Ready or Not

Who are the frontrunners in the global race to clean up trucks and gain technology leadership?

June 2023

A study by TRANSPORT & ENVIRONMENT

Transport & Environment

Published: June 2023

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Editeur responsable: William Todts, Executive Director

To cite this report
Transport & Environment. (2023). Ready or Not: Who are the frontrunners in the global race to clean up trucks and gain technology leadership?

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Acknowledgements

The findings and views put forward in this publication are the sole responsibility of the authors listed above. The authors are grateful for the external review from Eamonn Mulholland from the International Council on Clean Transportation, Ben Scott from Carbon Tracker, and Ricardo Garcia Coyne from CALSTART.

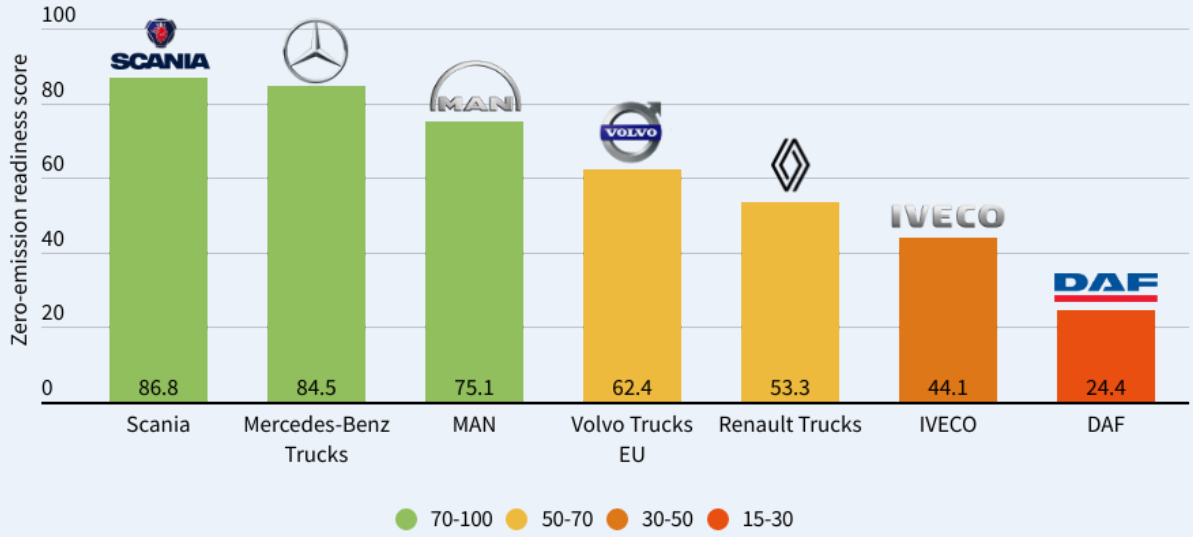
This report is not meant as financial advice.

Executive Summary

T&E ranked European truckmakers' readiness to transition fully to zero-emission truck sales. This report assesses the compatibility of their voluntary zero-emission sales announcements with climate needs, and the extent to which they are aligning their industrial plans and business activity with those targets. This helps identify the gap between announcement and plans, and the role for regulation to ensure a speedy transition. The report also looks into how European manufacturers perform compared to their counterparts in the US and China, assessing who is best positioned to win the ongoing global race for leadership on commercial vehicle technology.

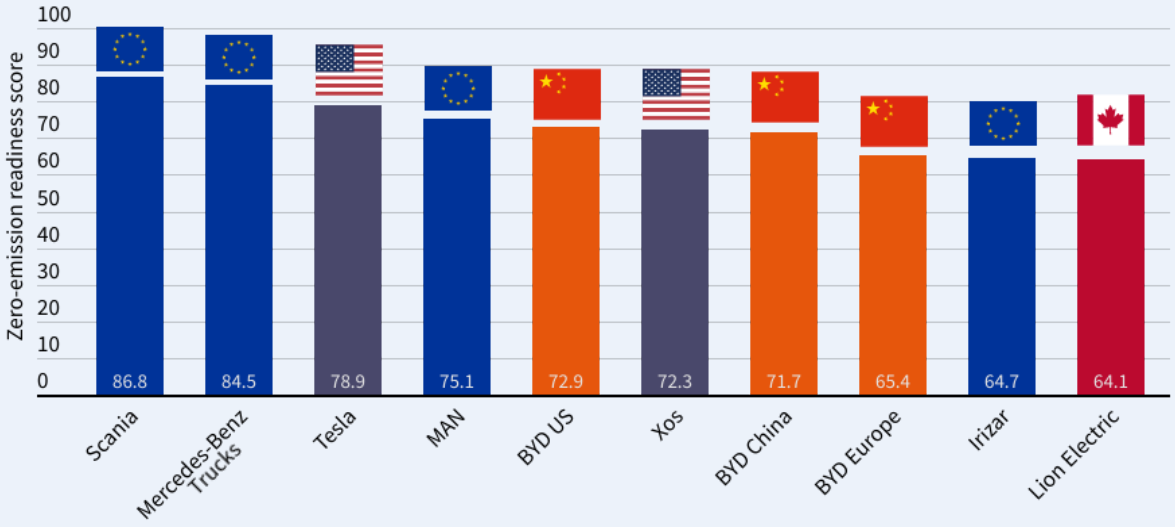
Scania, Mercedes-Benz Trucks, and MAN in the lead

Scania, Mercedes-Benz Trucks, and MAN are the three European frontrunners based on their announced ambition and strategy. All three aim for 100% new zero-emission truck (ZET) sales by 2040 or earlier. Volvo Trucks is the current market leader in battery-electric truck sales in Europe and the manufacturer with the most ambitious 2030 target (70% ZET sales share). But the company is not committed to only truly zero-emission technologies in the long term. Renault Trucks and IVECO Group are lagging behind in the transition. DAF closes the ranks with a very weak score, having no public ZET target for 2030, and scoring the lowest of all legacy manufacturers on battery value chain. Strong CO_2 standards for trucks are needed to ensure frontrunners keep their promises and laggards catch up.



Tesla and BYD outcompete most European truckmakers

When comparing readiness on a global scale, European manufacturers only have four representatives in the top ten. Both the US and China have champions in Tesla and BYD, the latter already selling trucks in all three regions. These new entrants on the truck market could pose a threat to established truckmakers in coming years. Both Tesla and BYD have experience in rapidly scaling up zero-emission manufacturing in the cars segment. They have built strong battery supply chains, including securing raw materials.



Compared to legacy US and Chinese truckmakers, European manufacturers appear to be better prepared to go to zero-emission, partly because forthcoming stronger heavy-duty vehicles (HDV) CO_2 standards have incentivised EU manufacturers to announce voluntary zero-emission sales targets for 2030 and 2040. However, voluntary commitments can be missed or changed, and we identified a gap with some of these manufacturers' industrial strategy. What matters is how fast the EU market will have to decarbonise compared to others, as regulations drive truckmakers to develop robust investment plans.

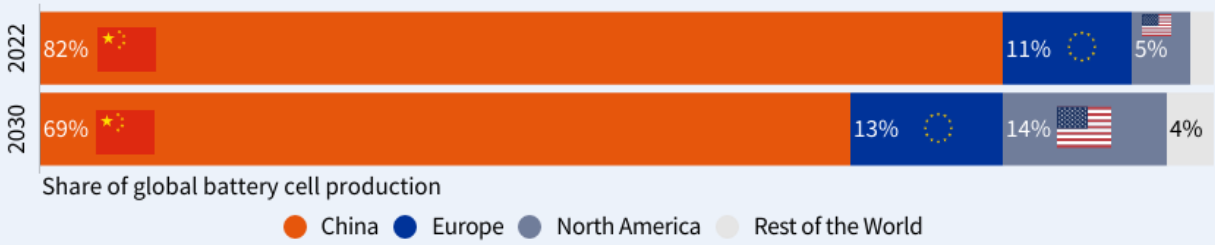
Looking ahead, the recently adopted Californian regulation to sell only zero-emission vehicles from 2036 is expected to spur major US truckmakers to decarbonise faster. With most EU OEM groups also active in other markets, this could potentially refocus group level investments from the EU to the US. Combined with the support for battery supply chains from the Inflation Reduction Act (IRA), the legacy US truck brands could quickly catch up and outpace European brands.

Stronger action needed to secure battery supply

Tesla, BYD, and TRATON's Scania and MAN are the only truckmakers to have secured long-term supplies of battery raw materials, which they did primarily to secure their car market segment. Truckmakers who are less connected to carmakers have to build their own battery value chains (either in-sourcing or through partnerships), and risk being too late to secure raw materials. Unless European truckmakers are part of comprehensive battery ecosystems, their leadership risks being challenged in the coming years. Ambitious HDV CO_2 standards are needed to create a signal for the battery industry to invest in Europe.

