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CO_2 emissions from trucks in the EU: An analysis of the heavy-duty CO_2 standards baseline data

Authors: Pierre-Louis Ragon, Felipe Rodríguez

Introduction

From the formulation of ambitions on climate change mitigation, to the implementation of binding reduction targets, regulating tailpipe CO_2 emissions from road vehicles is a long and complex process. For heavy-duty vehicles (HDVs) in the European Union (EU), the three-step approach described below has been adopted, with regulations building on each other, as shown in Figure 1.

1. The CO_2 emissions from all newly registered vehicles in the heavy truck segments with the largest sales volume are determined using the regulatory simulation tool known as VECTO, under the scope of the **certification regulation—regulation (EU) 2017/2400**. Testing of the CO_2 emissions-related properties of the components, systems, and separate technical units is conducted to generate inputs to the simulation tool.
2. The certified CO_2 emissions values and select associated VECTO inputs are reported by manufacturers on a yearly basis. In parallel, Member States also report basic data on all new truck registrations at the national level on a yearly basis. This is done under the scope of the **reporting and monitoring regulation—regulation (EU) 2018/956**. The European Energy Agency (EEA) oversees monitoring of the certification data on an annual basis on behalf of the European Commission. Each reporting period runs from the July 1 of a given year to June 30 of the following year.
3. Finally, in June 2019, the European Union adopted their first ever **CO_2 standards for trucks—regulation (EU) 2019/1242**—requiring manufacturers to reduce the CO_2 emissions of their newly registered trucks by 15% on average in 2025, and by 30% in 2030, compared to a 2020 baseline. The standards currently apply only to the four heavy truck segments with the largest sales volume and build upon the CO_2 emissions values determined and monitored under the scope of the two previous regulations. The first reporting period—July 1, 2019 to June 30, 2020—was set as the reference period against which the reduction targets for 2025 and 2030 are determined for each manufacturer.

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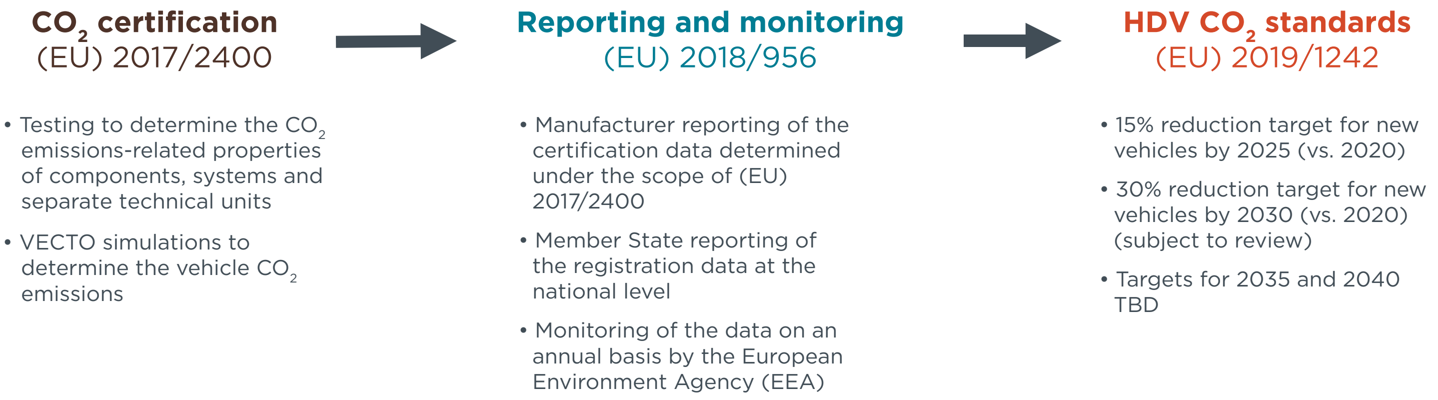


Figure 1. Regulatory process for heavy-duty vehicles CO_2 emissions in the EU.

Certification data from the first reporting and monitoring period were published by EEA on June 1, 2021. They are a valuable source of information to assess the values of the HDV CO_2 standards baseline, track the progress of truck manufacturers towards their reduction targets imposed by the standards, and understand the various technology pathways chosen by manufacturers to decarbonize their fleets. In addition, they inform the discussions on the review of the standards that will take place in 2022, when the European Commission will evaluate the reduction target for 2030 (-30%) and consider the introduction of binding targets for 2035 and 2040. Setting the right targets will be crucial in pushing the adoption of zero-emission HDVs (ZE-HDVs) and achieving the European Commission's climate neutrality goal for 2050. Other elements will also be discussed, including the modification of the incentive mechanism for ZE-HDVs to include different levels of incentive depending on the truck's driving range and freight activity, and the treatment of CO_2 emissions from vocational vehicles.

To support this discussion, we analyzed the baseline data to understand how the industry currently performs compared to the targets set out by the European Commission. First, we calculate and provide comments on the reference emission values for the HDV CO_2 standards. Then, we assess how the different manufacturers performed in the first reporting period—both compared to each other and to their respective targets. Finally, we provide insights into the preferred technology pathways for compliance and the adoption of CO_2 emissions reduction technologies across manufacturers and truck segments.

Reference emissions for the HDV CO_2 standards

Unless specified otherwise, all the data presented in this paper are extracted from the publicly available certification data monitored in the first reporting period according to regulation (EU) 2018/956, and were obtain from EEA's website (European Environment Agency, 2021).

Market segmentation for the EU's heavy-duty CO_2 regulations

To determine and regulate CO_2 emissions from trucks, the European Commission segments the truck market into vehicle groups according to their technical characteristics. Table 1 describes the market segmentation, together with the scope of each of the regulations introduced earlier. Sales shares are presented later in the paper.

Table 1. EU truck market segmentation for regulatory purposes.

Axle type	Chassis configuration	Gross vehicle weight (tonnes)	Vehicle groups	Covered by (EU) 2017/2400[a]	Covered by (EU) 2018/956[b]	Covered by (EU) 2019/1242[c]
4×2	Rigid	<7.5	Light and medium lorries	No	Yes	No
	Rigid/Tractor	7.5 – 10	1	Yes	Yes	No
	Rigid/Tractor	>10 – 12	2	Yes	Yes	No
	Rigid/Tractor	>12 – 16	3	Yes	Yes	No
	Rigid	>16	4	Yes	Yes	Yes
	Tractor	>16	5	Yes	Yes	Yes
4×4	Rigid	7.5 – 16	6	No	Yes	No
	Rigid	>16	7	No	Yes	No
	Tractor	>16	8	No	Yes	No
6×2	Rigid	all weights	9	Yes	Yes	Yes
	Tractor	all weights	10	Yes	Yes	Yes
6×4	Rigid	all weights	11	Yes	Yes	No
	Tractor	all weights	12	Yes	Yes	No
6×6	Rigid	all weights	13	No	Yes	No
	Tractor	all weights	14	No	Yes	No
8×2	Rigid	all weights	15	No	Yes	No
8×4	Rigid	all weights	16	Yes	Yes	No
8×6/8	Rigid	all weights	17	No	Yes	No

[a] Certification regulation
[b] Reporting and monitoring regulation
[c] HDV CO_2 standards

Although the manufacturer reporting of CO_2 emissions under regulation (EU) 2018/956 is only applicable to the vehicle segments targeted by the certification regulation, Member States report registration data from all HDV segments. Therefore, although regulation (EU) 2018/956 covers all segments, there are no data on the CO_2 emissions from light and medium lorries and from groups 6, 7, 8, 13, 14, 15 and 17, which are not covered by the certification regulation. In this paper, only the "Match" data from EEA's database—i.e., data from trucks for which both an OEM report and a Member State report are available—are analyzed.

The HDV CO_2 standards currently only apply to rigid and tractor trucks above 16 tonnes, with 4×2 and 6×2 axle configurations, which correspond to vehicle groups 4, 5, 9 and 10. Together, these groups, dubbed "regulated groups" henceforward, represented 65% of all HDV sales (trucks and buses) in the period 2019–2020 (Ragon and Rodríguez, 2020).

The regulated groups are further classified into subgroups according to cabin type (day or sleeper cab) and engine power rating, as shown in Table 2. For each subgroup, the CO_2 emissions of a newly registered truck are determined in VECTO using a specific combination of mission profiles. Mission profiles are defined as the combination of a test cycle—urban delivery (UD), regional delivery (RD) or long-haul (LH)—and a reference payload or low payload, the value of which is defined for each combination of vehicle subgroup and mission profile. The mission profile weightings for each subgroup, and the values of the payloads can be found in Annex 1 of regulation (EU) 2019/1242 (European Commission, 2019).

Table 2. Further division of the regulated groups into subgroups for the HDV CO_2 standards.

Group description	Group	Sub-group	Cabin type	Engine power	Reference annual mileage (km)	Average payload (tonnes)
Rigid, 4x2 axle, GVW > 16 t	4	4-UD	All	< 170 kW	60,000	2.65
		4-RD	Day cab	≥ 170 kW	78,000	3.18
			Sleeper cab	≥ 170 kW, < 265 kW		
		4-LH	Sleeper cab	≥ 265 kW	98,000	7.42
Tractor, 4x2 axle, GVW > 16 t	5	5-RD	Day cab	All	78,000	10.26
			Sleeper cab	< 265 kW		
		5-LH	Sleeper cab	≥ 265 kW	116,000	13.84
Rigid, 6x2 axle	9	9-RD	Day cab	All	73,000	6.28
		9-LH	Sleeper cab		108,000	13.4
Tractor, 6x2 axle	10	10-RD	Day cab	All	68,000	10.26
		10-LH	Sleeper cab		107,000	13.84

170,365 regulated trucks were sold during the baseline period (July 2019 – June 2020). The composition of the regulated truck market during this period, according to the vehicle subgroups of Table 2, is shown in Figure 2. Overall, long-haul trucks were by far the most represented truck segment, gathering 86% market share, of which 72% were tractor-trailers. The subgroup 5-LH alone accounted for 62% of the regulated truck registrations. On the other side of the spectrum, urban delivery trucks only represented 0.4% of the regulated truck market. A previous ICCT study shows that over 90% of non-regulated vehicles are rigid trucks, including smaller delivery trucks and vocational trucks (Ragon and Rodríguez, 2020).

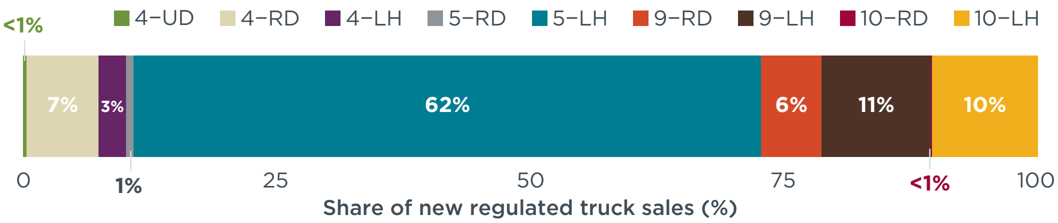


Figure 2. Regulated truck fleet composition in terms of the regulated subgroups of Table 2, in the baseline period (July 2019–June 2020).

Baseline CO_2 emissions

The HDV CO_2 standards set emissions reduction targets for each manufacturer based on common reference values, defined at the subgroup level. These values are then aggregated into a fleet-wide metric to assess compliance, as described later in this paper. For each subgroup, the reference CO_2 emissions are defined as the average emissions from all trucks registered by all manufacturers in the regulated groups during the baseline period, with the exception of vocational trucks, which can be excluded from the scope of the standards. For the remainder of the paper, the reference emissions are referred to as "the baseline."

Figure 3 shows the baseline value for each subgroup, alongside a histogram and a cumulative share plot of the distribution of the CO_2 emissions around this average. For the standards, CO_2 emissions are calculated per unit payload (in tonnes) and distance (in kilometers). Therefore, the unit used, gCO_2/t-km, accounts for the high variation in payload and distance travelled, i.e. freight activity, across subgroups.

