THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

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Within reach

The 2025 CO_2 targets for new heavy-duty vehicles in Europe

EAMONN MULHOLLAND, HUSSEIN BASMA, PIERRE-LOUIS RAGON, AND FELIPE RODRÍGUEZ

International Council on Clean Transportation
Fasanenstraße 85
10623 Berlin

communications@theicct.org | www.theicct.org | @TheICCT

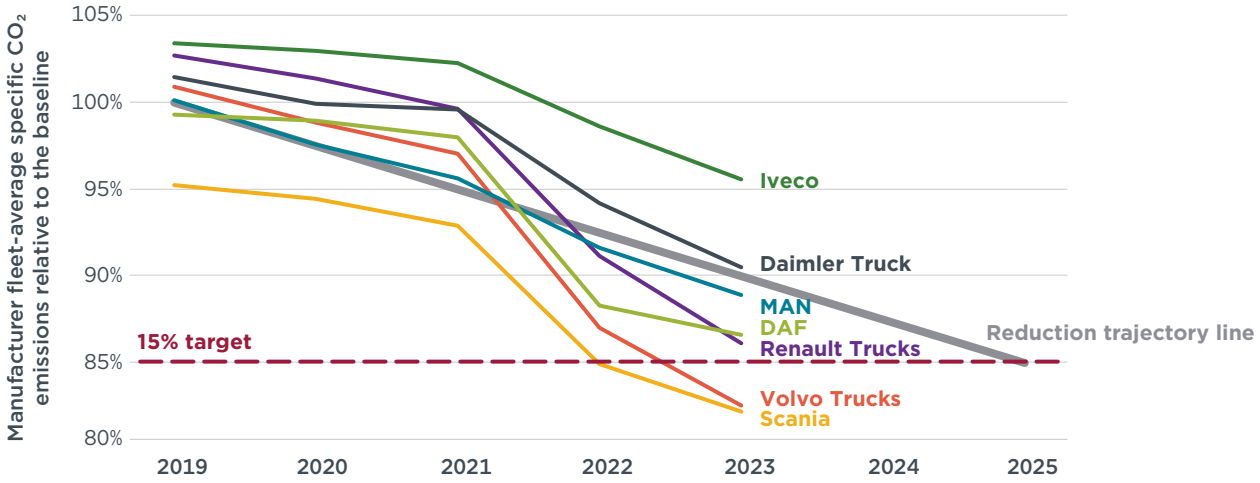
EXECUTIVE SUMMARY

Manufacturers of heavy-duty vehicles (HDVs) in the European Union face a CO_2 target for the first time in 2025. The average CO_2 emissions of most HDVs first registered in the 2025 reporting period (between July 1, 2025, and June 30, 2026) must be at least 15% lower than the average of all HDVs first registered in the 2019 reporting period (July 1, 2019–June 30, 2020).

This report considers the progress manufacturers have made toward this 15% target to date (Figure ES1) and the efforts required to achieve the target. We determine the effort of compliance required by establishing a status quo based upon the latest official CO_2 data from internal combustion vehicles (covering those first registered up to the 2023 reporting period) and the latest data from national statistics on the sale of zero-emission (ZE) HDVs (covering those first registered up to the 2024 reporting period).

Figure ES1

Fleet-average specific CO_2 emissions for HDV manufacturers, 2019–2023

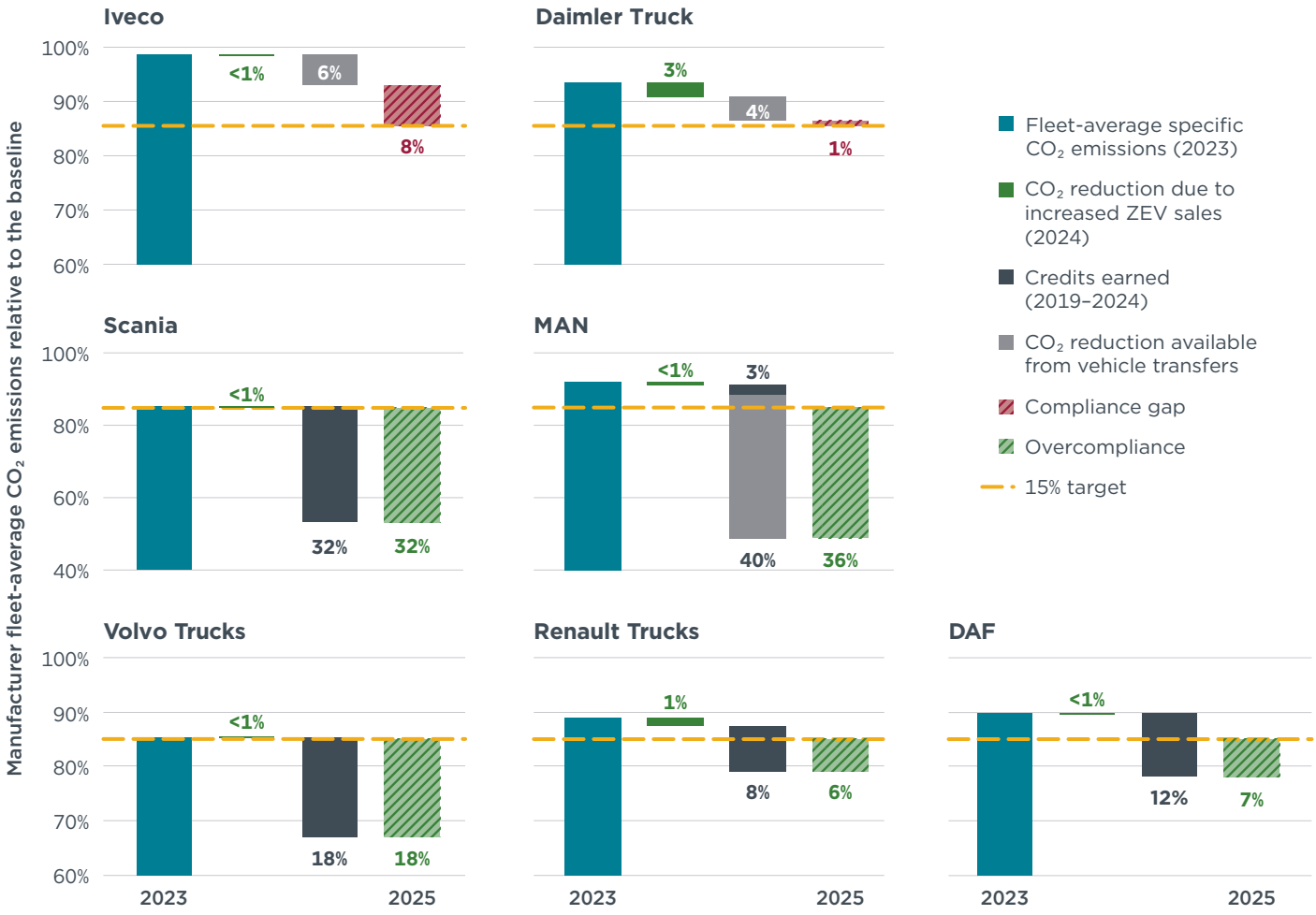


Note: Values are calculated using the original reference values as reported in (EU) 2021/781.

Based on this status quo and including the compliance flexibilities available in the CO_2 standards, we assess that **five out of the seven top manufacturers in the European Union will be compliant with their 15% target without making any further improvements to their fleet** (Figure ES2). Only Daimler Truck and Iveco have a compliance gap with the 15% target in 2025.

Figure ES2

Fleet-average specific CO_2 emissions for HDV manufacturers and the gap to compliance for their 2025 targets



Note: Values have been adjusted to account for the update to the reference emissions expected in 2025.

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Scania and Volvo Trucks will comfortably meet the 2025 target. Both of these manufacturers have already reduced their fleet-average CO_2 emissions by 15% in the 2023 reporting period. By selling the same vehicle technologies sold up to then, they will be compliant with the 2025 targets.

Renault Trucks and DAF will also meet the 2025 target thanks to early credit accumulation. Both manufacturers have amassed a significant number of early credits in the 2019–2023 period due to the low average CO_2 emissions of their vehicles sold during this period. These manufacturers could rely on the accumulated credits to meet the 15% target without making any further improvements to their vehicles between 2023 and 2025.

MAN can already meet the 2025 target by relying on compliance flexibilities. The CO_2 standards allow for connected manufacturers to transfer HDVs as a compliance flexibility. This allows Volvo Trucks and Renault Trucks (both part of Volvo Group) and MAN and Scania (both part of the TRATON Group) to freely transfer vehicles amongst each other. Scania has accumulated the largest share of credits of all manufacturers. If MAN were to transfer all its vehicles to Scania, effectively pooling their emissions, the credits already earned by Scania would be enough for MAN to also meet the 2025 target.

Daimler Truck will have to moderately improve its conventional vehicles or increase its ZE HDV share to reach the 2025 target. Non-connected manufacturers can trade a limited number of ZE HDVs amongst each other, and this flexibility can help Daimler Truck get to a 14% reduction relative to 2019 based on its status quo. To reach the 15% reduction, Daimler Truck would either have to increase its ZE HDV sales share to 3.4% in 2025 (up from 2% in 2024) or improve its diesel technology to represent the upper 50th percentile of its vehicles' performance sold up to June 2024. A combination of these measures is expected.

Iveco faces one of the more challenging paths to compliance among manufacturers. To avoid penalties in 2025, Iveco must also seek to maximize the ZE HDV transfer flexibility. In addition, it will have to improve the average performance of its conventional trucks to the 20th percentile registered in 2023 and also increase its ZE HDV sales share of vehicles covered under the scope of the CO_2 standard to around 1.5%, corresponding to sales of about 210 ZE HDVs. Iveco sold just 16 ZE HDVs in scope of the standards in 2024.

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1. INTRODUCTION

The heavy-duty vehicle (HDV) carbon dioxide (CO_2) standards in Europe require manufacturers to reduce their fleet-average CO_2 emissions from most of their new HDVs by 15% in 2025 relative to 2019 (European Parliament and Council, 2024).[1]

Each year, the European Environmental Agency (EEA) publishes data on the official CO_2 performance of newly registered HDVs that is used to determine the progress of each manufacturer towards their CO_2 emission targets. To date, the EEA has published 5 years' worth of CO_2 certification data, covering the period July 2019 through June 2024. A summary of the state of the market up to June 2022 can be found in Musa et al. (2024).

This paper examines manufacturers' progress in reducing the CO_2 emissions of their fleets to date to determine how close they are to meeting the 15% target in 2025. The paper uses the latest CO_2 certification data from the EEA up to June 2024 alongside market data on the sale of zero-emission (ZE) HDVs up to June 2025. It also explores the different compliance pathways manufacturers may pursue to meet their 15% CO_2 reduction target in 2025. It focuses on the top 7 HDV manufacturers by market share: Daimler Truck (19% of the EU truck market in 2024), Volvo Trucks (15%), MAN (14%), Scania (14%), Iveco (12%), DAF (11%), and Renault Trucks (8%).[2]

This paper is structured as follows. We first provide a summary of changes in the fleet-average CO_2 emissions of truck manufacturers since 2019, based on the latest certification data from the EEA. We next assess the state of internal combustion vehicle technologies and their recent market developments. The following section analyzes the market development of ZE HDVs in Europe up to June 2025. We proceed to discuss potential compliance pathways for each manufacturer to achieve their 2025 targets via ZE HDV adoption and improvements to conventional vehicles. We conclude with a summary of our findings.

1 Unless otherwise stated, all years in this paper refer to mid-year to mid-year reporting periods. For example, the 2019 reporting period runs from July 2019 through June 2020. There are also targets of 43% for 2030, 64% for 2035, and 90% for 2040; however, this paper focuses on the 15% target for 2025.

2 To date, Iveco has reported as two separate entities: Iveco S.p.A and Iveco Magirus. In January 2025, Iveco Group gave up control of Magirus, which was acquired by German private equity holding firm Mutares. Magirus predominantly produces firefighting vehicles, which are exempt from the CO_2 standards. As such, we only consider Iveco S.p.A., referred to as Iveco hereafter.

2. SUMMARY OF MANUFACTURERS' PROGRESS TOWARD THE 2025 CO2 EMISSIONS REDUCTION TARGET

2.1. OVERVIEW OF COMPLIANCE STRATEGIES

Europe's CO_2 standards require manufacturers to reduce the CO_2 emissions of most of their new vehicles by 15% in 2025 relative to 2019.[3] Each vehicle group is assigned a common reference emissions value based on the average CO_2 emissions of all vehicles in that group sold across all manufacturers in 2019. Each manufacturer's unique target is then calculated by applying a 15% reduction to each reference emission value and weighted by the manufacturer's sales share along with a factor based on the average milage and payload of the vehicle group (European Parliament and Council, 2024). For simplicity, we report CO_2 reductions as percentages relative to the 2019 baseline.