As China currently leads the battery market, it is unlikely that Chinese manufacturers will have trouble sourcing batteries. Meanwhile, the IRA will boost investments in battery manufacturing in the US. Already, two-thirds of battery capacity planned in Europe is potentially at risk if strong industrial

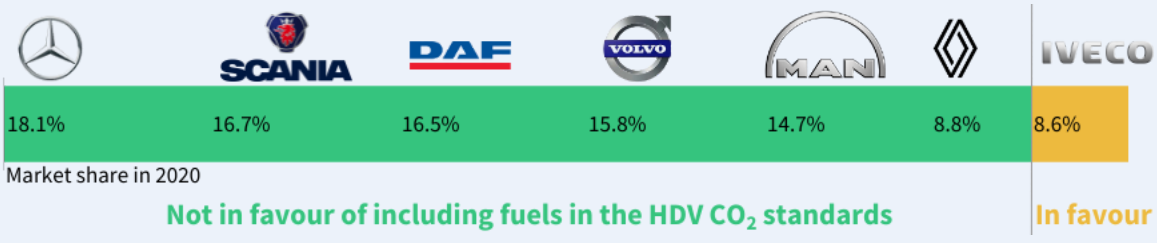
policy and funding is not put in place to secure the plans. Without strong signal and offtake from European truckmakers, parent companies with both European and US subsidiaries could prioritise developing battery supply chains in the US, where e-truck regulations are currently stronger.



How Europe can win the race

Europe can use the HDV CO_2 emission standards to ensure European truckmakers remain in the lead. This legislation is currently under review. But the new targets proposed by the European Commission are unlikely to deliver the needed push for frontrunners Scania, Mercedes-Benz Trucks, and MAN to remain ahead of the pack; for laggards IVECO and DAF to catch-up; and for newcomers Tesla and BYD not to outcompete those laggards. Instead lawmakers should:

- **Set a CO_2 reduction target of -65% in 2030**, in line with what leading manufacturers have already announced.
- **Set a CO_2 reduction target of -100% in 2035**. California has already adopted a 100% sales target for HDVs from 2036. The US as a whole has signed the Global Memorandum of Understanding, committing to 100% ZET sales by 2040. Without a similar 100% target, the EU risks falling behind as major truckmakers could shift investments away from Europe.
- **Extend the scope of the regulation** to small trucks and vocational and non-certified vehicles, so that all new trucks are regulated. California's zero-emission mandate covers all trucks without exemption, proving all truck categories can decarbonise.
- **Keep fuels out of the CO_2 standards**: biofuels and e-fuels are expensive and false climate solutions to decarbonise new trucks. Truckmakers opposed to including fuels in the regulation make up over 90% of the market, with only laggards in favour of such a scheme.



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1. The global race for zero-emission trucking

Rapid and deep reductions in greenhouse gas (GHG) emissions are needed to limit global warming to 1.5°C. Transportation is the second largest source of GHG emissions in the European Union[1], causing 25% of EU GHG emissions in 2019 [1]. Trucks and buses account for 6% of all GHG emissions in the EU [1]. In the United States, heavy-duty vehicles (HDV) cause 7% of total US emissions [2].

To decarbonise the sector, the European Commission unveiled in February 2023 its proposal to revise the HDV CO_2 standards, which would set tailpipe CO_2 reduction targets for new vehicle sales of -45% in 2030, -65% in 2035, and -90% in 2040.

Across the pond, the US Environmental Protection Agency released a proposal for Phase 3 of its GHG Emissions Standards for HDVs. The state of California already recently set a 100% ZET sales target for HDVs from 2036. Its vehicle regulations are typically adopted by other states which make up 35% of the US market [3]. The United States also adopted the Inflation Reduction Act (IRA) in August 2022, which will supercharge the uptake of zero-emission trucks (ZETs) by providing financial incentives until 2032.

While the ZET market is still in its infancy in Europe and North America, China has rapidly ramped up its ZET market in the last decade, and accounted for 90% of global ZET registrations in 2022 (compared to 2% for the US and 7% for the EU+UK) [4]. Subsidies were a major driver of the ZET uptake in China, and sales of electric trucks declined as subsidies were gradually phased down [5]. China now plans to strengthen its HDV fuel consumption standards, proposing to increase their stringency by 15% by 2025 compared to 2020 [6].

Apart from regulatory action, European original equipment manufacturers (OEMs) have announced voluntary targets to decarbonise their sales. This report assesses the compatibility of their voluntary announcements with climate needs, and the extent to which these OEMs are aligning their industrial plans and business activity with those targets.

The analysis is based on publicly available information. All major European OEMs have been given the opportunity to respond to the information included here and indicate any potential misinterpretations on T&E's part. Feedback from OEMs and reviewers was incorporated in the report where applicable.

The readiness of European OEMs to go to zero-emission is compared to international competitors and zero-emission truckmakers. (Annex 1 details the criteria for inclusion within the scope.) The aim is to identify ambition and implementation gaps, and draw lessons to ensure the road freight sector is set on a credible path to zero-emission by 2050. Buses are out of the scope of this report.

[1] When including international bunkers used for aviation and shipping in transport emissions, transportation is the largest source of GHG emissions in the EU (33% in 2019).

2. Measuring readiness

This section presents a broad overview of the zero-emission (ZE) readiness index, based on the electric vehicle readiness index previously developed by T&E for cars [7]. The two main index categories are ZE ambition and industrial strategy.

Zero-emission ambition is scored out of 40 points, and looks at the voluntary ZET targets OEMs have communicated for 2030 and 2040. Public commitments are important as they show policymakers what is feasible, as well as bring investment certainty for other economic actors (e.g. infrastructure providers or battery manufacturers). The ambition section also includes penalties for pursuing technologies which are incompatible with climate objectives, such as fossil gas, biofuels, and e-fuels in new trucks. Plans to use these fuels in the legacy fleet were not taken into account.

Industrial strategy is scored out of 60 points, and comprises ZET model line-up (22 points), securing ZE mobility value chains (20 points), energy strategy (12 points), and financing strategy (6 points).

Scores for all truckmakers, including data sources, are available in the supplementary materials accompanying this report.

2.1. Zero-emission truck ambition: /40 points

Being ready for zero-emission requires setting clear targets in line with climate needs. Achieving climate neutrality by 2050 requires the last polluting trucks to be sold by 2035 at the latest, as European trucks remain in the fleet for 20 years on average [8].

T&E recommends setting emission reduction targets for the HDV CO_2 standards of -65% in 2030 and -100% in 2035. This translates into ZE targets for new sales of 60% in 2030[2] and 100% in 2035 respectively.

However, OEMs have not announced targets for 2035, so their ambition is assessed on the basis of their 2040 announcements instead. As a result, the ZET sales shares required to score full points in this category are 60% in 2030 and 100% in 2040.

Voluntary announcements often use unclear language. For example, the European Automobile Manufacturers' Association (ACEA) and its members have released a statement aiming for all new trucks to be "fossil-free" by 2040 [9]. Where targets are not explicitly limited to truly zero-emission technologies (i.e. battery-electric, fuel cell hydrogen or hydrogen combustion), it is assumed that 80% of the announced target refers to ZET sales and 20% to sales of conventional trucks running on low-carbon fuels.

[2] Engine efficiency is assumed to improve by 0.5%–1.3% annually depending on the truck category. As a result, a -65% CO_2 target translates into a ZE target for new sales of 58% to 63%. This is rounded to 60% for simplicity.

2.2. Penalties for non–zero-emission technologies: /-13 points

Gas, biofuels, or e-fuels are often falsely touted as climate solutions to decarbonise new trucks, in spite of the environmental harm they commonly cause (CO_2 emissions, methane leakage, biodiversity loss, air and noise pollution, etc.) or their scarce availability while other sectors lack alternatives to decarbonise.

In addition, truckmakers have no control over how their trucks will be refuelled over their lifetime, so they cannot guarantee the emissions savings they claim. Relying on bio and e-fuels to decarbonise trucks shifts the responsibility for and the costs of the transition onto fuel suppliers and fleet operators, while letting OEMs off the hook.

Promoting or investing in false solutions also syphons investments away from truly zero-emission technologies. As a result, OEMs receive a penalty for each non–zero-emission technology they support.

2.2.1. Fossil gas trucks

Apart from CO_2 and nitrous oxides, gas trucks also emit small amounts of methane[3]. Methane slip can be particularly high during cold starts [10]. Though it does not accumulate in the atmosphere, methane is a far more potent greenhouse gas than CO_2, with a global warming potential 28 times superior to that of CO_2 over 100 years [11]. Increasing methane emissions could have devastating climate impacts and would increase the probability of breaching tipping points [12]. Gas cannot be a transitional technology as it increases near-term warming instead of relieving it.

Russia's invasion of Ukraine also highlighted Europe's high dependence on Russian gas. Prior to the war, the EU imported more than 40% of its fossil gas from Russia [13]. Energy prices surged in 2022, which led to a drop in demand [14]. Registrations of alternatively-fuelled trucks[4] fell by 20% in the EU. In Germany, they collapsed by 34% [15].

Therefore, truckmakers investing in gas trucks as a long-term strategy receive a penalty of three points.

2.2.2. Biofuels

Growing crops to produce biofuels causes biodiversity loss, increased GHG emissions from deforestation, and threatens food security [16][17]. Producing advanced biofuels from waste and residue feedstocks has the potential to bring emission savings, provided that stringent sustainability criteria are met. However, only very small quantities of advanced biofuels can be produced when strong sustainability criteria are applied. Biomass with existing use must be excluded, as otherwise industries which already use it may be

[3] Real-world emission savings of fossil gas trucks are negligible compared to diesel when considering the 100-year global warming potential (GWP) of methane — only a 7.5% reduction in well-to-wheel (WTW) GHG emissions. Worse still, gas trucks' GHG emissions can be 13.4% higher than diesel trucks' when considering methane's 20-year GWP [10].