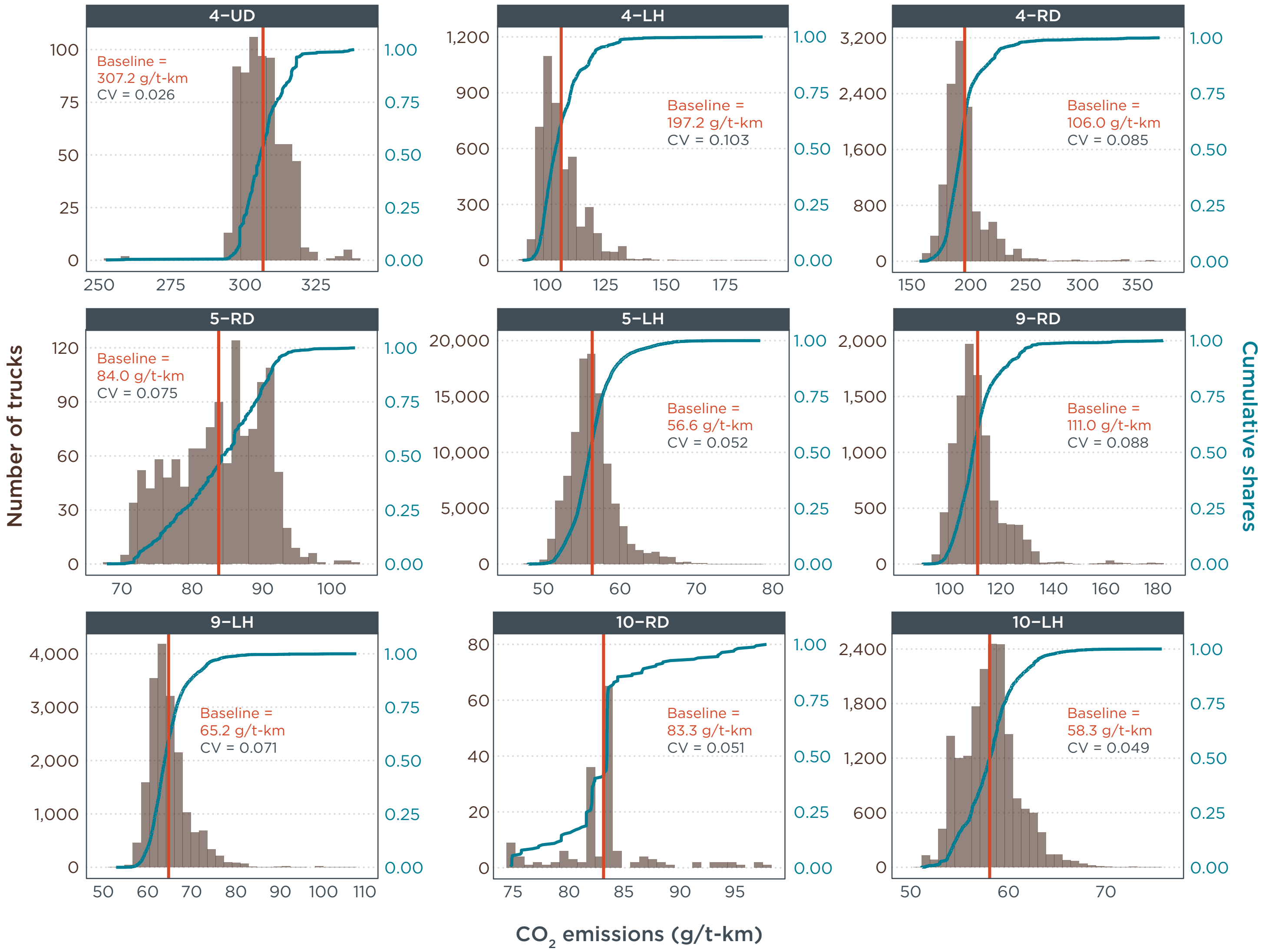


Figure 3. Reference CO_2 emissions and distribution for each subgroup. The vertical red line indicates the group average, serving as the subgroup's baseline, and the blue curve shows cumulative shares. CV = coefficient of variation (standard deviation divided by mean).

In general, trucks from subgroups with a higher average payload across all mission profiles show lower CO_2 emissions due to the metric used (g/t-km). Additionally, the relative share of different test cycles also has a large influence on CO_2 emissions. For instance, at similar weights and payloads (see Table 2), the subgroup 4-UD shows much higher emissions than subgroup 4-RD, as it is certified with a higher share of urban driving, which emits more per unit distance. Similarly, the LH subgroups, which have a higher share of motorway operation, show lower emissions. The coefficient of variation (CV), obtained by dividing the standard deviation of the CO_2 data series by the mean value for each subgroup, gives an indication of the spread of CO_2 emissions around the baseline. The CV was in the same order of magnitude in all cases, with relatively high values. This high variation translates a low uniformity in technology adoption and performance across models and manufacturers in all subgroups.

The baseline CO_2 emissions for each subgroup are shown again in Table 3. While the metric of interest for regulatory purposes is g/t-km, we also show two additional metrics included in the reported data regarding CO_2 emissions and fuel consumption, gCO_2/km, and l/100 km respectively, for reference purposes.

Table 3. CO_2 emissions and fuel consumption in the baseline reporting period

Sub-group	CO_2 emissions (gCO_2/t-km)	CO_2 emissions (gCO_2/km)	Fuel consumption (Liters/100 km)[a]
4-UD	307.2	814.1	31.1
4-RD	197.2	627.0	23.9
4-LH	106.0	786.4	30.0
5-RD	84.0	861.7	33.2
5-LH	56.6	783.5	30.0
9-RD	111.0	696.9	26.6
9-LH	65.2	873.3	33.4
10-RD	83.3	854.1	32.7
10-LH	58.3	806.5	30.8

[a] Data available for diesel trucks only.

Industry performance in the baseline period

Market overview

The regulated truck market in the EU is very consolidated, with seven brands from five parent manufacturers responsible for the quasi-totality of new truck sales. Figure 4 shows the market share of trucks counting towards the baseline for these leading brands. DAF Trucks was the top selling brand in the regulated groups with an 18.2% market share, closely followed by Scania (17.9%) and Mercedes-Benz (17.6%). Compared to previous ICCT HDV market analyses, DAF Trucks leading position in the regulated groups is a consequence of it having the lowest share of unregulated vehicles in its new truck fleet and strong market performance in 2019 and 2020 (Ragon and Rodríguez, 2020). The seven top selling brands together registered 99.6% of the trucks which counted towards the baseline, while the remaining 0.4% (around 600 trucks) were registered by the Turkish manufacturer Ford Otosan. Due to their small market shares, the remainder of this analysis focuses on the seven top selling brands only. A direct consequence of the observed market consolidation is that the baseline values could be significantly impacted by a single brand under- or over-performing with respect to the subgroup's average.

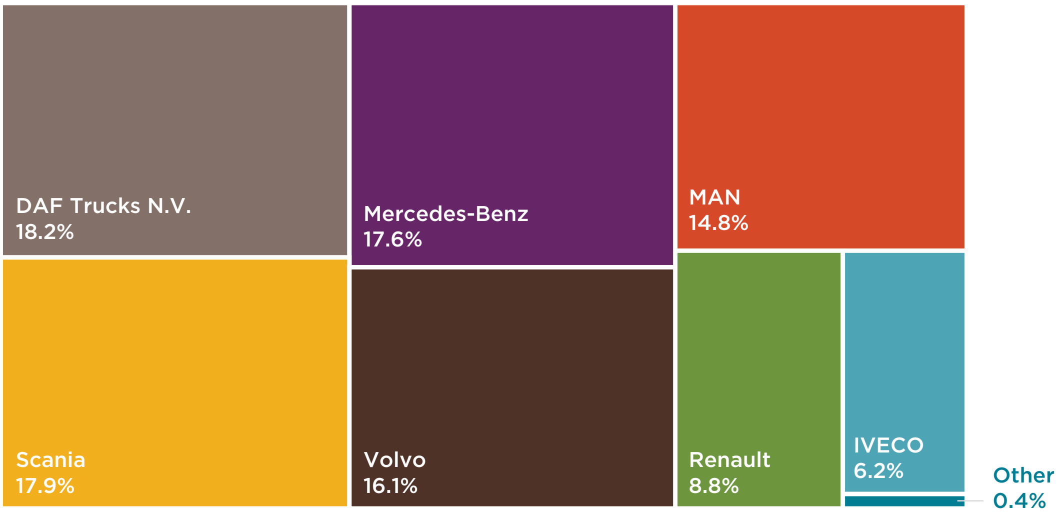


Figure 4. Market share of regulated trucks counting towards the baseline of the HDV CO_2 standards for the top-selling truck brands in the EU.

Manufacturers specialize in different truck segments. Figure 5 shows the new vehicle fleet composition for each of the top selling brands, excluding vocational trucks. Long-haul tractor-trailers from subgroups 5-LH and 10-LH largely dominate in all fleets. Still, there are significant variations in composition across brands. DAF Trucks sold the highest share of long-haul tractor-trailers (82%), followed by Volvo (77%) and Scania (73%). IVECO, Renault, and MAN, on the other side, sold important shares of regional delivery trucks, with subgroups 4-RD, 5-RD, and 9-RD together accounting for 27%, 22% and 19% of their new vehicle fleets, respectively. Only DAF Trucks sold a significant share of urban delivery (4-UD) trucks – 2%.

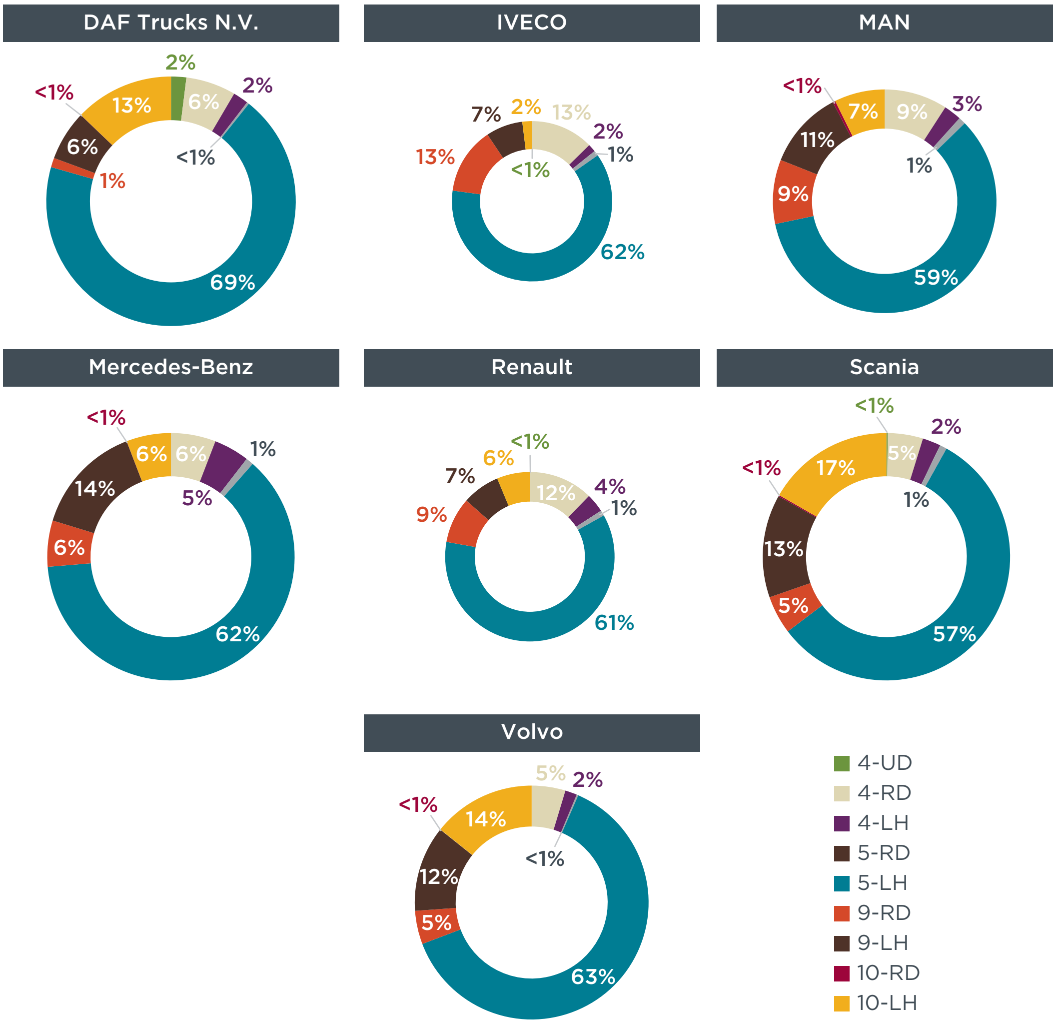


Figure 5. New vehicle fleet composition by regulated subgroups for the top-selling truck brands in the EU. The radius of the ring is proportional to the relative market share of each manufacturer.

