Electric trucks take charge

By 2035 all new electric freight trucks in Europe will be cheaper to run, drive as far and carry as much as diesel trucks

October 2022

Summary

Europe's heavy-duty climate problem

Heavy-duty trucks are responsible for 26% of greenhouse gas (GHG) emissions from road transport in Europe, while only accounting for 2% of the vehicles on the road. To reduce the EU's GHG emissions and reach climate neutrality by 2050, heavy-duty vehicles (HDVs) need to be entirely decarbonised. Given that trucks last on average more than 18 years on the road, this means ending the sale of all new freight trucks with combustion engines by 2035, with vocational vehicles following by 2040. This would reduce overall HDV emissions by 95% by mid century, with only a small share of the remaining fleet relying on diesel.

Feasibility of reaching 100% zero emission truck sales

Both amongst regulators and industry stakeholders, there is growing consensus that zero emission trucks - battery electric (BEVs) and fuel cell electric vehicles (FCEVs) - are the optimal way to decarbonise the road freight sector. However, the speed at which the transition from internal combustion engine vehicles (ICEVs) towards BEVs and FCEVs can take place is not yet clear to everyone.

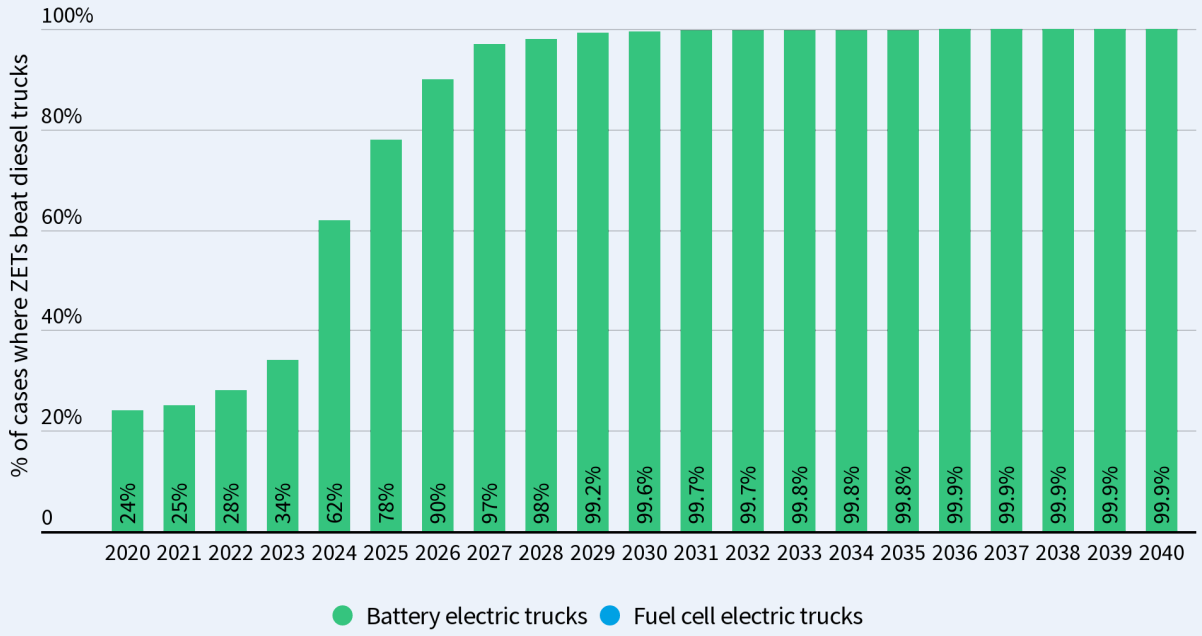
T&E in collaboration with *Agora Verkehrswende* commissioned the independent research organisation *Netherlands Organisation for Applied Scientific Research* (TNO) to answer this question. The report by TNO assesses the techno-economic feasibility of reaching 100% zero emission vehicle sales for urban and regional delivery and long-haul trucks for all EU countries and the United Kingdom. Ultimately, it answers the questions whether and how fast Europe can go to 100% zero emission for new freight truck sales.

The TNO report compares the Total Cost of Ownership (TCO) of diesel, BEVs and FCEVs and assesses when zero emission alternatives become cheaper to own and run. Operational requirements - such as sufficient driving range, no additional time losses due to recharging or refuelling, and similar

payload capabilities - are also important conditions for hauliers when switching to zero emission trucks, and were included in the analysis.

Results: all new freight trucks can be 100% zero emission by 2035

The TNO report shows that it is possible to fully transition all new freight trucks to zero emission cost-effectively and in time to meet Europe's climate targets. All new urban, regional and long-haul trucks can be zero emission by 2035 across all European markets, with some national markets such as in Northern Europe expected to go even faster. All new sales in those segments will have a lower TCO compared to diesel while delivering the same capabilities in terms of range, payload and driving times.