Compliance efforts to meet 2025 targets can be split into two distinct paths: improving the efficiency of conventional vehicles (i.e., diesel and natural gas vehicles) and increasing sales shares of ZE HDVs (i.e., battery electric, hydrogen fuel-cell, and hydrogen internal combustion engine vehicles).[4] Manufacturers have so far relied heavily on improving the performance of conventional vehicles as their main strategy of CO_2 emissions reduction. According to the official EEA data, from 2019 to 2023, manufacturers cut their fleet-average CO_2 emissions by 6%–13% mainly by improving conventional vehicle technologies, while ZE HDV sales contributed up to 6% of the reductions for some truck manufacturers (Figure 1).

3 The CO_2 target of 15% only applies to HDVs with a 4x2 axle configuration and a gross vehicle weight above 16 tonnes, and vehicles with a 6x2 axle configuration of any gross vehicle weight.

4 Hydrogen combustion vehicles are only considered ZE HDVs so long as their CO_2 emissions fall below 3 g CO_2/tonne-km.

Figure 1

CO_2 emissions reduction relative to the baseline for major manufacturers in the European Union up to the 2023 reporting period

Notes: The 2023 reporting period is from July 2023 to June 2024. The reference emissions are universal for all manufacturers and are based off the CO_2 emissions of vehicles across all manufacturers in 2019. This results in some manufacturers having above 100% in 2019 if their CO_2 emissions are higher than the average of all vehicles sold in that year, and vice versa. Values are calculated using the original reference values as reported in Commission Implementing Decision (EU) 2021/781 (2021).

Technologies to improve internal combustion vehicles include improvements in the efficiency of combustion engines and transmission systems, improvements in cabin aerodynamics, lower-friction tires, and advanced driver assistance systems (ADAS). A detailed look into how each manufacturer is performing concerning each of these technologies is presented in Section 3.

Sales of ZE HDVs remain limited but grew steadily up to June 2025, the end of the 2024 reporting period. According to certification data on new registrations from the EEA, 0.1% of the HDV categories covered under the scope of the standards were ZE in 2021, rising to 0.6% in 2022 and 1.1% in 2023. According to supplementary market data, these shares rose further to 1.7% in 2024.[5]

Most sales of ZE HDVs have been by two of the seven top manufacturers, Volvo Trucks and Renault Trucks. By June 2024, Volvo Trucks and Renault Trucks had reduced their fleet-average specific CO_2 emissions by 5.2 and 5.6 percentage points, respectively,

5 Supplementary data for the calendar year 2024 and January–June 2025 were supplied by Dataforce.

due to increased ZE HDV deployment. Iveco and Daimler Truck, for their part, have reduced their emissions by 1.9 and 2.1 percentage points, respectively, due to increased sales of ZE HDVs. In the case of Iveco, this has been almost exclusively through sales of ZE HDVs that fall outside the scope of the CO_2 standards but contribute to compliance through the zero- and low-emissions vehicle factor (see Section 2.2.2). For all other manufacturers, ZE HDV sales contributed less than 1% of emission reductions (Figure 1). Every major truck manufacturer in Europe now offers a broad portfolio of ZE HDV models, with more than 100 battery electric models and 20 fuel-cell electric models available in 2024 (European Commission, 2025b).

2.2. COMPLIANCE FLEXIBILITIES

2.2.1. Credits

Since 2019, manufacturers have been rewarded with early credits by outperforming the reduction trajectory line—a straight line drawn from 100% in 2019 (i.e., the reference period) to 85% in 2025 (i.e., the 15% target). Credits earned between 2019 and 2024 can be used to offset any debts accrued for non-compliance with the 2025 target and thus avoid potential penalties. These credits can only be used in 2025 and become invalid thereafter.

The number of credits in a given year is calculated by multiplying the number of vehicles registered per manufacturer by the difference between the reduction trajectory line and the manufacturer's average CO_2 emissions. Manufacturers are not penalized for their emissions performance until 2025. A more detailed description of this system is provided in our latest policy update on the HDV CO_2 standards (Mulholland, 2024).

Based on EEA data up to June 2024, five of the seven truck manufacturers—Scania, Volvo Trucks, DAF, MAN, and Renault Trucks—are below this reduction trajectory line and thus on track to comply with the 2025 CO_2 reduction targets while also accumulating early credits (Figure 2). Scania and Volvo Trucks both achieved fleet-average CO_2 reductions of over 15% in 2023, even without factoring in the early credits accrued.

Figure 2

Fleet-average specific CO_2 emissions and accumulated credits relative to the reduction trajectory line for each major manufacturer over the 2019–2023 reporting periods

Note: The yellow line represents the reduction trajectory line, under which a manufacturer earns early credits.

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2.2.2. ZLEV factor

Manufacturers can benefit from the sale of ZE HDVs in two ways: once from the lowering of the fleet-average specific CO_2 emissions, and a second time through the zero- and low-emission vehicle (ZLEV) factor.

The ZLEV factor offers an additional reduction in the manufacturer's fleet-average CO_2 emissions of up to 3% based on the share of ZE HDVs sold. HDVs that are not regulated by the standards (i.e., outside of Vehicle Energy Consumption calculation TOol [VECTO] groups 4, 5, 9, and 10) can only contribute a reduction of up to 1.5%.

From 2019 through 2024, the ZLEV factor is calculated using the following formula:

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

Where:

V is the total number of regulated HDVs (groups 4, 5, 9, and 10);

V_{conv} is the total number of regulated HDVs with conventional powertrains;

$ZLEV_{in}$ is the number of ZE HDVs within the regulated groups multiplied by 2;[6] and

ZEV_{out} is the resulting number of ZE HDVs outside of the regulated groups multiplied by 2 (ZEV_{out} cannot exceed 1.5% the value of V_{conv}).[7]

A manufacturer's fleet-average CO_2 emissions are reduced by their final ZLEV factor. The ZLEV factor achieved between 2019 and 2024 for each manufacturer is presented in Section 4.

2.2.3. Vehicle transfers

Vehicle transfers were introduced to the CO_2 standards in the revision made to the regulation in 2024 (European Parliament and Council, 2024). This allows a manufacturer to report another entity's vehicle as their own to comply with their CO_2 target. Different rules apply for conventional vehicles and ZE HDVs.

For conventional vehicles, manufacturers that share a parent company can transfer an unlimited number of vehicles between themselves. This flexibility allows manufacturers to share the burden of compliance across all entities covered by a parent manufacturer; in theory, a manufacturer could trade all its vehicles to a connected entity, effectively allowing it to pool emissions with another producer. This flexibility allows unlimited trading between Volvo Trucks and Renault Trucks (under Volvo Group) and Scania and MAN (under the TRATON Group).

Manufacturers not connected by a parent company can only trade ZE HDVs limited to 5% of the recipient's sales volume in any given reporting period. For example, consider Manufacturer A, which produces a high volume of ZE HDVs and does not need all of them to comply with its 15% target in 2025, and Manufacturer B, which produces 10,000 HDVs per year and is under-compliant and risks penalties. Manufacturer B may receive up to 500 of the ZE HDVs registered by Manufacturer A to help meet its 15%

6 Non-ZE HDVs with less than half the CO_2 emissions of their group's reference value qualify as a low-emission vehicles and receive a multiplication of between 1 and 2 depending on their emissions. No low-emission vehicles have yet been registered as part of the official certification data covering the period up to June 2024.

7 The double weighting for ZEV_{out} was removed in Regulation (EU) 2024/1610, which takes effect from the 2024 reporting period.

target. While not specified in the legislation, it is expected that Manufacturer B would pay a premium to Manufacturer A to use its vehicles for compliance purposes.

Transfers will only apply from 2024 onwards, and information on transfers between manufacturers will not be available until the publication of 2024 reporting period data by the EEA.

2.2.4. Emissions debt limit

Between 2025 and 2029, manufacturers will accrue debts if they have not reduced their CO_2 emissions by 15%. If a manufacturer does not have enough credits to offset these debts, they must pay an excess CO_2 emissions premium for non-compliance.

However, manufacturers can make use of an additional flexibility mechanism, the emissions debt limit, which allows manufacturers to borrow emissions worth up to 5% of the target. This allows a manufacturer to under-comply with the 15% reduction target by up to 5 percentage points cumulatively during the period 2025–2029 without paying a penalty, so long as they eventually compensate these debts with credits earned before 2030. For example, if a manufacturer only reduces their emissions by 10% in 2025, they will accrue debts up to 5% but will not have to pay a penalty. If they can earn credits worth 5% of the target before 2030, then they can use these credits to retroactively write off the debts accrued in 2025.

2.3. CHANGES TO THE BASELINE PERIOD

In April 2022, VECTO—a simulation tool that is used to certify the CO_2 emissions from HDVs—was updated to version 3.3.11.2675 (hereafter, VECTO 3.3). While VECTO is routinely updated, this version saw sizeable changes intended to more accurately reflect the real-world use of HDVs by updating how the long-haul cycle, gear shift strategy, and ADAS are accounted for. These changes resulted in significant reductions in the certified CO_2 emissions of HDVs without any actual vehicle improvements: the CO_2 emissions from a truck simulated using VECTO 3.3 and later would be about 3% less than those of the same truck simulated using a previous version of VECTO.

Compliance with CO_2 standards is measured by comparing a fleet's average CO_2 emissions in a given year with the reference emissions in 2019. As the reference emissions in 2019 were calculated using a version of VECTO older than VECTO 3.3, this grants an artificial CO_2 emission reduction to vehicles simulated using this version and its later iterations.

To correct this discrepancy, the European Commission plans to update the reference emissions from 2025 onwards by requesting that all manufacturers re-simulate their HDVs registered in the reference year of 2019 with VECTO 3.3 (European Commission, 2025a). However, since the change in VECTO occurred in 2022, this means that HDVs certified and registered in the years 2022, 2023, and 2024 will receive a CO_2 emissions reduction benefit, potentially resulting in credits, as they are compared with higher reference values calculated using the older version of VECTO.

Using the EEA's monitoring and reporting data, and considering identical vehicles simulated with VECTO versions both before and after this update, Table 1 presents the estimated impacts of this update on the reference emissions.[8]

8 We considered only vehicles with the same manufacturer, model name, VECTO group, curb mass, and ADAS and identical certification numbers for the engine, gearbox, torque converter, retarder, angle drive, axle gear, air drag, and all axles.

Table 1

Original and estimated updated reference emissions in the HDV CO_2 standards

VECTO group	Original reference emissions (g CO_2/tonne-km)	Estimated new reference emissions (g CO_2/tonne-km)	Difference
4-LH	105.96	100.86	-4.8%
4-RD	197.16	196.45	-0.4%
4-UD	307.23	308.19	0.3%
5-LH	56.60	54.63	-3.5%
5-RD	84.00	83.41	-0.7%
9-LH	65.16	63.26	-2.9%
9-RD	110.98	110.57	-0.4%
10-LH	58.26	56.58	-2.9%
10-RD	83.26	83.24	0.0%

3. CONVENTIONAL TRUCK TECHNOLOGY

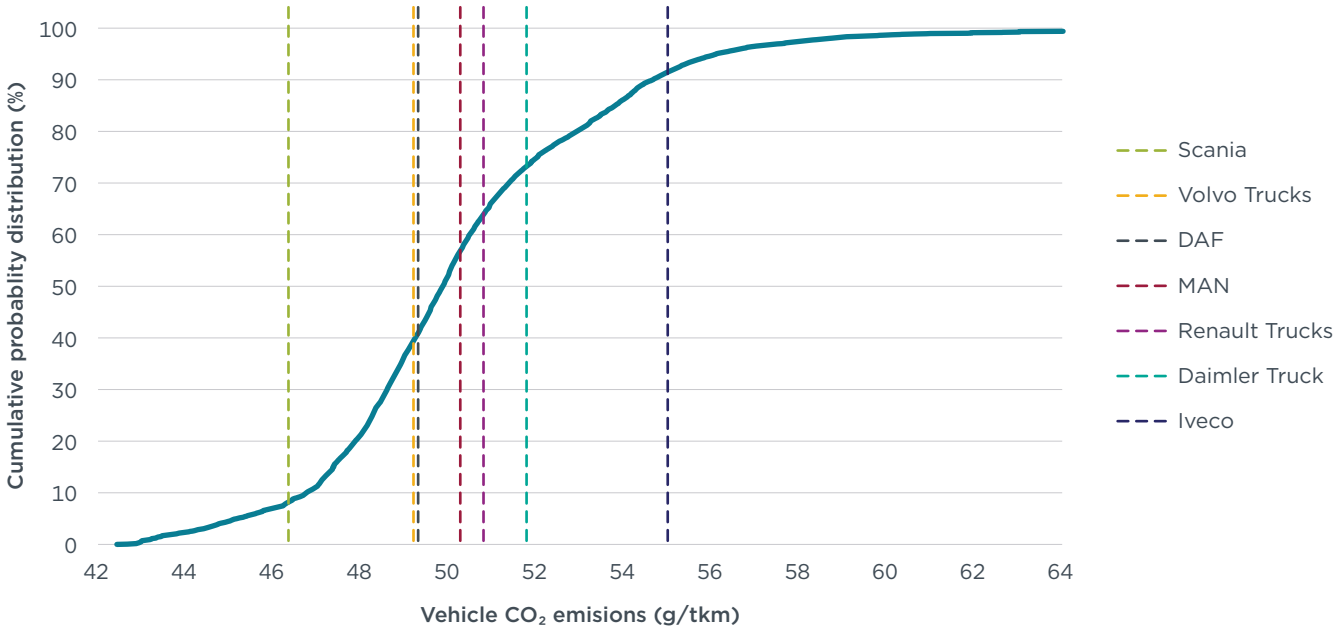
The certification data published by the EEA cover the fuel economy and CO_2 performance of most newly registered HDVs in Europe up to June 2024. It also includes information on vehicle components that are key determinants in the overall CO_2 emissions and fuel consumption of the vehicle, such as engine performance, aerodynamic drag, tire rolling resistance coefficients, and ADAS.