CO_2 emissions in the baseline period

The relative performance of the top-selling brands is best compared at the subgroup level, as the fleet-wide metric is largely influenced by variations in new vehicle fleets composition. Figure 6 shows how these brands performed with respect to each other and to the subgroup average, which serves as the baseline for the CO_2 standards. Additionally, the brand with the highest (in orange) and lowest (in green) CO_2 emissions in each subgroup is highlighted. Note that compliance with the standards is evaluated via the fleet-wide metric only, and therefore cannot be assessed from Figure 6.

In the *Technology analysis* section of this paper, we explore in detail the technologies that drove these different levels of emissions, as well as the impact of the flexibilities in the certification procedure on the reported performance.

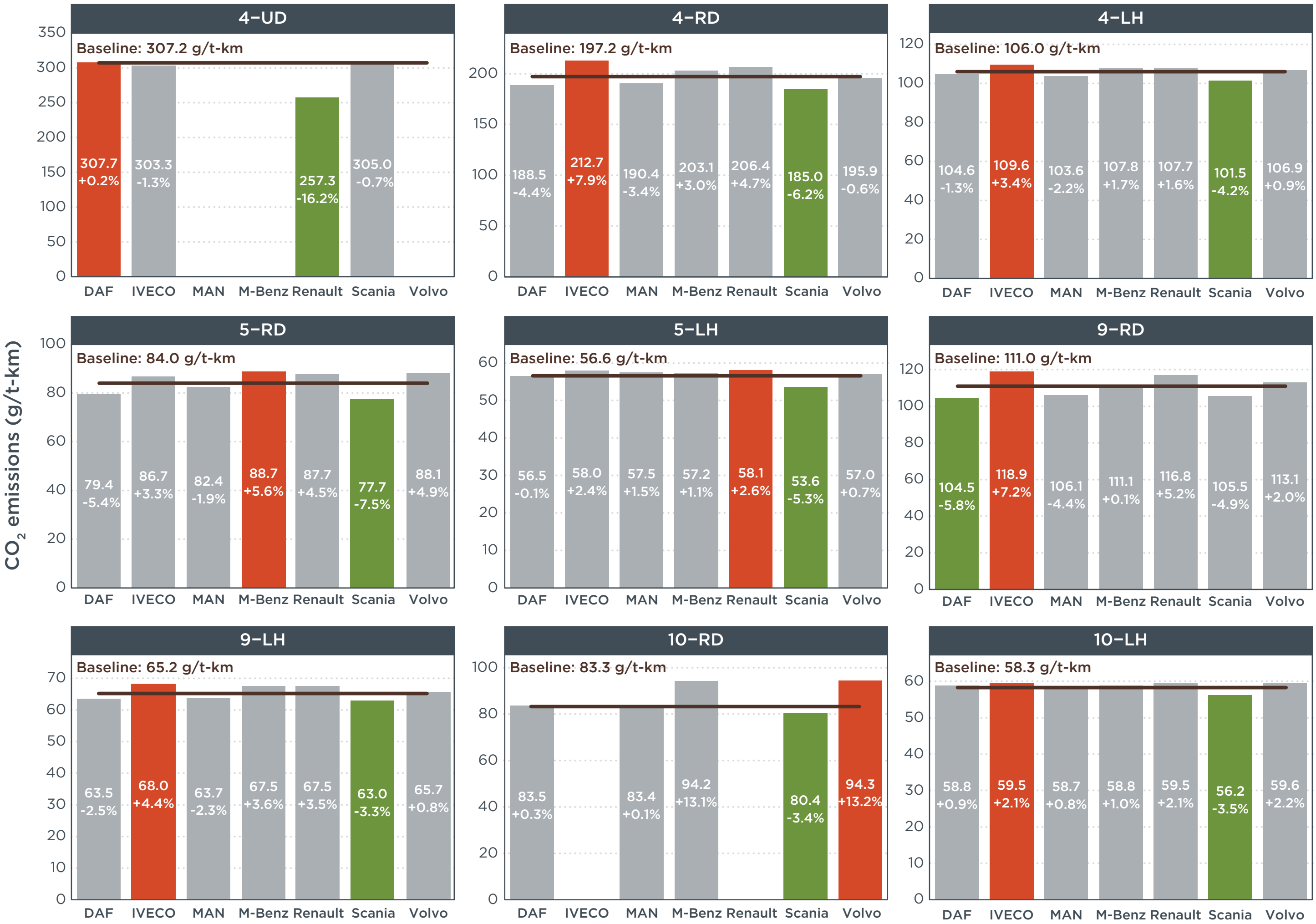


Figure 6. CO_2 emissions of the top-selling brands in each subgroup during the baseline period. The green bar highlights the brand with the lowest emissions in the subgroup, and the red bar the brand with the highest emissions. The data labels show the percent deviation with respect to the baseline.

Scania's CO_2 emissions in the baseline period were consistently lower than the average in all subgroups—between 0.7% (4-UD) and 7.5% (5-RD). Due to their high market shares in all subgroups, the resulting values are up to 2.1% lower than they would have been if Scania had performed at the average level of other brands, as shown in Table 3. In the subgroup with the largest sales volume, 5-LH, their emissions were 5.3% lower than the average, which drove the baseline for the subgroup down by a significant 1.0%. Conversely, Renault and IVECO were consistently higher than the average in seven of the eight subgroups in which they sold trucks, except for subgroup 4-UD, which has the lowest market share. MAN emitted less CO_2 than the average in most subgroups but emitted more than the average in the two long-haul tractor-trailer subgroups, 5-LH and 10-LH, which together accounted for 66.3% of their new regulated truck sales.

Table 4. Influence of Scania's performance on the HDV CO_2 standards baseline values.

Vehicle subgroup	Scania's market share in subgroup (%)	Baseline (g/t-km)	Baseline without Scania's impact (g/t-km)	Scania's impact
4-UD	7.9	307.2	307.4	**-0.06 %**
4-RD	11.7	197.2	198.8	**-0.82 %**
4-LH	15.6	106.0	106.8	**-0.79 %**
5-RD	22.3	84.0	85.8	**-2.14 %**
5-LH	16.4	56.6	57.2	**-1.04 %**
9-RD	15.2	111.0	112.0	**-0.88 %**
9-LH	22.3	65.2	65.8	**-0.95 %**
10-RD	30.9	83.3	84.5	**-1.52 %**
10-LH	28.8	58.3	59.1	**-1.42 %**

Compliance flexibilities

Manufacturer compliance is evaluated at the fleet level through a metric dubbed average specific CO_2 emissions, measured in gCO_2/t-km. The calculation of this metric is illustrated in Figure 7, and a more detailed discussion can be found in a previous ICCT policy update (Rodríguez, 2019). Additionally, a number of policy elements were introduced to provide compliance flexibilities to manufacturers. These include:

» A banking and borrowing scheme

» An incentive for zero- and low-emission vehicles

» The exclusion of vocational vehicles from the metric of the standards

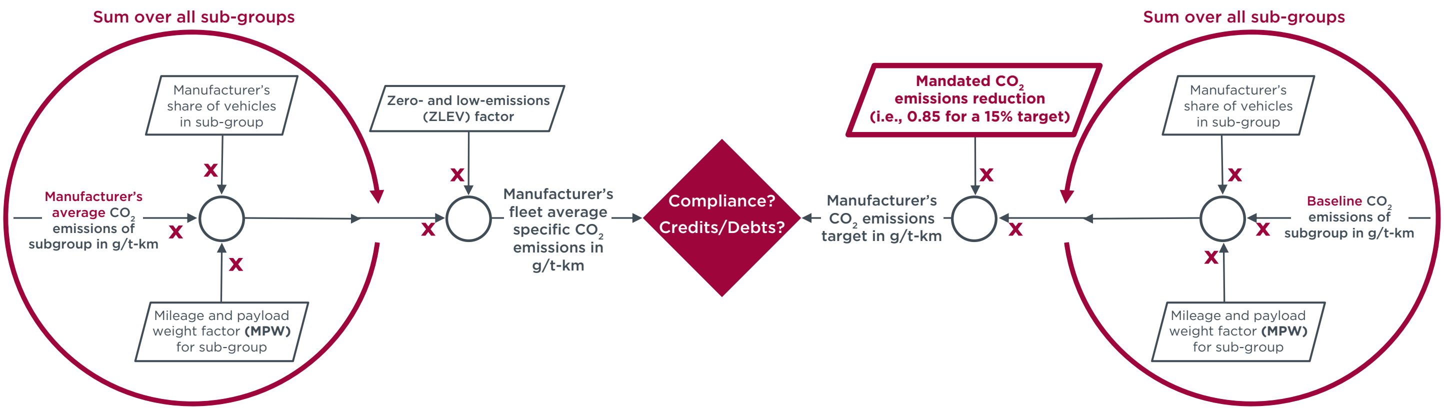


Figure 7. Determination of a manufacturer's average specific CO_2 emissions, reduction trajectory, compliance, and early-credits accumulation.

Credit and debt compliance flexibilities

The standards only introduce binding targets for 2025 and 2030, giving freedom to manufacturers in how they time their efforts for emissions reduction. Still, a banking and borrowing scheme was introduced to incentivize the early adoption of CO_2 saving technologies. For each manufacturer, a reduction trajectory is defined for every year through 2030 as a linear regression between the manufacturer's fleet average emissions in 2020 and its 2025 target, and then between its 2025 and 2030 targets. Manufacturers can accumulate credits in each reporting period if they perform under this reduction trajectory, and the accumulated credits can then be used to comply with the binding targets. Early improvements are therefore rewarded to a greater extent. Credits accumulated between 2020 and 2024 cannot be used beyond 2025. As no debt is accumulated before 2025, the period between 2019 and 2024 is dubbed the supercredit phase. In 2025, compliance is determined by assessing the difference between the potential debt accumulated in 2025 and the accumulated credits since 2020.

Starting in 2026, debt can be accumulated if a manufacturer emits more than its reduction trajectory and up to a certain level, above which immediate financial penalties apply. In 2030, compliance is assessed by taking the difference between the total debts or credits accumulated between 2025 and 2029. Non-compliance carries substantial financial penalties that are proportional to the average CO_2 exceedance per vehicle and the cumulative number of vehicles in the compliance period. The banking and borrowing scheme is currently scheduled to expire in 2030, although a potential extension will be discussed in the 2022 review.

Figure 8 shows the average specific CO_2 emissions of the top-selling brands in the first reporting period, together with their respective reduction trajectory for the banking and borrowing scheme and their 2025 and 2030 targets. These reduction trajectories are contingent on the fleet composition of a manufacturer across regulated subgroups and this analysis assumes the fleet compositions to be fixed at those present in the baseline reporting period (Figure 5). The accumulated credits for the first period are also shown in the figure.[1]

1 Our calculated values for the credits accumulated in the first reporting period differ from the official data published by the European Commission (European Commission, 2021a).

