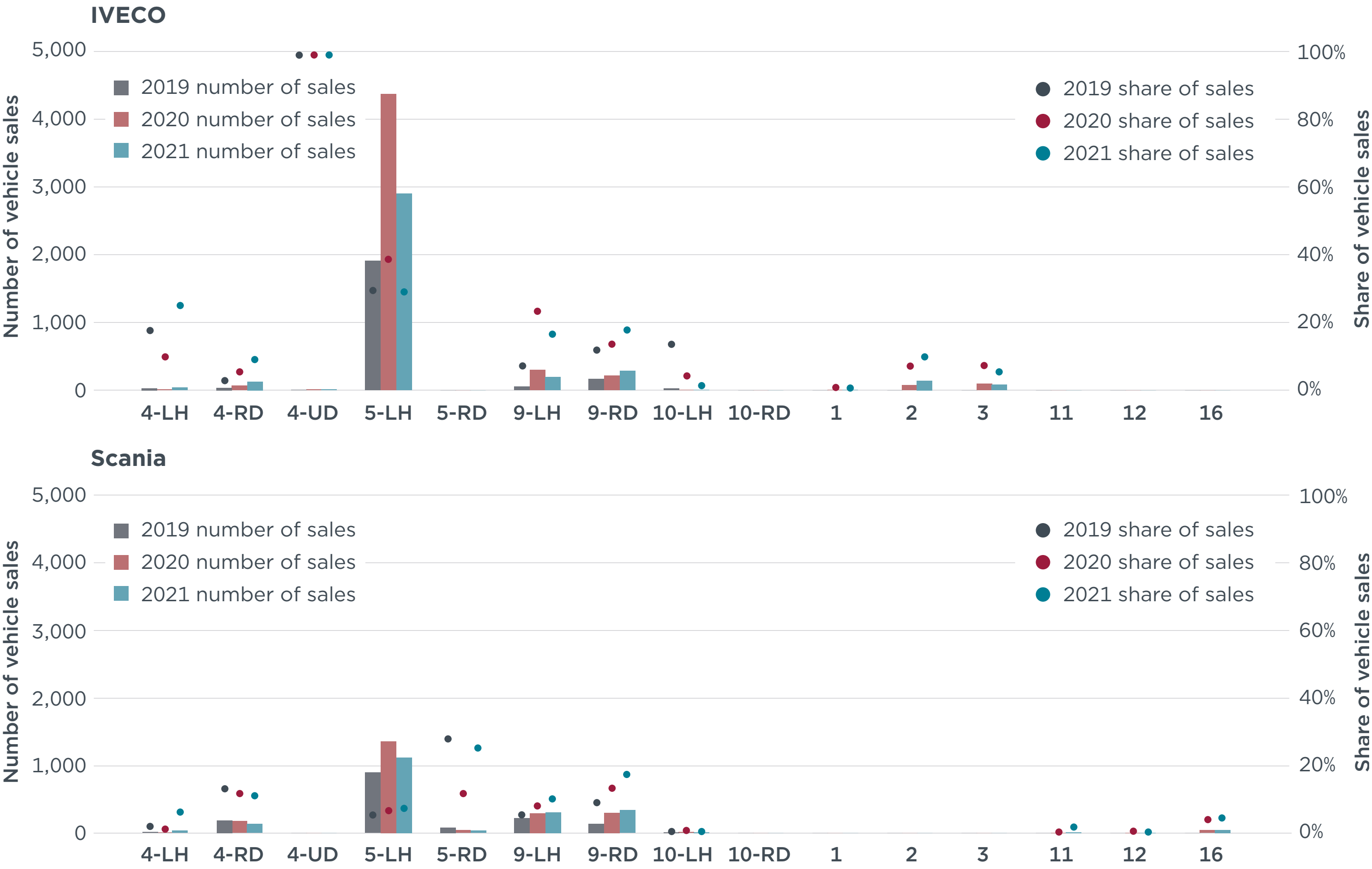
Based on the EEA data, diesel powertrains accounted for 97.07% of all regulated and unregulated truck groups in the 2021 reporting period. The share of alternative truck technologies was only 3%: natural gas trucks accounted for 2.8% of the registrations, zero-emission trucks for 0.13%, and ethanol for 0.004%. This section assesses the natural gas and zero-emission truck markets in the 2021 reporting period.

NATURAL GAS

For the third consecutive reporting period, IVECO and Scania were the largest players in the natural gas truck market, selling 3,825 and 2,034 vehicles, respectively, and accounting for 92% of all natural gas sales. Renault accounted for 5% of the market, followed by Mercedes-Benz with 2%, and Volvo with 1%. Figure 7 presents the sales and shares of natural gas vehicles for all certified truck subgroups, focusing on IVECO and Scania.

As shown in Figure 7, from 2020 to 2021, IVECO and Scania's cumulative market share decreased from 94% to 92%. IVECO's sales declined 26.7% from 5,220 vehicles in 2020 to 3,825 in 2021. Most of the reduction was due to the number of sales in Subgroup 5-LH, with approximately 1,500 fewer units sold in 2021 than in 2020.

Figure 7
Market share and sales of natural gas vehicles across all subgroups for IVECO and Scania



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Similarly, Scania's sales dropped 9.1% from 2,237 to 2,034 vehicles, primarily due to the drop in its 5-LH natural gas sales. Renault increased its market share from 3% (235 units) in 2020 to 5% (328 units) in 2021. Meanwhile, Mercedes-Benz maintained its 2021 market share of 2% (133 units).

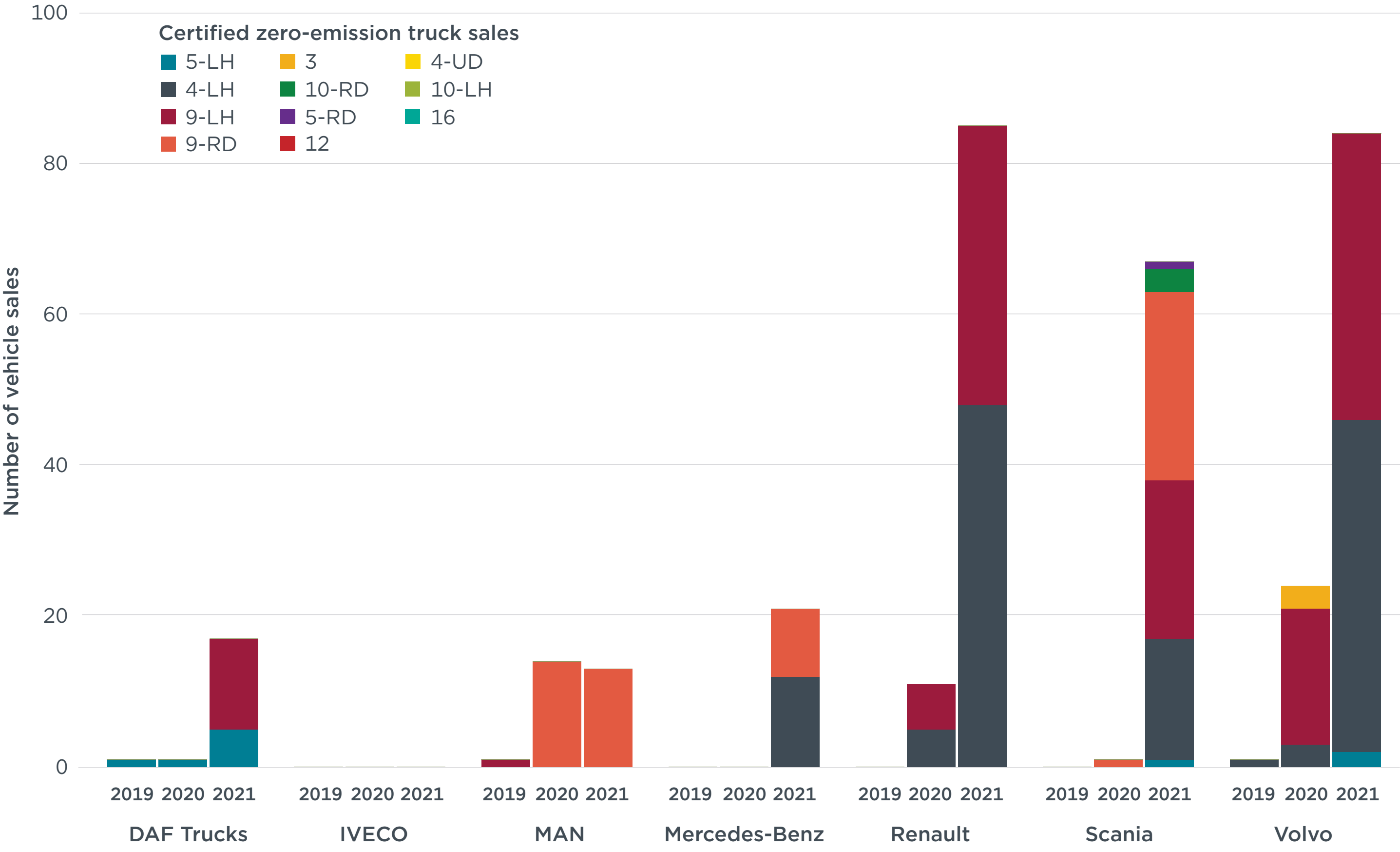
ZERO- AND LOW-EMISSION VEHICLES

The EEA monitoring and reporting data records the sales of zero-emission HDVs as reported by manufacturers, which are only obligated to report the sales of certified groups. However, EU Member States must report all sales of zero-emission HDVs to EEA, including both certified and noncertified groups. Data reported by Member States do not specify the vehicle group, so these vehicles are considered noncertified. Therefore, the sales of zero-emission HDVs are split into two categories: (1) certified vehicles reported by manufacturers and (2) noncertified vehicles reported by Member States.

Figure 8 shows the sales of certified zero-emission trucks in 2019, 2020, and 2021 for the seven top-selling manufacturers. Certified zero-emission vehicle production increased to 287 units in 2021, equivalent to a 0.13% share of sales, compared with just 3 units in 2019 and 51 in 2020. DAF produced 12 units of zero-emission 9-LH trucks, which were absent in their 2019 lineup. Renault markedly increased its output of zero-emission trucks with 48 units of 4-LH trucks and 37 units of 9-LH trucks, neither of which was produced in 2019, making Renault the highest-selling manufacturer of zero-emission trucks in 2021 when considering only certified trucks. Volvo expanded its production, selling 44 units of 4-LH trucks in 2021. Scania launched several models, selling 16 units of 4-LH trucks and 21 of 9-LH trucks. IVECO had no sales of certified zero-emission trucks during the 2021 reporting period.

Figure 8

Sales of certified zero-emission vehicles by vehicle subgroup and manufacturer in 2019, 2020, and 2021



Note: No certified zero-emission truck sales were reported for IVECO in 2019, 2020, or 2021; Mercedes-Benz in 2019 or 2020; and Renault and Scania in 2019.