In these certification data, HDVs are split into different vehicle categories based on their characteristics. This section compares key determinant components in Europe's dominant vehicle group, 5-LH (4x2 long-haul tractor-trailers), which accounted for 75% of all HDV sales covered under the scope of the CO_2 standards in 2023 (EEA, 2025).

Figure 3 shows the cumulative probability distribution of the CO_2 emissions for VECTO group 5-LH, highlighting the manufacturer's sales-weighted average. On average, Scania trucks emit the least amount of CO_2 in this group (46.4 g CO_2/tonne-km [tkm], 7% below the fleet median), while Iveco's emit the most (55 g CO_2/tkm, 10.3% above the fleet median).

Figure 3

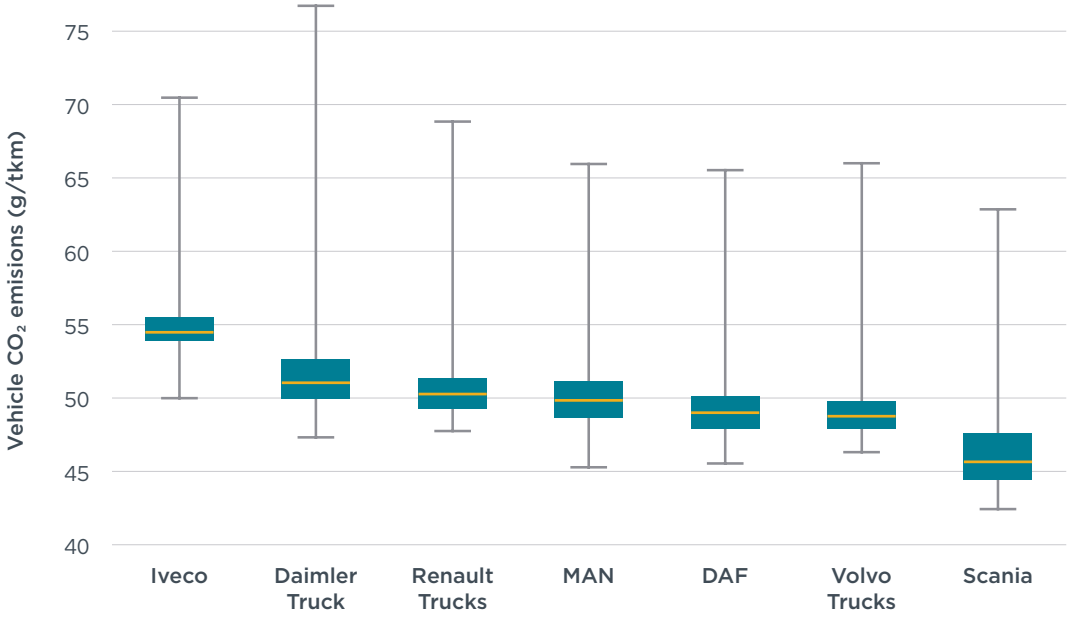
Cumulative probability distribution of the vehicle CO_2 emissions of VECTO group 5-LH in the 2023 reporting period, considering all truck manufacturers



Note: The vertical lines correspond to the manufacturer's sales-weighted average.

Manufacturers' HDV CO_2 emissions are generally concentrated in a narrow band across their fleet of 5-LH vehicles sold (Figure 4), but their best-in-class truck models show 7%–10% lower CO_2 emissions than their fleet median.

Figure 4
Whisker plot of the vehicle CO_2 emissions per truck manufacturer of VECTO group 5-LH in the 2023 reporting period



Notes: The whiskers show the distribution's minimum and maximum, the box shows the first and third quartiles, and the yellow line denotes the median.

The wide variation in CO_2 emissions shown in Figure 4 can be explained by differences in four main components of an HDV:

1. Internal combustion engine and transmission technology;
2. Cabin design and aerodynamics;
3. Tire technology; and
4. ADAS.

This section compares the performance of each manufacturer across these technologies in their diesel- and natural gas-powered HDVs, focusing on group 5-LH vehicles. For each component, we first focus on the performance according to the official certification data available from the EEA covering the period up to 2023 and then present any notable technology advances in these components over the period 2023–2025, based on public announcements from manufacturers.

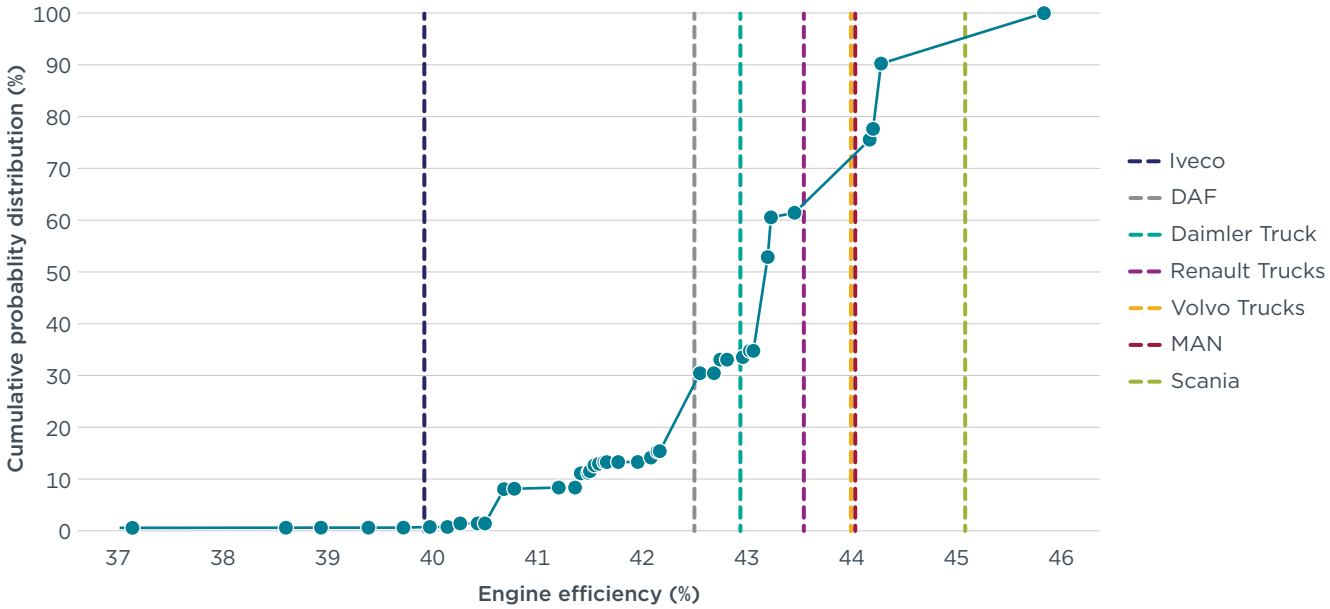
3.1. INTERNAL COMBUSTION ENGINE AND TRANSMISSION TECHNOLOGY

3.1.1. Status in 2023

Despite the technological maturity of internal combustion engines, there was wide variation in the efficiency of engines deployed in HDVs over the 2023 reporting period (Figure 5). The average across all HDVs sold by the top 7 manufacturers stood at 43.2%, with Scania leading with 45.1% average efficiency and Iveco ranking lowest with 39.9%. Very few engine models exceeded 45% in the 2023 reporting period.

Figure 5

Cumulative probability distribution of the average engine efficiency of VECTO group 5-LH trucks tested over the World Harmonized Transient Cycle in 2023



Note: The vertical lines correspond to the manufacturer's sales-weighted average.

Table 2 summarizes the fleet-average, manufacturer-average, and manufacturer best-in-class average engine efficiency tested over the WHTC. The fleet-wide average engine efficiency was 42.7%, with Scania recording the highest manufacturer average, at 45.1%, and Iveco the lowest, at 39.1%. Scania's best-in-class engines had an efficiency of 45.8%, followed by Volvo Trucks and Renault Trucks at 44.3% and MAN at 44.2%.

Table 2

Fleet-average, manufacturer-average, and manufacturer best-in-class average engine efficiency of VECTO group 5-LH trucks tested over the WHTC in 2023

Manufacturer	Manufacturer average	Manufacturer best-in-class	Fleet average
DAF	42.5%	42.5%	
MAN	44.0%	44.2%	
Iveco	39.9%	40.7%	
Volvo Trucks	44.0%	44.3%	43.2%
Daimler Truck	42.9%	43.2%	
Renault Trucks	43.5%	44.3%	
Scania	45.1%	45.8%	

Iveco's relatively poor performance may be partly attributed to their higher share of natural gas vehicle sales compared with other manufacturers. Natural gas engines are generally less efficient than diesel engines, and almost 8% of Iveco's 5-LH sales in 2023 were fueled by natural gas. This is down from almost 21% in 2022, which explains Iveco's improved performance when it comes to the average engine efficiency. The only other manufacturers that sold natural gas 5-LH vehicles were Scania and Volvo, with 5-LH sales shares of 0.33% and 1%, respectively.

3.1.2. Recent engine and transmission developments

Public announcements from manufacturers indicate that many have improved their best-in-class engine efficiencies, which may improve their performance beyond that reported in the EEA's certification data.

Scania and MAN, under the TRATON Group, have each announced engines with peak efficiencies in excess of 50%, with Scania claiming a combined powertrain fuel savings of 8% from this engine alone (MAN, n.d.; Scania, 2021).

Iveco introduced the XCursor 13 engine as part of its model year 2024 product line-up. Through an optimized transmission and engine weight reduction of 10%, Iveco estimates a CO_2 emissions reduction of 7% compared with its predecessor (Iveco S.p.A., 2025).

Daimler Truck started to deliver its OM471 engine to new trucks in late 2022. The manufacturer estimates a 4% reduction in fuel consumption through advanced turbocharging and transmission (Daimler Truck, 2022). The engine is deployed in Daimler Truck's Actros and Arocs models.

In mid-2024, Volvo launched a new 17-liter engine, primarily intended for demanding applications rather than long-haul operations but compatible with the manufacturer's FH16 model. This engine can achieve an estimated 5% reduction in fuel consumption compared to its predecessor, signaling continued development across Volvo Trucks's engine portfolio (Volvo Trucks, 2024b).

Table 3 summarizes these latest engine and transmission technology developments.

Table 3
Latest engine and transmission technology for long-haul tractor trailers

Manufacturer	Engine	Transmission	Description	Fuel savings compared with previous generation
DAF	New PACCAR MX13	Automated transmission with new axle ratios	~150 rpm engine down-speeding; Miller valve timing.	3%–10%
IVECO	New X-Cursor 13	Generation 2 Traxon automated gearbox	10% weight reduction	N/A
MAN	D30 PowerLion	TipMatic 14 semi-automatic transmission	> 50% peak efficiency	N/A
Daimler Truck	OM471	–	Advanced turbocharging	4%
Renault Trucks	DE13TC	–	Turbo compound	10%
Scania	Super 13-L	Opticruise gearbox with R756 rear axle	50% peak efficiency	8%
Volvo Trucks	New D17	N/A	N/A	5%

European truck manufacturers have also recently introduced updated transmissions designed to optimize powertrain efficiency and reduce fuel consumption, particularly in long-haul applications. DAF and Iveco have adopted new generations of the ZF TraXon automated gearbox, which enables down-speeding and reduced vehicle weight. MAN has introduced the TipMatic 14, a lighter 14-speed semi-automatic transmission paired with the D30 engine, improving drivetrain efficiency. Scania's updated Opticruise gearbox, combined with the R756 rear axle, supports low engine speeds and efficient torque delivery.