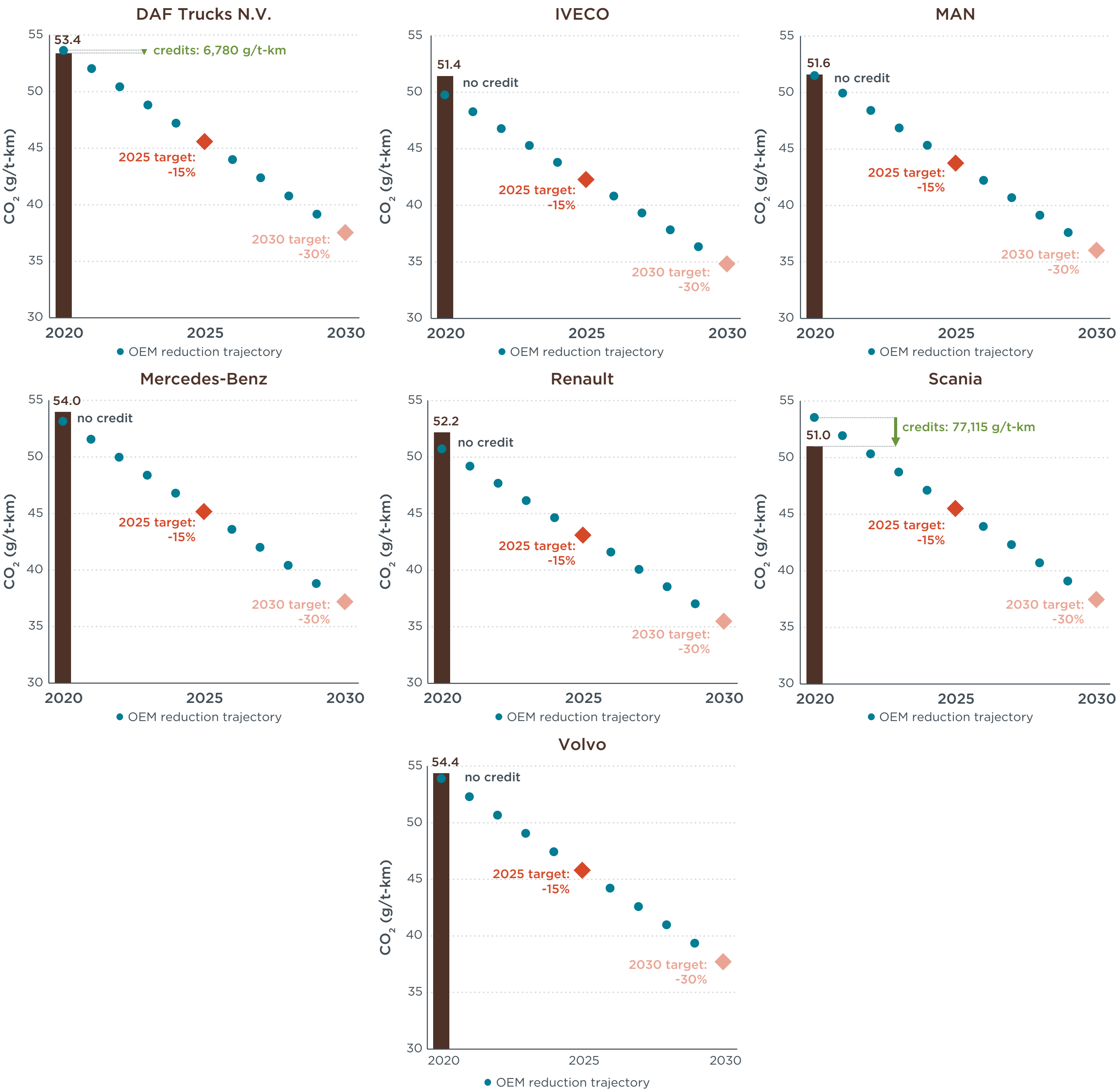


Figure 8. Fleet-wide average CO2 emissions and target for the accumulation of early credits in the first reporting period for each of the top selling manufacturers.

Since the magnitude of the CO_2 emissions shown in Figure 8 for each manufacturer depends on its sales share across subgroups, the relative performance of the different brands cannot be assessed by comparing the different panels of Figure 8. Instead, each manufacturer's performance should only be compared to its own reduction trajectory.

In this first reporting period, only Scania and DAF Trucks performed below their reduction trajectories, accumulating early-credits that can be used towards compliance in 2025. Despite having low emissions in the urban and regional delivery subgroups, MAN failed to emit less than their trajectory at the fleet level due to their poorer performance in the long-haul tractor-trailer subgroups.

Scania's average specific emissions were 4.7% below their trajectory for the 2019–2020 reporting period, leading to the accumulation of a significant amount of early-credits of 77,115 g/t-km. At a penalty value of €4,250 per gCO_2/t-km for non-compliance in 2025, the accumulated credits can be valued at approximately €328 million. Provided that their sales volumes and distribution across subgroups remain fixed at the same level as in the baseline period, Scania would have already achieved 31% of the emissions reduction required to comply with their 2025 target—estimated at 245,306 g/t-km—with still five years to go.

DAF Trucks' average specific emissions were 0.4% below their trajectory, leading to the accumulation of 6,780 g/t-km of early credits, valued at approximately €29 million under the applicable penalties for 2025.

While Scania is well underway to comply with their 2025 target, their performance in the baseline period also increased the required efforts for other truck makers to comply with their respective targets. Table 4 shows how Scania impacted the baseline values in each subgroup. At the fleet level, Scania's performance has led to an average increase of 1% in the other brands required efforts to comply with their 2025 and 2030 reduction targets, as shown in Table 5.

Table 5. Influence of Scania's performance on the efforts required from other truck manufacturers to comply with their respective CO_2 emissions reduction targets.

	DAF Trucks N.V.	IVECO	MAN	Mercedes-Benz	Renault	Volvo
Current 2025 target (g/t-km) [a]	53.6	49.7	51.5	53.2	50.7	53.9
2025 target w/o Scania (g/t-km) [a]	54.2	50.2	52.0	53.7	51.2	54.5
Additional reduction effort (%)	**1.03 %**	**0.98 %**	**1.00 %**	**1.00 %**	**0.99 %**	**1.04 %**

[a] Assuming the same sales volumes and subgroup composition as the baseline period.

Vocational vehicles

Manufacturers can declare some trucks from the regulated groups as vocational vehicles and exclude them from the metric of the standards. These trucks are used for special purposes, such as garbage collection or construction works, but are included in the regulated groups due to their technical specifications. The European Commission estimated that these trucks have a minor contribution on the fleet's overall CO_2 emissions and, given the lower cost-effectiveness of reducing emissions from these trucks compared to goods vehicles, decided to exclude them from the standards. Still, there is no clear technical definition, and therefore no clear legal framework, for the exclusion of these trucks.

As shown in Table 6, DAF Trucks and Mercedes-Benz declared a significant number of vocational trucks in the first reporting period. For these two brands, the average engine efficiency over the World Harmonized Transient Cycle (WHTC) for vocational trucks was significantly lower than the average for the trucks included in the metric of the standard (3% and 4% lower, respectively). Additionally, their vocational trucks had significantly higher (5% and 6%, respectively) tire rolling resistance coefficients (RRC), which largely contribute to the truck's energy consumption. By removing these high-emitting vehicles from the metric of the standards, these brands achieved CO_2 emissions reduction at the fleet-level of 1.4% and 1.7%, respectively. To prevent a CO_2 leak from the standards and mandate performance improvements on these vehicles, the introduction of engine CO_2 standards for vocational trucks will be discussed in the 2022 review of the standards.

Table 6. Impact of excluding high-emitting vocational trucks from each brand's fleet-average CO_2 emissions.

	DAF Trucks N.V.	Mercedes-Benz
Number of vocational trucks	1,851	1,315
Average engine efficiency of included trucks[a] (%)	42.6	41.9
Average engine efficiency of vocational trucks (%)	41.4	40.1
Average RRC of included trucks[1] (kg/tonne)	5.55	5.58
Average RRC of vocational trucks (kg/tonne)	5.81	5.92
Reduction in fleet-average CO_2 emissions obtained by excluding vocational trucks (%)	**1.7 %**	**1.4 %**

[a] Included in the metric of the CO_2 standards, both for the computation of the baseline values and the evaluation of the manufacturer's compliance.

Zero- and low-emission vehicles incentive

To push manufacturers to increase the shares of zero-emission HDVs in their fleets, the HDV CO_2 standards introduce a zero- and low-emission vehicle (ZLEV) incentive mechanism. In the super-credits phase (2019 to 2024), zero-emission vehicles are counted as two vehicles and low-emission vehicles, defined as those with emissions lower than 50% below the subgroup's baseline, are counted as between one and two vehicles depending on the level of their emissions (one for a vehicle 50% below the baseline, increasing linearly to two for a vehicle 100% below the baseline). Additionally, a ZLEV factor is defined as follows, which multiplies the fleet average emissions of a manufacturer to obtain the final metric as shown in Figure 7:

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

Where V is the total number of regulated HDVs, V_{conv} is the total number of regulated HDVs with conventional powertrains, $ZLEV_{in}$ is the resulting number of ZLEV vehicles within the regulated groups after accounting for super-credits, and ZEV_{out} is the number of ZEV vehicles outside of the regulated groups multiplied by 2.

Starting from 2025, the benchmark phase of the incentive introduces a ZEV sales benchmark of 2% to benefit from any ZLEV incentive. In both the super-credits and benchmark phases of the incentive, the ZLEV factor is capped at a minimum of 0.97, meaning it can only reduce the compliance efforts by a maximum of 3%.

In the first reporting period, only three zero-emission vehicles from the top-selling brands were reported in the EEA database. Although it is acknowledged that more zero-emission trucks were sold in this period, these are currently not covered by the current provisions of the certification regulation, (EU) 2017/2400, explaining their absence from the database. Additionally, no truck qualified as low-emission. The ZLEV incentive mechanism therefore had no influence in the first reporting period.

However, we used an alternative database[2] to estimate the actual number of zero-emission vehicles registered by each brand and the resulting impact that their inclusion would have on their average specific emissions once these vehicles are covered by the CO_2 certification regulation. Table 7 shows the values of the current and estimated ZLEV factors for the top-selling brands in the baseline period.[3]

2 Historical data supplied by IHS Global SA; Copyright © IHS Global SA, 2019. As data are only available for full calendar years, we used data from (ACEA, 2021) to extract only the sales corresponding to the first reporting period (July 2019–June 2020).

3 Our calculated values for the ZLEV factors in the first reporting period differ from the official data published by the European Commission (European Commission, 2021a).

Table 7. Influence of factoring in all ZE-HDV registrations on the top selling brands average specific CO_2 emissions.

Manufacturer	DAF Trucks N.V.	IVECO	MAN	Mercedes-Benz	Renault	Scania	Volvo
Current ZLEV factor	0.9999	1.0000	0.9999	1.0000	1.0000	1.0000	0.9999
Estimated number of LEV	0	0	0	0	0	0	0
Estimated number of ZEV	6	4	10	12	4	1	10
Estimated ZLEV factor	0.9996	0.9992	0.9992	0.9992	0.9995	0.9999	0.9993
Potential reduction in fleet average specific emissions	**0.03%**	**0.08%**	**0.07%**	**0.08%**	**0.05%**	**0.01%**	**0.07%**

Even with data from this enhanced database, the number of ZE-HDV sales registered by the major truck brands in the EU was still insignificant in the first reporting period, being limited to a few pilot models. Factoring in these sales would have only reduced fleet-wide emissions by less than 0.1% for all top-selling brands. However, we expect these numbers to grow rapidly in the following reporting periods, as manufacturers have started to announce plans to transition to 100% ZE-HDV sales: 10% of the sales volume by 2025 and 50% by 2030 for Scania; 50% by 2030 and 100% by 2040 for Volvo; 100% by 2039 for Mercedes-Benz; 60% delivery trucks and 40% long-haul trucks by 2030 for MAN; and full de-fossilization by 2040 for both IVECO and DAF Trucks (European Truck Manufacturers Aiming for 100% Electric, 2021), in line with ACEA's views on the topic (Potsdam Institute for Climate Impact Research, 2020).