Note: Fuel cell electric trucks were included in the analysis and represent up to 0.02% of cases in 2040

For urban delivery trucks, the ZEV uptake potential is very high already today. More than 70% of them are currently cheaper to own and run while fulfilling the operational needs. The ZEV uptake potential of regional delivery trucks will increase rapidly to 90% by mid decade. Both urban and regional delivery trucks will reach virtually 100% by 2030.

Long-haul trucks will initially have a slower increase in uptake potential but grow quickly to 80% by 2026 and 99.5% by 2030. Market uptake in the long-haul segment almost exclusively consists of BEVs. FCEVs have a consistently higher TCO than diesel throughout the 2030s and account for only 0.1% of long-haul sales (0.02% of total freight sales), beating diesel in a few countries with extremely high distances and low hydrogen costs.

Aggregating all urban, regional delivery and long-haul trucks, ZEV uptake potential reaches 99.6% in 2030 and 99.8% by 2035. This means that virtually all new freight trucks could switch to zero emission from a cost and operational perspective already by 2030. Only a tiny fraction of long-haul truck sales with use cases for extremely high daily distances remain favourable for diesel in 2035. However, simply adding an extra stop to charge during the day would flip the balance towards BEVs also in those use cases. As BEVs have a much lower TCO than diesel trucks, this would still be more cost-efficient than sticking to the diesel truck, even when taking the small addition in rest time into account.

TNO's analysis indicates that the trajectory of the ZEV uptake will be similar across European regions. The difference is the smallest for urban and regional delivery trucks which reach virtually 100% uptake potential in 2030 in all regions. For long-haul trucks the difference is slightly larger, with Northern Europe already reaching 99% by 2026, while it takes until 2030 in Southern Europe.

Regulation is needed to deliver ZEV uptake potential

The ZEV uptake potential indicates the year by which a ZEV is cheaper to run, while driving as far and fast and carrying as much as diesel trucks. This does not mean that this potential will automatically materialise. For example, in more than 70% of cases, zero emission urban delivery trucks already beat diesel today. But ZEVs do not make up 70% of new sales in the urban delivery segment today.

One of the reasons for this is that truck makers are not yet producing ZEVs at scale, meaning hauliers interested in benefiting from these lower costs are often not able to purchase a ZEV. The working assumption of the analysis by TNO is that the decision to buy a zero emission truck depends on the TCO and meeting the operational capabilities of diesel trucks. In reality, regulations are needed for truck makers to overcome the inherent costs and change in production and business models required. This only underscores the need for strong supply-side policy to shift production and develop supply chains towards zero emission trucks fast enough.

Implications for the review of the truck CO_2 standards

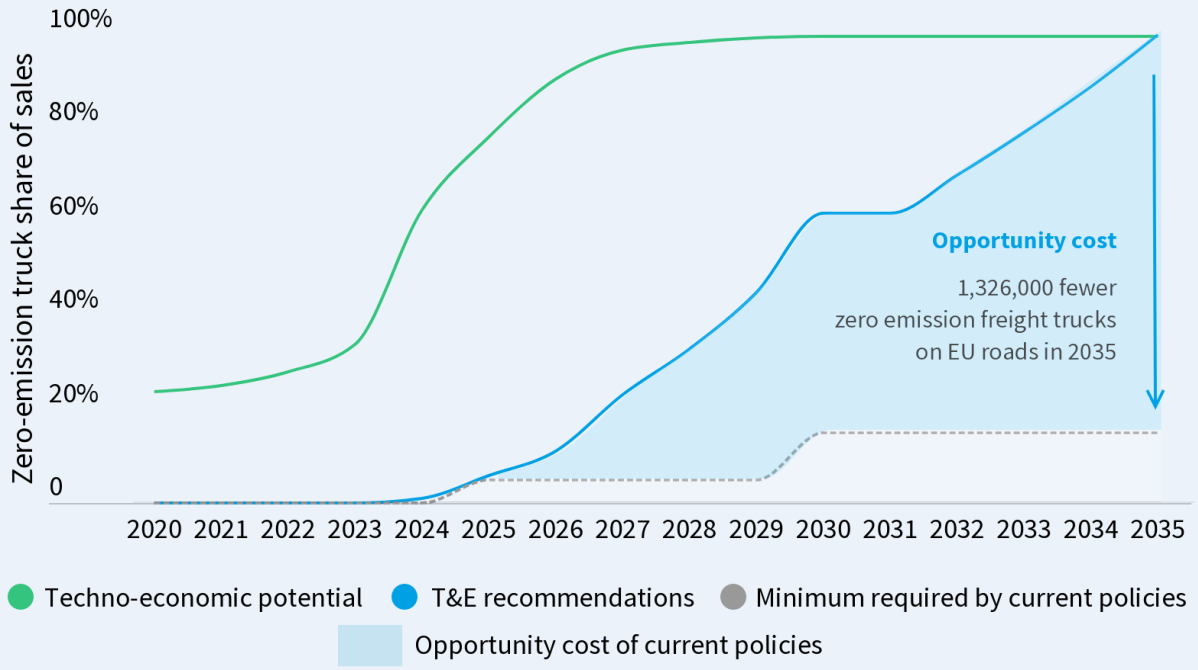
The forthcoming review of the HDV CO_2 standards is the opportunity to put the European HDV sector on a trajectory in line with climate neutrality. The evidence clearly shows that this is not only feasible, but would also bring massive economic benefits for the industry and society as a whole.