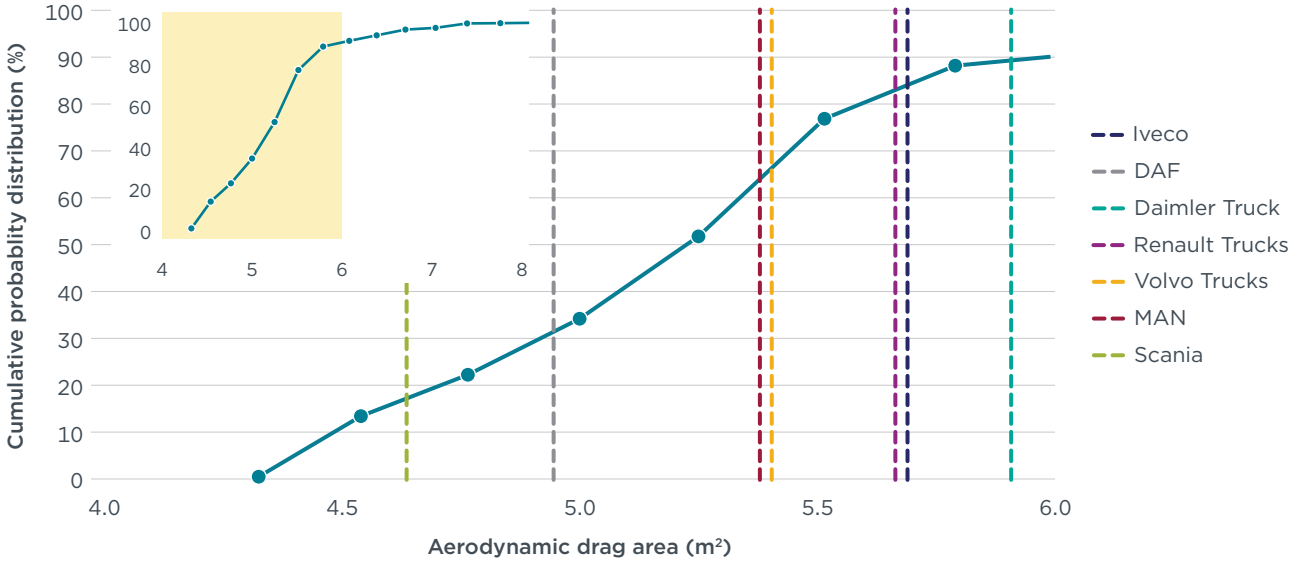
3.2. CABIN DESIGN AND AERODYNAMICS

3.2.1. Status in 2023

Reducing aerodynamic drag can significantly reduce CO_2 emissions. This is especially the case for long-haul trucks that travel consistently at high driving speeds, such as group 5-LH vehicles, which operate predominantly on motorways.

Figure 6 shows the distribution of the vehicle aerodynamic drag area for group 5-LH trucks from all truck manufacturers.[9] The vertical lines correspond to the manufacturer's sales-weighted average. Scania has consistently reported a superior aerodynamic drag performance compared to its competitors, with a sales-weighted average aerodynamic area around the 20th percentile of the fleet-wide distribution across all manufacturers. This was found to be one of the main reasons behind Scania's better CO_2 performance since the 2019 reporting period (Ragon & Rodríguez, 2021).

Figure 6
Cumulative probability distribution of the vehicle aerodynamic drag area of VECTO group 5-LH trucks in the 2023 reporting period



Note: The vertical lines correspond to the manufacturer's sales-weighted average.

Table 4 shows the fleet-average, manufacturer-average, and manufacturer best-in-class aerodynamic drag area for group 5-LH trucks. Scania's average performance (4.9 m^2) and best-in-class performance (4.3 m^2) were 15% and 20% lower than the fleet-wide average, respectively. Daimler Truck recorded the highest manufacturer-average aerodynamic area at around 5.9 m^2, 9% above the fleet-wide average.

9 As part of the reporting procedures and to avoid disclosing commercially sensitive information, manufacturers are only required to declare the range of aerodynamic values which their cabin falls under. For example, a manufacturer may report an air drag value of A12, which means their coefficient of drag by the area (otherwise known as the CdXA values) is between 4.88 m^2 and 5.12 m^2. A list of these ranges is available in Part C of Annex I to Regulation (EU) 2018/956. We take the middle point of these ranges when determining a manufacturer's CdXA value.

Table 4

Fleet-average, manufacturer-average, and manufacturer best-in-class aerodynamic drag area of VECTO group 5-LH trucks in the 2023 reporting period

Manufacturer	Manufacturer average (m^2)	Manufacturer best-in-class (m^2)	Fleet average (m^2)
DAF	4.9	4.3	5.4
MAN	5.4	4.3	
Iveco	5.7	5.5	
Volvo Trucks	5.4	5.0	
Daimler Truck	5.9	5.3	
Renault Trucks	5.7	5.3	
Scania	4.6	4.3	

DAF significantly improved the aerodynamic drag of its vehicles, from an average value of 5.9 m^2 in 2021 to 4.9 m^2 in 2023, following the introduction of its new XF, XG, and XG+ series in 2021. The new cabin is 160 mm longer, along with other features including air fenders, aero seals, under hood aerodynamic design improvement, side skirts, and improved windscreen design. DAF reported resulting fuel savings of 3%–7% (DAF, n.d.).

Also in 2021, Scania announced a new extended version of its R and S cabins, which were elongated in the front by 270 mm. This is expected to improve their aerodynamic drag (Gowans, 2021).

3.2.2. Recent product developments in aerodynamics

With the introduction of Regulation (EU) 2021/535, which set the technical specifications for the type-approval of vehicles in relation to the General Safety Regulation (EU) 2019/2144, manufacturers have been granted an allowance of 80–900 mm to the length of their cabins as of July 2022. Manufacturers have since made several notable changes to their vehicle designs, including the launch of elongated cabins and the replacement of exterior mirrors with camera monitoring systems, both of which have the potential to reduce air drag.

Daimler Truck introduced its ProCabin for its Actros L model, featuring an 80 mm increase in length. Scheduled to go into production at the end of 2024, the new cabin design is expected to achieve a reduction in fuel consumption of 3% (Daimler Truck, 2024).

Volvo introduced the FH Aero in 2024, with production planned for 2025. The model features an elongated cabin design with an extra 240 mm of length and a camera monitoring system to replacing exterior mirrors. Volvo claims this new design can achieve a reduction in fuel consumption of 5% (Volvo Trucks, 2024a).

Iveco's latest S-Way model employs integrated deflectors, corner fins, and a reshaped roof, achieving a 13.5% reduction in air drag and a 3% reduction in fuel consumption (Iveco S.p.A., n.d.-b).

DAF released a new generation of trucks in 2024 with improvements to the aerodynamics, claiming a 3% reduction in fuel consumption owing to both aerodynamic improvements and driveline enhancements (DAF, 2024).

These aerodynamics technology developments are summarized in Table 5.

Table 5

Latest aerodynamics technology for long-haul tractor trailers

Manufacturer	Newest cabin	Front length extension (mm)	Fuel savings compared to previous generation
DAF	XF/XG/XG+	160	3%
IVECO	S-Way 2025		3%
Daimler Truck	ProCabin	80	3%
Volvo Trucks	FH Aero	240	

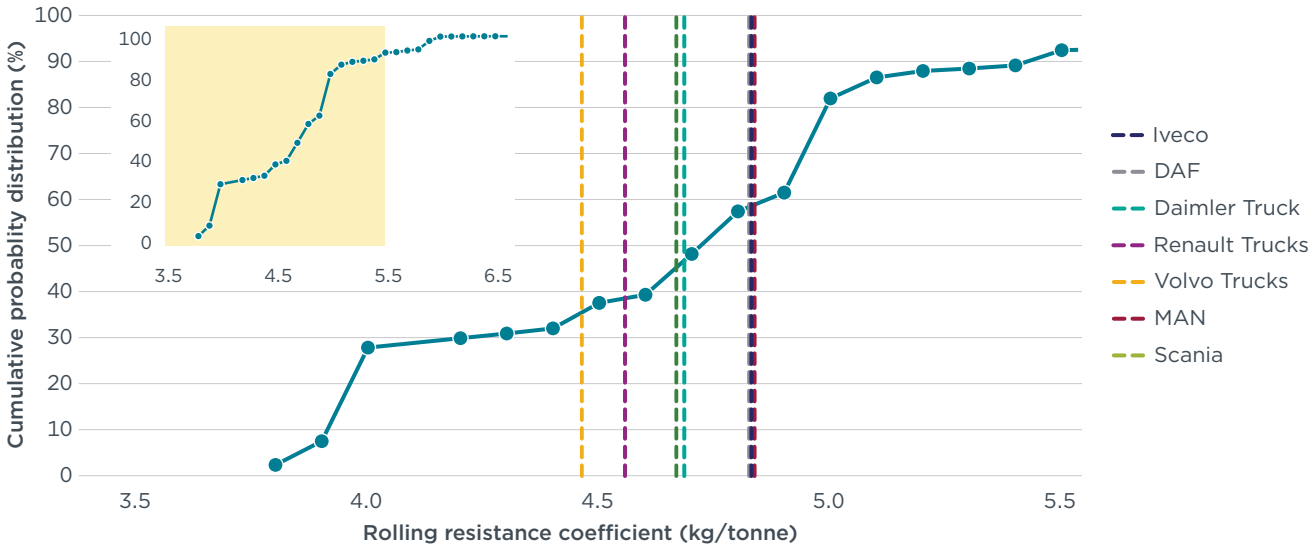
3.3. TIRE TECHNOLOGY

3.3.1. Status in 2023

Tire rolling resistance can substantially affect vehicle fuel consumption and CO_2 emissions. This is more evident in heavy vehicles, given the proportional relationship between vehicle weight and the frictional force due to tire rolling resistance. Figure 7 and Table 6 show the fleet-wide and manufacturer-specific rolling resistance data. While tire technology is not developed directly by HDV manufacturers, manufacturers can use tires with lower rolling resistance when certifying the CO_2 emissions of their vehicles.

Figure 7

Cumulative probability distribution of the tire rolling resistance coefficient for VECTO group 5-LH trucks in the 2023 reporting period



Note: The vertical lines correspond to the manufacturer sales-weighted average.

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As shown in Figure 7, Volvo and Renault have been using more efficient tires to certify their trucks, with around 3.5% lower rolling resistance than the fleet-wide average for group 5-LH. As shown in Table 6, all OEMs deployed the same best-in-class tires across some VECTO group 5-LH truck models, with a rolling resistance coefficient of 3.8 kg/tonne, which is 20% lower than the fleet average.

Table 6

Fleet-average, manufacturer-average, and manufacturer best-in-class rolling resistance coefficient for VECTO group 5-LH trucks in the 2023 reporting period

Manufacturer	Manufacturer average (kg/tonne)	Manufacturer best-in-class (kg/tonne)	Fleet-average (kg/tonne
DAF	4.8	3.8	
MAN	4.8	3.8	
Iveco	4.8	3.8	
Volvo Trucks	4.5	3.8	4.7
Daimler Truck	4.7	3.8	
Renault Trucks	4.6	3.8	
Scania	4.7	3.8	

3.4. ADVANCED DRIVER ASSISTANCE SYSTEMS

3.4.1. Status in 2023

ADAS technologies can reduce CO_2 emissions by optimizing driving strategies. For each new certified vehicle, manufacturers can declare the use (or non-use) of four ADAS technologies in VECTO: eco-roll, predictive cruise control (PCC), active front grill, and pulse and glide.[10] For eco-roll and PCC, up to VECTO version 3.3.10, a standard CO_2 emission reduction factor was applied depending on the VECTO group, drive cycle, and payload. This was referred to as ADAS Phase 1, and those standard factors were conservatively set due to a lack of data. As of May 2022, the new VECTO version 3.3.11 implemented ADAS Phase 2, wherein a simulation-in-the-loop approach was considered to better reflect the actual CO_2 emissions reduction of ADAS technologies. Implementation of ADAS Phase 2 almost doubles the CO_2 reduction factors for the PCC and eco-roll technologies. Active front grill and pulse and glide technologies are reported voluntarily and do not result in any reduction in a vehicle's certified CO_2 emissions.