Most of the ZE-HDV pilot models being developed are urban and regional delivery trucks with low electric ranges, while models and prototypes for long-haul trucks seem to be lagging. Still, both types of trucks are currently given equal incentives in the EU HDV CO_2 standards. To address this issue, the European Commission will discuss revising the ZLEV factor and to include a distinction in terms of driving range and freight activity, as part of the 2022 review of the standards.

Technology analysis

The variations in CO_2 emissions across manufacturers can be explained by different rates of technology adoption. As the availability of cost-effective technology potential depends on a truck's characteristics and use profile, the variations in fleet composition observed in the *Market overview* section of this paper are expected to have an impact on the manufacturers' chosen pathways to comply with their respective targets.

It usually requires the least amount of effort to reduce the fuel consumption of long-haul tractor-trailers by improving the road load and engine efficiency, for several reasons. First, reductions in aerodynamic drag and tire rolling resistance typically lead to greater savings due to the high speed conditions. Additionally, these trucks are usually equipped with large engines, which operate under steady conditions, for which it is easier to increase the efficiency. Finally, it is easier to benefit from economies of scale in this segment, which has the largest market share. Manufacturers with a higher share of these trucks could therefore benefit from technology improvements to a larger extent. There was evidence of this in the first reporting period, as the two brands that accumulated early credits (DAF Trucks and Scania) also had among the highest shares of long-haul tractor-trailers in their fleets.

Conversely, there is consensus that urban and regional delivery trucks can transition faster to zero-emission technologies due to their shorter driving ranges and a better access to charging and refueling infrastructure in cities. The future Alternative Fuels Infrastructure Regulation (AFIR) will define particularly ambitious requirements for infrastructure density in select urban nodes, providing more charging opportunities for urban trucks (European Commission, 2021b). Therefore, manufacturers with higher shares of trucks in these segments could benefit from switching to ZE-HDVs earlier.

In this section we analyze the technical characteristics of the trucks reported within the scope of regulation (EU) 2018/956 to identify the main technology areas that influenced CO_2 performance in the first reporting period. The full summary of the overall market performance, by vehicle subgroup and technology area, can be found in a separate ICCT publication.

Powertrain CO_2 performance

Engine efficiency

The truck market in the EU is still widely dominated by conventional powertrains with internal combustion engines; ZE-HDVs currently have a negligible market penetration, as described in the previous section. Yet, there are several technology pathways that manufacturers can explore at the engine level to reduce CO_2 emissions. The most straightforward way to do so is to improve engine efficiency by including advanced technologies such as advanced waste heat recovery systems, advanced turbocharging, and cylinder deactivation, to name a few.

In the EU, engine CO_2 emissions are certified on an engine dynamometer test over various cycles during type-approval. The certified performance of the engine is then used as an input to the VECTO tool to determine the truck's CO_2 emissions. Here, we look at the engine certified data over the WHTC to determine the relative manufacturers performance at the engine level. To obtain average thermal efficiency from the engine's certified CO_2 emissions, reported in g/kWh, we used VECTO's standard fuel properties for both diesel and natural gas—that is, lower heating values of 42.7 MJ/kg and 45.1 MJ/kg and carbon contents of 3.13 $kgCO_2$/kgFuel and 2.77 $kgCO_2$/kgFuel, respectively.

Further, for each manufacturer, we used specific combinations of engine displacement and rated power to define individual engine models. Figure 9 shows the calculated engine efficiency of the different engine models for each of the top-selling truck brands in the first reporting period. The in-use engine efficiency is expected to deviate slightly from the efficiency obtained from the WHTC emissions, however the data presented here are assumed to be representative of real-world performance.

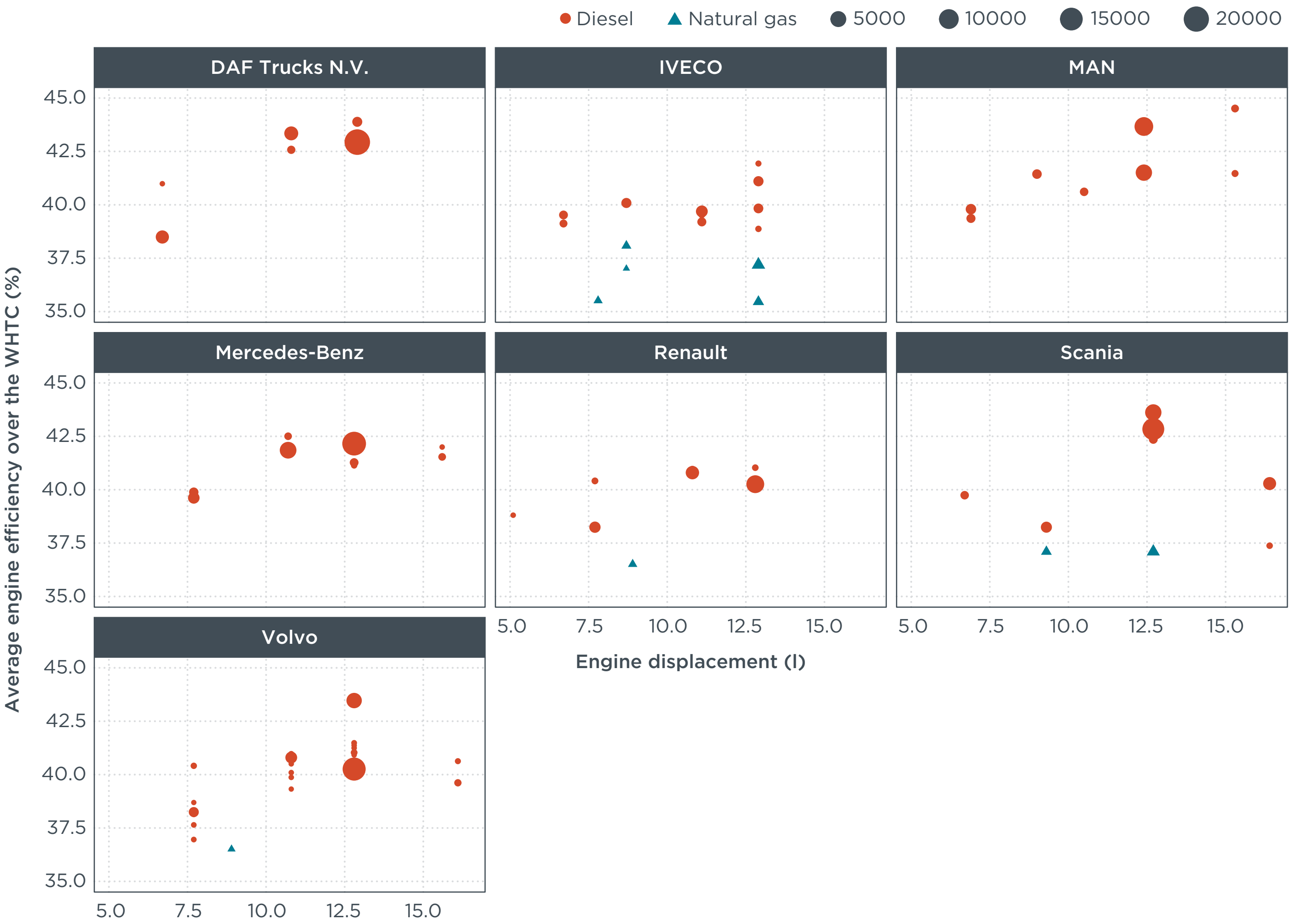


Figure 9. Calculated cycle-averaged engine efficiency (WHTC) for the top-selling manufacturers. Each engine's specific combination of displacement and rated power is associated with an engine model. The size of the points represents the number of trucks equipped with each engine model.

DAF Trucks and MAN had the most efficient engines overall, both with fleet averages of 42.6%, closely followed by Scania at 42.4%. The most efficient model was MAN's D38 15.3-liter engine, which reached 44.5% average thermal efficiency over the WHTC cycle and are equipped on 354 trucks in the dataset. The second most efficient models were PACCAR's MX-13 12.9-liter engine reaching 43.9% efficiency (1,214 trucks) followed by MAN's D2676 12.4-liter engine reaching 43.8% efficiency (4,130 trucks). Natural gas engines, represented by triangles in Figure 9, had much lower thermal efficiencies in general than their diesel counterparts. The best performing model, IVECO's CURSOR 9 8.7-liter engine, only reached 38.1% efficiency. Overall, larger displacements were found to lead to higher cycle-averaged engine efficiency over the WHTC.

Fuel type

Four of the seven top selling truck brands, IVECO and Scania most notably, marketed natural gas models. Figure 10 shows the shares of natural gas truck sales in each subgroup for these manufacturers.

Figure 10. Shares of different fuel types for each of the top selling manufacturers and vehicle subgroups. Only the manufacturers selling natural gas trucks are represented here.

IVECO made the most significant investments in natural gas trucks, which represented 22% of their overall sales, including 30% of long-haul tractor-trailers, in the first reporting period. Scania also sold a significant number of natural gas trucks, although they represented much lower shares of the brand's overall fleet (5% of subgroup 5-LH and of all trucks). Renault and Volvo also sold natural gas trucks in this period, although to a much smaller extent. Additionally, Volvo sold 1,017 dual-fuel (diesel and natural gas) trucks, equipped with high pressure direct injection (HPDI) engines. However, these are not included here as the VECTO versions during the baseline period did not yet cover this engine technology. As the tool is updated to include HPDI engines, these trucks will be included retroactively in the metric of the CO_2 standards. Mercedes-Benz sold 8 natural gas trucks only and are therefore not represented in Figure 10. Finally, ethanol trucks still have negligible market penetration, with only Scania selling 22 units in the subgroup 5-LH.

Despite the technology being adopted widely by some manufacturers, data from the first reporting period showed the limitations in the CO_2 emissions reduction potential of natural gas. Figure 9 illustrates that natural gas engines are substantially less efficient than their diesel counterparts, however natural gas does have a lower carbon intensity than diesel. Figure 11 compares the two technologies in detail at the vehicle (left) and engine (right) level for long-haul tractor-trailer subgroup 5-LH, which contained the largest number of natural gas trucks.