[4] Natural gas, liquefied petroleum gas, biofuels, ethanol

forced to revert back to food and feed stock, leading to the negative climate and environmental impacts mentioned above.

Yet the industry often touts Hydrotreated Vegetable Oil (HVO) as a "renewable diesel". HVO is a biofuel production pathway that differs from traditional biodiesel. This type of biofuel can be directly blended with conventional diesel without limits, but it comes with the same negative climate and social impacts as other biofuels if it is produced from food or feed crops [18].

While HVO made from waste or residues (e.g. used cooking oil or animal fats) can in some cases bring emission savings, such feedstocks are only available in very limited volumes and are expected to be primarily used to produce sustainable aviation fuels (SAF) [19]. Currently, 45% of HVO consumed is made from palm and palm derivatives, while used cooking oil and animal fats make up 20% and 19% respectively [20].

High demand can incentivise fraud, such as mixing with virgin oil that can lead to deforestation [21], or induce competition with existing uses, pushing non-biofuel industries towards unsustainable feedstocks [22]. There is little visibility regarding the sustainability of imported biofuels.

Biomethane is the other main biofuel raising interest from the trucking sector. Like all biofuels, to be truly sustainable it can only be produced in limited quantities. What's more, methane slip can potentially wipe out all GHG savings compared to fossil gas [23].

Gas truck manufacturers tout that GHG emissions can be reduced by 90%–95% when running on advanced biomethane[5] [24][25]. However, advanced biomethane is not a scalable climate solution for trucks, due to its high price and low availability [10].

Therefore, advanced biofuels are not a scalable climate solution for road transport. Truckmakers who bet on biofuels to decarbonise their sales receive a penalty of three points.

2.2.3. e-fuels

Producing e-fuels is a highly energy-intensive process which makes inefficient use of renewable electricity [26]. Refuelling a conventional truck with synthetic diesel[6] would cost 50% more and emit 3 times more GHG than driving a battery-electric truck in 2035 [27].

Production volumes will remain low in the foreseeable future, and would not suffice to meet demand from aviation, shipping, and the chemical industry, which have no alternatives to decarbonise [28]. As a result, truckmakers advocating for e-fuels as a climate solution for new trucks are deducted three points.

[5] Advanced biomethane is produced from anaerobic digestion or biomass gasification of waste and residue feedstocks.
[6] Compliant with RED II.

2.2.4. Supporting the introduction of fuels in the EU HDV CO_2 standards

The EU HDV CO_2 standards apply to manufacturers, who have to cut their average fleet emissions either by improving the fuel efficiency of their new conventional trucks or by selling zero-emission trucks. While the sections above look into whether a manufacturer sees bio- or e-fuels as long-term solutions for new truck sales, this section analyses whether OEMs also support introducing a mechanism in the HDV CO_2 standards accounting for the contribution of so-called "renewable and low-carbon fuels" (e.g. a fuel crediting system or a carbon correction factor). This is assessed based on truckmakers' responses to the public consultation for the review of the regulation [29].

Supporting the introduction of fuels into the HDV CO_2 standards signals that the truckmaker in question seeks to divest itself from its climate responsibility, and instead shift the burden onto the energy sector. As a result OEMs in favour of including fuels receive a penalty of four points.

2.3. Developing e-optimised trucks: /22 points

Being ready for the transition to zero-emission requires offering a broad portfolio of ZET models which are optimised for the use of electricity or hydrogen.

The design of future ZETs should not be dictated by the design of diesel trucks. For instance, freeing the space under the cab traditionally reserved for the engine opens up new possibilities to redesign the cab, for example to improve aerodynamics or driver field of vision. The switch to electric powertrains also creates opportunities to integrate elements in the chassis to improve efficiency.

Therefore, truckmakers earn points if at least one ZET model in their existing or planned portfolio has a clean sheet design with an e-optimised cab, its electric motor(s) integrated in the axle or wheels, or a range of at least 450 km:

- **E-optimised cab** — In the EU, truckmakers have had the possibility of optimising their cab design to improve aerodynamics, direct vision, safety, and driver comfort since 2020. The extra cab length allowed since then (up to 90 cm) can help accommodate drivetrain components of ZE technologies. Redesigning cabs sends a strong signal that the OEM is committed to ZETs. Progressive truckmakers are expected to have ZE strategies that go hand in hand with their safety strategy to improve drivers' field of vision.
- **Motor integration** — improves truck efficiency, and shows that the OEM is redesigning their trucks based on what makes sense for electric drives, rather than sticking with what worked for diesel powertrains.
- **Range** — having at least one truck with a range above 450 km in the portfolio allows customers to decarbonise their long-haul operations [30], from where 73% of truck emissions originate [31].

Lastly, trucks are used for a wide variety of operations, such as long-haul freight, urban and regional delivery, construction works, garbage collection, etc. Truckmakers are awarded points for offering a high number of medium and heavy ZETs which are adapted to different uses and can meet the needs of different customers.

2.4. Investing in the e-mobility value chain: /20 points

As truckmakers shift to ZETs, they must invest in new value chains to secure the most valuable components in their trucks. For conventional trucks, most of the value lies in the diesel powertrain. For battery-electric trucks (BETs), the two most valuable components are the battery and the electric drive. For fuel cell electric trucks (FCETs), they are the fuel cell and the hydrogen storage system, with the electric drive in third position [32].

On batteries, truckmakers are awarded points for their industrial strategy on manufacturing battery cells and packs, securing raw materials, recycling and reusing batteries, and innovation. The number of points depends on supply security and commitment (e.g. in-house production, long-term agreement, etc).

For other components, truckmakers earn points for manufacturing either the electric drive (e-motor or e-axle) or the fuel cell system.

2.5. Charging and hydrogen refuelling strategy: /12 points

Long-haul trucks, which operate for multiple days or weeks without returning to their depot, will need public charging and refuelling infrastructure for their operations. The majority of trucks in Europe however drive less than 500 km a day and return to their depot overnight [30]. The majority of truck charging will therefore occur at private or semi-public locations such as depots and loading places.

Energy infrastructure for ZETs is still in its early stages of deployment. The Alternative Fuels Infrastructure Regulation (AFIR) was recently adopted, and will oblige all EU member states to develop a basic charging network. Truckmakers are awarded points for engaging in the rollout of this public infrastructure. For private charging, fleet operators will need planning support to set up (semi-)private charging.

Truckmakers are awarded points for supplying their customers with chargers or hydrogen refuelling (H_2) supply; and providing consulting services to help them with site-planning, installation, route management, etc.

2.6. ZET financing: /6 points

As zero-emission truck production is ramped up, economies of scale will bring down the upfront purchase cost of ZETs. Today however, BETs are on average 1–2 times more expensive to purchase than their diesel counterparts and FCETs 2 times [30]. This can be a barrier for the many small and medium enterprises (SMEs) in the sector to reap the benefits from the lower total cost of ownership (TCO) of ZETs.

Truckmakers who provide innovative financing such as turnkey solutions (for example Truck-as-a-Service, EV-as-a-Service, Fleet-as-a-Service, or Mobility-as-a-Service) receive six points. OEMs who provide other ZET-dedicated financing, such as preferential interest rates or battery leasing, receive half of the points.

3. How ready are European truckmakers?

3.1. Results for legacy European truckmakers

Scania, Mercedes-Benz Trucks, and MAN are frontrunners in the transition to zero-emission, scoring above 70 points (Fig.1). Volvo Trucks and Renault Trucks finish mid-table. IVECO trails a bit behind, and DAF comes last.

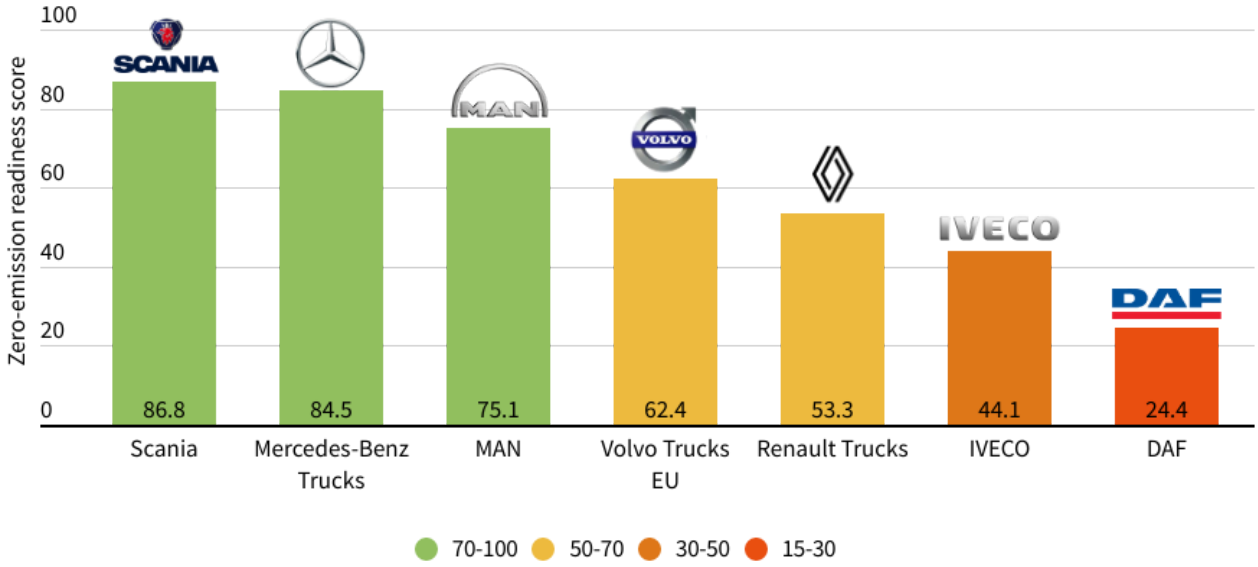


Figure 1. Zero-emission readiness scores of legacy European truckmakers

The breakdown by category clarifies the different OEM strategies, and potential room for improvement (Fig.2). TRATON's **Scania** scores the highest on industrial strategy, as it has a large line-up of heavy ZET models, and a comprehensive battery value chain, charging, and financing strategy.