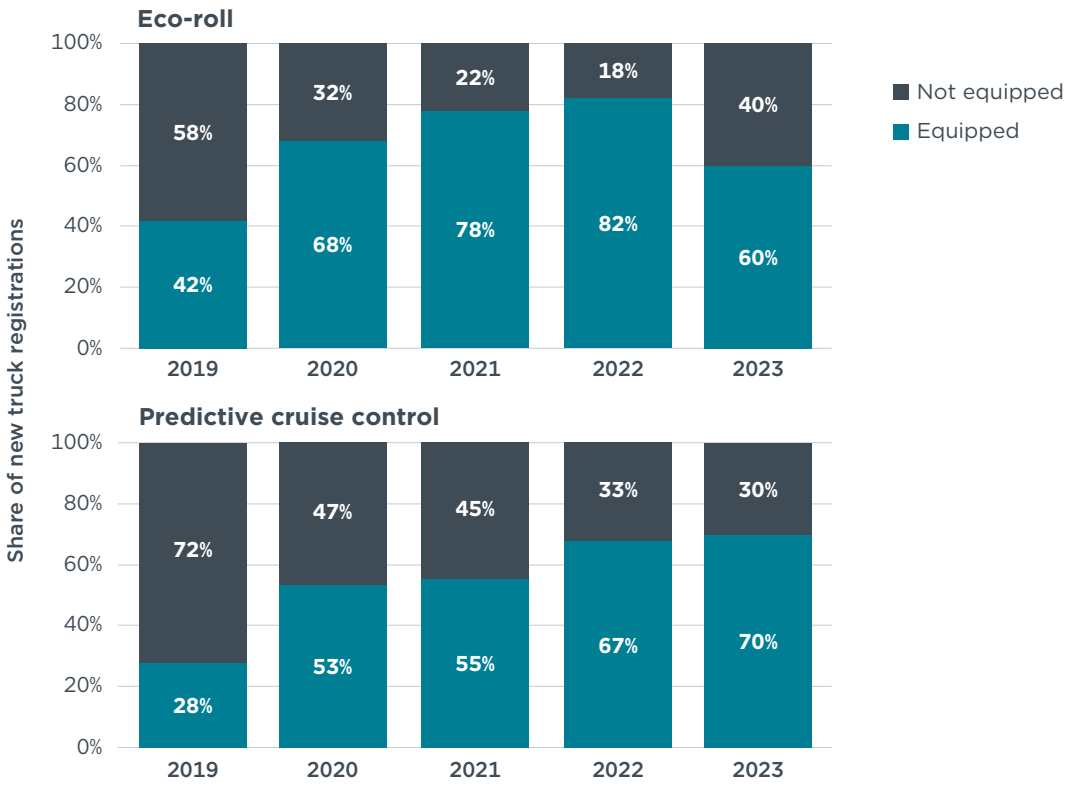
As of 2023, 60% of registered vehicles were reported to use the eco-roll technology, a drop from 82% in 2022 but up from 42% in 2019. Meanwhile, 70% of vehicles were equipped with predictive cruise control in 2023, relative to 28% in 2019 (See Figure 8).

To better reflect the real-world CO_2 reductions achieved by manufacturers' ADAS technologies, an update was made at the end of 2022 to the gradient profile of the long-haul driving cycle used in VECTO 3.3. With the new cycle, VECTO calculates fuel savings of 2.2% from the use of ADAS technology in newly certified conventional diesel vehicles, compared with 1.1% savings with the old cycle, corresponding to a further 2.2% reduction in CO_2 emissions over the new cycle (Rexeis et al., 2020).

10 Eco-roll is an autonomous feature that estimates when it is worth rolling down longer gradients in neutral. PCC is a feature that uses satellite data to predict the optimal driving strategy for the upcoming road segment; among all ADAS technologies listed in VECTO, it is the most effective at reducing CO_2 emissions. An active front grill is a technology that can open and close the grill vents to reduce air drag; the grill automatically closes at higher speeds. Pulse and glide is 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 8

Use of CO_2 reduction technologies across the top 7 truck manufacturers, 2019–2023



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3.4.2. Recent product developments in driving assistance systems

As of 2023, most manufacturers had declared that the majority of their trucks were equipped with ADAS technology capable of reducing their official fleet-average specific CO_2 emissions. This section focuses on manufacturers that have had a low penetration of ADAS technologies.

Scania has reported that approximately half of its trucks have either eco-roll or PCC. The manufacturer introduced a new PCC system in 2023 to be applied to all of its new trucks with the G25 and G33 gearboxes from June 2023, claiming an additional 2% fuel savings compared to HDVs operating without this ADAS (Scania, 2023).

Iveco has declared that nearly all of its HDVs are equipped with eco-roll technology, but that only half have PCC. In 2023, Iveco announced that it had integrated PCC as part of a suite of upgrades to its S-Way range (Iveco S.p.A., 2023).

MAN declared that approximately 70% of its HDVs offered PCC in 2022. The automaker offers the MAN EfficientCruise on its TGS and TGX models.

4. ZERO-EMISSION VEHICLE MARKET DEVELOPMENT

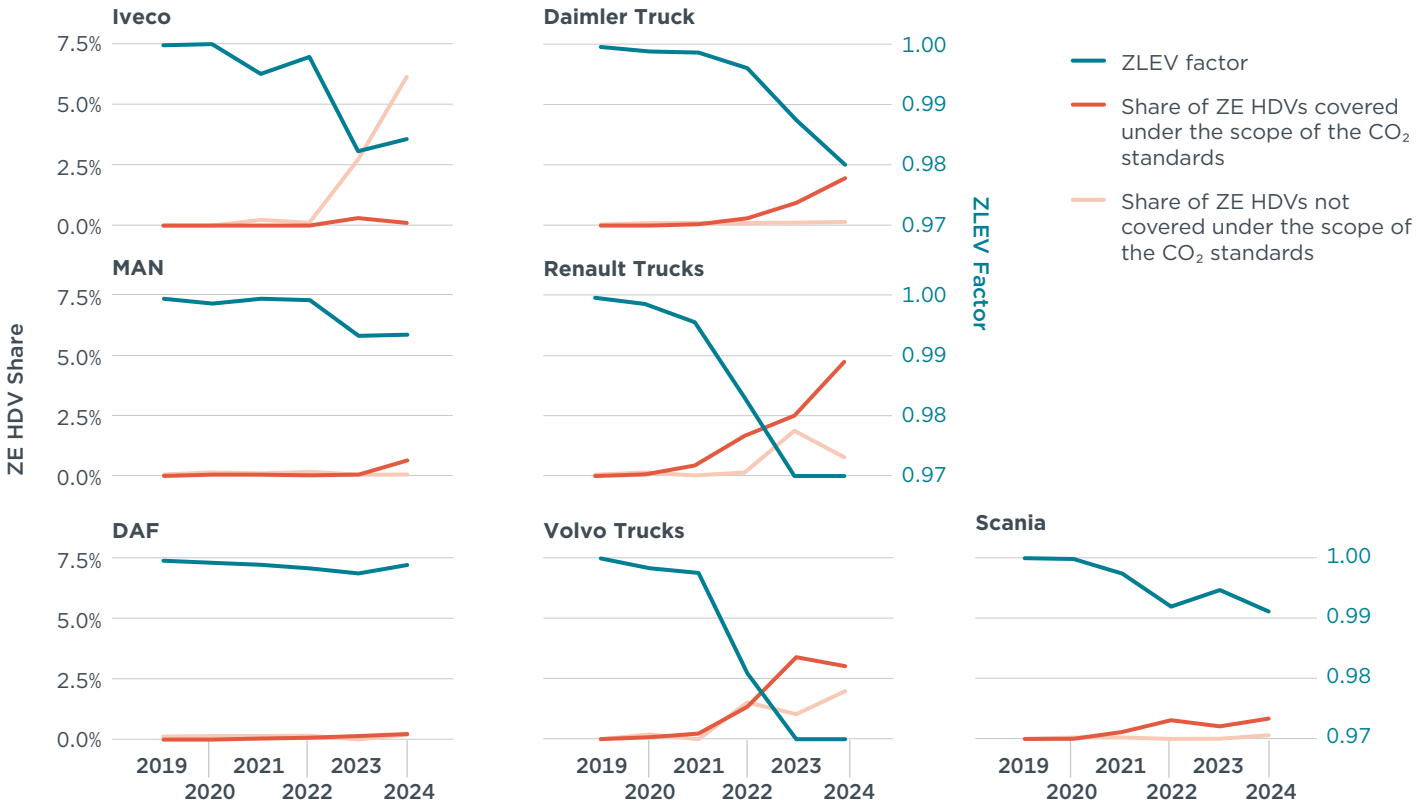
The ZE HDV market in the European Union is nascent but growing rapidly. In 2024, 8,200 ZE trucks were sold in the region, representing 2.5% of total sales. This is a four-fold increase from just two years prior, when 2,100 ZE trucks were sold (0.7% share) (Mulholland & Ragon, 2024).

ZE HDVs contribute towards a manufacturer's compliance with the CO_2 standards in two ways: once from lowering the fleet-average CO_2 emissions of the manufacturer, and again through the ZLEV factor. The ZLEV factor allows a manufacturer to artificially reduce their CO_2 emissions by a maximum of 3%, as described in Section 2.2.2.

Increasing sales of ZE HDVs that are in the scope of the CO_2 standards (hereafter, ZEV_{in}) can contribute towards the full 3% reduction potential of the ZLEV factor.[11] ZE HDVs that fall outside of the scope of the CO_2 standards (hereafter, ZEV_{out}) can only contribute a maximum of 1.5% towards the ZLEV factor.

Few manufacturers have significantly increased sales of ZEV_{in} vehicles, with just Daimler Truck, Renault Trucks, and Volvo Trucks increasing their share beyond 1% by 2024 (Figure 9). The latter two of these manufacturers have already maxed out their ZLEV factor contributions in 2023, both achieving a factor of 0.97, which corresponds to a 3% reduction of their fleet-average CO_2 emissions. Iveco has increased its ZEV_{out} sales shares significantly since 2022 due to the success of its eDaily model. While Iveco sold just 20 ZEV_{in} vehicles in 2024, it sold 1,300 ZEV_{out} vehicles the same year, which helped to drive its ZLEV factor down to 0.985, reaching the 1.5% cap.

Figure 9
ZE HDV shares and ZLEV factor by manufacturer, 2019–2024



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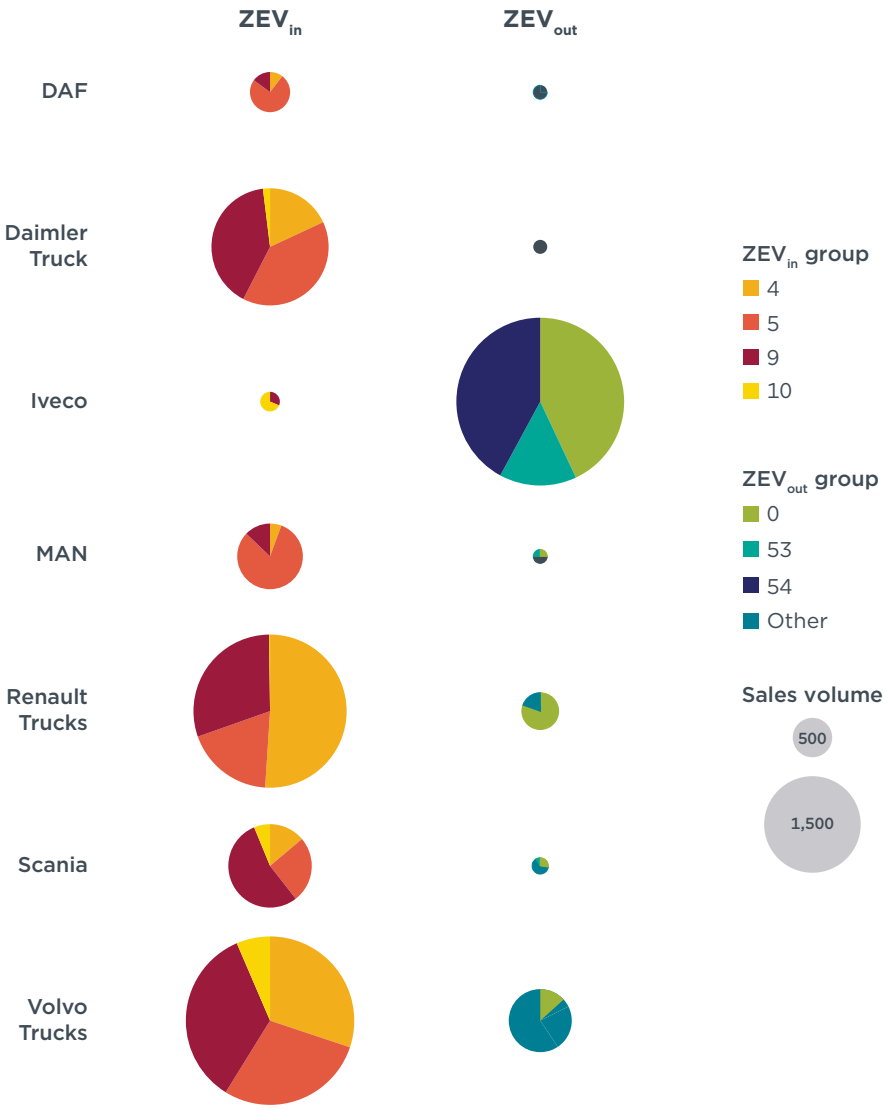
11 ZEV_{in} covers VECTO groups 4, 5, 9, and 10.

As shown in Figure 10, most ZEV_{in} vehicles sold in 2024 were rigid body trucks (i.e., groups 4 and 9). While the ZLEV factor does not discern between vehicle categories within ZEV_{in}, manufacturers have the most to gain from selling tractor-trailers due to the weighting mechanism known as the mileage, payload, and weighting (MPW) factor. The MPW factor assigns a weight to each vehicle category based on the assumed annual mileage it drives and payload it carries. The European Union's most common truck type, a 4x2 tractor-trailer with a sleeper cab (group 5-LH), receives the highest weighting of 1, while a 4x2 rigid truck with a day cab (group 4-RD) receives a weighting of just 0.15. In other words, a zero-emission 5-LH truck contributes 6 times more to a manufacturer's fleet-average CO_2 emissions compared with a zero-emission 4-RD truck.