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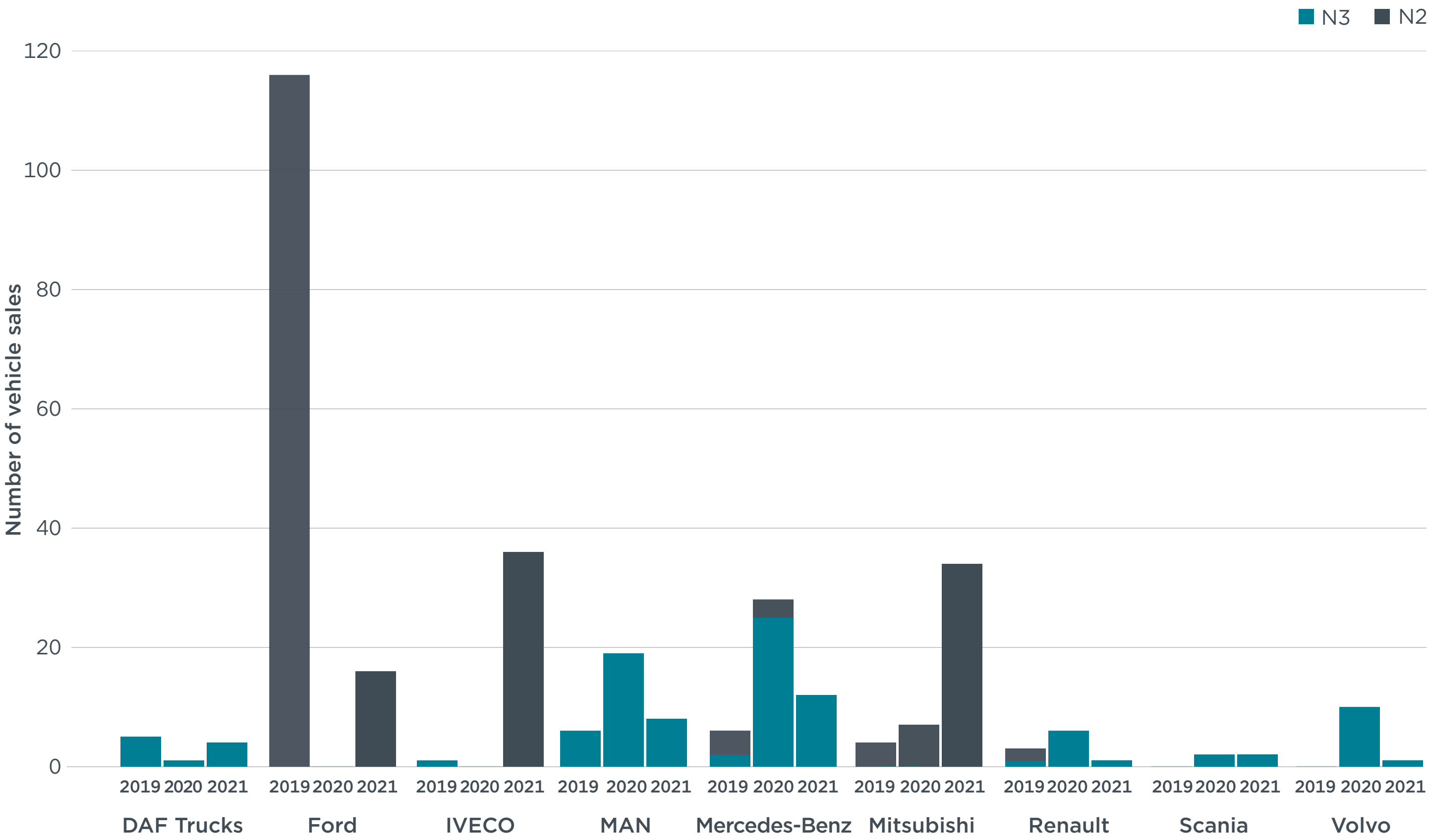
Figure 9 shows the sales of noncertified zero-emission vehicles by vehicle type and manufacturer in 2019, 2020, and 2021, as reported by EU Member States. Member States do not report the VECTO group but instead specify whether the registered vehicle is an N2 or N3 vehicle.[2] Except for IVECO and Mitsubishi, all manufacturers showed meager sales for noncertified zero-emission trucks, below 20 units in 2021.

2 N2 vehicles are trucks used for the carriage of goods and have a maximum gross vehicle weight between 3.5 tonnes and 12 tonnes. N3 vehicles are trucks used for the carriage of goods and have a maximum gross vehicle weight exceeding 12 tonnes.

Figure 9
Sales of noncertified zero-emission trucks by vehicle type and manufacturer in 2019, 2020, and 2021



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ZERO- AND LOW-EMISSION VEHICLE FACTOR

Sales of zero-emission vehicles give manufacturers more flexibility in meeting their CO_2 reduction targets. This is reflected in the zero- and low-emission vehicle (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 $ZLEV_{in}$ (for regulated vehicles) and ZEV_{out} (for unregulated vehicles). Every low-emission truck within the regulated classes, i.e., a vehicle with an emissions level of less than 50% of its subgroup's average, receives a weighting between one and two towards $ZLEV_{in,}$ dependent on its emissions. 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.

Table 6 shows the ZLEV factor of the top-selling manufacturers in the 2019, 2020, and 2021 reporting periods. IVECO calculated the lowest ZLEV factor in 2021 at 0.9951, followed closely by Renault at 0.9956, and Scania at 0.9970.

Table 6
Zero- and low-emission vehicle factor for each manufacturer in 2019 and 2020

	DAF Trucks	IVECO	MAN	Mercedes-Benz	Renault	Scania	Volvo
2019	0.9996	0.9998	0.9994	0.9996	0.9996	1.000	1.000
2020	1.0000	1.0000	0.9980	0.9989	0.9986	0.9998	0.9983
2021	0.9989	0.9951	0.9989	0.9988	0.9956	0.9970	0.9976

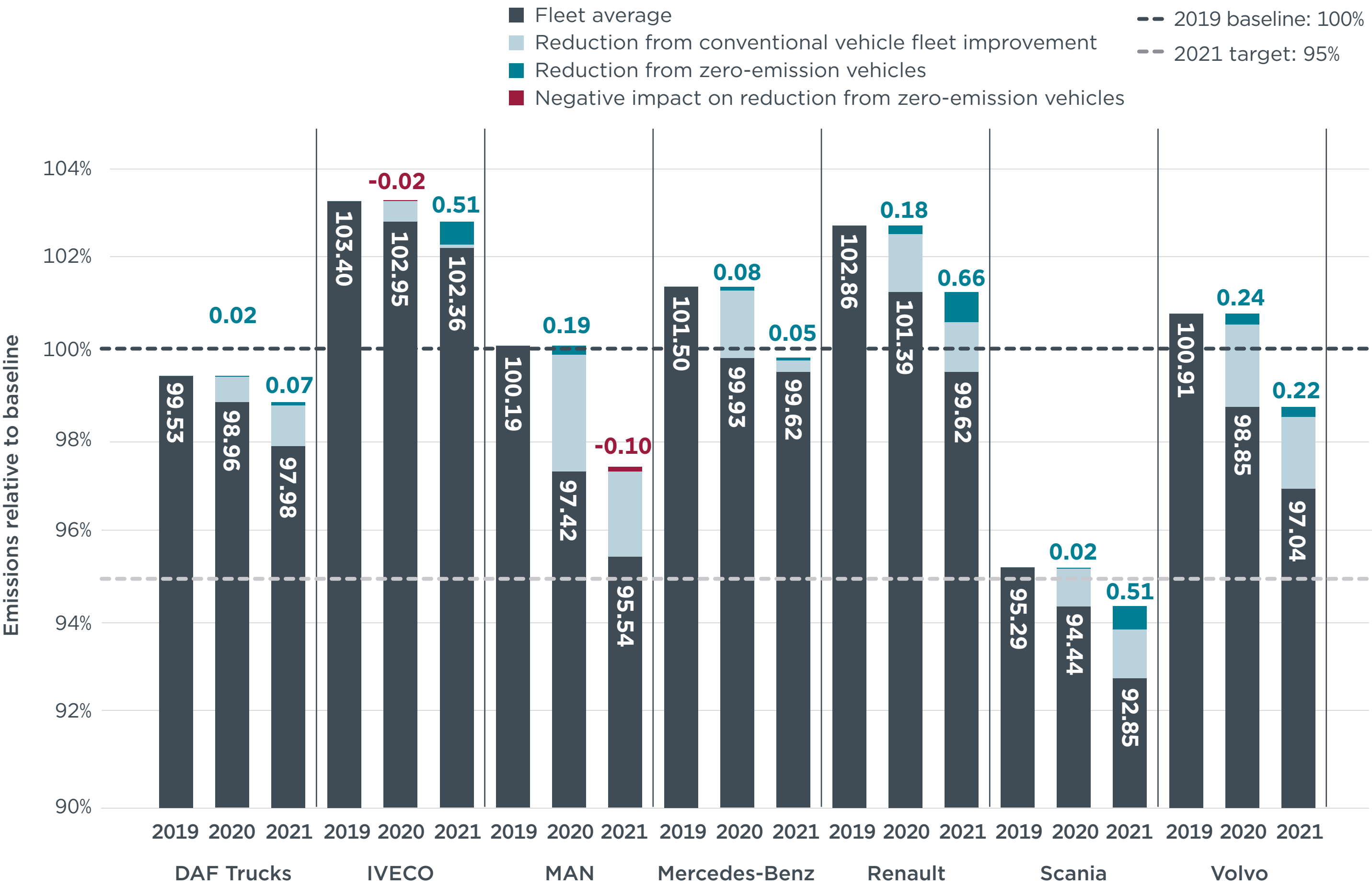
CO_2 REDUCTION PATHWAYS BY MANUFACTURER

The previous section highlights manufacturers' progress toward meeting their CO_2 reduction targets until 2025 by calculating their fleet-average specific CO_2 emissions relative to their reduction trajectory. Manufacturers can reduce their fleet-average CO_2 emissions by improving the performance of their conventional vehicles—such as by enhancing engine efficiency and reducing aerodynamic drag—or by selling more zero-emission vehicles. This section explains the different CO_2 reduction pathways pursued by manufacturers and quantifies what portion of their reduced CO_2 emissions is from improvements in conventional vehicle performance and what portion is from selling ZEVs.

Figure 10 shows the breakdown of CO_2 emissions relative to each manufacturer's reduction trajectory. The grey bars show normalized CO_2 emissions relative to the reduction trajectory for each manufacturer, the same information presented in the previous section. The difference between the CO_2 emissions in two consecutive years for a specific manufacturer is the manufacturer's emissions reduction, which is attributed to conventional vehicle fleets or ZEV sales. As explained below, the ZEV contribution might be negative under certain circumstances.

Figure 10

Breakdown of fleet-average specific CO_2 emissions relative to the reduction trajectory for the seven top-selling manufacturers



Note: Numbers above each bar represent in percentage points the positive or negative impact of zero-emission vehicle sales on fleet-average CO_2 emissions.