Mercedes-Benz Trucks scores the highest on ZE ambition, as it aims to reach 60% ZET sales by 2030, and 100% ZET sales by 2039. The main areas of improvement are securing battery raw materials, and developing an e-optimised cab.

Similarly to Scania, TRATON's **MAN** could raise its 2030 target (currently 40% for long-haul and 60% for urban and regional delivery). Additionally, it could improve its line-up by increasing the number of ZET models in its portfolio, and by deploying e-optimised cabs. Although MAN has developed such a cab for the MAN CitE, this is only a concept vehicle. MAN's battery cell supply is secured in the long-term thanks to PowerCo, the battery division of TRATON's parent Volkswagen Group.

Volvo Trucks' middle-of-the-road results in this readiness ranking is in sharp contrast with its current performance. In 2022, Volvo Trucks was the market leader in battery-electric truck sales in Europe, with a 32% market share [33]. In the first quarter of 2023, its market share rose to 50% [34]. Looking at the global

ZET market in 2022 however, Volvo Trucks only held 1.1% of the market [4]. Volvo Trucks also shows the most ZE ambition for 2030, with a 70% ZET target.

Despite being an early mover on ZETs, Volvo Trucks however does not appear committed to fully go zero-emission in the long-term. Its performance is weighed down by its support for gas trucks and biofuels, though it opposes the inclusion of fuels in the HDV CO_2 standards. Committing to 100% truly zero-emission technologies by 2040 would go a long way in improving its score.

Renault Trucks' strategy is closely aligned with Volvo Trucks, except for its lower 2030 target of only 50% ZETs.

On industrial strategy, both of Volvo Group's OEMs could improve their model line-up to be able to compete with frontrunners. None of their models have the e-motor integrated in the axle or wheels, and their only trucks with either an e-optimised cab or 450-km range are prototypes.

The aforementioned OEM groups — TRATON (Scania and MAN), Daimler Truck (Mercedes-Benz Trucks), Volvo Group (Volvo Trucks and Renault Trucks) — have all invested in a common joint venture for charging infrastructure: Milence. Milence aims at deploying fast and megawatt charging across Europe, with a stated goal of 1,700 charging points for trucks and coaches by 2027 [35].

IVECO is the only OEM to receive all penalties, as it is fully betting on gas trucks and renewable and low-carbon fuels to decarbonise its sales, going as far as supporting the inclusion of fuels in the HDV CO_2 standards. IVECO is the only truck OEM who is a member of the eFuel Alliance[7] [37] and of the Natural & bio Gas Vehicle Association (NGVA) [38], two industry associations focused on e-fuel- and gas-powered vehicles respectively.

DAF is the only European truckmaker without a public ZET sales target for 2030. As a result, it scores the lowest of all European OEMs on ZE ambition. DAF also scores the lowest on industrial readiness. Its battery supply is secured only through agreements with multiple suppliers, including a long-term agreement with Romeo Power (now acquired by Nikola Motor, and experiencing financial difficulties [39]).

[7] T&E's assessment is based on IVECO's response to the HDV CO_2 public consultation. It should be noted that IVECO's CEO Gerrit Marx recently called e-fuels the "champagne of propulsion" due to their high cost, recognising they are not a viable way to decarbonise the automotive industry [36].

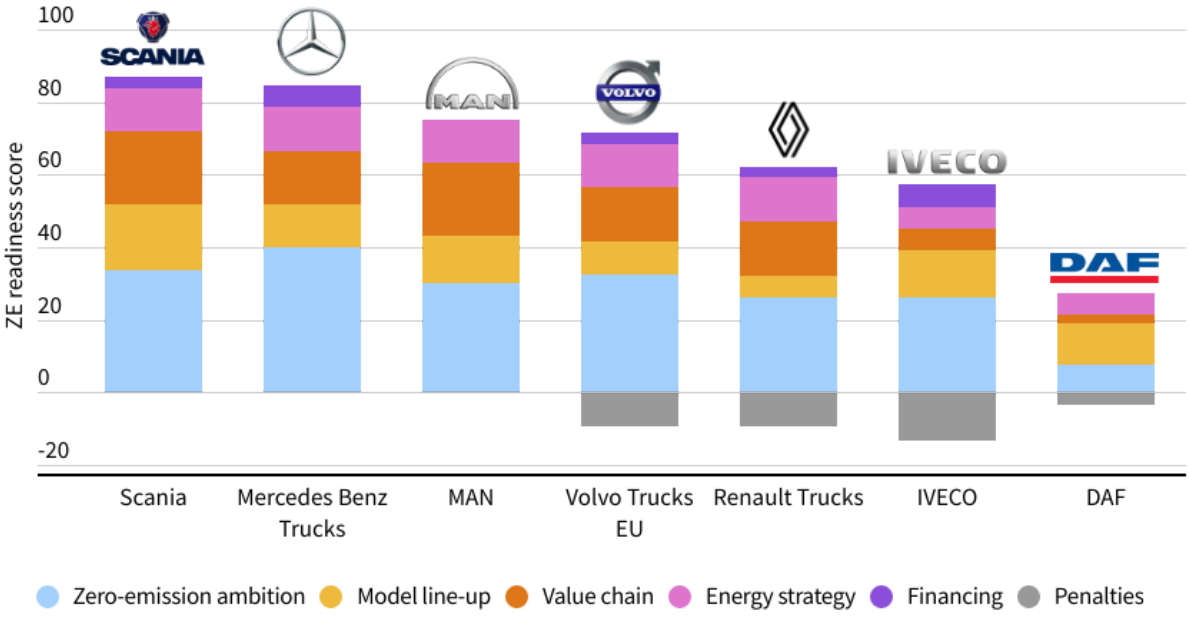


Figure 2. Zero-emission readiness scores of legacy European truckmakers, broken down by category

Plotting industrial strategy score (scaled to 100%) versus ZE ambition score (scaled to 100%) helps identify potential gaps between announcements and plans (Fig.3). This helps understand where regulation can play a role to speed up the transition. For manufacturers receiving penalties, the dot represents the full score including penalties, while the range ends where the manufacturer would have scored without penalties for non-zero-emission technologies.

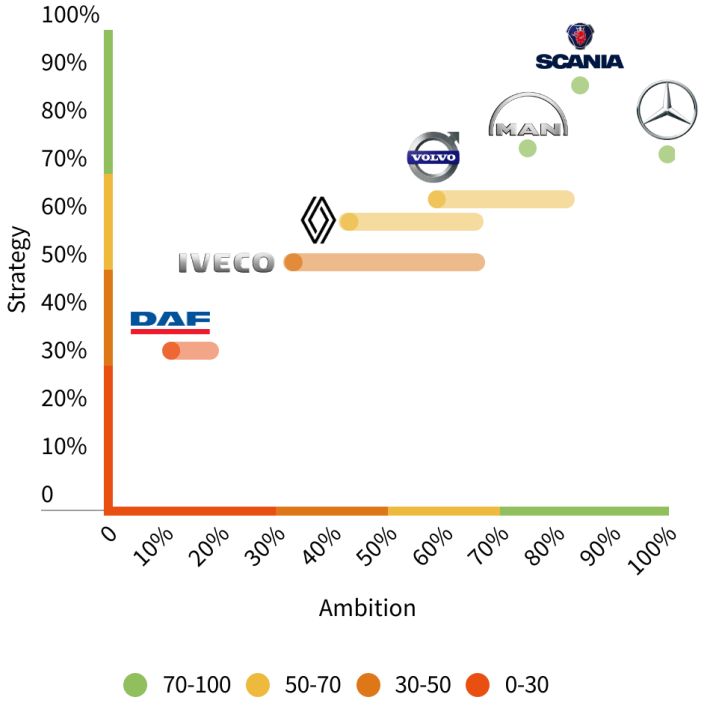


Figure 3. Zero-emission ambition vs industrial strategy for European truckmakers

Looking first at the frontrunners (ranked by industrial strategy score), **Scania** scores the highest on strategy (88%), slightly overperforming the ambition of its announced targets (84%). **MAN** scores 75% on both ambition and strategy, suggesting that its voluntary announcements are in line with its current industrial strategy. On the contrary, **Mercedes-Benz Trucks** scores the highest on ambition (100%), but falls short on industrial strategy (74%). This is the largest ambition-strategy gap among European truckmakers. This indicates a potential risk that they may not be prepared to meet their voluntary targets.

The four remaining European OEMs all receive at least one penalty for pursuing non-zero-emission truck technologies as climate solutions. Their ambition score (scaled to 100%) is presented both with and without penalties. This is because penalties have a corrective effect, bringing ambition closer in line with strategy.