Roughly one third of the ZEV_{in} sales by Volvo Trucks and Daimler Truck in 2024 were group 5.[12] While sales of ZE HDVs from MAN were comparatively lower, the vast majority of their ZEV_{in} sales were from group 5.

Figure 10
ZE HDV sales in July 2023–June 2024 by manufacturer and VECTO category



Notes: The size of the pie represents the total sales volume.

12 The information necessary to determine which sub-group a vehicle falls into (e.g., 5-RD or 5-LH) was not available from the market data we used for 2024. We can thus only report vehicles in terms of their group (e.g., group 5).

5. RESULTS AND DISCUSSION

5.1. SUMMARY OF FINDINGS UNDER A STATUS QUO SCENARIO

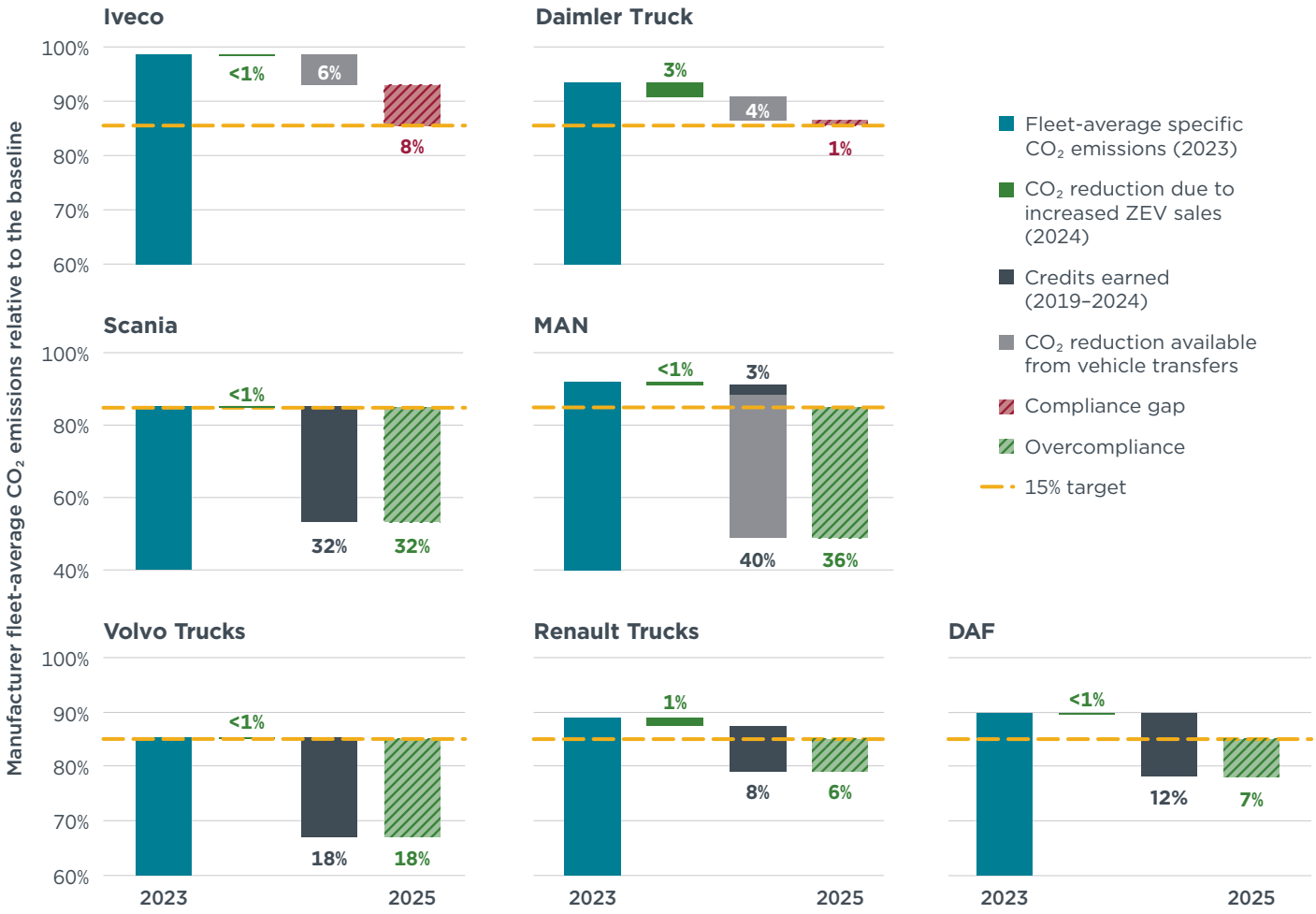
To determine how close manufacturers are to meeting the 15% target in 2025, we established a status quo scenario that calculates the fleet-average specific CO_2 emissions for each manufacturer using the state of their conventional technology in the 2023 reporting period, based on the EEA certification data (see Section 3), and the most recent sales data of ZE HDVs available in the 2024 reporting period (see Section 4), based on quarterly market data we obtained from Dataforce.

We then considered the flexibilities within the standards that can be used to meet the 15% target. This includes credits earned for overcompliance over the 2019–2024 period (see Figure 2), and the use of the vehicle transfer mechanism.[13] The transfer mechanism allows significant flexibility to manufacturers under the same parent company, as they can transfer vehicles amongst themselves with no limit. As noted above, non-connected manufacturers, such as Iveco, Daimler Truck, and DAF, may only receive or send transfers of ZE HDVs up to a limit of 5% of their total sales volume in a given year.

In this status quo scenario, five out of the seven manufacturers are already in compliance with the 15% CO_2 reduction target (Figure 11), so long as they continue to sell the same share of ZE HDVs in 2025 as they did in 2024. Only Iveco and Daimler Truck are not yet compliant with the 15% target under our status quo scenario. If their conventional trucks do not improve as expected beyond their 2023 performance, or their ZE HDV sales shares do not increase compared with 2024, Iveco and Daimler Truck would miss the target by 14% and 6%, respectively. Utilizing the ZE HDV transfer flexibility to its full extent would reduce this gap to 8% and 1%. These two manufacturers would thus need to adjust their product portfolios in 2025 to meet the 15% target.

13 Credits have, at the time of writing, only been awarded up to 2022. We calculated the credits that would be earned by manufacturers in the period 2023–2024 based on the state of the technology sold in 2022 and the ZE HDVs sold in 2023 and 2024.

Figure 11
Compliance gap for manufacturers, 2023–2025



Note: These values use the corrected reference emissions as detailed in Section 2.3.

The remainder of this section examines potential compliance pathways for the top 7 manufacturers. Table 7 summarizes the compliance levers manufacturers may need to pursue based on their status quo.

Table 7
Compliance levers different for manufacturers based on their status quo

	Credits earned (2019–2024)	Vehicle transfer	ICE technology improvement	Increase in ZEV sales
DAF	✓	✗	✗	✗
Volvo Trucks	✓	✗	✗	✗
Scania	✓	✗	✗	✗
Renault Trucks	✓	✗	✗	✗
MAN	✓	✓	✗	✗
Iveco	NA	✓	✓	✓
Daimler Truck	NA	✓	✓	✓

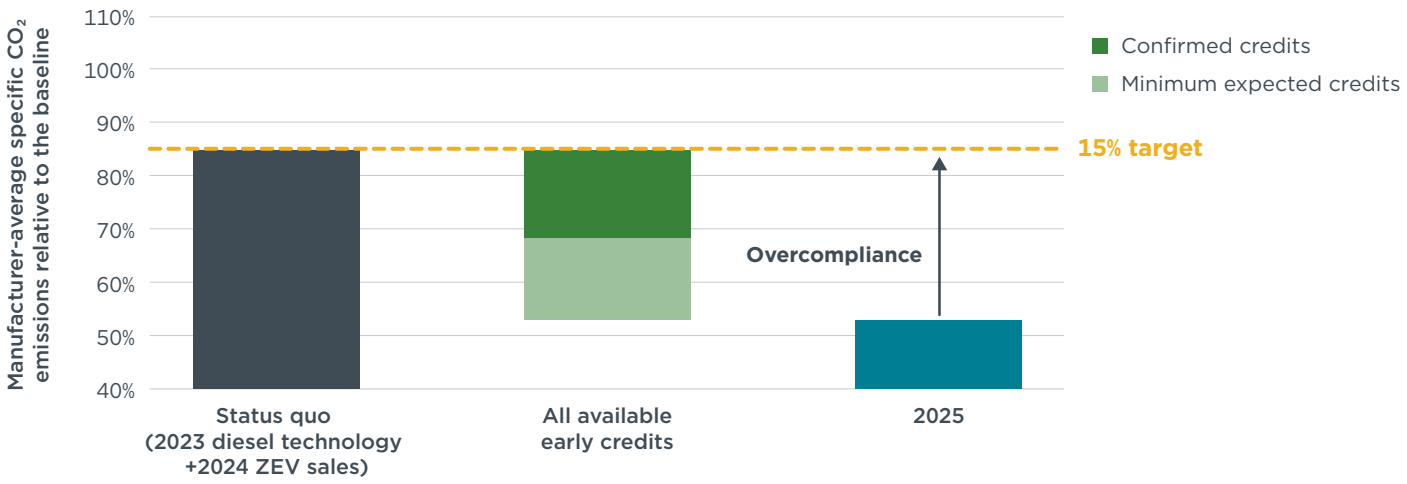
5.2. MANUFACTURER COMPLIANCE PATHWAYS

This section examines manufacturer-specific compliance pathways, beginning with those expected to comply with the targets more easily.

5.2.1. Scania

Scania is on track to comply with its 2025 target, continuously recording CO_2 emissions below its trajectory line and accumulating extensive early credits. Figure 12 shows the manufacturer's easiest possible compliance pathway. Scania's status quo emissions in 2025, considering its 2023 diesel technology and 2024 ZEV sales, are already 0.2 percentage points below its target. Between the 2019 and the 2022 reporting periods, Scania accumulated 286,300 g CO_2/tkm worth of credits, referred to as "confirmed credits" as they are officially recognized in European Commission implementing decisions. The automaker is expected to accumulate further credits in the 2023 and 2024 reporting periods, mainly due to its low diesel truck CO_2 emissions in the 2023 reporting period; we refer to those as "minimum expected credits," which are estimated to be around 265,000 g CO_2/tkm.

Figure 12
Scania's CO_2 emissions reduction compliance pathways



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Considering its confirmed and minimum expected early credits, Scania is comfortably on track to comply with the 2025 target, without using any of its accumulated credits. Moreover, if Scania manages to sell more of its lower emission truck models, further improves its diesel trucks beyond its 2022 technology (which is highly likely based on our analysis in Section 3), or further increases its ZEV sales shares relative to 2024, it may be able to accumulate additional credits.

5.2.2. Volvo Trucks

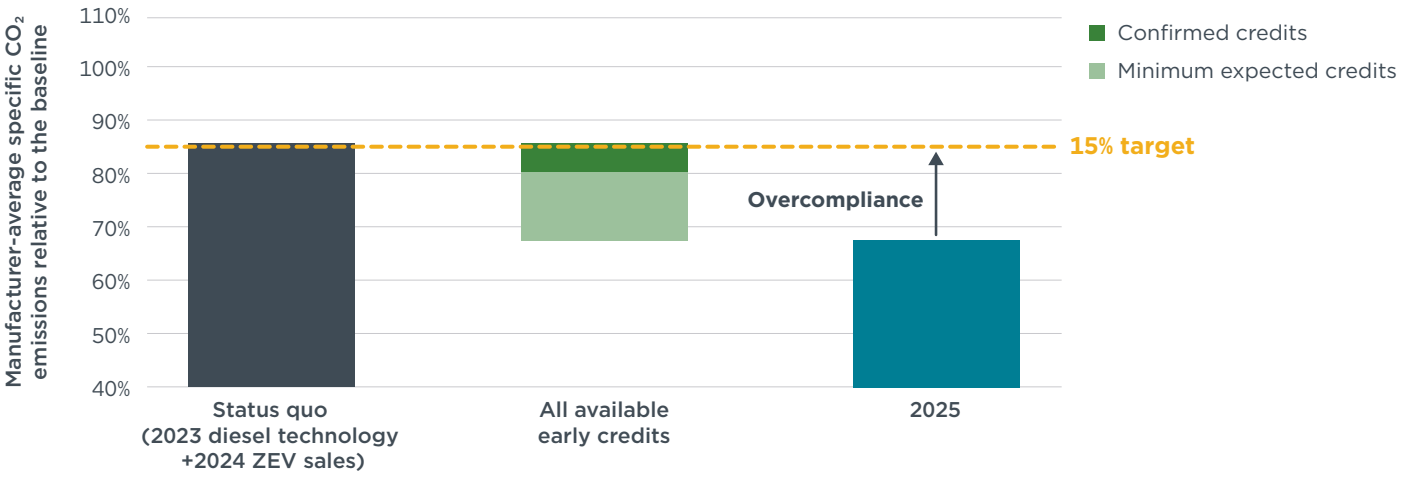
Volvo Trucks has been leading the ZEV race in the European Union, recording the highest ZEV sales and sales shares among all European manufacturers. In the 2023 reporting period, Volvo Trucks registered more than 1,350 ZEV sales (mostly tractor-trailers), representing more than 3.2% of Volvo Trucks' total sales of regulated VECTO groups. Combined with the continuous development of its diesel technology, this means that Volvo Trucks' CO_2 emissions performance under our status quo scenario, considering its 2023 diesel technology and 2024 ZEV sales, puts it only 0.7 percentage points above its target.