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Scania, which is the only manufacturer on track to meet its 2025 reduction target, improved its performance from 2020 to 2021 by 1.58 pp; 0.51 of the points were from ZEV sales. This means that almost one third of Scania's improved CO_2 emissions performance was due to ZEV sales, and two thirds was due to improved conventional vehicle fleet performance. Similarly, Renault's performance improved due to a combination of higher ZEV sales and continuous improvement in its conventional vehicle fleet emissions performance. IVECO improved its emissions by 0.58 pp, with 0.51 of the points coming from selling more ZEVs. Although IVECO had the lowest reduction in emissions among all manufacturers, it is also the manufacturer that had ZEVs contribute the most to its emissions-reduction performance.

In some cases, ZEV sales negatively contributed to a manufacturer's performance, as is the case for IVECO in 2020 and MAN in 2021. IVECO sold one ZEV in 2019 and none in 2020, while MAN sold 33 ZEVs in 2020 and 21 in 2021. In these two cases, the decreasing share of ZEV sales resulted in a negative ZEV contribution to the manufacturer's total CO_2 emissions-reduction performance.

As shown in the mathematical formulation presented in Appendix B, the sales share of ZEVs in a manufacturer's fleet is not the sole determinant of the ZEV contribution. How much a single ZEV contributes to emissions reduction is determined by the CO_2 emissions of the conventional vehicle the ZEV is replacing. If a ZEV is replacing a less-polluting diesel vehicle, the ZEV's contribution to reducing CO_2 emissions will be less. This explains some of the behaviors observed in Figure 6. For example, Volvo increased the sales share of ZEVs from 2020 to 2021, yet the ZEV contribution to emissions reduction decreased. The ZEV increase was seen across Subgroup 9-LH as well as 4-LH, although the latter subgroup's sales shares were very low. Although Volvo's sales share of ZEVs increased in these subgroups from 0.59% in 2020 to 1.09% in 2021, the CO_2 emissions of the conventional vehicle fleet decreased by 6%, diluting the contribution of higher ZEV sales. Table A3 in the appendix provides additional data to help understand this behavior.

COMPARISON WITH OFFICIALLY REPORTED VALUES

Every year, the European Commission publishes an implementing decision with certain CO_2 emission values per manufacturer, as well as average specific CO_2 emissions of all new heavy-duty vehicles registered in the European Union. The implementing decision shows official fleet-average specific CO_2 emissions, the CO_2 emissions-reduction trajectory, the ZLEV factor, and the number of emission credits per manufacturer based on the monitoring and reporting data. Table 7 summarizes the official values reported for 2021 compared with those calculated from our own analysis.

Table 7

Comparison of official CO_2 values, zero- and low-emission vehicle factors, and credits with the ICCT's estimated values for the 2021 reporting period

	Variable	DAF Trucks	MAN	Mercedes- Benz	Renault	Scania	Volvo
International Council on Clean Transportation	Reduction trajectory	97.98%	95.53%	99.63%	99.62%	92.85%	97.03%
Commission Implementing Decision (EU) 2024/2165	Reduction trajectory	98.05%	95.56%	99.64%	99.62%	92.87%	97.26%
ICCT	Average specific CO_2 emissions in g CO_2/tkm	54.23	49.73	53.23	50.85	49.23	52.83
(EU) 2024/2165	Average specific CO_2 emissions in g CO_2/tkm	54.26	49.74	53.23	50.85	49.23	52.94
ICCT	ZLEV factor	0.999	0.999	0.999	0.996	0.997	0.998
(EU) 2024/2165	ZLEV factor	1.000	0.999	0.999	0.995	0.997	0.998
ICCT	Credits in g CO_2/tkm	0	0	0	0	27,587	0
(EU) 2024/2165	Credits in g CO_2/tkm	0	0	0	0	27,392	0

In general, there is a good alignment between the values calculated based on our analysis and the official values published by the European Commission for the 2021 reporting period. There is very little difference, if any, in the calculation of the reduction trajectory, the emissions under which a manufacturer receives credits, except our values are slightly lower for Volvo. No difference is apparent from the calculation of the ZLEV factor, with the exception of DAF. Some slight discrepancies are also found in the calculation of the average specific CO_2 emission values.

TECHNOLOGY ANALYSIS

Tailpipe CO_2 emissions from trucks can be reduced either by reducing the vehicle energy/power demand or by improving the efficiency of the energy/power supply unit. Reducing the vehicle power demand implies reducing the resistive forces the vehicle is subject to during operation, such as aerodynamic, rolling resistance, and gravitational forces. This is achieved by reducing the vehicle's aerodynamic drag, the tires' rolling resistance, and the vehicle weight, among other actions. On the other hand, improving the efficiency of the power supply unit implies enhancing the efficiency of the internal combustion engine.

This section summarizes technology improvements to understand how they contribute to reducing tailpipe CO_2 emissions.

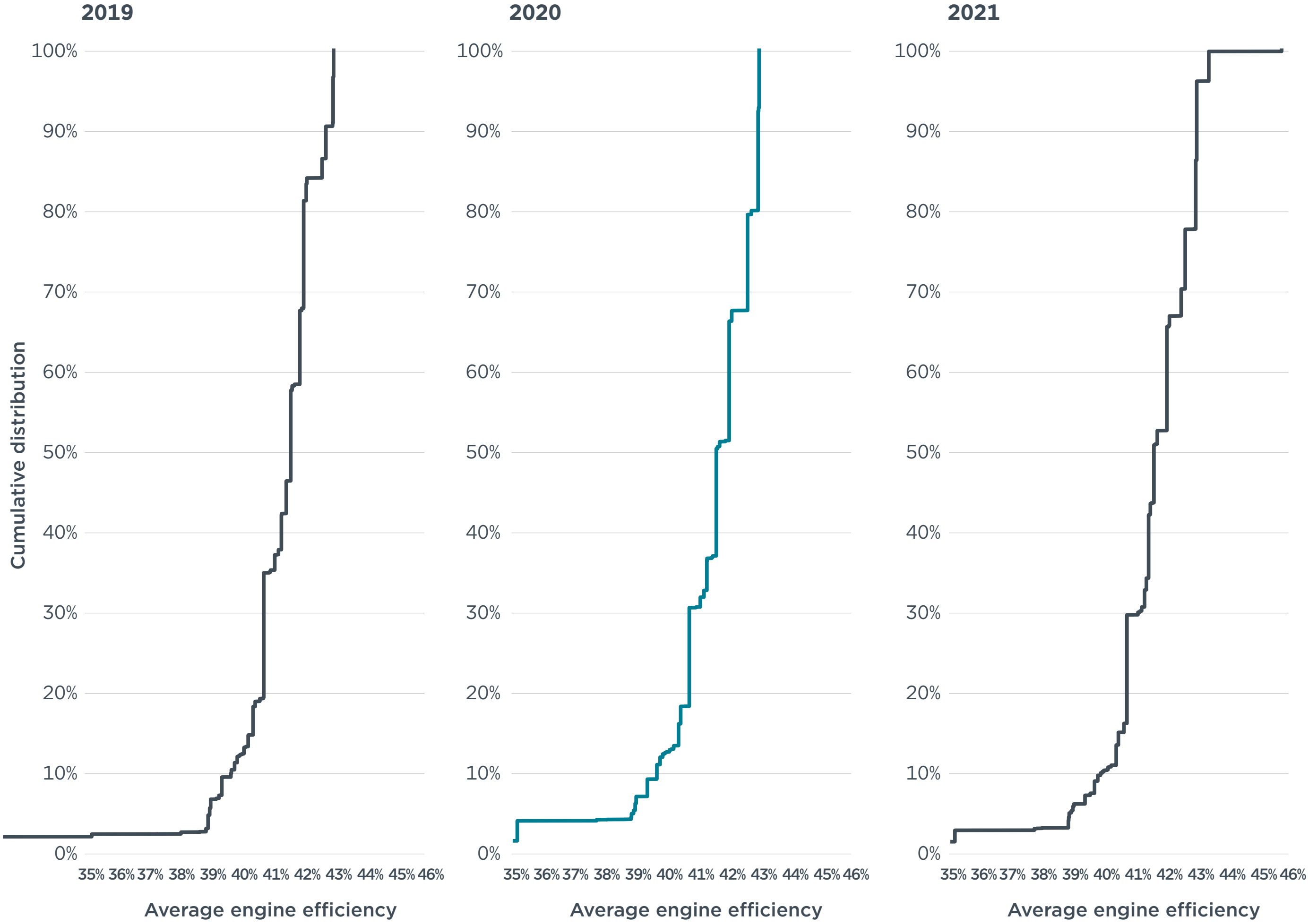
ENGINE EFFICIENCY

The average engine efficiency, as measured by dynamometer tests for type approval under the World Harmonized Transient Cycle (WHTC), exhibited notable changes across different manufacturers' vehicle subgroups between 2019 and 2021.

The sales-weighted average engine efficiency, considering all manufacturers in the 2021 reporting period, was 41.47% compared with 41.35% in 2020 and 41.17% in 2021. Figure 11 shows the efficiency distribution for all regulated engines sold in the 2019, 2020, and 2021 reporting periods. In 2021, 22.1% of engines recorded average efficiencies higher than or equal to 43%, compared with only 9.5% in 2019. Only 10.1% of the engines recorded an average efficiency below 40% in 2021, compared with 12.2% in 2019. The data show an increasing share of higher-efficiency engines.

Figure 11

Cumulative distribution of average engine efficiency for regulated vehicles in the 2019, 2020, and 2021 reporting periods



Note: Average engine efficiency was measured under the World Harmonized Transient Cycle.