Volvo Trucks scores 65% on industrial strategy. This is far off its publicly announced climate leadership (81%), which scores even above MAN. Taking into account penalties for betting on gas and biofuels helps understand where the implementation gap is coming from. Penalties reduce Volvo Trucks' ambition score to 59%, exposing its faltering long-term commitment to the transition. Similarly, **Renault Trucks** scores 60% on industrial strategy, higher than its ambition with penalties (43%) but lower than its ambition without (66%). **IVECO** scores 51% on strategy, higher than its 33% on ambition accounting for penalties, but lower than its ambition score based on voluntary announcements alone (66%). All three have a gap between their voluntary targets and their current industrial strategy.

Lastly, **DAF** scores 33% on industrial strategy, higher than its ambition score with penalties (11%) and without (19%). This is primarily because of its very low level of climate ambition.

3.2. Comparison to North American and Chinese truckmakers

In addition to ranking European OEMs against each other, their readiness to go to zero-emission is also compared to that of their counterparts in the US and China. This is of interest in the context of the ongoing global race for industrial leadership on zero-emission vehicle technology, as well as to assess whether a parent group possibly has different strategies depending on the region where a subsidiary is active.

Annex 1 explains how the Northern American and Chinese OEMs included here were selected. OEMs which were analysed but scored under 15 points are excluded here. While some of these might represent a large amount of sales in their own region, the purpose of this report is to contrast EU OEMs to leading OEMs in other parts of the world which could either grow to threaten European industry leadership on commercial vehicle technology, or which are connected entities to European OEMs and could impact internal OEM group policy and regional prioritisation.

Fifteen of the OEMs analysed here score above 50 points (Fig.4), only six of which are legacy OEMs. The overall leader is Scania, followed by Mercedes-Benz Trucks, Tesla, MAN, and BYD US.

When considering only legacy OEMs, European truckmakers appear to be better prepared than their international competitors to go to zero-emission. However when looking only at new entrants, US and Chinese ZE truckmakers[8] far outcompete European startups.

European leadership is partially explained by a higher tendency to set targets. In Europe, DAF is the only OEM without a ZET target for 2030, and all OEMs have 2040 targets. But only two legacy Chinese OEMs and four legacy US OEMs have either 2030 or 2040 targets for ZET sales.

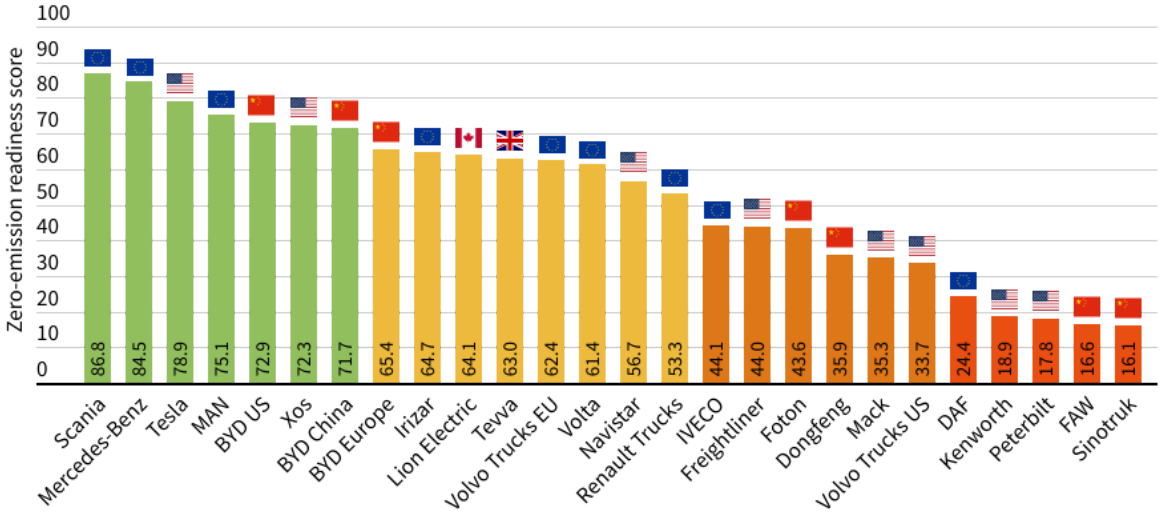


Figure 4. Zero-emission readiness scores of selected truckmakers in Europe, China, and the US

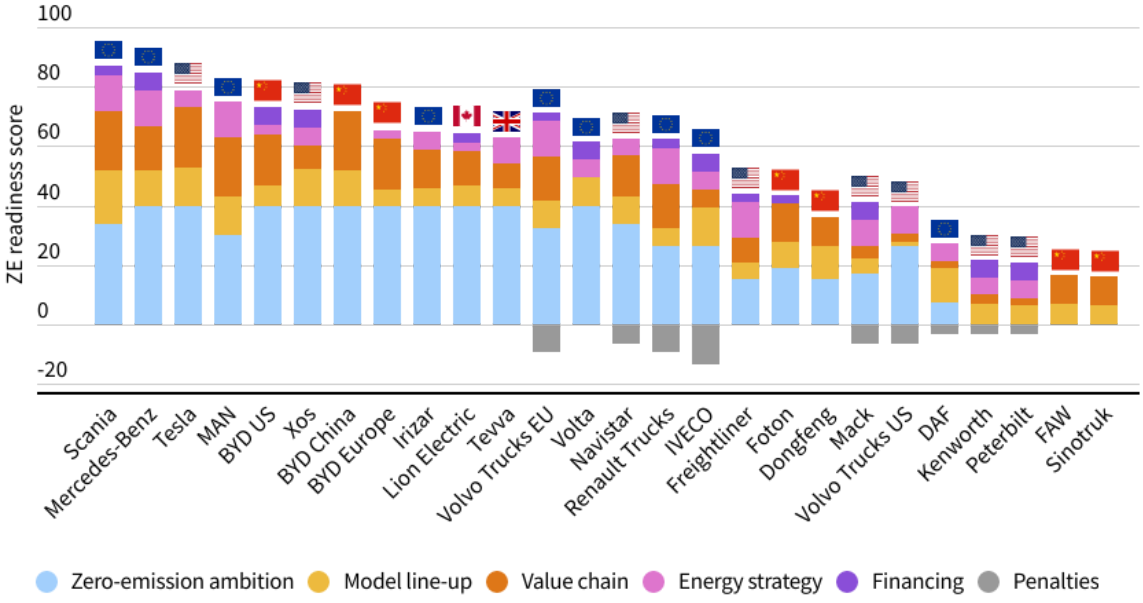


Figure 5. Zero-emission readiness scores, broken down by category

[8] Here, a ZE truckmaker is an OEM which in a given region only produces ZETs. Some produce cars or buses with internal combustion engines (e.g. BYD, Irizar).

3.2.1. United States & Canada

All truckmakers responsible for at least 10% of truck production in the US and Canada were analysed, as well as ZE truckmakers. Most legacy US OEMs are part of groups traditionally headed by European companies — e.g. Freightliner by Daimler Truck; Navistar by TRATON; Mack and Volvo Trucks by Volvo Group. The exception is Paccar, a US OEM group which comprises Kenworth and Peterbilt in the US, and DAF in the EU.

Tesla leads the US ranking despite having only one ZET model on offer, the Tesla Semi. The Semi meets all quality criteria considered here: range, e-optimised cab, and electric drivetrain integration. In addition, Tesla is heavily invested in battery supply chains, and is the only US OEM to score all points on value chain strategy.

Xos offers 3 medium-duty and 3 heavy-duty ZETs, including the ET-One, a concept vehicle meeting all three quality criteria. Xos also offers turnkey solutions called "Fleet-as-a-Service".

Lion Electric is the only ZE OEM which offers financial services but no innovative turnkey solutions. It was forced to develop its own battery strategy after Romeo Power allegedly broke their long-term agreement. After it was purchased by Lion Electric's competitor, Nikola Motor, Romeo Power stopped supplying Lion Electric with battery packs [40].

TRATON's **Navistar** scores the highest among legacy US manufacturers, but well below TRATON's European brands Scania and MAN. Navistar has made conflicting statements about its long-term ZE ambition, both claiming to have set clear ambitions of 100% ZE new vehicle sales by 2040 [41] and forecasting that 10% to 15% of long-haul applications will be fuelled by alternative fuels in the long-term [42].

Daimler Truck's **Freightliner** is the only legacy US OEM other than Navistar to have set a target of 100% ZETs by 2040. It is also the only legacy US OEM to score all points on energy strategy. However, Freightliner's battery strategy appears limited to a long-term supply agreement between its parent Daimler Truck and CATL. Unlike Mercedes-Benz Trucks, Freightliner has not announced a ZET sales target for 2030.

Following Freightliner are Volvo Group North America's two OEMs: Mack and Volvo Trucks. In spite of its lower ZE ambition — only a 35% ZET target for 2030 —, **Mack** outperforms Volvo Trucks North America thanks to its industrial strategy. In particular, Mack offers Vehicle-as-a-Service to its customers.

Volvo Trucks North America has set a target of 50% ZET sales by 2030, i.e. 20 points lower than its European counterpart. It currently leads the heavy ZET market in North America, owning a market share of almost 50% in 2022 [33]. Its relatively poor performance in this ranking is due to a very low score on industrial strategy. It scores the worst of all legacy OEMs on model line-up.