Figure 13 shows Volvo Trucks' easiest possible compliance pathways, highlighting its confirmed and minimum expected early credits, which Volvo Trucks can use to offset

emissions above its 2025 target. Volvo Trucks will only need to use around 4% of its accumulated early credits to offset its 2025 emissions, leaving approximately 350,000 g CO_2/tkm worth of credits that could be passed to connected manufacturers or expire beyond 2025. Like Scania, Volvo Trucks may be able to comply with the 2025 target without using any of its accumulated credits if it increases its ZEV sales in 2025, further improves the CO_2 emissions of its diesel fleet by selling more of its best performing truck models, or improves its diesel technology as highlighted in Section 3. Overall, Volvo Trucks is expected to easily comply with its 2025 15% CO_2 reduction target.

Figure 13

Volvo Trucks' CO_2 emissions reduction compliance pathways



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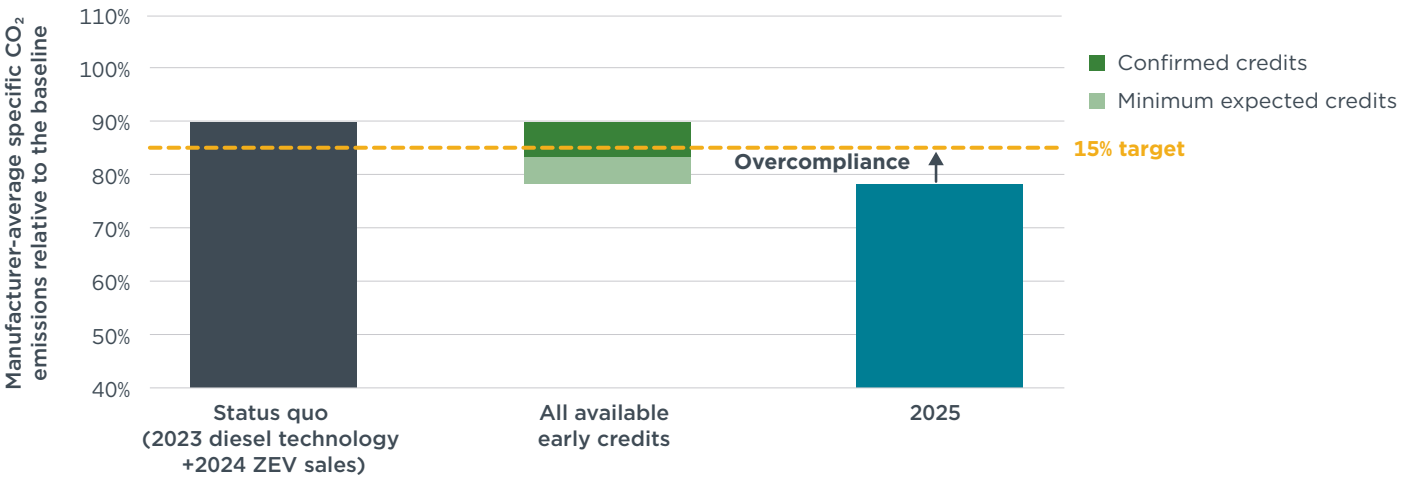
5.2.3. DAF

The status quo scenario analysis shows that if DAF does not improve its diesel trucks beyond its 2023 technology and only sells as many ZEVs as it did in the 2024 reporting period, it would be 4.8 percentage points above the 2025 target. However, like Scania and Volvo Trucks, DAF has accumulated early credits, with just under 100,000 g CO_2/tkm worth of confirmed credits in addition to 75,000 g CO_2/tkm minimum expected credits in the 2023 and 2024 reporting periods. As shown in Figure 14, DAF can offset all of the emissions above its target in 2025 using 42% of the accumulated early credits, which puts DAF well on track to comply with its 2025 target.

Figure 14

DAF's CO_2 emissions reduction compliance pathways



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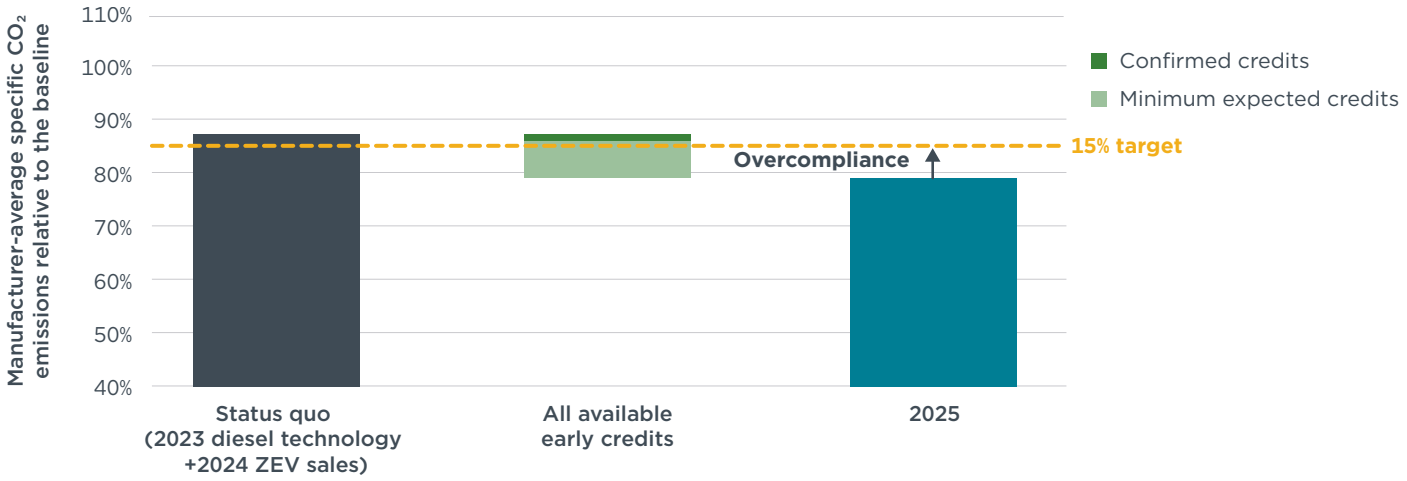
5.2.4. Renault Trucks

Renault Trucks is among the leading truck manufacturers in the European Union when it comes to ZEV sales. In the 2024 reporting period, Renault Trucks sold close to 1,000 electric trucks, which was around 5% of its total sales of regulated VECTO groups. This leaves Renault Trucks only 2.2 percentage points above the target in our status quo scenario.

Like other manufacturers, Renault Trucks can close its compliance gap by relying on early accumulated credits (Figure 15). While Renault Trucks only accumulated around 14,000 g CO_2/tkm of confirmed credits up to the 2022 reporting period, we expect it to accumulate close to 70,000 g CO_2/tkm of credits during the 2023 and 2024 reporting periods, based on 2023 official reporting data. Renault Trucks would then only need to use 25% of its early credits to comply with the 2025 15% reduction target.

Figure 15

Renault Trucks' CO_2 emissions reduction compliance pathways



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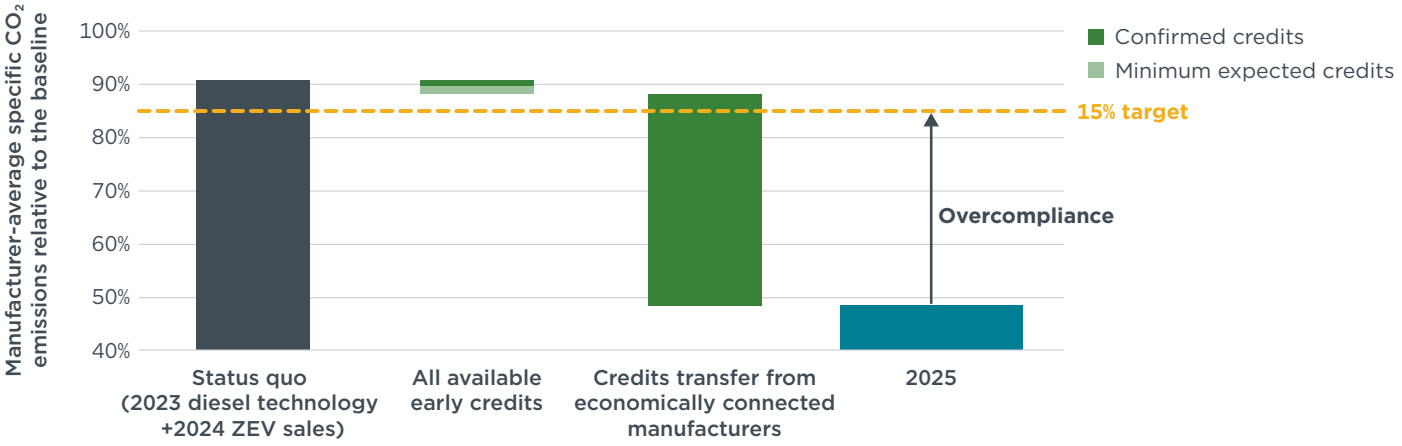
5.2.5. MAN

MAN has continuously improved its CO_2 emissions performance, mainly due to its constantly developing diesel truck technology. Between the 2019 and 2023 reporting periods, MAN stayed close to its emissions reduction trajectory line and thus did not accumulate many early credits. The status quo scenario analysis indicates that MAN will be 5.8 percentage points above its reduction target if it does not improve its diesel trucks beyond its 2023 technology or sell more ZEVs.

To offset those emissions without extensive early credits, MAN can make use of the flexibility of the HDV CO_2 standards that allow truck manufacturers under the same parent company to exchange unlimited credits. Figure 16 presents a compliance pathway for MAN in which credits transferred from Scania would be more than enough to offset MAN's emissions. In this pathway, MAN would only need 10% of Scania's remaining credits after accounting for Scania's own credit needs in 2025.

Figure 16

MAN's CO_2 emissions reduction compliance pathways



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5.2.6. Daimler Truck

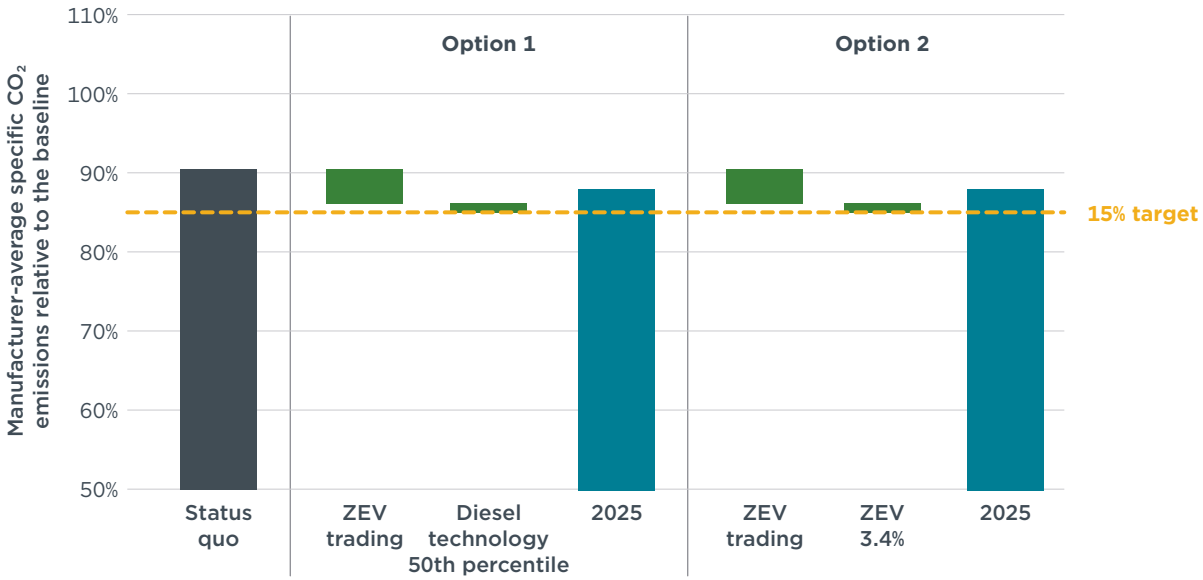
Daimler Truck showed limited progress towards meeting its 2025 target between the 2019 and 2022 reporting periods but came closer to its emissions reduction trajectory in the 2023 reporting period. Considering its 2023 diesel trucks technology and ZEV sales during the 2024 reporting period, the status quo scenario analysis indicates that Daimler Truck is expected to be 5.4 percentage points above its 2025 target, meaning improvements to diesel trucks and/or a rapid growth in ZE HDV sales are imperative to avoid paying penalties in 2025. While Daimler Truck did not accumulate early credits and is not expected to accumulate credits in the 2023 and 2024 reporting periods, it still has various compliance pathways available. First, although Daimler Truck is not connected to any manufacturer with early credit surpluses, it can still trade ZE HDVs with other manufacturers up to 5% of its total sales. Furthermore, the manufacturer is expected to improve its diesel technology relative to its 2023 offerings, as discussed in section 3, and to increase its ZEV sales shares with the production of the eActros 600.