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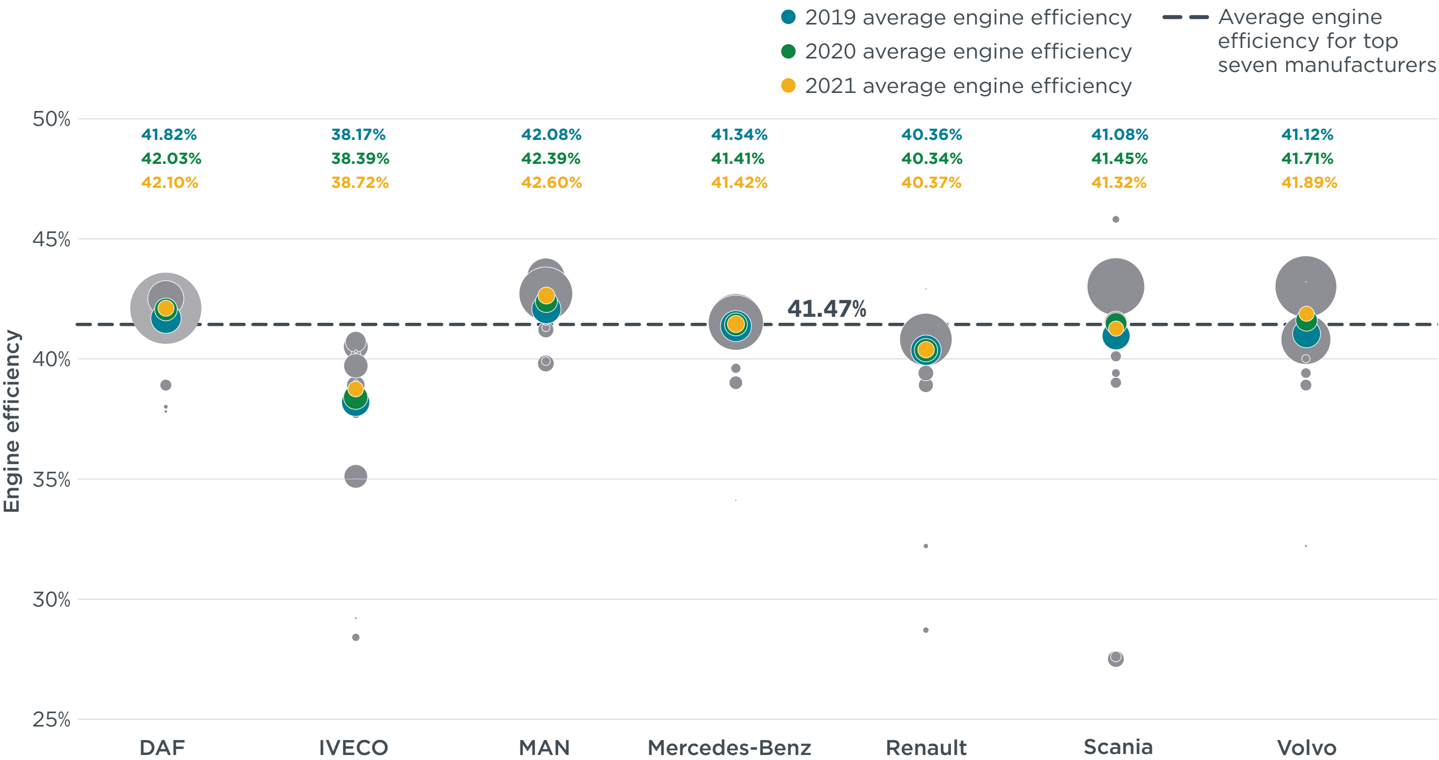
Figure 12 shows the average engine efficiency under the WHTC for all subgroups per manufacturer. MAN had the highest sales-weighted average engine efficiency of 42.6% across all subgroups in 2021 compared with 42.39% in 2020 and 42.08% in 2019. DAF follows with an average engine efficiency of 42.10% in 2021, while IVECO records the lowest engine efficiency at 38.72%. Volvo and Ford recorded a 0.2 pp increase in engine efficiency, while Renault and Mercedes-Benz recorded a minor improvement. Contrary to the trend seen for other manufacturers, Scania recorded a decrease in average engine efficiency, 41.32% in 2021 compared with 41.45% in 2020, driven by a reduction in the average engine efficiency of Subgroup 5-LH, as is discussed later in this section.

Figure 12

Reported average engine efficiency the top seven manufacturers for truck sales



Notes: The size of the bubbles represents the distribution of sales volume for each manufacturer in 2021 by engine efficiency, as measured under the World Harmonized Transient Cycle. Only regulated subgroups are considered.

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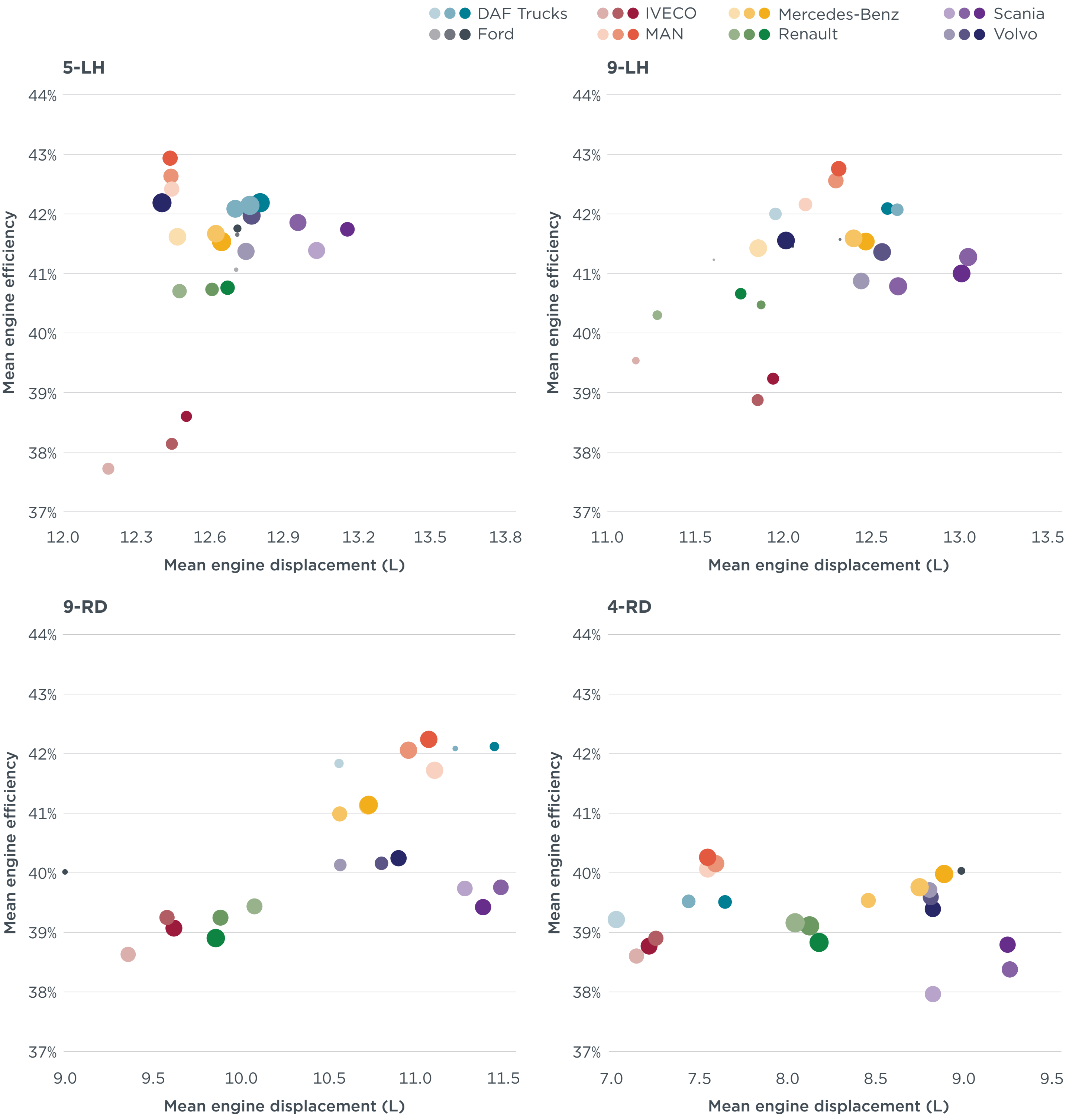
Digging deeper into the engine efficiency improvement, Figure 13 shows the average engine efficiency as a function of the engine displacement for the top-selling and most-polluting subgroups 5-LH, 9-LH, 9-RD, and 4-RD. For Subgroup 5-LH, MAN recorded the highest mean engine efficiency in 2021 at 42.9%—up from 42.62% in 2020 and 42.41% in 2019—while maintaining the same engine displacement. The worst performer in this subgroup was IVECO with an average engine efficiency of 38.59% in 2021 along with continuously increasing engine displacement since 2019. Scania and Mercedes-Benz recorded a reduction in engine efficiency between 2020 and 2021 and an increase in engine displacement. Similar trends are observed for the other subgroups, with MAN recording the highest engine efficiency.

Figure 13

Engine efficiency and displacement for each manufacturer by subgroup



Note: Size of marker represents market share of each manufacturer within a subgroup for that year. Shades of color represent years from lightest (2019) to darkest (2021). Average engine efficiency was measured under the World Harmonized Transient Cycle.

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AERODYNAMICS

The vehicle's aerodynamic drag area is a pivotal design feature that affects the vehicle's energy efficiency. The aerodynamic force resisting the vehicle during motion is proportional to the square of the vehicle speed. Therefore, the energy efficiency of trucks driving at higher speeds is highly dependent on their aerodynamic performance.

The truck drag area is defined as the product of the drag coefficient (Cd) and frontal area (A) and is written as CdA. According to certification protocols, VECTO standardizes a basic tractor-trailer model without aerodynamic adaptations, requiring that any CdA improvements be realized through cab modifications. A legislative update by the European Commission in 2022 mandates that, from 2024 onward, trailer manufacturers must disclose their emissions when the trailers are paired with a standard motorized tractor (Commission Implementing Regulation (EU) 2022/1362).

The drag area values are clustered into different bins, with higher bin numbers representing higher CdA values. These values range from between 0 and 3 m^2 for Bin A1 to between 8.77 m^2 and 9.21 m^2 for Bin A24. To simplify data visualization, we consider the midpoint of each bin range. Data on the range boundaries and midpoints are documented in Table A2 in the appendix.

The sales-weighted average aerodynamic drag area, considering all manufacturers in the 2021 reporting period, was 5.63 m^2. This is 0.2% lower than the average CdA value reported in 2020 at 5.64, and 0.5% lower than the 2019 average.

Figure 14 presents the distribution of CdA values across all originally regulated vehicles for all manufacturers in the 2019, 2020, and 2021 reporting periods. There was a significant reduction in the percentage of trucks with reported CdA values in Bins A15 and A16, accompanied by an increase in the shares of trucks with reported CdA values in Bins A12 and A13, indicating a reduction in the fleet-total CdA. In 2021, 4.5% and 25% of trucks reported CdA values in bins A16 and A15, respectively, down from 7% and 28% in 2019. In parallel, 16% and 5% of trucks reported CdA values in Bins A13 and A12 in 2021, up from 9% and 2% in 2019, respectively.