Paccar's **Kenworth** and **Peterbilt** come last among selected US truckmakers, scoring slightly below the EU's DAF, which is also part of Paccar. They are the only US truckmakers included in this ranking which have not set ZET targets for 2030 or 2040. Instead, Paccar forecasts that by 2060, only 63% of its truck sales will be zero-emission [43].

Ford is the only major US truck manufacturer not included in this ranking, due to scoring under 15 points. It is mostly focused on smaller medium-duty trucks such as pick-ups, which are used as passenger vehicles rather than for freight. In the US, Ford is not yet active in the race to decarbonise trucks.

3.2.2. China

China currently leads the ZET market, with a 90% market share in global sales in 2022 [4]. Its legacy truckmakers are highly dependent on CATL for their batteries [5]. ZETs produced by legacy Chinese truckmakers rarely have electric motors integrated into axles or wheels, or e-optimised cabs.

All truckmakers accounting for at least 10% of Chinese truck production were analysed. Regarding ZE truckmakers, China has the most ZE OEMs of all regions [44]. For simplicity, this analysis only looked at BYD, which currently is the only Chinese ZE truckmaker active on the EU market[9].

BYD US ranks fifth in the overall ranking. It scores almost all points on value chain strategy, falling short only on battery reuse and recycling. BYD US offers EV-as-a-Service solutions to its customers, thus scoring all points on financing strategy. However, none of its models have at least 450 km of range, or an e-optimised cab; nor does it invest in a nationwide charging network.

BYD China has more ZET models on offer (10 models) than BYD US (4 models), but it lacks innovative financial or energy services, hence why it scores lower than its US division.

BYD Europe has the fewest number of ZET models of all three BYD divisions considered here (2 models). Like BYD US it offers chargers to its ZET customers; but it does not have schemes such as EV-as-a-Service. Overall, BYD Europe scores just shy of the frontrunner threshold of 70 points.

Trailing far behind BYD is **Foton**: the second largest manufacturer of both conventional trucks and ZETs in China [5]. Foton held 10.9% of the global ZET market in 2022 [4]. Foton recently announced a target of 50% new energy vehicles in 2030, but hasn't set ZET targets for 2040. To help its customers finance their trucks, Foton offers battery-leasing through a joint venture with CATL [45].

Dongfeng Trucks is the largest manufacturer of ZETs in China, and made up 11.6% of the ZET market in 2022 [4]. It has set a target of carbon neutrality in operations by 2040 [46], but lacks a 2030 target. Dongfeng scores relatively well on model line-up, as it offers seven medium ZETs and 4 heavy ZETs,

[9] Here, BYD qualifies as a ZE truckmaker as all the trucks it produces are ZETs, based on KGP data. However, BYD also produces vehicles with internal combustion engines in other segments (e.g. cars).

including one model with a range above 450 km. However, it does not support its ZET customers with either energy or dedicated financial services.

FAW is the largest truck manufacturer in China. It accounted for 6.0% of the global ZET market in 2022 [4]. It is the only OEM analysed here with battery-swapping models on offer. The technology is currently led by smaller players [5].

CNHTC/Sinotruk comes last in this ranking. While it accounted for only 1.5% of the global ZET market in 2022, it held 18.3% of the FCET market [4].

All the legacy Chinese OEMs mentioned above are state-owned. As a result their supply of batteries and raw materials is assumed to be secure.

3.2.3. European zero-emission truckmakers

Unlike in other regions where new entrants perform better than legacy truckmakers, in Europe zero-emission truckmakers do not lead the ranking.

Irizar, Tevva, and Volta Trucks all have similar scores falling between 61 and 65 points. **Irizar** is an established bus and coach manufacturer, and therefore has an existing value chain and energy strategy. **Tevva** is the only ZE OEM with a partnership to develop both charging and hydrogen infrastructure [47]. **Volta Trucks** is the only OEM included in this analysis who does not score any points in value chain strategy. However, its Volta Zero boasts a clean sheet design, and Volta Trucks offers Truck-as-a-Service.

4. Conclusion and lessons for future competitiveness

4.1. Legacy truckmakers

Legacy European OEMs demonstrate a wide range of readiness levels, going from three frontrunners scoring above 70 points (Scania, Mercedes-Benz Trucks, MAN), to one laggard scoring below 30 points (DAF). Volvo Trucks scores above 50 points, while Renault Trucks and IVECO score under the average.

Contrary to European OEMs, legacy US and Chinese OEMs are less likely to have set ZET targets for themselves for 2030 and 2040, which negatively impacts their ZE ambition score. This is partly due to the forthcoming EU CO_2 standards for HDVs having spurred EU OEMs to announce voluntary targets. This ranking is developed from a European point of view where voluntary targets matter greatly for policymaking.

When looking beyond voluntary targets to industrial strategy, none of the legacy US and Chinese manufacturers develop their own battery packs or cells. Broadly speaking, European OEMs appear to be well-positioned compared to their legacy competitors in the US and China. This is in spite of China's first-mover advantage.

For OEM groups with both European and US subsidiaries, the European divisions currently score higher than their US counterparts. However, California just adopted its Advanced Clean Fleets Regulation, which mandates manufacturers to sell only ZE medium-duty and heavy-duty trucks from 2036, without exception [48]. California is the US leader on environmental regulation, with other states usually adopting similar standards. As a result, it is expected that US truckmakers will adapt their ZE strategy to meet California's diesel end date. Parent companies could shift investments away from Europe and into the US to cope with the most stringent regulation. Such a move could be aided by the broad financial support available for battery and hydrogen supply chains under the Inflation Reduction Act.

4.2. New entrants

Both the US and China also have emerging champions with Tesla and BYD. Tesla ranks first in this analysis, and BYD ranks well in all three regions. Unlike smaller manufacturers, both Tesla and BYD have experience in rapidly scaling up manufacturing zero-emission cars. Together, Tesla and BYD make up 40% of the global battery-electric car market [49]. Unless legacy truckmakers get serious about ZETs, Tesla and BYD look poised to repeat their success story with zero-emission trucks.

New entrants have the advantage of being able to focus on low-hanging fruit, that is to say segments which are easier to electrify and where high volumes can quickly lead to economies of scale. But legacy truckmakers need to decarbonise their entire line-up, including truck segments where the economic benefits of switching to ZETs take longer to materialise. Legacy OEMs must therefore ensure they move fast on high-volume segments to avoid losing their leadership to smaller ZE OEMs.

4.3. Battery supply chains

Looking ahead, truckmakers should get more active in battery supply chains. Tesla, BYD, and TRATON are the only manufacturers to have secured long-term supplies of battery raw materials. In all three cases, they benefited from their own or their Group's efforts to secure this supply for the car market segment. Other manufacturers are either less integrated with carmakers or not connected at all. As a result, they must build their battery value chains from the ground up (alone or through partnerships), and risk being late to secure raw materials.

Although Chinese OEMs other than BYD are heavily dependent on CATL for their batteries, in practice this should not hinder their transition to ZETs. Dongfeng, Foton, CNHTC, FAW, Shaanxi Auto are all state-owned companies. As nine of the top ten battery cell manufacturers in 2030 are expected to be Chinese, it is unlikely that Chinese OEMs will have trouble sourcing batteries. For example, they could source their batteries from CALB, a state-backed battery maker expected to be the third largest cell producer in 2030 [50].

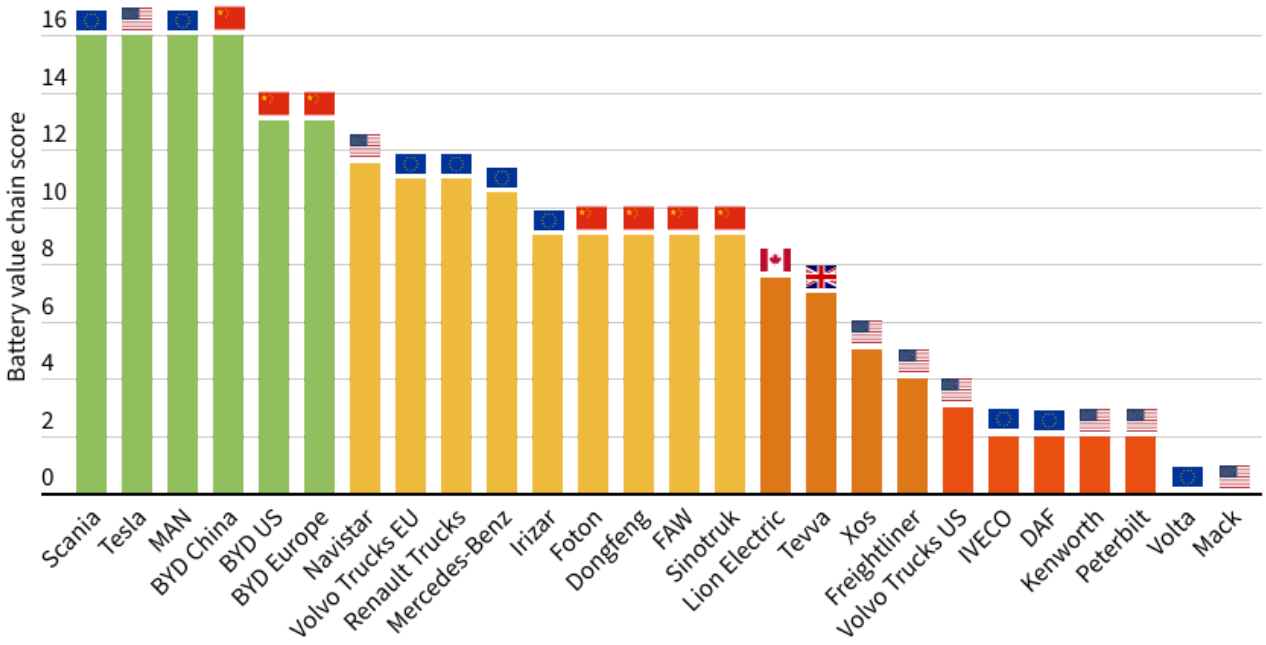


Figure 6. Battery value chain score

In the US, the Inflation Reduction Act (IRA) is expected to boost investments in battery manufacturing at the expense of projects in Europe. Already, two-thirds of battery capacity planned in Europe is at risk as a result of the IRA [51]. Parent companies with both European and US OEMs could prioritise developing battery supply chains in the US, where production will be subsidised.