The techno-economic feasibility of zero emission trucking is by itself thus not enough to enable the market ramp-up. Without strong supply-side policy in the form of ambitious CO_2 standards, the ZEV uptake potential identified by TNO would be merely hypothetical and fail to materialise in reality. This would deprive transport operators from benefiting from the rapidly increasing cost advantage of transitioning to electric trucks.

Set a trajectory to 100% new zero emission freight trucks by 2035

The CO_2 standards currently only regulate heavy lorries which are responsible for 64% of all emissions from HDVs. This analysis highlights that the regulation can and must be extended to all and cover small and medium lorries, but also to all vocational trucks as well as trailers.

By 2035, a CO_2 reduction target of -100% should apply to heavy lorries (above 16 tonnes). Medium lorries (7.4 - 16 tonnes) should be regulated via the same common CO_2 reduction target as heavy lorries. A ZEV sales target of 100% should apply to small lorries (3.5 - 7.4 tonnes) in 2035 and to vocational vehicles in 2040. Given that the majority of small and vocational trucks will not be certified under VECTO, a ZEV sales target should be applied to those.



Note: Assumes ZEV uptake across all freight trucks, including currently regulated and unregulated vehicle groups

Enable a faster ramp-up until 2030

The TNO report finds a ZEV uptake potential of 99.6% for all urban, regional delivery and long-haul trucks by 2030 already. The current CO_2 reduction targets on the other hand would only deliver about 15% ZEV sales across the small, medium and heavy lorries segments. This shows a huge cost-effective potential to scale up ZEVs much faster than currently foreseen by the legislation.

The CO_2 targets for medium and heavy lorries therefore need to increase to -65% in 2030 and a new intermediate target of -30% should be introduced for 2027. T&E analysis shows that a CO_2 target of -65% for medium and heavy lorries would deliver 659,000 ZEVs on EU+UK roads by 2030. This amounts to just 7% more ZEVs than what truck makers have already announced publicly for the

end of the decade, while still being significantly below the techno-economic potential. For small lorries, a ZEV sales target of 35% should be introduced in 2027 and increased to 70% by 2030 reflecting their already high ZEV uptake potential in those years. A first ZEV sales target of 15% should apply to vocational vehicles in 2027. Subsequent targets should be set for 2030 (30%) and 2035 (80%).

Give no role to fuels in regulating new sales

Using e-fuels in the road freight sector is inefficient and unnecessary as zero emission alternatives exist. E-fuels would be the most costly compliance option for truck makers, transport operators and society as a whole. Trucks are heavily used capital goods that run for more than one million kilometres over their lifetime. This means that energy and fuel costs dominate the TCO, rendering combustion trucks running on e-diesel uncompetitive.

Conclusions

If European policy-makers do not agree on more ambitious CO_2 standards as part of the upcoming review, including a target to reduce CO_2 emissions from new freight trucks by 100%, they would fail to send the necessary market signal and create investment certainty for Europe's industry.

Failing to do so would put Europe's technological edge in the heavy-duty segment at risk just as the U.S. is joining China in the race to industrial leadership following the passage of the *Inflation Reduction Act*. In the worst case, it could lead to Europe's domestic automotive and supplier industry falling behind and losing its global leadership to the growing competition from overseas.

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1. Introduction

1.1. Europe's heavy-duty climate problem

Heavy-duty trucks - or all road vehicles above 3.5 tonnes moving goods - are responsible for 26% of greenhouse gas (GHG) emissions from road transport in Europe,[1] while only accounting for 2% of the vehicles on the road.[2] If no action is taken, these emissions will continue to grow. The European Commission expects truck activity in the European Union (EU) to further increase by 44% between 2020 and 2050.[3]

To reduce CO_2 emissions quickly enough and reach climate neutrality by 2050, heavy-duty vehicles (HDVs) need to be entirely decarbonised. Zero emission vehicles (ZEVs) are the only available technology which can cut emissions from new sales quickly, fully decarbonise the heavy-duty sector in the long-term, and eliminate harmful air pollution. The lifecycle GHG emissions of battery electric trucks (BEVs) in Europe are already around 50% lower than their diesel counterparts and will continue to decrease further over the coming years.[4,5]

Given that on average most trucks last more than 18 years on the road, this means ending the sale of all new HDVs with combustion engines by 2035 is necessary to reach the EU's 2050 climate neutrality objective. T&E analysis[6] shows that reaching 100% zero emission vehicle sales for all freight trucks[7] by 2035 (and for vocational vehicles by 2040) would reduce the sector's overall GHG emissions by 95% by mid century, with only a small number of old diesel vehicles remaining in the legacy fleet. Reaching 100% ZEV sales for freight trucks only by 2040 would fall short of the EU's climate targets: HDV emissions would only be reduced by 89% in 2050, with 20% of the remaining fleet still running on diesel.