Figure 14

Percentage of originally regulated trucks with a reported drag coefficient value (CdA) by bin number in the 2019, 2020, and 2021 reporting periods

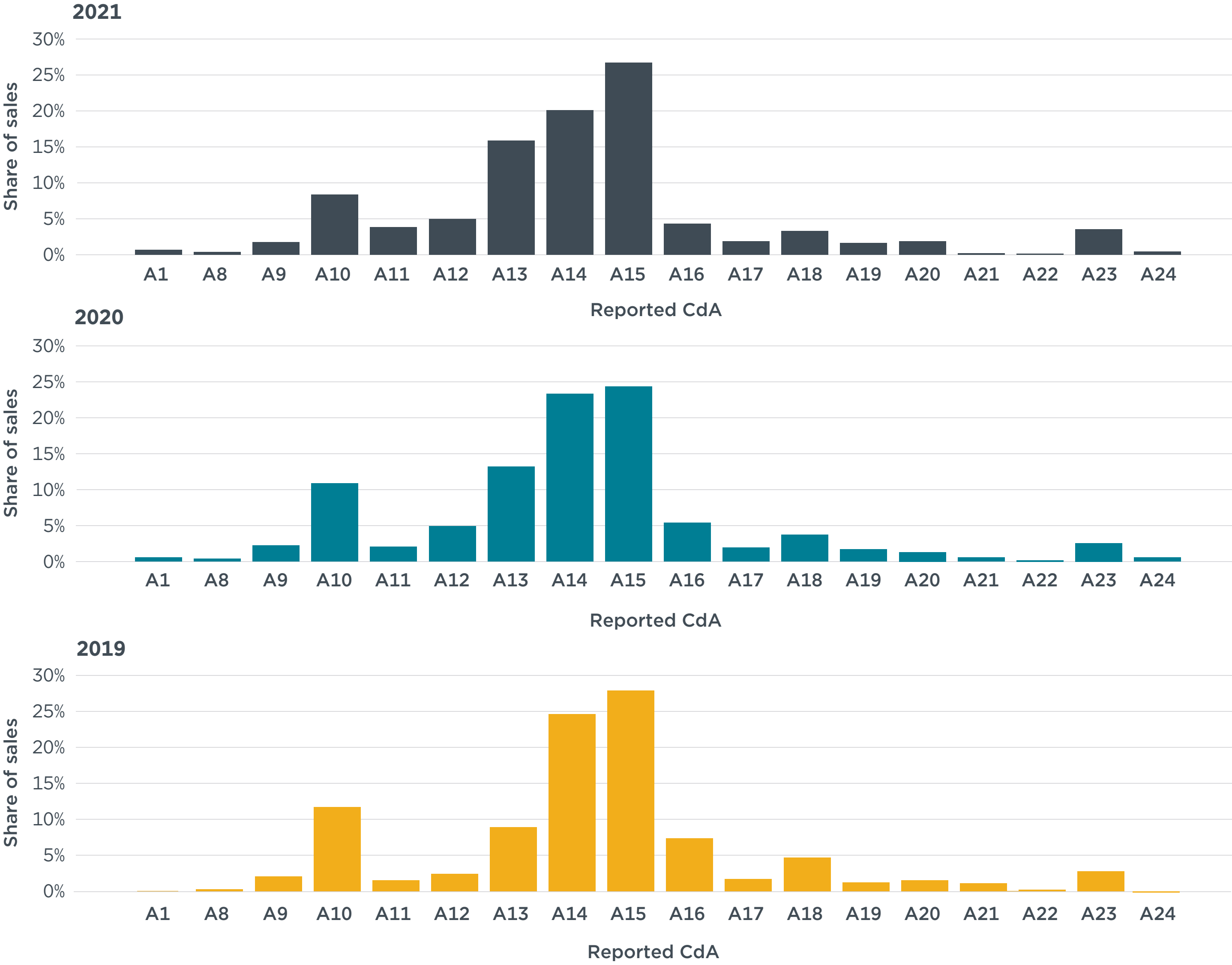

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Figure 15 provides a detailed breakdown of drag coefficients for major manufacturers for the 2019, 2020, and 2021 reporting periods. Scania maintained a superior aerodynamic performance for the third consecutive year compared with other manufacturers. In 2021, Scania had an average CdA of 4.71 m^2, 16.34% lower than the average for the top manufacturers of 5.63 m^2. Scania's 2021 performance showed a minor improvement, going from 4.74 m^2 in 2019 to 4.71 m^2.

Figure 15

Reported air drag values by manufacturer

Note: The size of the bubbles reflects the distribution of sales volume for each manufacturer in 2021 by CdA value. The diamonds and the data labels represent the manufacturer's average drag area across all subgroups for different years.

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The worst aerodynamic performance in 2021 was recorded by IVECO (8% above the average), Mercedes-Benz (6.2%), and Ford (5.7%). MAN and Volvo demonstrated improvements of 5% and 8%, respectively, in 2021 compared with 2019. IVECO's reported CdA values increased approximately 3% to 6.08 m^2 in 2021 relative to 2019. Manufacturers can either report the actual measured CdA value or the subgroup standard CdA value, which is usually significantly higher than the reported measured values by manufacturers. One reason for manufacturers to report the standard subgroup values is to reduce costs, especially given that no debts are accumulated until 2025, so noncompliance is not penalized until the 2025 reporting period. If a manufacturer increases the share of trucks with the standard CdA value, the average CdA value will naturally increase. Table 8 shows the percentage of trucks reporting the standard CdA values. IVECO's share increased to 12.7% in 2021, up from 6.7% in 2020 and only 0.03% in 2019. This may explain the deteriorated aerodynamic performance of the IVECO trucks. Focusing on the measured values only, IVECO's aerodynamic performance witnessed a slight improvement in 2021 relative to 2020.

Table 8
Percentage of each manufacturer's trucks reporting the standard aerodynamic drag area (CdA) value in the 2019, 2020, and 2021 reporting periods

Manufacturer	Percentage of trucks reporting the subgroup standard CdA value		
	2019	2020	2021
IVECO	0.03%	6.7%	12.7%
Mercedes-Benz	10.55%	8.76%	7.43%
DAF	0.17%	0.18%	5.67%
Scania	0%	0%	0.24%
Ford	3.01%	0%	0%

Table 9 presents the average CdA for all subgroups for the 2019, 2020, and 2021 reporting periods, highlighting the change in the drag area for reporting period 2021 relative to 2019. Subgroups 5-LH and 9-LH exhibited reductions in CdA values by 0.9% and 1.6%, respectively, between 2019 and 2021. Subgroup 4-LH recorded the most significant reduction at 3.8%. Although Subgroup 10-RD recorded a 7.5% reduction in CdA, the total sales volume for this subgroup in 2021 was 45 units, which is a small statistical sample size.

Subgroups 9-RD and 4-RD showed an increase in CdA of 5.2% and 2.7%, respectively, between 2019 and 2021. These subgroups are mainly assigned regional delivery mission profiles, so the CdA's impact on fuel consumption is not as high as it would be for a long-haul mission profile that assumes higher vehicle speeds are sustained throughout the cycle. Although customers may be less interested in purchasing delivery trucks equipped with advanced and more expensive aerodynamic technologies, the data show that most manufacturers offer the same truck model with advanced aerodynamic packages even for regional delivery groups.

Table 9

Vehicle aerodynamic drag area (CdA) by subgroup in the 2019, 2020, and 2021 reporting periods

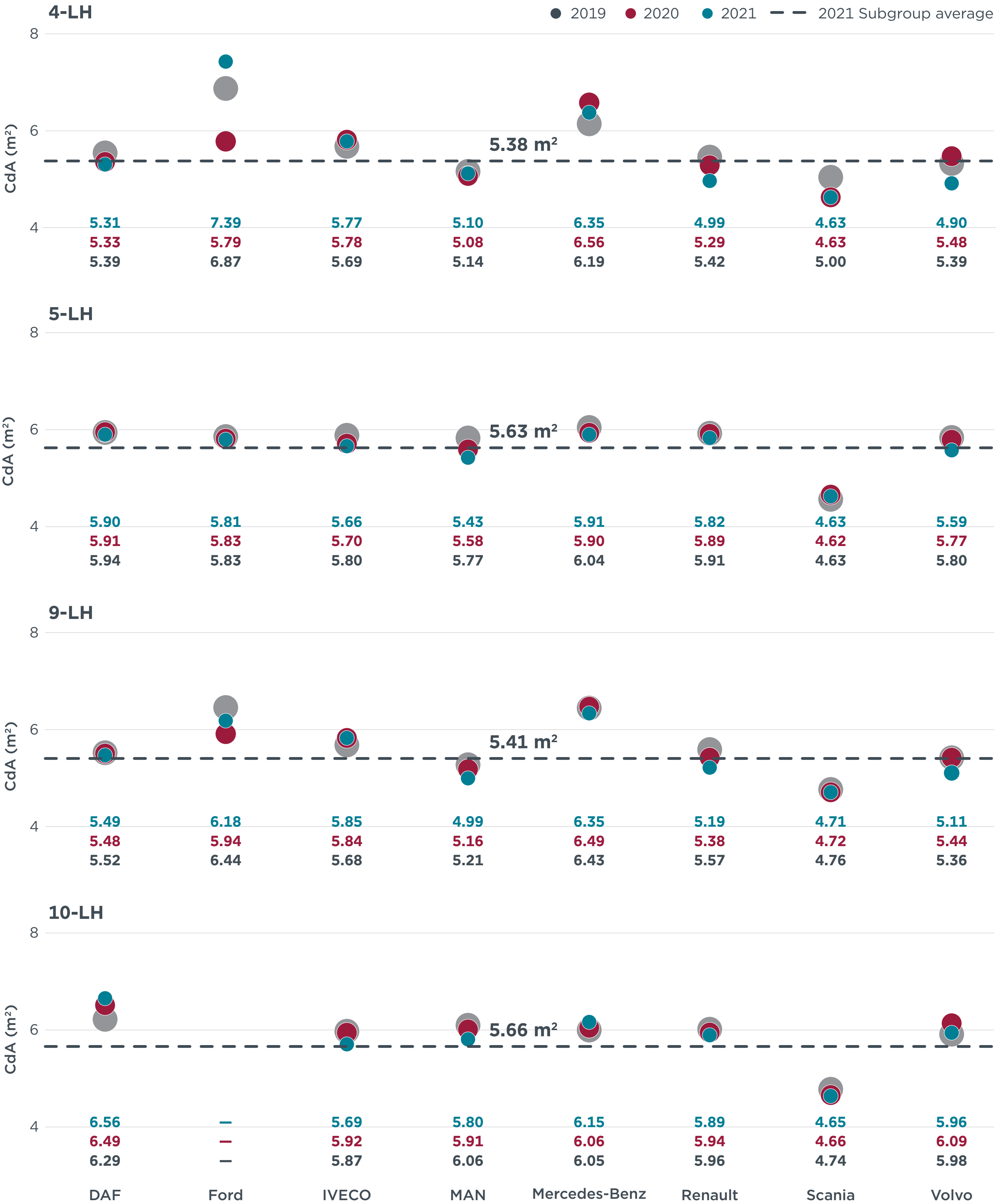
Vehicle Subgroup		CdA (m^2)			
		2019	2020	2021	2019 to 2021 change
Originally regulated subgroups	4-LH	5.59	5.53	5.38	−3.8%
	4-RD	5.57	5.69	5.72	2.7%
	4-UD	5.32	5.34	5.26	−1.1%
	5-LH	5.68	5.62	5.63	−0.9%
	5-RD	7.17	7.08	7.31	2.0%
	9-LH	5.50	5.51	5.41	−1.6%
	9-RD	5.57	5.78	5.86	5.2%
	10-LH	5.71	5.65	5.66	−0.9%
	10-RD	7.36	8.03	6.81	−7.5%
	Average	5.66	5.64	5.63	−0.5%
Newly regulated subgroups	1		4.99	5.21	
	2		5.08	5.07	
	3		5.42	5.43	
	11		5.56	5.70	
	12		6.54	6.36	
	16		7.32	6.75	

Note: Red cells imply a year-to-year increase in aerodynamic drag area, while green cells imply a year-to-year decrease in aerodynamic drag area.

Figure 16 illustrates different manufacturers' average CdA for the four main long-haul subgroups: 4-LH, 5-LH, 9-LH, and 10-LH. Three manufacturers recorded a large reduction in CdA for Subgroup 5-LH, with MAN 5.9% lower, Volvo 3.6% lower, and IVECO 2.4% lower in 2021 compared with 2019. The remaining manufacturers showed a minor improvement in CdA. A remarkable 8% reduction is witnessed for Volvo and Renault in Subgroup 4-LH, although both manufacturers sold only about 500 units each in this subgroup in the 2021 reporting period.