With the target to sell only zero-emission trucks from 2036 in California now in place, these groups now also have a strong incentive to ramp up zero-emission production in the US, which could lead to the scoring of companies such as Freightliner, Navistar, Mack, Volvo Trucks, Peterbilt, and Kenworth improving considerably over the next years. This will have important implications for European truckmakers, as half of heavy trucks built in the US rely on European technology [52].

By 2030, the US will almost triple its share of global battery cell production to 14% [53], from 5% currently [54]. China would remain the world leader, accounting for 69% of global production [53] (Fig.7).

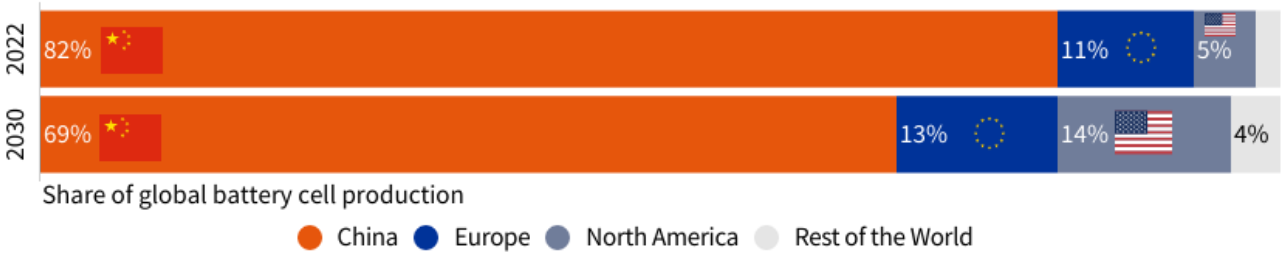


Figure 7. Share of global battery cell production by region

As a result, the leadership of legacy European truckmakers risks being challenged in coming years, unless they develop strong battery ecosystems, including not only cell manufacturing, innovation, and recycling, but securing raw materials as well.

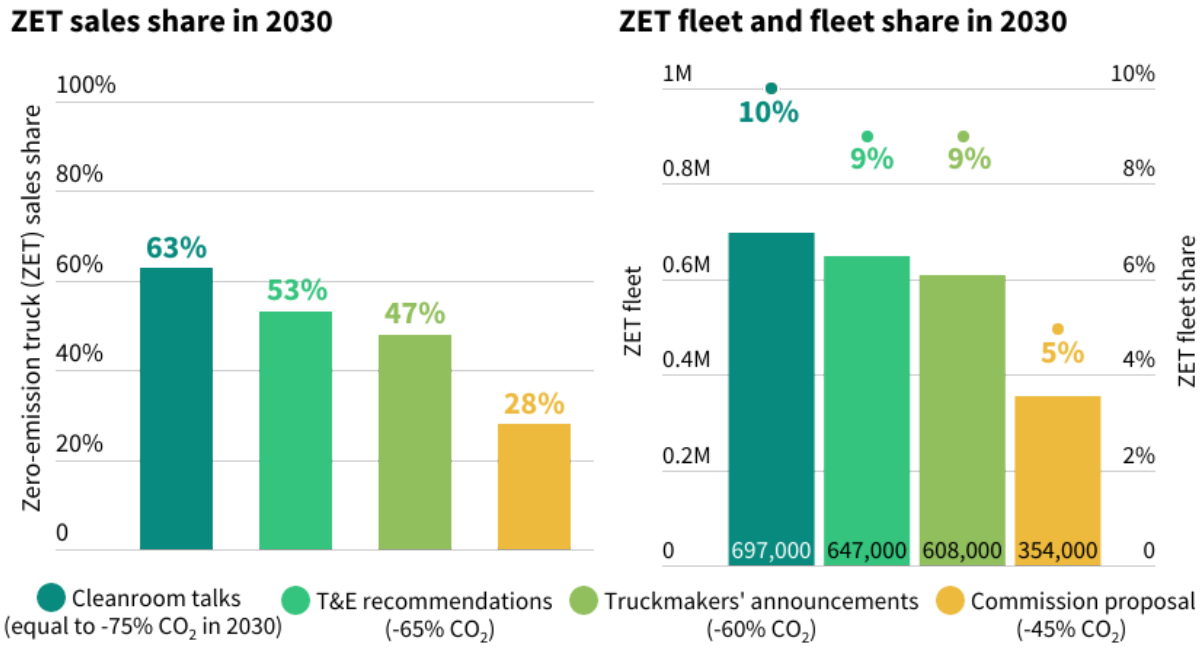
Based on announced gigafactory projects, European battery cell production has the potential to reach 1.4 TWh in 2030 [55]. This would be enough to meet European battery demand in 2030 — estimated at 0.9–1.2 TWh — for electric vehicles (both light- and heavy-duty) and energy stationary storage. However, regulatory certainty and a comprehensive European battery strategy is required to ensure planned investments materialise.

Regulations mandating them to increase production of zero-emission vehicles, such as the EU HDV CO_2 standards, can play a key role in ensuring Europe retains its global leadership. The ambition level of the legislation's 2030 target will be key in that regard.

5. Policy recommendations

The Commission's proposed 2030 target of -45% CO_2 reduction would result in only 28% of new truck sales to be ZETs in 2030. Yet, according to their own voluntary public targets, OEMs are already planning for 47% of their sales to be ZETs in 2030. During talks with German authorities, European truck manufacturers even indicated that 63% of new truck sales above 12t in Europe will be zero-emission in 2030 [56] (Fig.8).

Rather than lag behind voluntary announcements, regulation should lead the market. Therefore, **T&E recommends setting a 2030 target of -65% CO_2** in addition to extending the scope of the regulation to small trucks and vocational and non-certified vehicles. This would result in 53% ZET sales in 2030 (all truck categories combined), as on top of that T&E assumes engine efficiency to improve by 0.5%–1.3% per year.



Notes: Scope includes EU+UK (in line with the scope of truck makers' announcements) and refers to all vehicle groups, except for the Cleanroom talks where only sales from 12 t GVW are considered. The Commission's proposal exempts 20% of HDV sales.

Figure 8. Summary of ZET uptake and stock in 2030 in different scenarios

The European Commission's HDV CO_2 standards proposal does not label trucks running on e-fuels or biofuels as zero-emission. While the oil industry and combustion engine supply chain is heavily lobbying for the inclusion of fuels in the regulation, almost all European OEMs are not in favour of such an inclusion. Together these OEMs account for 91% of EU sales [29, 57] (Fig.9).

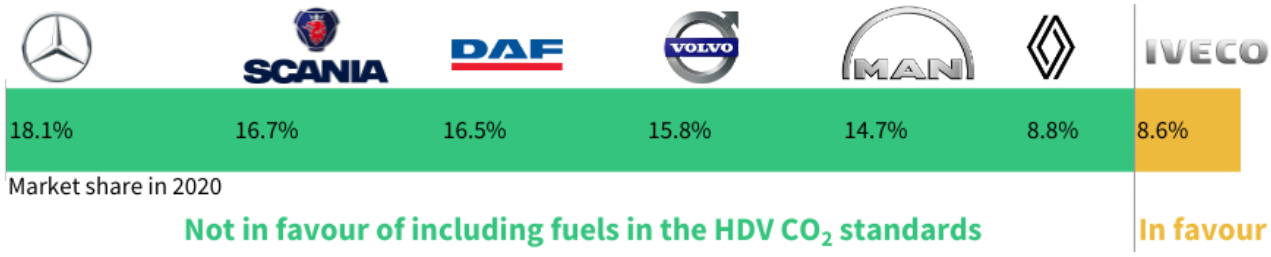


Figure 9. Market share in 2020 of EU truckmakers, and their position on including fuels in the CO_2 standards

IVECO is in fact the only OEM in favour of including fuels in the HDV CO_2 standards [29]. It lags behind new entrants and most of its European competitors. Rather than make the necessary investments to decarbonise its fleet, IVECO appears to want to keep selling its existing diesel and gas trucks on the vague promise that fuels will get cleaner.

Lastly, a 100% CO_2 reduction is needed to provide market certainty. California has recently adopted its Advanced Clean Fleets Act, which mandates all new HDVs to be zero-emission by 2036, without exception

(including so-called vocational vehicles such as garbage and construction trucks). In comparison, the Commission's proposed target of 90% CO2 reduction by 2040, applying to only 80% of the market, falls disastrously short.