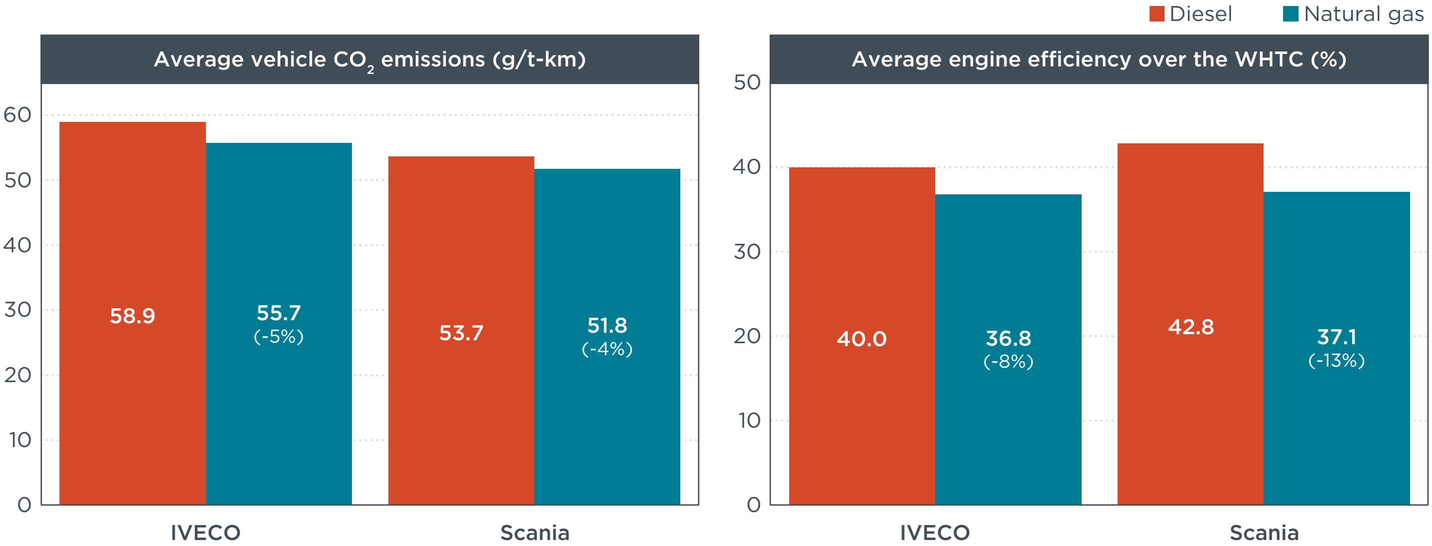


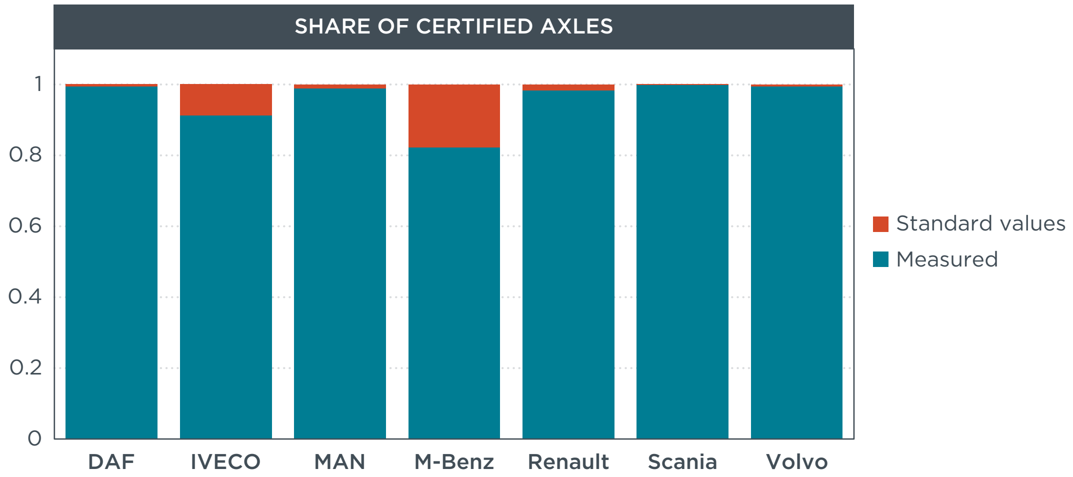
Figure 11. CO_2 emissions of engines in the subgroup 5-LH, certified over the WHTC cycle, for the two main manufacturers of natural gas trucks.

Despite the lower carbon content of natural gas, the left panel of Figure 11 shows that, for long-haul tractor-trailers, natural gas vehicles manufactured by IVECO and Scania only emit on average 5% and 4% less CO_2, respectively, than their diesel counterparts. This can be explained by the much lower engine efficiency of natural gas trucks—8% lower on average for IVECO and 13% lower for Scania—shown on the right panel of Figure 11. Across all brands, 5-LH natural gas tractor-trailers emitted in average 4% less than diesel ones. This marginal improvement is underwhelming compared to the hopes placed in this technology for CO_2 emissions reduction. IVECO, most notably, described natural gas as the only viable option to achieve the climate neutrality goal for 2050 (IVECO, 2020). There are, therefore, concerns as to whether manufacturers that rely uniquely on this technology for CO_2 reduction will be able to comply with their targets set out by the standards.

Drivetrain

Drivetrain design is central to optimizing a vehicle's energy efficiency. Innovative transmission technologies can help achieve efficiency improvements on the engine by operating it at its most efficient operating point. In addition, ensuring minimal power-transmission losses between the engine and the wheels helps to considerably reduce a vehicle's energy consumption. The torque losses from transmissions and axles are certified under the scope of regulation (EU) 2017/2400 and serve as an input to the VECTO tool to certify vehicles CO_2 emissions. The publicly available dataset does not include the value of these losses. However, it includes data on the certification option that manufacturers opt for to certify transmissions and axles losses from each of their trucks.

As for all components and separate technical units covered by the regulation, the transmission's torque losses can be certified using either "standard" values (in this case, calculated using a standard formula) or by measuring them in three different levels of complexity (Options 1, 2, and 3). Increasing levels of complexity lead to a higher accuracy in the reported losses, but also to higher certification costs. Thus, manufacturers are faced with a trade-off. For axle torque losses, only two options are available – either measured or standard values, calculated using generic efficiency values. Figure 12 shows the options chosen by the top-selling truck brands to certify both transmission and axle torque losses.



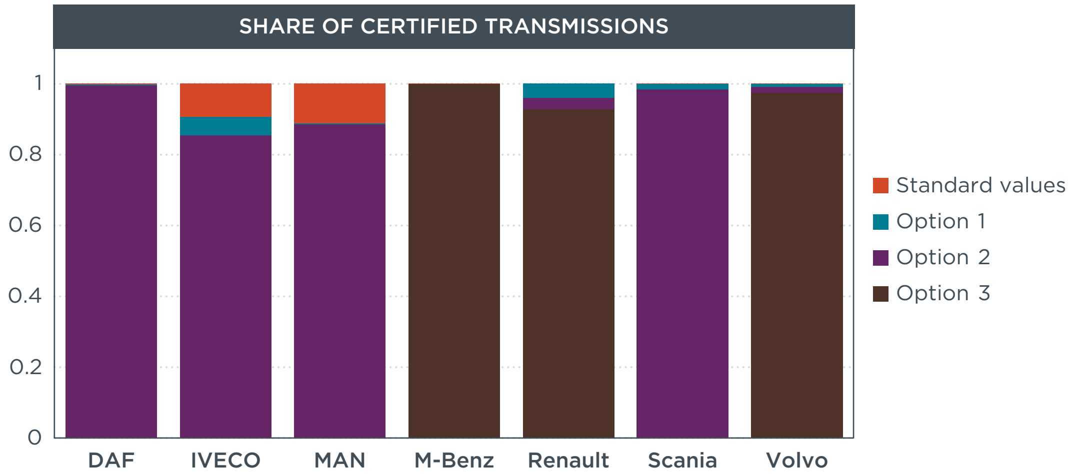


Figure 12. Certification options chosen by the top selling brands to certify axle (top) and transmission (bottom) torque losses.

For transmission torque losses, only MAN (11%) and IVECO (9%) used significant shares of standard values. Otherwise, manufacturers opted predominantly for the more complex measurement options (Options 2 and 3), generally leading to lower reported torque losses and, therefore, lower CO_2 emissions. For axle torque losses, only Mercedes-Benz (18%) and IVECO (9%) used standard values to a significant extent, consistently leading to higher vehicle CO_2 emissions. The brands using significant shares of standard values to certify drivetrain torque losses could reach improvements in their reported CO_2 emissions by switching to measured values only, requiring marginal investments in certification.

Road load reduction

Aerodynamics

To reduce a truck's CO_2 emissions, there are several ways to reduce its energy demand, including lessening the road load by reducing tire rolling resistance, air drag, and weight. For trucks in particular, air drag contributes to about 40% of the usable mechanical energy produced by the engine (Delgado, Rodríguez, and Muncrief, 2017), hence the crucial importance of optimizing the aerodynamic performance of a truck. For each certified truck, the air drag area ($C_d \times A$, in m^2) is defined as the product of the drag coefficient (C_d) and the cross-sectional area of the truck (A). Air drag area values are determined under the scope of the certification regulation and serve as an input for VECTO simulations. The values are reported as a range (A1 to A24) of about 0.15 m^2, as defined in Part C of Annex I of the reporting and monitoring regulation, (EU) 2018/956. In our analysis, we assumed that the air drag area for each truck was at the median value of the range. For instance, a truck for which the specified range is A3, i.e 3.15 to 3.31 m^2, is assumed to have an air drag value of 3.23 m^2.

To compare the aerodynamic performance of the top selling brands, we focused on long-haul tractor-trailers from subgroup 5-LH only, for which improvements in aerodynamics lead to the largest savings in fuel consumption and CO_2 emissions. Figure 13 shows the measured air drag area values certified by the top-selling truck brands.

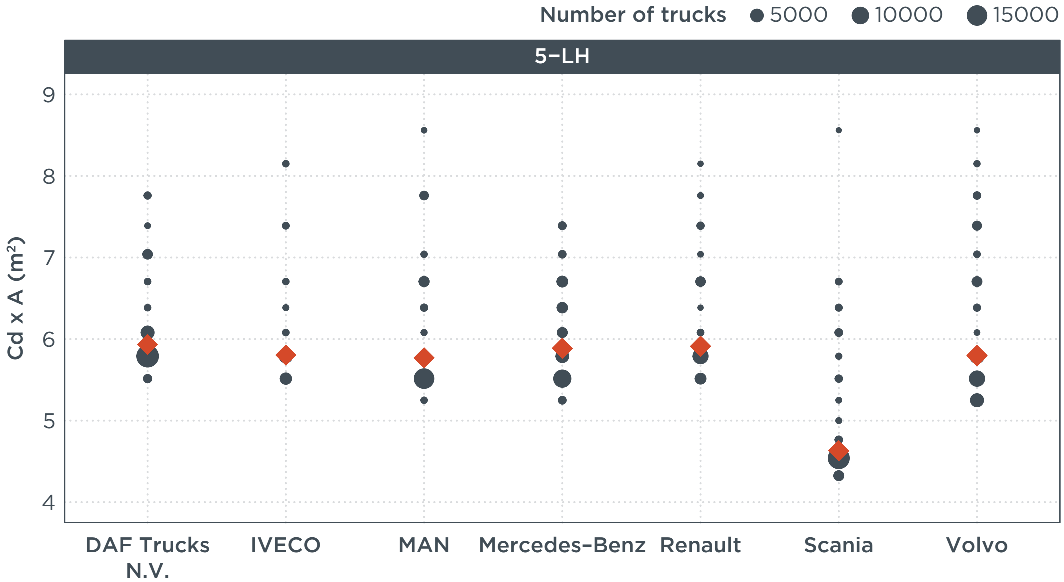


Figure 13. Distribution of measured air drag areas for the top-selling brands. Each datapoint represents an air drag are value, with size proportional to the number of trucks. The orange diamonds correspond to the brand's average C_d×A value for subgroup 5-LH.

Overall, the reported air drag area of Scania trucks were by far the lowest, with an average C_d×A of 4.63 m^2 for subgroup 5-LH, whereas all other brands had averages concentrated between 5.77 m^2 and 5.93 m^2. Of Scania's 5-LH trucks, 83% were certified with an air drag area of 4.54 m^2. With such a big gap with other brands, aerodynamics can certainly be considered as the main driver of Scania's performance observed in Figure 6 and Figure 8. On the other side, DAF trucks had the highest average air drag for their 5-LH tractor-trailers, but still managed to accumulate credits in the first reporting period by performing well in other technology areas such as engine efficiency.

As for drivetrain torque losses, manufacturers have the option to either use standard air drag values or to measure them. The standard values for air drag are conservative and lead to a substantial overestimation of the truck's CO_2 emissions. However, the costs of the constant speed tests used to determine the air drag experimentally can be large. So, the trade-off between certification cost and reported CO_2 performance is even more important than with the certification of transmission torque losses. Moreover, truck models can be grouped into families to reduce the number of constant speed tests required. Scania was rewarded with the best performance by a significant margin, leading to the accumulation of significant credits in the first reporting period.

Mercedes-Benz certified 6% of their 5-LH trucks with standard air drag values, more than any other brand. To quantify how this impacted their trucks' CO_2 performance, we compared a hypothetical case where they used measured values only to the current scenario. As shown in Figure 14, we found that their CO_2 emissions would have been 1% lower in the hypothetical case, bringing them almost to the value of the subgroup's baseline. At the fleet level, this 1% difference would have translated into a 0.6% reduction in CO_2 emissions.