1.2. Truck industry headed for zero emissions, but EU leadership at stake

Truck makers have already announced that they intend to ramp up ZEV sales over the coming years: An estimated 7% of total truck sales will be zero emission by 2025, rising to 44% by 2030 on average and up to 60% for individual manufacturers.[8]

[1] UNFCCC (2022). GHG data from UNFCCC. Link.
[2] ACEA (2022). Report – Vehicles in use, Europe 2022. Link.
[3] European Commission (2021). EU reference scenario 2020. Link.
[4] European Commission (2020). Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA. Link.
[5] Scania (2021). Scania publishes life cycle assessment of battery electric vehicles. Link.
[6] Transport & Environment (2022). Addressing the heavy-duty climate problem. Link.
[7] Trucks which are used for the delivery of goods are referred to here as 'freight trucks'. They are distinct from the so-called 'vocational vehicles' such as construction or special purpose trucks which may be harder to electrify due to economic or operational challenges.
[8] Transport & Environment. (2021). EU truck targets too weak to incentivise transition to zero-emission vehicles. Link.

Europe's largest truck manufacturer Daimler has gone even further and announced to only sell zero emission trucks from 2039 in Europe.[9] Scania is also aiming to go fully electric by 2040[10] and has pledged to fully transition to zero emission trucks by that date under the 'Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles'.[11]

However, these are only voluntary announcements. Changing technology requires significant transformation of and investment in manufacturing, workforce and supply chains. Without a strong regulatory driver to invest, scale up and sell those trucks, voluntary commitments will not materialise on their own. Given the increasing demand for batteries and critical raw materials, electric trucks will also compete with cars and vans. This requires a strong signal to ramp up the battery supply chain also for the upcoming demand from the heavy-duty sector.

The main policy in Europe to require truckmakers to invest and supply clean truck models are the HDV CO_2 standards. If European policy-makers do not agree on more ambitious CO_2 standards as part of the upcoming review, they would fail to send the necessary market signal and create investment certainty for Europe's industry.

Today Europe's original equipment manufacturers (OEMs) are world leaders in developing commercial vehicle technology. They have established a growing presence in global and emerging markets, including the U.S., China and India.[12,13,14] Failing to set a target to reduce CO_2 emissions from new freight trucks by 100% would put Europe's technological edge in the heavy-duty segment at risk just when the U.S. is joining China in the race for industrial leadership following the passage of the *Inflation Reduction Act*. In the worst case, it could lead to Europe's domestic automotive and supplier industry falling behind and losing its global leadership to the growing competition from overseas.

1.3. Governments pledge 100% zero emission truck sales

Governments around the world are recognising the growing momentum for zero emission trucks. Regulators are realising that effective, stringent and forward-looking regulation can accelerate the market uptake of zero emission vehicles and support their domestic industries to thrive. Besides stimulating the demand for clean trucks and the roll-out of infrastructure, emissions performance standards and sales targets requiring manufacturers to sell more ZEVs are effective policies to scale the supply of clean vehicles and bring down their costs. The European CO_2 standards for new cars

[9] Daimler (2019). Daimler Trucks & Buses targets completely CO2-neutral fleet of new vehicles by 2039 in key regions. Link.
[10] Eurotransport (2022). Scania ab 2040 nur noch elektrisch. Link.
[11] Calstart (2022). Global MoU Subnational Government & Private Sector Endorsers. Link.
[12] ICCT (2020). Race to zero. How manufacturers are positioned for zero emission commercial trucks and buses in North America. Link.
[13] ICCT (2021). The evolution of commercial vehicles in China: a retrospective evaluation of fuel consumption standards and recommendations for the future. Link.
[14] ICCT (2021). Market analysis of heavy-duty vehicles in India for fiscal years 2019–20 and 2020–21. Link.

and vans are the living proof of this: ensuring compliance with the regulation, car manufacturer sales of battery electric cars quintupled between 2019 and 2021.[15]

9 European governments have already pledged to transition to 100% ZE-HDV sales by 2040 under the Global Memorandum of Understanding (MoU) including the Netherlands, Portugal, Austria, Denmark, Finland and Luxembourg, the UK, Norway and Switzerland. Other countries have also set targets to reach 100% ZE-HDV sales such as Canada, Turkey, New Zealand, Chile and Uruguay as well as 16 U.S. states led by California.[16]

2. Feasibility of reaching 100% zero emission truck sales

Both amongst regulators and industry stakeholders, there is growing consensus that zero emission trucks - battery electric (BEVs) and fuel cell electric vehicles (FCEVs) - are the optimal way to decarbonise the road freight sector. However, the speed at which the transition from internal combustion engine vehicles (ICEVs) towards BEVs and FCEVs can take place is not yet clear to everyone.