Figure 16

Comparison of aerodynamic drag area (CdA) by manufacturer and subgroup in the 2019, 2020, and 2021 reporting periods



		DAF	Ford	IVECO	MAN	Mercedes-Benz	Renault	Scania	Volvo
4-LH	2021	5.31	7.39	5.77	5.10	6.35	4.99	4.63	4.90
4-LH	2020	5.33	5.79	5.78	5.08	6.56	5.29	4.63	5.48
4-LH	2019	5.39	6.87	5.69	5.14	6.19	5.42	5.00	5.39
5-LH	2021	5.90	5.81	5.66	5.43	5.91	5.82	4.63	5.59
5-LH	2020	5.91	5.83	5.70	5.58	5.90	5.89	4.62	5.77
5-LH	2019	5.94	5.83	5.80	5.77	6.04	5.91	4.63	5.80
9-LH	2021	5.49	6.18	5.85	4.99	6.35	5.19	4.71	5.11
9-LH	2020	5.48	5.94	5.84	5.16	6.49	5.38	4.72	5.44
9-LH	2019	5.52	6.44	5.68	5.21	6.43	5.57	4.76	5.36
10-LH	2021	6.56	—	5.69	5.80	6.15	5.89	4.65	5.96
10-LH	2020	6.49	—	5.92	5.91	6.06	5.94	4.66	6.09
10-LH	2019	6.29	—	5.87	6.06	6.05	5.96	4.74	5.98

Note: The size of the marker highlights differences among years and does not represent any other variable.

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VEHICLE CURB WEIGHT

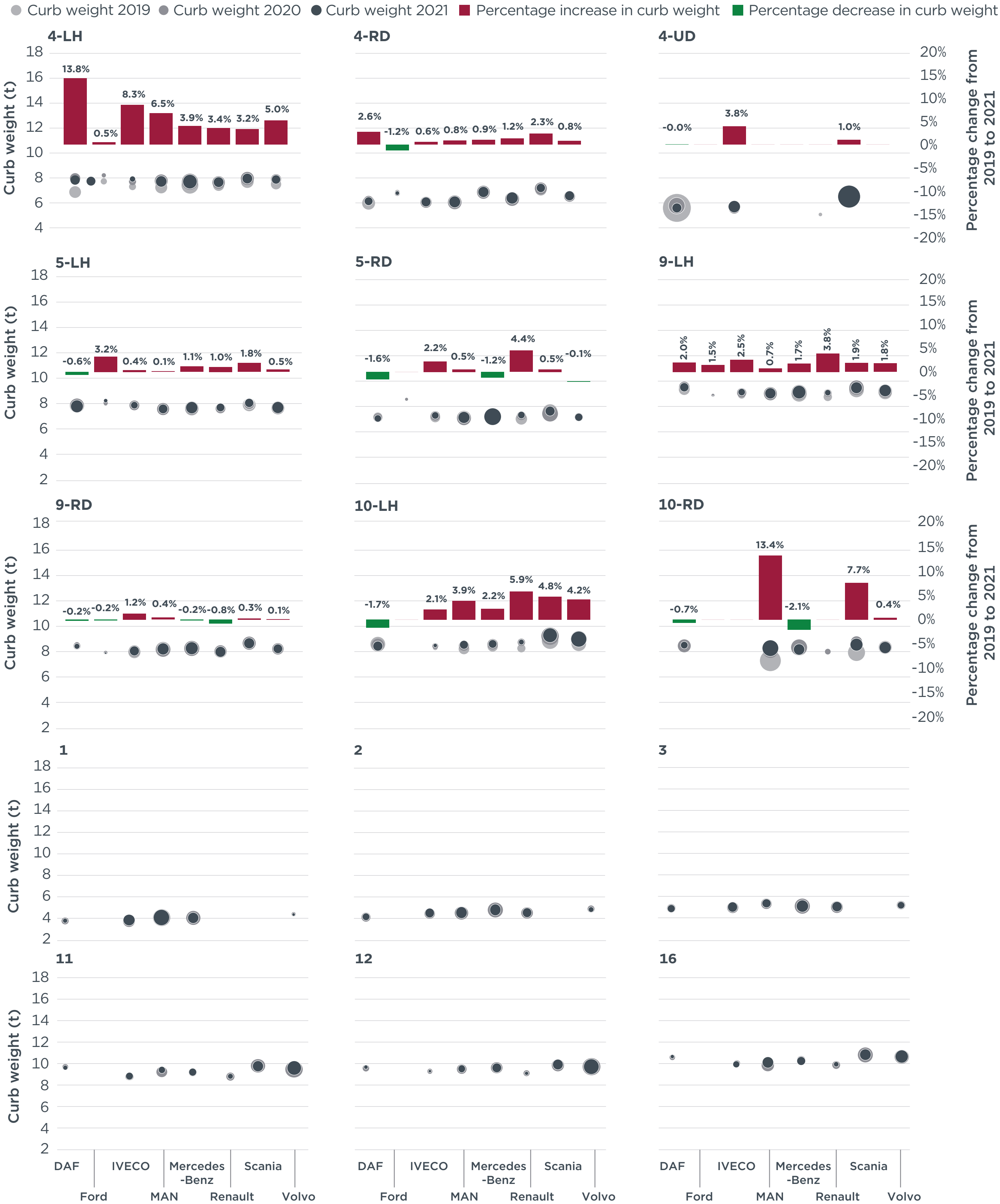
Truck weight significantly impacts energy consumption, with heavier trucks requiring more energy to overcome rolling resistance and gravitational force. Substitution of lighter materials, particularly in the chassis frame and body, offers a means to enhance vehicle efficiency. Figure 17 shows the average curb weight per manufacturer per subgroup for the 2019, 2020, and 2021 reporting periods and the percentage change in curb weight between 2019 and 2021. Across the highest-selling and most-polluting subgroups—5-LH, 9-LH, 5-RD, and 4-RD—most manufacturers with significant sales numbers report a minor increase in curb weight of less than 2%.

The highest increase in curb weight was in Subgroup 4-LH. DAF recorded a 13.8% increase in curb weight in 2021 relative to 2019 for this subgroup. The DAF LF—a model in the 4-LH subgroup marketed as a light- and medium-duty urban truck with curb weights ranging from 5 tons to 7 tons—accounted for close to 30% of DAF's sales in 2019. No sales of the DAF LF model were recorded in 2021. Instead, the DAF CF and XF models—marketed as heavy-haul, long-distance trucks with curb weights of 7 tons to 9 tons—made up the majority of the sales in this subgroup. Other subgroups that show a large increase in curb weight above 2% are mainly low in sales numbers.

For the newly regulated subgroups, minimal to no change was recorded between the 2020 and 2021 reporting periods.

Figure 17

Curb weight by manufacturer and vehicle subgroup and percentage change in curb weight from 2019 to 2021



Note: Newly regulated subgroups (1, 2, 3, 11, 12, and 16) had little to no change in curb weight between the 2020 and 2021 reporting periods; only the 2021 curb weight is shown in the figure for these groups.

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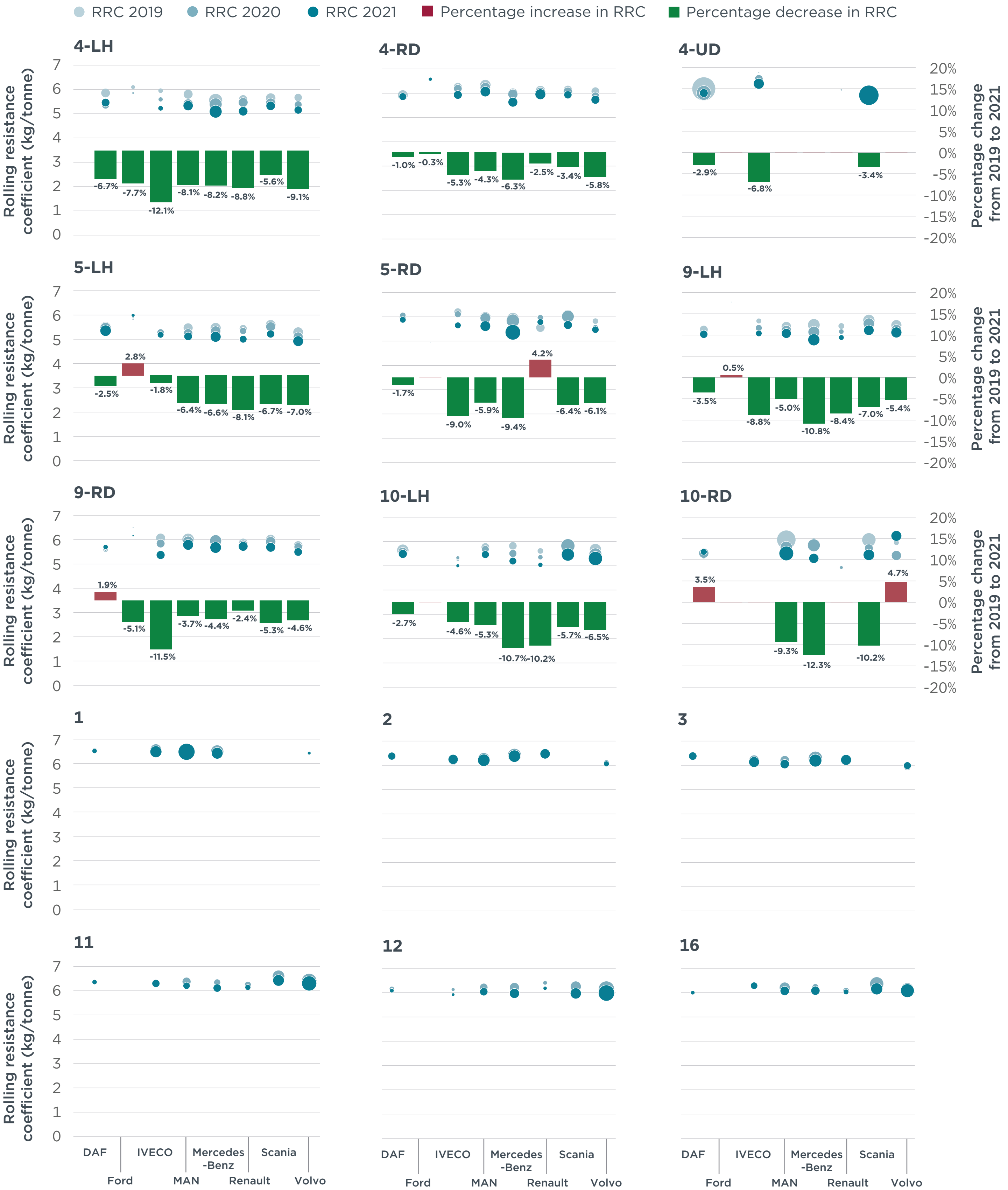
ROLLING RESISTANCE OF TIRES

The rolling resistance coefficient (RRC) measures the frictional force resisting the rotation of tires. The sales-weighted average RRC for originally regulated groups in the 2021 reporting period was 5.24 kg/tonne. This is 3.6% lower than the average value reported in 2020 of 5.54 kg/tonne, and 6.2% lower the 2019 average.