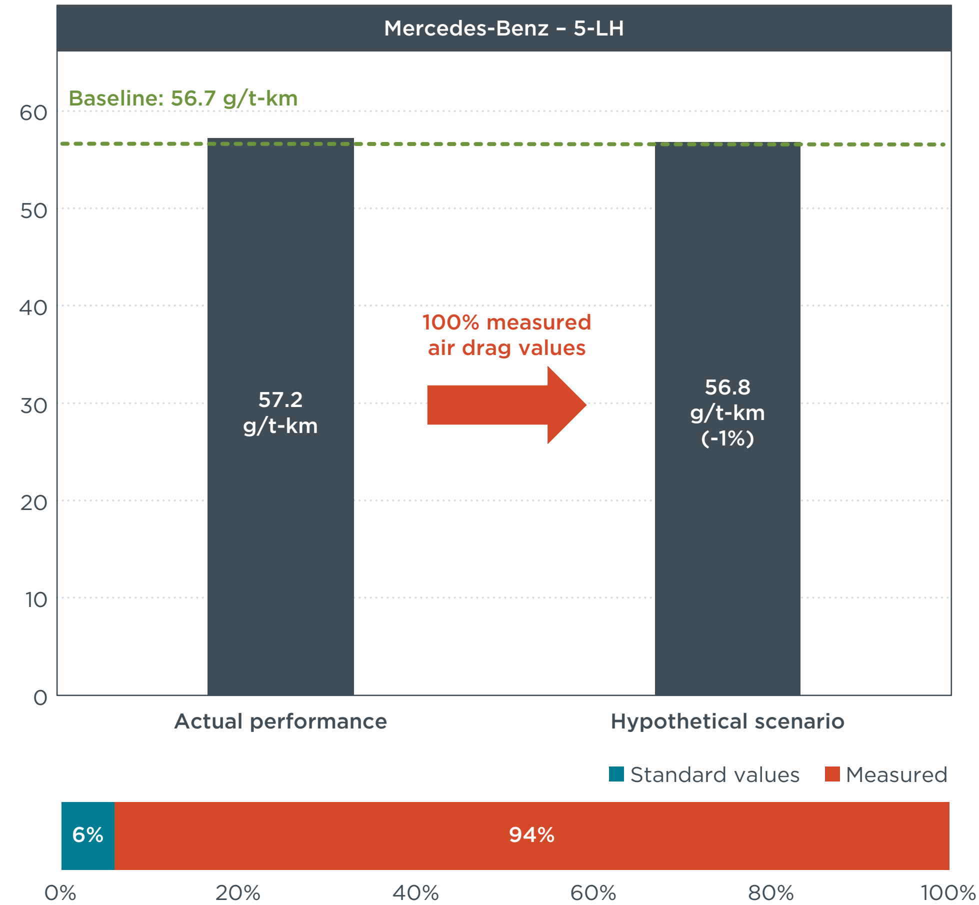


Figure 14. Impact of using standard air drag values on Mercedes-Benz's 5-LH average CO_2 emissions.

Tire rolling resistance and light-weighting

Depending on the payload, the weight of a tractor unit typically represents between 20% (fully loaded) and 50% (empty) of a total tractor-trailer's combined weight. Additionally, the energy dissipated by the rolling resistance of the tires on the road is also significant—about 40% of the usable energy produced by the engine (Delgado, Rodríguez, and Muncrief, 2017). Therefore, reducing the energy consumption associated with these two road load components is key in achieving CO_2 emissions reduction in trucks. In the first reporting period, all brands performed at very comparable levels in all subgroups for these two technology areas, as shown in Figure 15. The subgroups with the largest variations in performance across brands were also those with the smaller number of trucks (4-UD, 4-LH, 5-RD, and 10-RD), and therefore do not have a significant impact on fleet-level emissions.

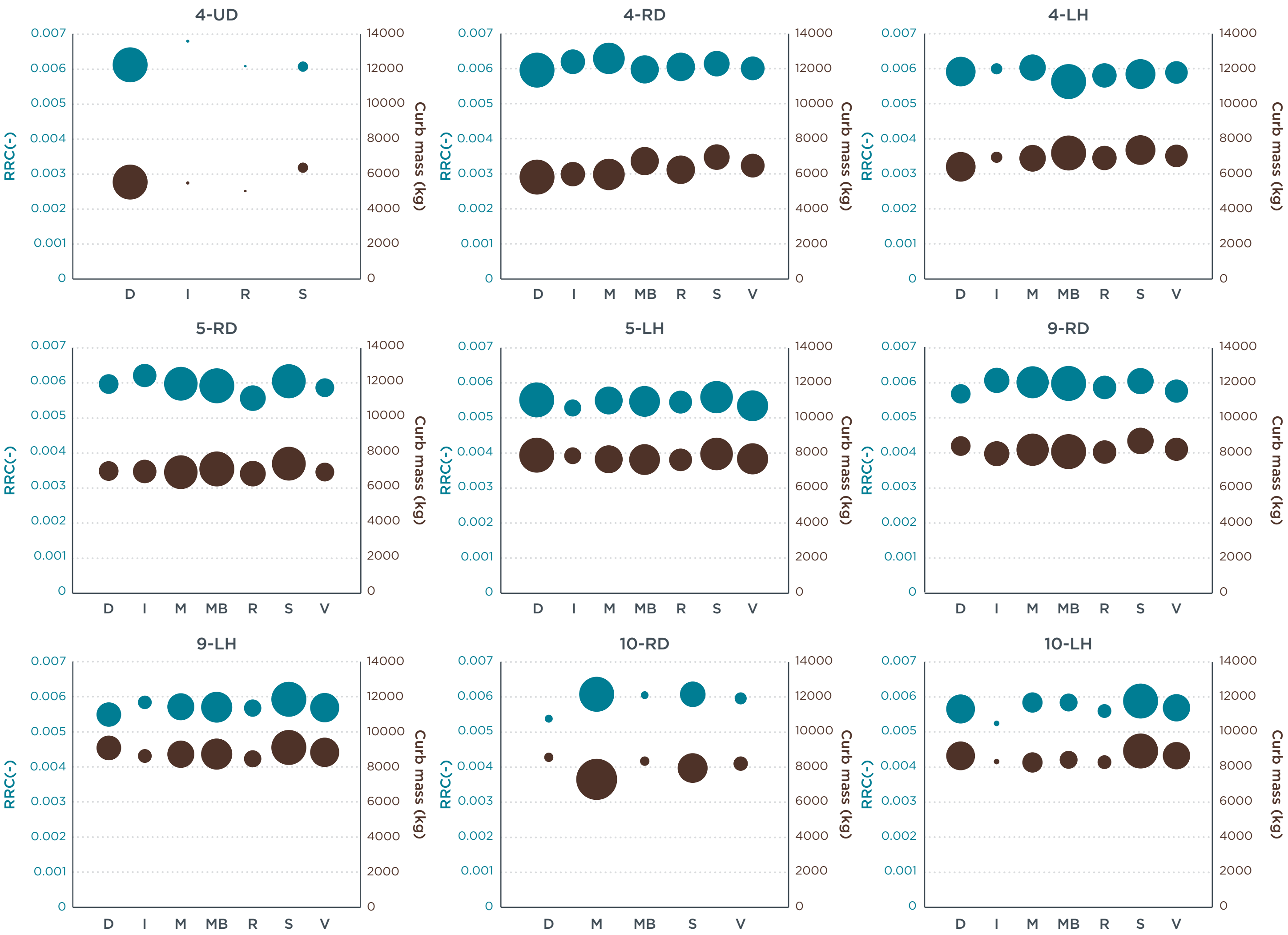


Figure 15. Tire rolling resistance coefficient (RRC) and curb mass of trucks from the top-selling brands (D = DAF Trucks, I = IVECO, M = MAN, MB = Mercedes-Benz, R = Renault, S = Scania, V = Volvo), for each subgroup. The size of the bubbles represents the brand's market shares in the subgroup.

Auxiliary technologies and power take-off

Auxiliaries, such as engine fans and cabin air conditioning systems, as well as power take-offs used on trucks for special applications, also contribute to the energy consumption of a truck, whether it is ICE-powered or zero-emission. When certifying their trucks' CO_2 emissions in VECTO, manufacturers must choose from a list of options the technology used for five key auxiliary devices: engine fan; steering pump; pneumatic system; electric system; and heating, ventilation, and air conditioning (HVAC). VECTO then computes the associated average auxiliary power consumption over each cycle, and the resulting impact on powertrain energy consumption and CO_2 emissions, according to Annex IX of the certification regulation. Figure 16 shows the shares of subgroup 5-LH trucks equipped with the different technologies for four of the five key auxiliary devices. For the HVAC system, VECTO currently only has a "default" option. Data on the power consumption and impact of CO_2 emissions from the auxiliaries are not communicated in the public dataset.

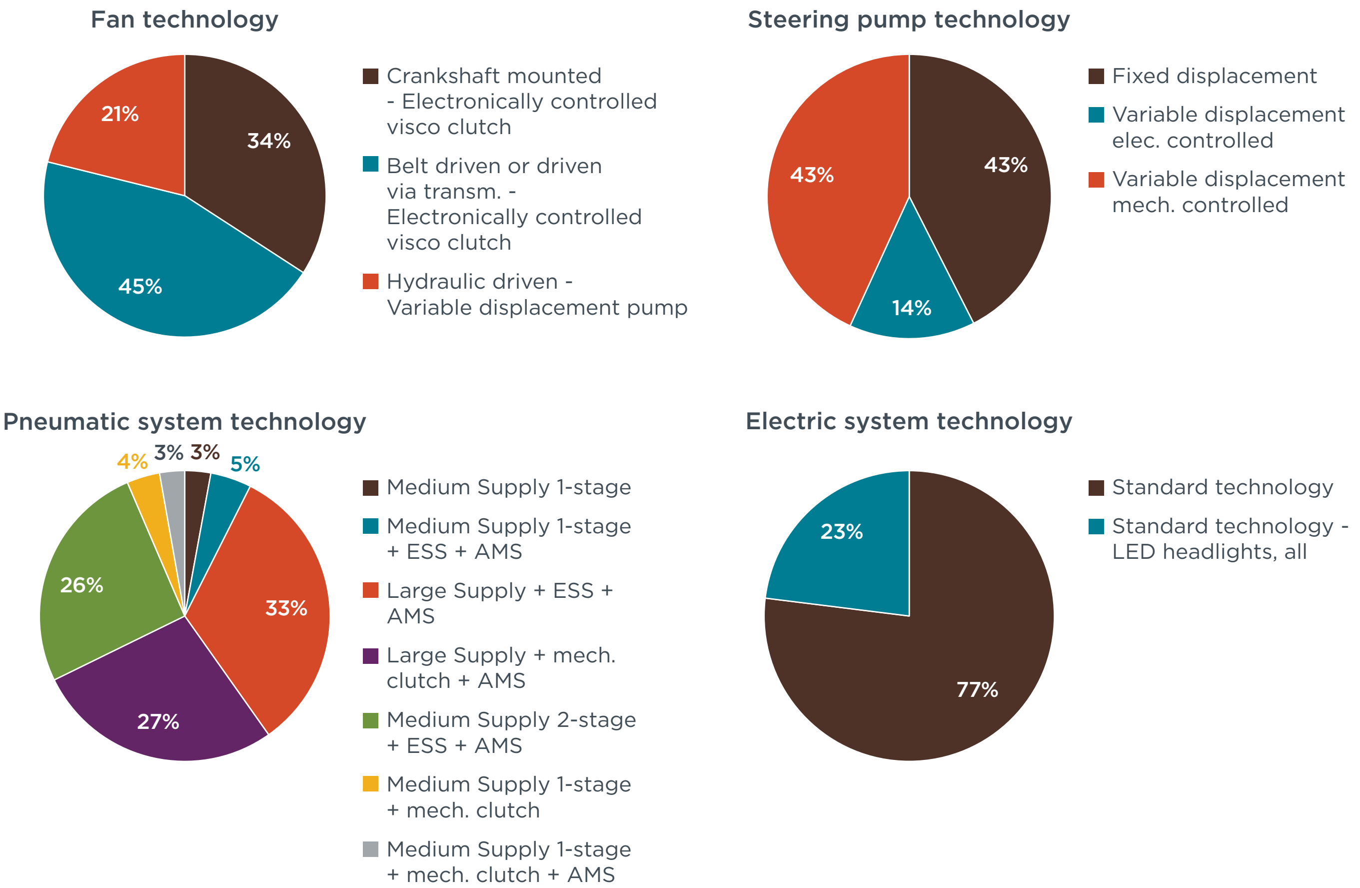


Figure 16. Shares of 5-LH trucks equipped with different technologies for key auxiliary equipment (EES = Energy Saving System, AMS = Air Management System).