While European OEMs appear to be better prepared than their US counterparts for now, such a gap in regulatory ambition could spell the end of European leadership in both climate policy and commercial vehicle technology. It is already clear that a large part of the EU OEMs good performance is based on voluntary commitments, which in the absence of regulation might not materialise. **T&E therefore recommends setting a 100% CO_2 reduction target in 2035.** This is needed both for the climate and for industrial leadership.

Ambition	Mercedes-Benz Trucks	Scania	MAN	Volvo Trucks	Renault Trucks	IVECO	DAF
2030 ZET target	60%	50%	44%	70%	50%	50%	
2040 ZET target*	100%	100%	100%	80%	80%	80%	80%
Support gas trucks	No	No	No	Yes	Yes	Yes	No
Support biofuels in new trucks	No	No	No	Yes	Yes	Yes	No
Support e-fuels in new trucks	No	No	No	No	No	Yes	Yes
Position on the inclusion of fuels in the HDV CO2 standards	Opposed	Opposed	Opposed	Opposed	Opposed	In favour	Neutral

* Announcements for 100% fossil-free truck sales are assumed to be 80% zero-emission truck sales.

Strategy	Mercedes-Benz Trucks	Scania	MAN	Volvo Trucks	Renault Trucks	IVECO	DAF
Number of (planned) medium zero-emission trucks	1	0	1	1	1	2	0
Number of (planned) heavy zero-emission trucks	4	7	3	5	4	2	4
At least one truck with 450 km range	✓	✓	✓	✓	✗	✓	✓
At least one truck with an e-optimised cab	✗	✗	–	✗	–	–	✗
At least one truck with its e-motor integrated in the axle or wheels	✓	✓	✓	✗	✗	✓	✓
e-drivetrain manufacturing	✓	✓	✓	✓	✓	✓	✗
Battery pack manufacturing	✓	✓	✓	✓	✓	–	–
Battery cell manufacturing	–	✓	✓	✓	✓	✗	✗
Raw materials security	✗	✓	✓	✗	✗	✗	✗
Battery recycling	–	✓	✓	✓	✓	✗	✗
Battery innovation	✓	✓	✓	✗	✗	✗	✗
Charging support to customers	✓	✓	✓	✓	✓	✓	✓
Investing in a charging network	✓	✓	✓	✓	✓	✗	✗
Financing solutions dedicated to zero-emission trucks	✓	✗	✗	–	–	✓	✗

✓ Yes – Partially ✗ No

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Annex 1. Market coverage of selected truckmakers

The core European truckmakers under consideration are IVECO Group's IVECO, Daimler Truck's Mercedes-Benz Trucks, Paccar's DAF, TRATON's MAN and Scania, and Volvo Group's Renault Trucks and Volvo Trucks. Together, they account for 98% of European truck production [44]. Daimler Truck's FUSO is not analysed here due to its low share of European truck production (1%, [44]).

The core North American truckmakers included in the analysis are all OEMs accounting for at least 10% of US and Canadian truck production. They are Daimler Truck's Freightliner, Ford, Paccar's Kenworth and Peterbilt, and Volvo Group's Mack and Volvo Trucks, and Ford. TRATON's Navistar, despite representing only 6% of US truck production, was also included to provide a point of comparison to TRATON's MAN and Scania. Together, they make up around 85% of US truck production [44]. Daimler Truck's Western Star is not included due to its low share of US truck production (3%, [44]).

The core Chinese truckmakers included in the analysis are all OEMs responsible for at least 10% of Chinese truck production: Foton, CNHTC/Sinotruk, Dongfeng, FAW, and Shaanxi Auto. Together they represent more than 80% of Chinese truck production [44].

The zero-emission truckmakers considered are all OEMs who in a given region only produce zero-emission trucks. In Europe, they are BYD, Hyzon, Irizar, Tevva, and Volta. In the US and Canada they are BYD, Lion Electric, Nikola Motor, Tesla, and Xos. In China, there are sixteen zero-emission truckmakers by this definition. Only BYD was analysed, as it is the only one with global presence.

Lastly, Nikola Motor and Hyzon are both excluded from the report due to their current financial troubles [58, 59][60]. Results are not shown for OEMs scoring under 15 points.

Annex 2. Methodology

Information on OEM zero-emission strategies was collected from publicly available materials, such as press announcements, company sustainability reports on Environment, Society, and Governance (ESG), brochures, etc. In some cases, data were obtained from personal communication, or were derived from KGP Auto's tracking of ZET models [44].

European OEMs were surveyed in April and May 2023 to provide them with the opportunity to correct or supply additional information.

The scoring methodology is originally derived from EV readiness ranking created by T&E to assess carmakers' electrification strategies and was adapted to account for truck specificities [7]. The weights attributed to each category were determined based on expert group consultation.

The scoring methodology is adapted to the current stage of the transition to ZETs. In later stages, weights associated with supporting energy infrastructure deployment and offering dedicated financing will be reduced; while weights associated with securing raw materials should increase.

Category	Points	Calculation method
Zero-emission ambition	**/40**	
ZET share target in 2030	/25	25 points for setting a ZET share target of 60% or above in 2030, and no points for a target of 20% or under (in line with what compliance with the current EU HDV CO_2 2030 target would require). Scores for shares between 20% and 60% are calculated based on min-max normalisation.
ZET share target in 2040	/15	15 points for setting a ZET share target of 100% by 2040, and no points for a target of 60% or under (as that is a 10-year delay compared to what the climate urgency requires). Scores for shares between 60% and 100% are calculated based on min-max normalisation. Where the announced target includes non-ZETs, (e.g. "fossil-free") it is assumed that ZETs make up 80% of the announced target.
Penalties for false solutions	**/-13**	
Gas	/-3	Minus three points for publicly promoting gas trucks as a long-term climate solution.
Biofuels	/-3	Minus three points for publicly promoting biofuels as a long-term climate solution in new trucks.

Synthetic fuels	/-3	Minus three points for publicly promoting synthetic fuels as a long-term climate solution in new trucks.
Fuel credits	/-4	Minus four points for supporting the inclusion of a fuel crediting mechanism in the HDV CO_2 standards.
Industrial strategy	**/60**	
Model line-up	**/22**	
e-optimised cab	/4	Four points if at least one model in their planned ZET line-up has an e-optimised cab (only two points if that model is a concept vehicle or part of a research project).
Motor integration in axle/wheels	/4	Four points if at least one model in their planned ZET line-up has its motor(s) integrated in the axle or wheels.
Range above 450 km	/4	Four points if at least one model in their planned ZET line-up has a range above 450 km (only two points if that model is a prototype)
Number of (planned) heavy ZETs	/6	Six points for offering the highest observed number of zero-emission heavy-duty trucks (7). Scores for numbers of models between 0 and 7 are calculated based on min-max normalisation. For OEMs who are not active in the medium-duty segment, the number of planned heavy ZETs is scored out of ten points instead of out of six.
Number of (planned) medium ZETs	/4	Four points for offering the highest number of zero-emission medium-duty trucks (7). Scores for numbers of models between 0 and 7 are calculated based on min-max normalisation.
Components value chains	**/20**	
Battery manufacturing (excluding cells)	/4	Four points for in-house production; three points for a strategic partnership, or for state-owned Chinese OEMs (in which case supply is assumed secure); two points for a long-term supply agreement; one point for having multiple suppliers.
Battery cell manufacturing	/4	Four points for in-house production (including from parent company, or an OEM belonging to the same group); three points for investment or long-term agreement combined with in-house pilot production, or for state-owned OEMs; two points for a long-term agreement; one point for having multiple suppliers.
Securing raw materials	/3	Three points for securing a long-term supply of battery materials (including from its parent company).
Manufacturing electric drivetrain / fuel cell	/4	Four points for in-house production of either the e-motor, e-axle, or fuel cell; three points for a joint venture or

		strategic partnership; two points for a long-term agreement; one point for a joint project; 0.5 point for having multiple suppliers.
Battery recycling	/3	Three points for in-house, or doing recycling through partners; 1.5 point for a joint research project; 0.5 point for a non-specific statement on reuse and recycling.
Battery R&D / innovation	/2	Two points for in-battery R&D.
Energy strategy	**/12**	
Investing in charging network	/6	Six points for investing in charging network (including through a joint venture)
Providing chargers / H_2 supply	/3	Three points for providing chargers or H_2 supply to customers.
Consulting services for charging	/3	Three points for providing charging consulting services to customers (e.g. site planning).
Financing strategy	**/6**	
ZET financing	/6	Six points for providing turnkey solutions, or three points for other ZET-specific financing services (e.g. battery leasing, lower interest rates).

Annex 3. Summary of results for European OEMs

Truckmaker	Overall score (/100)	ZET targets (/40)	Non-ZE technologies (/-13)	Model portolio (/22)	Value chain (/20)	Energy (/12)	Financing (/6)
Scania	**87**	34	0	18	20	12	3
Mercedes-Benz Trucks	**85**	40	0	12	15	12	6
MAN	**75**	30	0	13	20	12	0
Volvo Trucks EU	**62**	33	-9	9	15	12	3
Renault Trucks	**53**	26	-9	6	15	12	3
IVECO	**44**	26	-13	13	6	6	6
DAF	**24**	8	-3	11	3	6	0