Some observers still question whether it is feasible from a cost and operational perspective to transition all freight truck segments to 100% zero emission sales in the timeframe which is needed to achieve Europe's climate targets, i.e. by 2035 at the latest. Others raise questions with regards to potential operational limitations of battery electric and hydrogen trucks such as insufficient vehicle ranges, additional downtime due to longer charging and refuelling times, or potential payload[17] losses.

2.1. Context, scope and approach of the analysis

T&E, in collaboration with *Agora Verkehrswende*, commissioned the independent research organisation *Netherlands Organisation for Applied Scientific Research* (TNO) to answer exactly these questions. The report by TNO[18] assesses the techno-economic feasibility of reaching 100% zero emission vehicle sales for urban and regional delivery, long-haul trucks as well as construction trucks for all EU countries and the United Kingdom (UK). Ultimately, it answers the questions whether and how fast Europe can legislate for 100% new zero emission sales for freight trucks.

Trucks which are used for the delivery of goods are referred to here as 'freight trucks'. They are distinct from so-called 'vocational vehicles' such as construction or special purpose trucks. The freight trucks in the urban, regional delivery and long-haul segments which were included in the analysis are defined as small, medium and heavy lorries in the HDV CO_2 emissions standards. They

[15] EEA (2022). Monitoring of CO2 emissions from new passenger cars. Link.
[16] ICCT (2022). Internal combustion engine phase-outs. Link.
[17] 'Payload' refers to the weight of cargo a truck is capable and permitted to carry in addition to the vehicle's empty weight.
[18] TNO (2022). Techno-economic uptake potential of zero-emission trucks in Europe. Link.

make up the bulk of heavy-duty vehicle sales and emissions in the EU: 78% of new HDV sales and 92% of CO_2 emissions from new sales (see Figure 1).