Although the data presented in Figure 16 are representative of the long-haul tractor-trailer market overall, there was a significant variability in the technologies adopted by different manufacturers. For instance, all DAF 5-LH trucks were equipped with a hydraulic driven fan, while over 95% of such trucks from Mercedes-Benz and Scania had crankshaft-mounted fans, and all other manufacturers opted for belt-driven fans. The same variability was observed for the other auxiliaries, highlighting the different technology pathways adopted by the industry.

Additionally, power take-offs can be installed either during the first stage manufacturing by the original equipment manufacturer, or at a later manufacturing stage by the body builder. In the former case, the original equipment manufacturer must declare the presence of a power take-off in VECTO, which results in higher certified CO_2 emissions for the truck. In the first reporting period, between 18% (DAF Trucks) and 36% (MAN) of trucks were certified with a power take-off.

Market penetration of advanced CO_2 emissions reduction technologies

The latest developments in the VECTO simulation tool for CO_2 certification included the possibility for manufacturers to declare additional CO_2 emissions reduction technologies, including both advanced powertrain technologies and aerodynamic features. The resulting CO_2 savings from some of these technologies are computed by VECTO using models predefined in the certification regulation. In this section, we evaluate the market penetration of these advanced technologies for long-haul tractor-trailers from subgroup 5-LH only, which benefit the most from these advanced technologies.

At the powertrain level, the presence or lack of a number of Advanced Driver-Assistance Systems (ADAS) technologies are declared by manufacturers as a compulsory input for VECTO simulations. Unfortunately, there are caveats in the reported data, as older VECTO versions (up to v3.3.0.1433) that ran into the baseline period did not have this feature. Therefore, we assessed market penetration of ADAS technologies from the most recently reported data only. These include predictive cruise control and eco-roll, which use topological maps and GPS data to predict the optimum acceleration and coasting strategies for the upcoming road segment. VECTO also has an option to declare trucks equipped with engine stop/start, which would benefit mainly urban delivery trucks, however no use of this technology was declared in the first reporting period.

Additionally, a number of advanced technologies are declared in VECTO on a voluntary basis for monitoring purposes only. The CO_2 saving potential of these technologies is not reflected in the certified CO_2 values. From the powertrain side, this mainly includes the pulse and glide technology, which consists of alternating phases of accelerating to a higher speed by running the engine at a higher load than required where the engine is more efficient (pulse) and then coasting in neutral gear to a lower speed (glide). By increasing the idling time, pulse and glide aims to maximize the benefits of eco-roll, resulting in potential savings in fuel consumption. Figure 17 shows the market penetration for each of these powertrain technologies for tractor-trailers in the subgroup 5-LH. According to the reported data, 31% of the trucks in subgroup 5-LH were equipped with predictive cruise control, while 44% were equipped with eco-roll (without engine stop). Although other brands also use pulse and glide, only Mercedes-Benz declared the use of this technology when certifying their trucks in VECTO. Of their 5-LH tractor-trailers, 92% were certified with pulse and glide. As this technology is not currently covered by the certification procedure, no CO_2 benefits are attributed to its use.

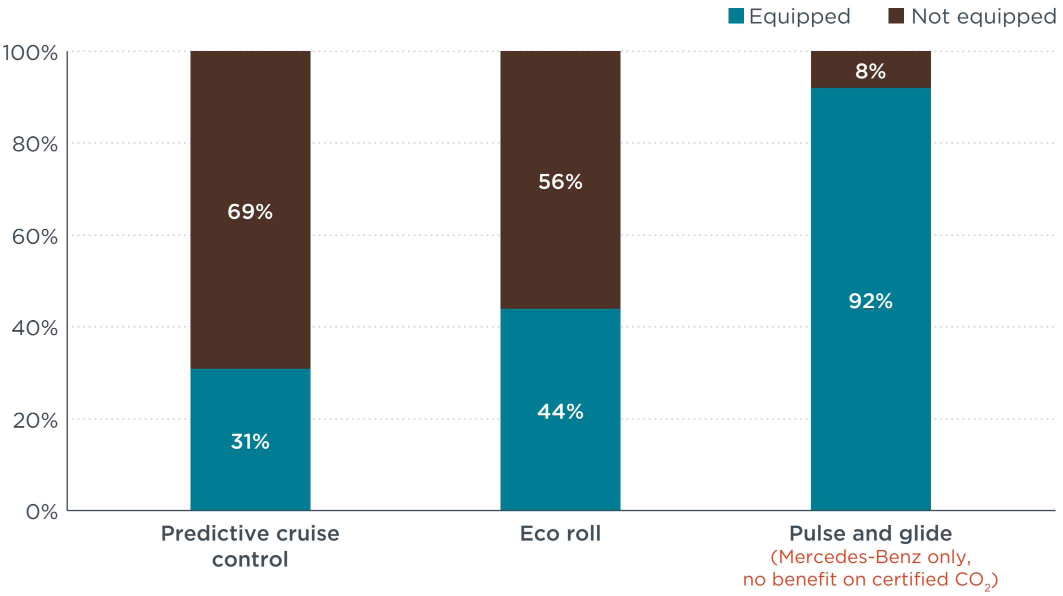


Figure 17. Market penetration of advanced powertrain technologies for CO_2 emissions reduction in the subgroup 5-LH.

Other aerodynamic features can also be declared voluntarily in VECTO as advanced CO_2 reduction technologies for monitoring purposes. Side skirts, for example, reduce air drag by preventing air penetration in their underbody, while roof fairings reduce air drag induced by the difference in geometry between the tractor and the trailer, both areas being key in the generation of air drag in tractor-trailers. Side skirts and roof fairings were only declared by Ford Otosan in a fraction of their trucks. However, other manufacturers use such aerodynamic devices extensively in their tractor-trucks and are considered standard equipment. Active grills at the front of tractor units can open or close depending on the operating conditions of the truck. Shutting the front grill allows for further air drag reduction and can help achieve faster engine warm-up to improve efficiency and reduce cold-start pollutant emissions. Active front grills were only declared by Mercedes-Benz, on 86% of their 5-LH trucks (22,746 units).

Key findings and conclusions

The monitoring and reporting dataset on the CO_2 performance of trucks and buses in the EU is a valuable and unique resource. No other jurisdiction around the globe has made publicly available this wealth of data to ensure a high level of transparency, enabling society to make well-informed policy decisions to promote the uptake of more energy-efficient heavy-duty vehicles. Furthermore, the release of the official certification data allows, for the first time, a leveled comparison of the CO_2 and fuel consumption performance of heavy-duty vehicle manufacturers.

A thorough analysis of the first monitoring and reporting dataset leads us to the following key findings:

» **The baseline CO_2 emissions of each subgroup are largely influenced by the payloads set by the regulation:** While the fuel consumption values across the different truck subgroups oscillated between 24 L/100 km and 33 L/100 km, the specific CO_2 emissions showed greater variation. Urban delivery trucks with a 4×2 axle configuration (4-UD) emitted on average 307 gCO_2/t-km, that is over five times as much than long-haul tractor-trailers (5-LH) with emissions of 57 gCO_2/t-km. This stark difference in payload- and distance-specific CO_2 emissions is largely driven by the regulatory payloads set by the regulation.

» **The specific CO_2 emissions across vehicles show substantial variability around the mean value:** For most vehicle subgroups, the baseline data show a large spread around the mean. For the most important truck subgroup, long-haul tractor-trailers (5-LH), there was a 63% difference between the best and worst performing vehicles. This indicates that, even today, there is a large technology potential not being exploited by manufacturers and truck buyers.

» **The regulated truck segments show high market consolidated:** While DAF Trucks was the top selling brand in the regulated groups with 18.2% market share, three vehicle manufacturers, owning more than one brand, together accounted for 76% of the regulated truck market. Traton Group, parent company of MAN and Scania, had a 33% market share. Volvo Group, owner of Volvo Trucks and Renault Trucks, was responsible for 25% of new regulated trucks. Finally, Daimler Trucks, with its main brand Mercedes-Benz, accounted for 18%.

» **Scania outperformed its competitors in most vehicle subgroups:** The CO_2 emissions of the Swedish manufacturer during the baseline period were consistently lower than the average in all subgroups, and they had the best CO_2 performance in seven of the nine subgroups (all but 4-UD and 9-RD). Due to their high market shares in all subgroups, they consistently lowered the baseline values that will be used to define the future stringency of the CO_2 standards. Scania's fleet average specific emissions were 4.7% below their reference emissions, leading to the accumulation of 77,115 g/t-km worth of early credits. These accumulated credits can be valued at approximately €328 million when using the 2025 non-compliance penalty of €4,250 per gCO2/t-km.

» **No widespread misapplication of the vocational vehicle flexibility could be determined:** Manufacturers can self-declare some trucks from the regulated groups as vocational vehicles, such as refuse collection trucks, and exclude them from the metric of the standards. Over 3,000 vocational trucks were declared in the first reporting period, mostly by DAF Trucks and Mercedes-Benz. Had these vehicles been included in the baseline data, the fleet averaged CO_2 emissions of these brands would have increased by 1.4% and 1.7%, respectively. This result shows the importance of the adoption of a measure to address the CO_2 emissions from these vehicles.

- **The number of zero- and low-emission vehicles was insignificant and limited to a few pilot models:** During the first reporting period, a total of 47 zero-emission trucks were registered by the top-selling brands in the regulated groups. There were no low-emission trucks—defined as having less than half the baseline CO_2 emissions of the respective subgroup—registered. The low market penetration of zero-emission trucks had virtually no impact on the manufacturers' fleet average emissions. The zero- and low-emissions vehicle factor, designed to incentivize the adoption of these vehicles, would reduce the reported emissions in less than 0.1% if they were to be fully accounted.
- **The variations in CO_2 emissions across manufacturers can be explained by different rates of technology adoption:** DAF Trucks and MAN had the most efficient engines, with an average engine efficiency of 42.6% over the WHTC and the top performing models having efficiencies over the WHTC of around 44%.

  Natural gas engines, preferred by IVECO, had much lower thermal efficiencies than diesel. The best performing model, an IVECO engine, only reached 38.1% efficiency over the WHTC. At the vehicle level, this low engine efficiency largely offsets the potential gains from the lower carbon content of natural gas. For long-haul tractor-trailers (5-LH), IVECO's new natural gas vehicles emitted more than Scania's new diesel vehicles.

  Aerodynamics were the main driver of Scania's good CO_2 performance, reporting the lowest average air drag values at 4.63 m^2 for long-haul tractor-trailers (5-LH)—around 20% lower than the average of other manufacturers. DAF trucks had the highest average air drag for long-haul tractor-trailers, which was compensated for by better engine efficiency, leading to fleet average CO_2 emissions just below their reference value. On the other hand, all brands performed at similar levels in all subgroups for tire rolling resistance and light-weighting technologies.

The different technology pathways followed by manufacturers, and the high spread in CO_2 emissions between them, indicate that there are a significant number of technologies available to improve the CO_2 emissions of trucks. To ensure that the monitoring and reporting data is an accurate representation of the performance of trucks on the road, and that the CO_2 standards achieve their goals of reducing fleet-wide emissions, closer attention must be placed on the existing certification and reporting tolerances and flexibilities. Diligent market surveillance and enforcement activities—through conformity of production and the in-service verification testing—are fundamental to assuring the trustworthiness of the reported data.

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