Data on the highest-selling and most-polluting subgroups—5-LH, 9-LH, 5-RD, and 4-RD—show that most manufacturers with significant sales numbers have continuously reduced the RRC for the second year in a row; the reduction in RRC is 6%–10% from 2019 to 2021, as shown in Figure 17. Mercedes-Benz is the top performer, followed by Volvo and Scania.

Figure 18

Rolling resistance coefficient (RRC) by manufacturer and vehicle subgroup and percentage change in RRC from 2019 to 2021



Note: Newly regulated subgroups (1, 2, 3, 11, 12, and 16) had little to no change in RRC between the 2020 and 2021 reporting periods; only the 2021 RRC is shown in the figure for these groups.

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CO_2 EMISSIONS REDUCTION TECHNOLOGIES

The certification process requires manufacturers to report a range of advanced driver assistance systems (ADAS) technologies. These technologies, already considered in VECTO, provide CO_2 savings for manufacturers. The technologies include:

» **Eco-roll**: an autonomous feature that estimates when it is worth rolling down longer gradients in neutral.

» **Predictive cruise control**: a feature that uses satellite data to predict the optimum driving strategy for the upcoming road segment.

Manufacturers may also voluntarily report other CO_2-saving technologies, although they have no impact on their certified CO_2 values. These include:

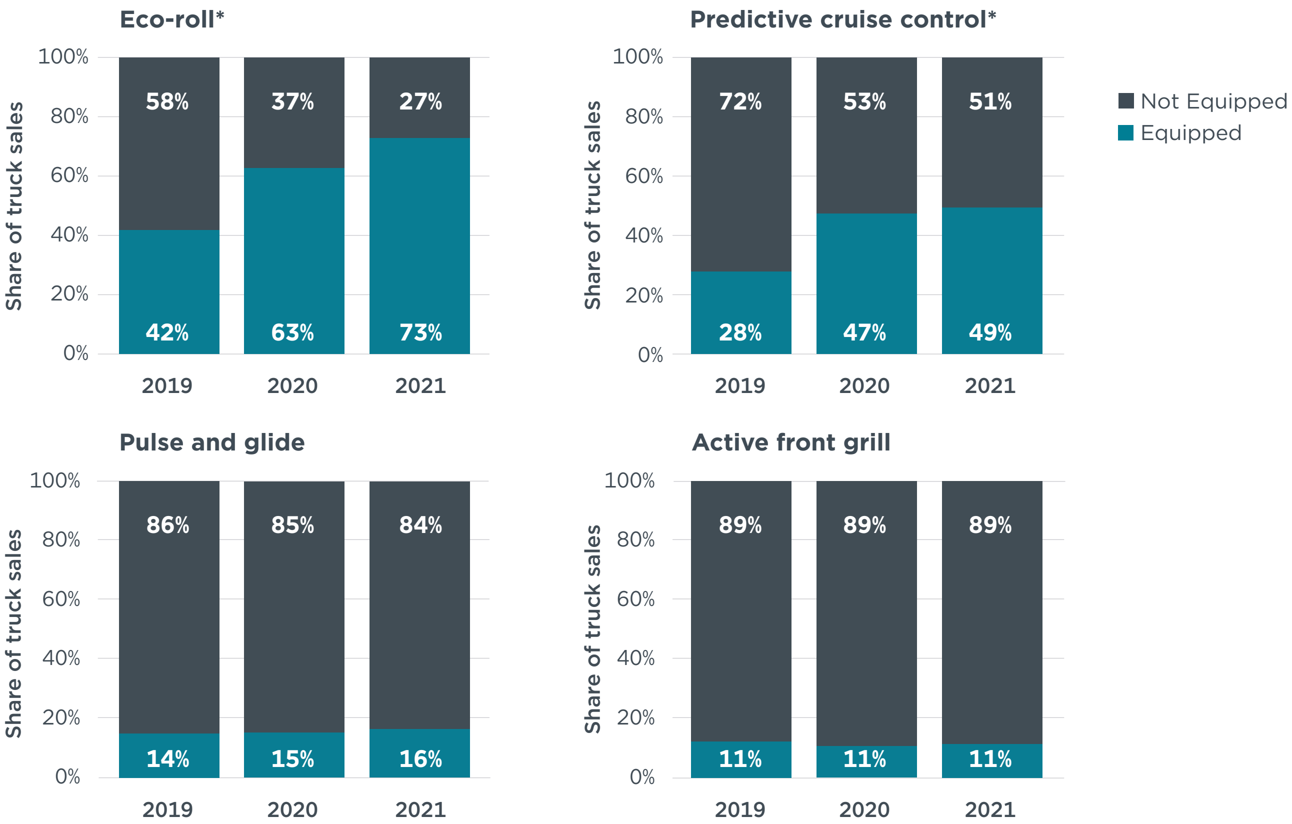
» **Active front grill**: a technology that can open and close the grill vents to reduce air drag; the grill automatically closes at higher speeds.

» **Pulse and glide:** an engine-control strategy that runs the engine at a higher load than necessary and then coasts to a lower speed to improve efficiency.

Figure 19 presents the share of vehicles equipped with ADAS and other CO_2-saving technologies for the 2019, 2020, and 2021 reporting periods. The data show an increase in the share of trucks equipped with eco-roll and predictive cruise control technologies. Specifically, the share of trucks with eco-roll increased from 42% in 2019 to 73% in 2021, and those equipped with predictive cruise control represented 49% of all sales in 2021, up from 28% in 2019.

Figure 19

Use of CO_2 reduction technologies across all truck manufacturers in the 2019, 2020, and 2021 reporting periods



*Technology is mandatory to report.

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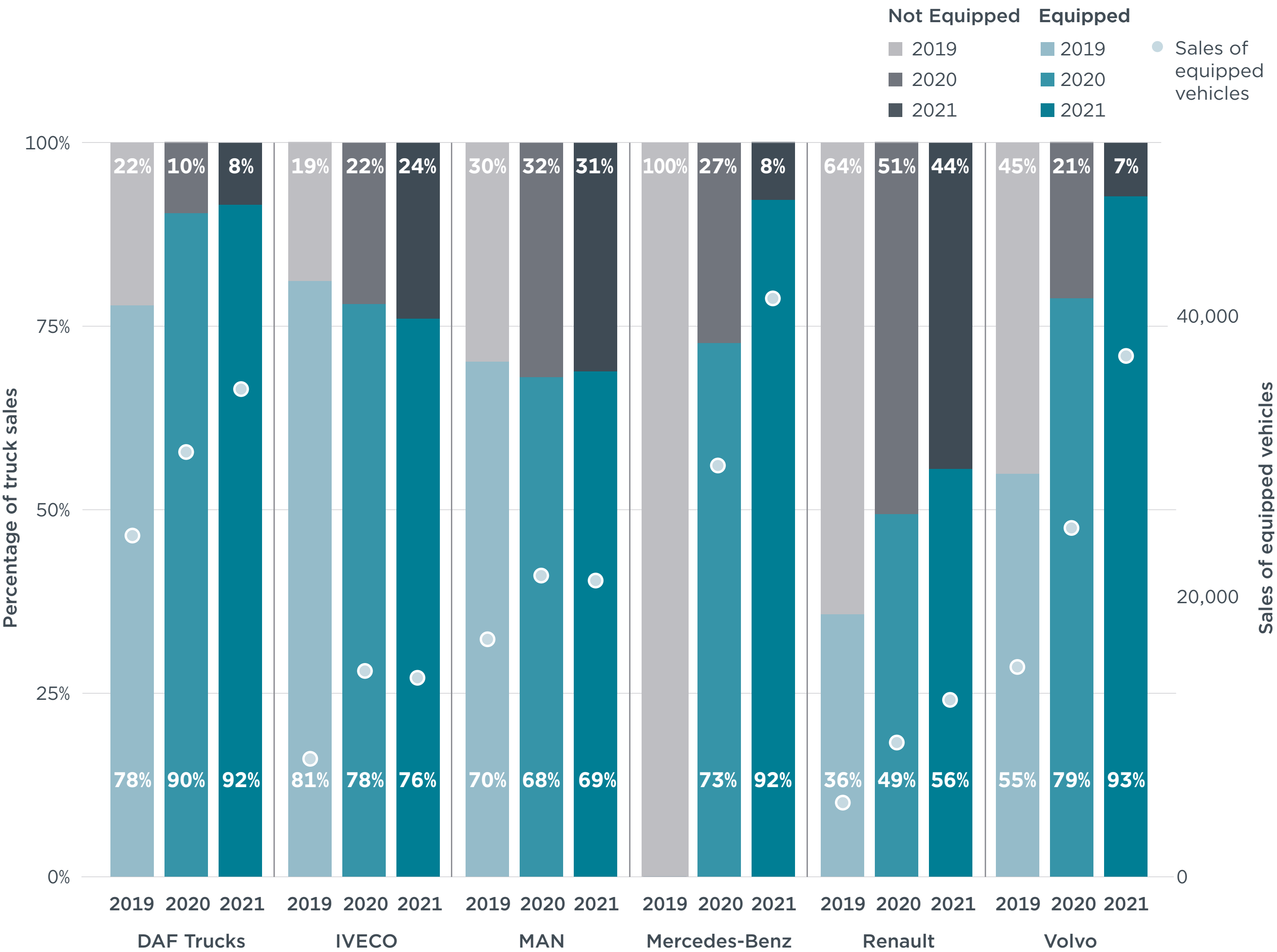
Figure 20 shows the adoption of eco-roll technology by manufacturer. The data show that Mercedes-Benz, DAF, and Volvo had the largest technology adoption in the market, with their sales of trucks equipped with eco-roll technology increasing for the second year in a row. Meanwhile, IVECO and MAN show little to no increase in their sales of trucks equipped with eco-roll.

Figure 20

Fleet share and number of trucks sold with eco-roll technology for each manufacturer



Note: Scania did not report selling any trucks with eco-roll technology in 2019, 2020, or 2021.

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CONCLUSIONS

The European Commission released the CO_2 emissions and fuel economy performance for trucks in Europe for the third reporting period of 2021. After analyzing the official certified data published by the EEA, we arrive at the following main conclusions:

» **EU fleet-average emissions have decreased by 0.56% annually between 2019 and 2021, which is significantly below the 2.5% annual reduction needed to meet the 2025 targets**. The fleet-average specific emissions of originally regulated trucks decreased from 52.7 g CO_2/tkm to 52.1 g CO_2/tkm between 2019 and 2021.

» **Scania is the only manufacturer on track to meet its 2025 targets**. For the third reporting period in a row, Scania remained the least-emitting manufacturer, with emissions 7.1% below the baseline level in the 2021 reporting period. This is primarily driven by Scania's superior aerodynamic performance, around 16% lower than the average. This increased Scania's cumulative credits total to 154,331 g CO_2/tkm, putting the company firmly on track to meet 2025 reduction targets.

» **IVECO remained the highest-emitting manufacturer in the 2021 reporting period, recording 7.4% higher emissions above its reduction trajectory**. IVECO's performance is driven by its aerodynamic and engine performance. In the 2021 reporting period, IVECO recorded the highest average aerodynamic drag area, 8% higher than the average. In addition, IVECO recorded the lowest average engine efficiency as tested under the WHTC at 38.72%, the only manufacturer with an average efficiency below 40%.