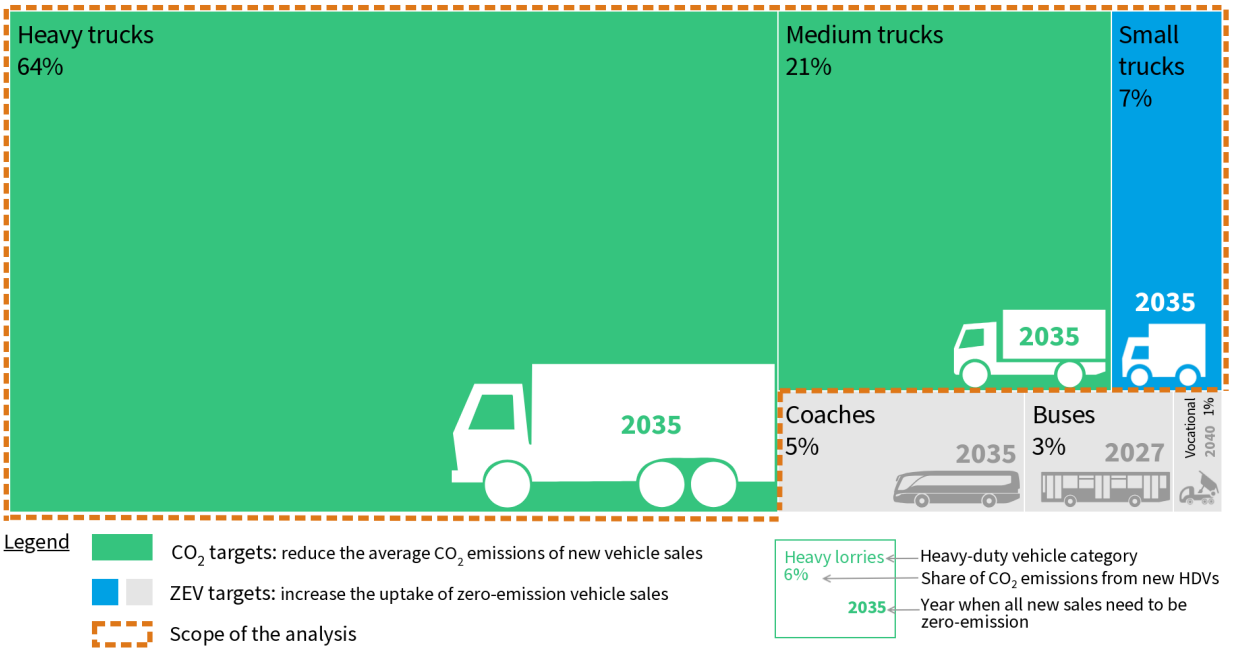


Figure 1. HDV types within the scope of the analysis

In the context of the TNO analysis, 'techno-economic feasibility' means that a zero emission truck is cheaper to own and run and matches the capabilities of diesel for a particular use case: the same driving range, no downtime due to recharging or refuelling and the same payload capacity.[19] The modelling of the ZEV uptake potential is based on the working assumption that ambitious HDV CO_2 emissions performance standards will be adopted which would guarantee sufficient supply of clean vehicles and dropping technology costs due to increasing economies of scale. This makes more ambitious HDV CO_2 standards paramount to achieving the potential of the identified cost-effective uptake potential of clean trucks in Europe.

The TNO report looks into two scenarios: One examines the uptake potential of zero emission truck sales if it was purely driven by the market, but provided that there is enough supply of ZEVs which requires more ambitious HDV CO_2 standards. The other scenario describes an accelerated market uptake potential in the 2020s by taking into account existing and announced demand-side policies such as national vehicle purchase incentives in seven European countries, CO_2-based road tolls and a European emissions trading system for road transport fuels.[20]

[19] Capabilities which were considered for the analysis are the ability to drive the required daily distances, carry the same payload and result in no additional downtime due to recharging or refuelling.
[20] The included demand-side policies are either already implemented today (purchase incentives in a number of European countries), will be implemented in the near future (CO_2-based truck tolls based on the new obligations under the Eurovignette directive), or are currently being agreed at EU level (ETS for road transport fuels)

2.2. Results: all new freight trucks can be 100% zero emission by 2035

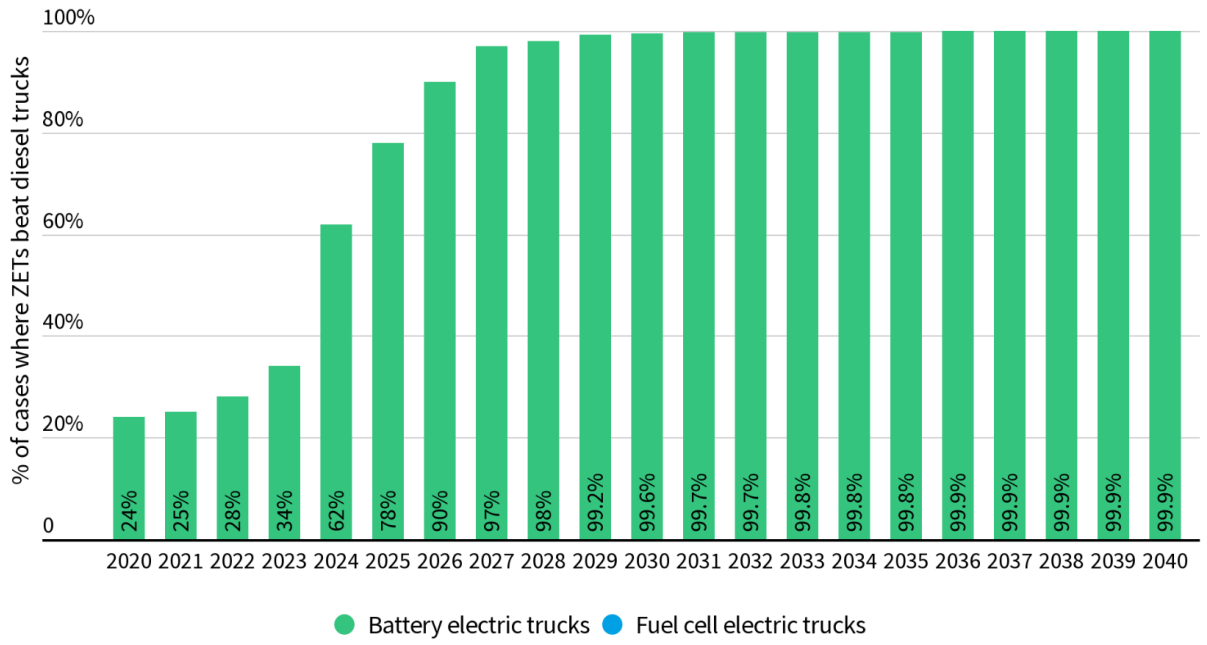
The TNO report shows that it is possible to fully transition all new freight trucks to zero emission cost-effectively and in time to meet Europe's climate targets. All new urban, regional and long-haul trucks can be zero emission by 2035 across all European markets, with some national markets such as in Northern Europe expected to go even faster. All new sales in those segments will have a lower total cost of ownership (TCO)[21] compared to diesel while delivering the same capabilities in terms of range, payload and driving times.

For urban delivery trucks, the ZEV uptake potential is very high already today. More than 70% of them are currently cheaper to own and run while fulfilling the operational needs. In 2030 this increases to 100%. The ZEV uptake potential of regional delivery trucks will increase rapidly from the early 2020s, reaching 90% by mid decade and virtually 100% by 2030.