Figure 17 shows two possible compliance pathways for Daimler Truck, labeled Option 1 and Option 2. In both options, we assume Daimler Trucks will benefit from the ZEV trading mechanism, acquiring ZEVs from the likes of Volvo Trucks, Renault Trucks, and Scania. According to our estimates, ZEV trading puts Daimler Truck very close to its 2025 target, with a slight undercompliance of 1.2%.

In Option 1, Daimler Truck could close the remaining gap by improving the CO_2 performance of its diesel fleet, which can be achieved by selling more of the better-performing diesel truck models available as of 2023, defined as the 50th percentile of its 2023 fleet. For VECTO group 5-LH trucks, this translates to a ~1.6% CO_2 emissions reduction between 2023 and 2025. This would allow Daimler Truck to meet its CO_2 reduction target.

For Option 2, we calculated the required ZEV sales share for Daimler Truck to bridge the compliance gap of 3.4%. This is about 1.7 times higher than the Daimler Truck ZE HDV sales share in the 2024 reporting period, which was 2%. This represents a case in which Daimler Truck does not improve its diesel technology between 2023 and 2025, which is highly unlikely.

Figure 17
Daimler Truck's CO_2 emissions reduction compliance pathways



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We anticipate Daimler Truck's compliance strategy to fall in between the two options analyzed in this study. While its pathway to compliance is not as straightforward as for other manufacturers, it can benefit from the flexibilities provided by the HDV CO_2 standards, allowing for several possible compliance options.

5.2.7. Iveco

Iveco has shown the least progress among manufacturers, consistently recording CO_2 emissions above its emissions reduction trajectory between the 2019 and 2023 reporting periods. Iveco diesel technology stagnated between 2019 and 2022, and its natural gas powertrains did not capitalize on the lower carbon content of the fuel. While Iveco has been a leader in electrifying large vans, it has been late to introduce ZE HDV models in series production for heavier regulated segments. Those two factors put Iveco at a high risk of non-compliance. The status quo scenario analysis, considering its 2023 conventional trucks technology and ZEV sales during the 2024 reporting period, suggests that Iveco will be above its CO_2 reduction target by 12.6 percentage points. While Iveco can still pursue several pathways to comply with its targets and avoid paying penalties, its path is less flexible than other manufacturers, given that it did not accumulate any early credits, is not expected to accumulate credits in the 2023 and 2024 reporting periods, and is not connected to other manufacturers for the purpose of ZEV trading.

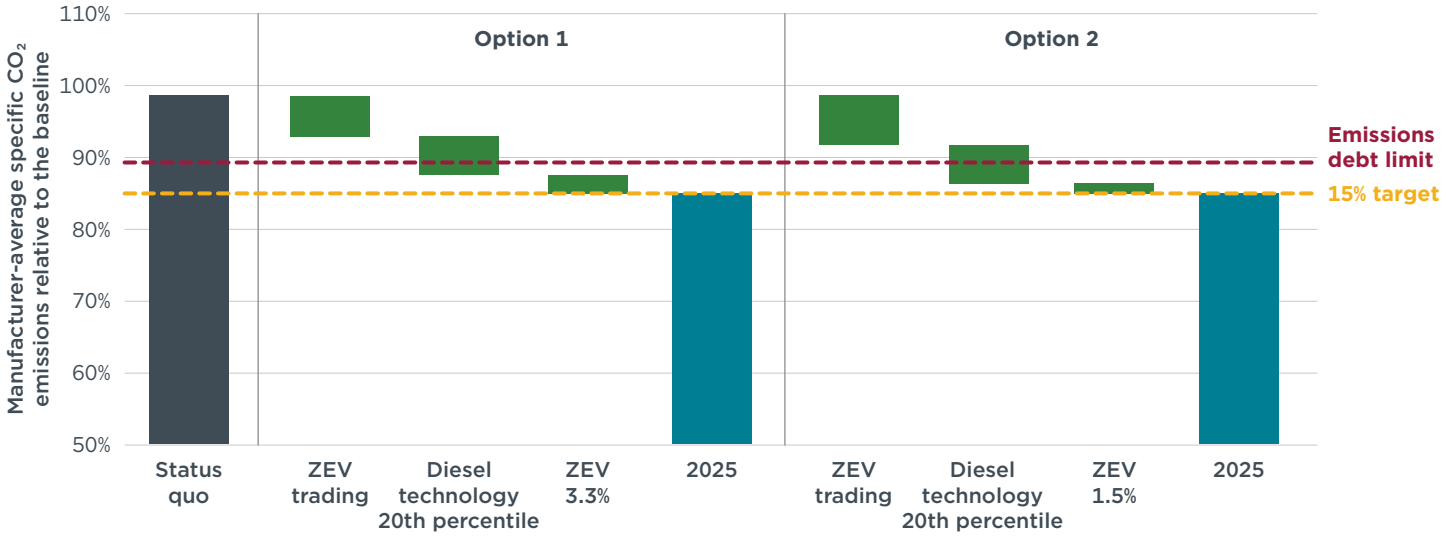
Figure 18 shows Iveco's possible compliance pathways, considering two options. Both options assume Iveco will benefit from the ZE HDV trading mechanism with other manufacturers. Iveco can acquire ZEVs from any other manufacturer, up to 5% of its total sales volumes. This is equivalent to 695 ZEVs for Iveco, which can be secured

by trading with either Volvo Trucks, Renault Trucks, or Scania, which can trade up to 1,200, 950, and 285 ZEVs, respectively.

Option 1 assumes that, in addition, Iveco improves its gas and diesel technology to the 20th percentile of its own fleet in 2023. For VECTO group 5-LH trucks, this is close to a 5% reduction in average CO_2 emissions between 2023 and 2025. This can be achieved by either selling more of its best-performing trucks or the introduction of new products as summarized in Section 3. This combination of ZE HDV trading and conventional technology improvement is sufficient for Iveco to avoid paying penalties in 2025. If Iveco were to meet the 15% reduction target directly in 2025, its ZE HDV sales share must be around 3.3%, corresponding to sales of about 450 ZE HDVs in the regulated VECTO groups.

We also examined another option in which Iveco focuses on increasing ZEV sales of long-haul groups, given their higher contribution to the average CO_2 emissions. In this Option 2, Iveco would need to increase its ZEV sales share to 1.5% to comply. This is 50% fewer ZEVs than for Option 1, at approximately 210 vehicles.

Figure 18
Iveco's CO_2 emissions reduction compliance pathways



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In any case, Iveco's pathway to compliance will require a fast renewal of its product portfolio. We estimate that Iveco can avoid paying penalties in 2025 by making use of the compliance flexibilities in the HDV CO_2 standards, mainly through ZE HDV trading, and also taking advantage of the emissions debt limit.

6. CONCLUSIONS

HDV manufacturers in the European Union face a CO_2 emissions reduction target of 15% in 2025 relative to 2019. This paper has examined the most recent information available from the sector to determine how far manufacturers are from this target, relying on the latest official CO_2 information on internal combustion HDVs from the EEA up to June 2024 and ZE HDV sales shares up to June 2025 from national statistics.

We found that **five of the seven top manufacturers in the European Union are on track to be compliant with their 15% target without making any further improvements to their fleet**. Daimler Truck and Iveco were the only manufactures found to have a compliance gap.

Scania and Volvo Trucks can comfortably meet the 2025 target. Both manufacturers already reduced their fleet-average CO_2 emissions by 15% in the 2023 reporting period. By selling the same vehicle technologies that they sold up to then, they will be compliant with the 2025 targets.

Renault Trucks and DAF are also positioned to meet the 2025 target thanks to early credit accumulation in the 2019–2023 period. Both manufacturers amassed a significant number of early credits in the 2019–2023 period due to the performance of their vehicles sold during this period. Even without making any further improvements to their vehicles between 2023 and 2025, these manufacturers could rely on the accumulated credits to meet the 15% target.

MAN can already meet the 2025 target by relying on compliance flexibilities. The CO_2 standards allow for manufacturers with the same parent company to transfer HDVs as a compliance flexibility. This allows Volvo Trucks and Renault Trucks (connected by Volvo Group) and MAN and Scania (connected by the TRATON Group) to freely transfer vehicles amongst each other. Scania has accumulated the largest share of credits of all manufacturers. If MAN were to transfer all its vehicles to Scania (effectively pooling their emissions), the credits already earned by Scania would be enough for MAN to also meet the 2025 target.

Daimler Truck could close its compliance gap through moderate increases in either the performance of their diesel vehicles or in their ZE HDV sales. By maximizing the use of the zero-emission transfer flexibility, Daimler could be fully compliant in 2025 by either increasing its share of zero-emission sales to 3.4% in 2025 (up from 2% in 2024), or by improving its diesel technology to the 50th percentile of its vehicles' performance in 2023. A combination of these measures is expected.

Iveco faces one of the more challenging paths to compliance among manufacturers. To avoid penalties in 2025, Iveco can maximize use of the vehicle transfer flexibility to use another manufacturer's ZE HDVs (limited up to 5% of Iveco's annual sales) for compliance. In addition, it would need to improve the average performance of its conventional trucks to the 20th percentile registered in 2023, by either selling more of its best-performing trucks or updating its truck portfolio. To avoid any credit debts in 2025, Iveco would need to increase its ZE HDV sales volume in key regulated segments to reach 450 electric long-haul trucks, or a 3.3% sales share.

Most manufacturers are on track, and compliance with 2025 targets is either ensured or within reach. Despite relying on conservative assumptions, this analysis finds that most manufacturers are already on track to meet the 2025 CO_2 reduction target. For those not yet compliant, the regulation provides clear and realistic pathways to close the gap through technology improvements and the use of compliance flexibilities. With zero-emission truck adoption accelerating and the expected continuous enhancements in conventional vehicle performance, the 2025 targets are well within reach for the European Union's HDV industry.

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ANNEX

FORECASTED TECHNOLOGY DEVELOPMENT (2025 AND BEYOND)

To forecast the CO_2 emissions of future trucks, we developed a regression model based on the EEA monitoring and reporting data for the 2023 reporting period, correlating truck CO_2 emissions to the state of the main technologies driving those emissions, including the air drag coefficient, rolling resistance coefficient of the driving and steering axles, and average engine efficiency over the WHTC. A separate regression model was developed for every VECTO group. Equation 1 shows the generic regression model; as an illustrative example, Table 8 shows the regression model coefficients for VECTO group 5-LH, considering all manufacturers.

$$\widetilde{CO_2} = (A_1 \times X_1) + (A_2 \times X_2) + (A_3 \times X_3) + (A_4 \times X_4) + k \qquad \text{(Equation 1)}$$

Where:

- $\widetilde{CO_2}$ is the predicted CO_2 emissions value normalized to the sample's maximum value;
- *X1* is the air drag coefficient normalized to the maximum air drag value;
- *X2* is the engine average efficiency over the WHTC normalized to the maximum engine average efficiency value;
- *X3* is the steering axle rolling resistance coefficient normalized to the maximum drive axle rolling resistance coefficient value;
- *X4* is the driving axle rolling resistance coefficient normalized to the maximum driven axle rolling resistance coefficient value;
- *An* is the regression coefficient of technology n; and
- *k* is a constant.

Table 8

Regression model coefficients and p-values

Technology metric	Regression coefficient	Sample maximum value	p-value	R^2
Aerodynamic drag coefficient (X_1)	0.37	8.56 m^2	< 0.001	
Average engine efficiency (X_2)	-0.41	45.82 %	< 0.001	
Steering axle RRC (X_3)	0.05	7.5 kg/tonne	< 0.001	0.83
Driving axle RRC (X_4)	0.08	7.5 kg/tonne	< 0.001	
Constant (k)	0.72	-	-	

The model shows that trucks' CO_2 emissions are most sensitive to the air drag coefficient, with a 0.4% drop in CO_2 emissions for every 1% drop in aerodynamic drag, which is related to the high speeds observed over the long-haul cycle. The engine efficiency variable is associated with a negative regression coefficient, implying an opposite correlation with CO_2 emissions.

www.theicct.org

communications@theicct.org

@theicct.org

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