» **MAN, Volvo, and Renault recorded the largest reductions in emissions between the 2020 and 2021 reporting periods**. The mentioned manufacturers further reduced their emissions by 1.8 pp to 1.9 pp. MAN increased its average engine efficiency by a significant 0.21 pp and managed to reduce its aerodynamic drag area by 5%. Similarly, Volvo increased its average engine efficiency by 0.18 pp and reduced its aerodynamic drag by 3.5%. Renault's performance was mainly driven by a substantial reduction in rolling resistance across Subgroups 5-LH and 9-LH—which accounted for more than three quarters of Renault's sales in the 2021 reporting period—accompanied by an increase in their ZEV sales.

» **Manufacturers are pursuing different strategies to meet their CO_2 emissions reduction targets**. The reductions by DAF, Mercedes-Benz, and MAN were mainly due to improvements in the conventional vehicle fleet, namely diesel and natural gas trucks. Scania, Renault, and Volvo pursued a mixed approach with continuous improvement in conventional vehicle performance and an increasing share of zero-emission vehicles. IVECO's natural gas and diesel vehicles recorded a negligible reduction in emissions in 2021 relative to 2020; the majority of IVECO's emissions reduction came from increasing ZEV sales.

» **Continuous improvement is observed in engine, aerodynamic drag, and tire technology.** The average engine efficiency under the WHTC increased by 0.11 pp between the 2020 and 2021 reporting periods. The average aerodynamic drag area improved by 3.7% across the entire fleet, including all manufacturers. Tire rolling resistance improved by 3.7%, while the average curb weight of the vehicles-decreased by 0.042% between 2020 and 2021.

» **Most newly regulated subgroups did not record any considerable improvement in their CO_2 emissions between the 2020 and 2021 reporting periods.** On the contrary, Subgroup 1 and vocational vehicles recorded a 3% to 4% increase in emissions. Manufacturers of these newly regulated groups, which include medium-duty delivery, construction, and vocational trucks, were only required to report emissions performance data starting in 2020.

» **The share of zero-emission vehicles in the 2021 reporting period remains very low at 0.13%, despite more than a five-fold increase in sales volumes relative to 2020**. There were 287 certified ZEVs sold in 2021, up from 51 in 2020 and three in 2019. This was mainly driven by Volvo, Scania, and Renault, which all increased sales of zero-emission heavy- and medium-duty rigid trucks. At the same time, natural gas sales shares decreased to 2.8% in 2021, down from 3.9% in 2020.

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APPENDIX A: SUPPLEMENTARY DATA

Table A1

Fuel economy of all certified truck groups in the 2019, 2020, and 2021 reporting periods

	Vehicle subgroup	Fuel consumption (L/100 km)			Mileage and payload weighting factor
		2019	2020	2021	
Originally regulated subgroups	4-LH	29.74	28.85	27.35	0.45
	4-RD	23.35	23.22	23.02	0.15
	4-UD	30.88	27.64	25.21	0.10
	5-LH	29.17	28.27	28.54	1.00
	5-RD	31.15	31.73	31.96	0.50
	9-LH	32.85	31.62	31.27	0.90
	9-RD	25.48	25.34	24.72	0.29
	10-LH	30.76	30.88	30.58	0.92
	10-RD	32.65	34.68	30.98	0.43
Newly regulated subgroups	1	Not reported	22.59	23.27	0.05
	2		23.69	23.57	0.09
	3		26.28	26.47	0.13
	11		32.31	31.79	0.12
	12		39.12	38.78	0.41
	16		40.86	40.94	0.37

Table A2

Bins and ranges for aerodynamic drag areas

Bin	Minimum value	Maximum value	Range midpoint
A1	0	3	1.5
A2	3	3.15	3.075
A3	3.15	3.31	3.23
A4	3.31	3.48	3.395
A5	3.48	3.65	3.565
A6	3.65	3.83	3.74
A7	3.83	4.02	3.925
A8	4.02	4.22	4.12
A9	4.22	4.43	4.325
A10	4.43	4.65	4.54
A11	4.65	4.88	4.765
A12	4.88	5.12	5
A13	5.12	5.38	5.25
A14	5.38	5.65	5.515
A15	5.65	5.93	5.79
A16	5.93	6.23	6.08
A17	6.23	6.54	6.385
A18	6.54	6.87	6.705
A19	6.87	7.21	7.04
A20	7.21	7.57	7.39
A21	7.57	7.95	7.76
A22	7.95	8.35	8.15
A23	8.35	8.77	8.56
A24	8.77	9.21	8.99

APPENDIX B: CO_2 REDUCTION PATHWAYS

The European Commission defines the emission performance of a manufacturer in a given year (Regulation (EU) 2019/1242) as per the following equation:

$$ZLEV_N \times \frac{\sum_{i=1}^{SG}[C^i_{N+1} \times (1-Z^i_{N+1}) \times S^i_N \times M^i}{\sum_{i=1}^{SG}[S^i_{N+1} \times M^i \times R^i]} \quad -ZLEV_{N+1} \times \frac{\sum_{i=1}^{SG}[C^i_{N+1} \times (1-Z^i_{N+1}) \times S^i_{N+1} \times M^i}{\sum_{i=1}^{SG}[S^i_{N+1} \times M^i \times R^i]}$$

Where:

C^i_N is the conventional vehicle fleet average CO_2 emissions in year *N* for subgroup *i*;

Z^i_N is the share of zero-emission vehicles in year *N* for subgroup *i*;

S^i_N is the share of subgroup *i* in year *N*;

M^i is the MPW factor of subgroup *i*;

R^i is the reference CO_2 emissions of subgroup *i*;

$ZLEV_N$	is the zero- and low-emission vehicle factor in year N; and
SG	is the subgroup.

To simplify the mathematical derivation, we consider only two subgroups, a and b. The previous expressions can be written as:

$$ZLEV_N \times \frac{C_N^a \times (1\text{-}Z_{N+1}^a) \times S_N^a \times M^a + C_N^b \times (1\text{-}Z_N^b) \times S_N^b \times M^b}{S_N^a \times M^a \times R^a + S_N^b \times M^b \times R^b}$$

$$-ZLEV_{N+1} \times \frac{C_{N+1}^a \times (1\text{-}Z_{N+1}^a) \times S_{N+1}^a \times M^a + C_{N+1}^b \times (1\text{-}Z_{N+1}) \times S_{N+1}^b \times M^b}{S_{N+1}^a \times M^a \times R^a + S_{N+1}^b \times M^b \times R^b}$$

Expanding the previous equation and rearranging and factoring the different terms allow us to express the manufacturer's CO_2 reduction in a specific subgroup *a* (referred to as Delta^a) as follows:

$$Delta^a = \frac{A}{B} \times (ZLEV_N \times C_N^a - ZLEV_{N+1} \times C_{N+1}^a) + \frac{k \times ZLEV_N \times C_N^a - p \times ZLEV_{N+1} \times C_{N+1}^a}{B}$$

$$+ \frac{A}{B} \times (ZLEV_{N+1} \times Z_{N+1}^a \times C_{N+1}^a - ZLEV_N \times Z_N^a \times C_N^a) + \frac{p \times ZLEV_{N+1} \times Z_{N+1}^a \times C_{N+1}^a - k \times ZLEV_N \times Z_N^a \times C_N^a}{B}$$

Where:

A	equals $S_N^a \times S_{N+1}^a \times M^{a2} \times R^a$;
B	equals $\sum_x (M^x \times R^x \times S_N^x) \times \sum_x (M^x \times R^x S_{N+1}^x)\ \forall\ x\ in\ subgroups$;
k	equals $\sum_x (S_N^a \times S_{N+1}^x \times M^a \times M^x \times R^x)\ \forall\ x\ in\ subgroups - \{a\}$; and
p	equals $\sum_x (S_{N+1}^a \times S_N^x \times M^a \times M^x \times R^x)\ \forall\ x\ in\ subgroups - \{a\}$.

In this final equation, the last two terms directly refer to the contribution of ZEV sales to the manufacturer's CO_2 emissions reduction. The first two terms correspond to the contribution of the conventional vehicle fleet and some contributions from the zero- and low-emission venicle (ZLEV) factor. To solely quantify the contribution of conventional vehicle fleets, we assume the ZLEV factor equals one. Then, the difference between the first two terms of the equation above and the conventional vehicle fleet contribution is added to the ZEV contribution, as it is directly the result of the ZLEV factor, which is defined by the sales of ZEVs.

Table B1

Emissions performance and zero-emission vehicle (ZEV) sales for a selection of subgroups and manufacturers

Manufacturer	Year	VECTO subgroup	CO_2 emissions (g/tkm)	Number of conventional vehicles sold	Number of ZEVs sold	ZEV share of truck sales
Mercedes-Benz	2021	9-RD	110.4	2,716	9	0.33%
Mercedes-Benz	2021	4-LH	105.7	1,005	12	1.18%
Mercedes-Benz	2020	9-RD	110.91	3,074	0	0.00%
Mercedes-Benz	2020	4-LH	106.96	876	0	0.00%
Mercedes-Benz	2019	9-RD	111.13	1,812	0	0.00%
Mercedes-Benz	2019	4-LH	107.74	1,394	0	0.00%
Volvo	2019	4-LH	106.88	445	1	0.22%
Volvo	2019	5-LH	56.99	17,226	0	0.00%
Volvo	2019	9-LH	65.66	3,255	0	0.00%
Volvo	2020	4-LH	103.90	303	3	0.99%
Volvo	2021	4-LH	100.50	404	44	10.89%
Volvo	2020	3	202.89	655	3	0.46%
Volvo	2020	9-LH	64.74	3,066	18	0.59%
Volvo	2021	5-LH	53.38	27,863	2	0.01%
Volvo	2021	9-LH	60.81	3,477	38	1.09%
DAF Trucks	2019	5-LH	56.52	21,286	1	0.00%
DAF Trucks	2020	5-LH	56.24	26,184	1	0.00%
DAF Trucks	2021	5-LH	55.69	30,856	5	0.02%
DAF Trucks	2021	9-LH	62.41	1,822	12	0.66%
MAN	2019	9-LH	63.69	2,846	1	0.04%
MAN	2020	9-RD	103.61	2,565	14	0.55%
MAN	2021	9-RD	102.41	2,371	13	0.55%
Renault	2020	4-LH	103.34	498	5	1.00%
Renault	2020	9-LH	64.51	765	6	0.78%
Renault	2021	4-LH	101.81	528	48	9.09%
Renault	2021	9-LH	63.27	861	37	4.30%
Scania	2020	9-RD	105.26	2,240	1	0.04%
Scania	2021	10-RD	81.27	9	3	33.33%
Scania	2021	4-LH	96.71	539	16	2.97%
Scania	2021	5-LH	52.58	15,495	1	0.01%
Scania	2021	5-RD	75.21	132	1	0.76%
Scania	2021	9-LH	61.33	3,020	21	0.70%
Scania	2021	9-RD	103.95	1,934	25	1.29%

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