Long-haul trucks will initially have a slower increase in uptake potential but grow quickly to 80% by 2026 and 99.5% by 2030. Market uptake in the long-haul segment almost exclusively consists of BEVs. FCEVs have a consistently higher TCO than diesel throughout the 2030s and account for only 0.1% of long-haul sales, beating diesel in a few countries with extremely high distances and low hydrogen costs.

Aggregating all urban, regional delivery and long-haul trucks, ZEV uptake potential reaches 99.6% in 2030 and 99.8% by 2035 (see Figure 2). This means that virtually all new freight trucks could switch to zero emission from a cost and operational perspective already by 2030. Only a tiny fraction of long-haul truck sales with use cases for extremely high daily distances remain favourable for diesel in 2035 if no small changes are made to operations. FCEVs account for 0.02% of total sales.

[21] The TCO results presented here include the vehicle purchase costs, depreciated over time and distance driven, as well as energy costs, maintenance costs, infrastructure costs and road tolls for some jurisdictions. It does not include driver costs, financing costs, vehicle registration, circulation taxes or overheads.



Note: Fuel cell electric trucks were included in the analysis and represent up to 0.02% of cases in 2040

Figure 2. Share of sales where zero emission trucks beat diesel trucks

However, simply adding an extra stop to charge during the day would flip the balance towards BEVs also in those use cases. As BEVs have a much lower TCO than diesel trucks, this would still be more cost-efficient than sticking to the diesel truck, even when taking the small addition in rest time into account. Future technology innovations such as solid state batteries, could possibly reduce these charging times significantly beyond what was assumed in the analysis and make an extra charging stop redundant.

Overall, this results in 100% of new freight trucks being capable of going zero emission by 2035, with a tiny proportion possibly needing to make small adjustments to their operations, while still being cheaper to own and run than their diesel counterpart.

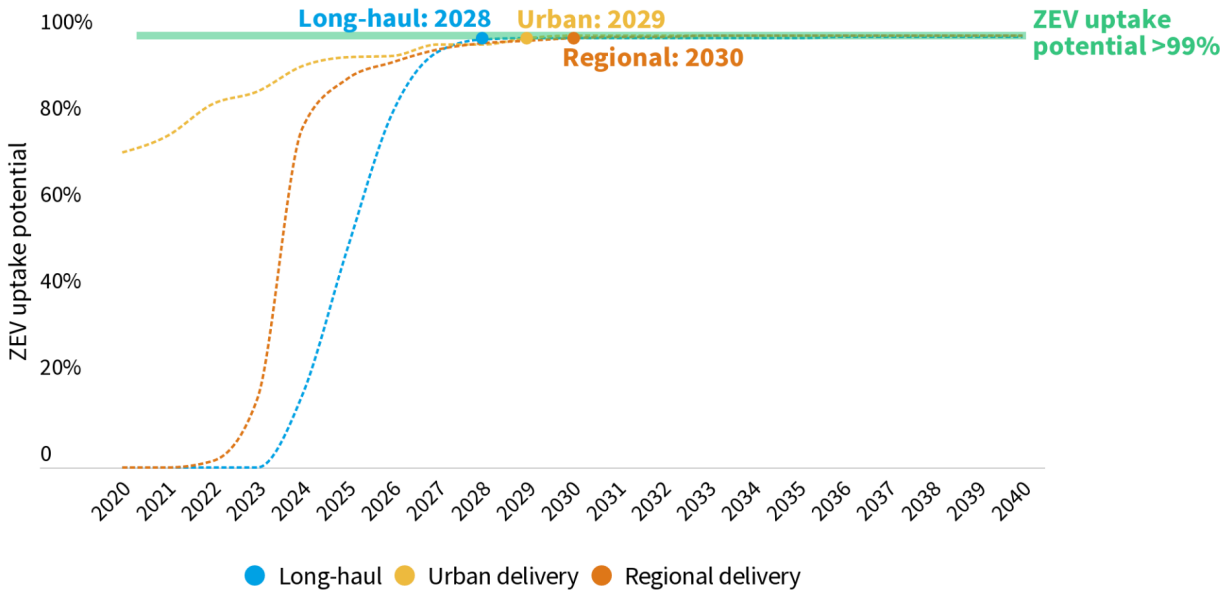


Figure 3. Year when ZEV uptake potential reaches > 99%

The ZEV uptake potential indicates the year by which a ZEV is cheaper to run, while driving as far and fast and carrying as much as diesel trucks. This does not mean that this potential will automatically materialise. For example, in more than 70% of cases, zero emission urban delivery trucks already beat diesel today. But ZEVs do not make up 70% of new sales in the urban delivery segment today. One of the reasons for this is that truck makers are not yet producing ZEVs at scale, meaning hauliers interested in benefiting from these lower costs are often not able to purchase a ZEV.

The working assumption of the analysis by TNO is that the decision to buy a zero emission truck depends on the TCO and meeting the operational capabilities of diesel trucks. In reality, other potential factors can inhibit the current and future uptake such as funding and financing barriers, charging and refuelling infrastructure and, most importantly, limited supply of clean vehicles. This only underscores the need for strong supply-side policy to shift production and develop supply chains towards zero emission trucks fast enough.

2.3. Similar ZEV uptake potential across European regions

TNO's analysis indicates that the ZEV uptake trajectory will be similar across European regions. Unlike for passenger cars where there may be reasons to expect the ZEV uptake to happen slightly delayed depending on the region,[22] trucking is a European cross-border business which is primarily driven by costs and conducted by companies which operate across the EU single road freight market.

For example, the demand for clean technologies such as for improving fuel efficiency of diesel trucks is equally high across Europe. Vehicle registration data shows that long-haul truck sales newly

[22] BNEF (2021). Hitting the EV inflection point. Link.

registered in Eastern and Central European member states were as fuel efficient as those in Western European countries, and sometimes even better.[23] A similar dynamic can also be expected for the transition to ZEVs following their increasing cost-competitiveness with diesel.

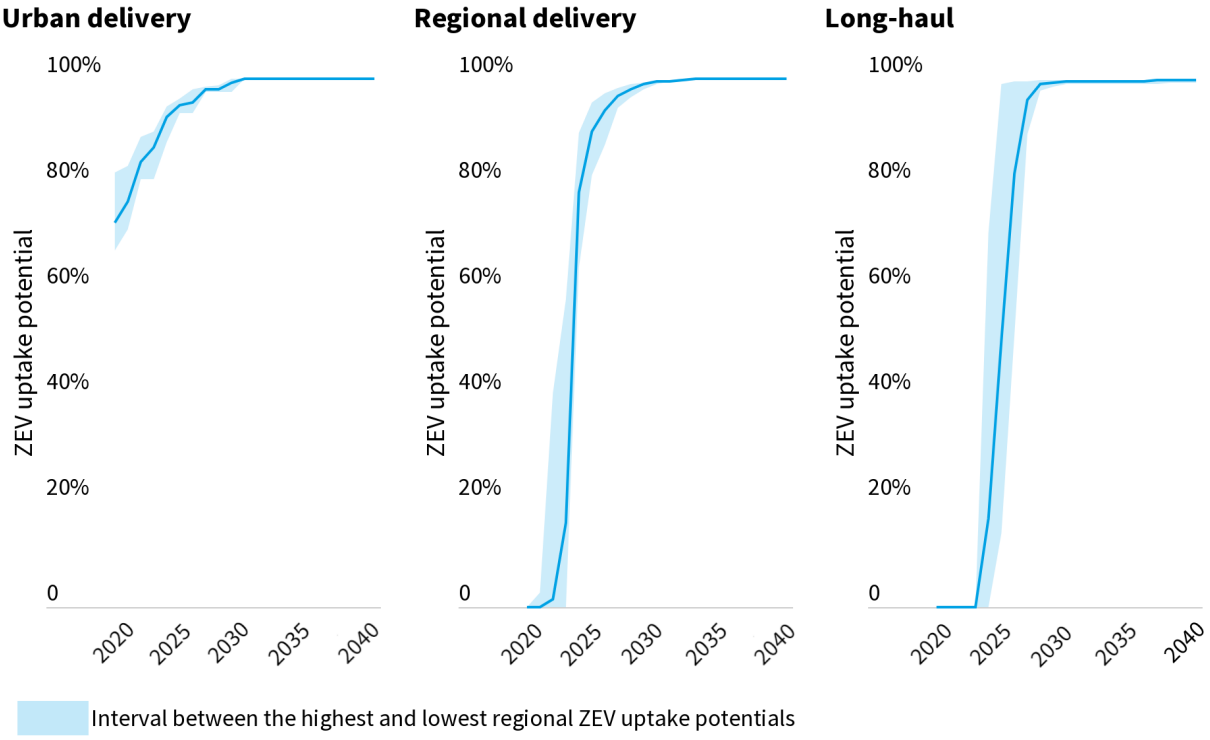


Figure 4. ZEV uptake potential across European regions

Figure 4 illustrates the fairly similar ZEV uptake potential for Northern, Western, Southern, Central and Eastern Europe. The difference is the smallest for urban and regional delivery trucks, which reach virtually 100% uptake potential in 2030 in all regions. For long-haul trucks the difference is slightly larger, with Northern Europe already reaching 99% by 2026, while it takes until 2030 in Southern Europe.

2.4. Costs, range and operations of electric trucks compared to diesel

In contrast to privately owned passenger cars where upfront prices matter most to consumers,[24] trucks (like all commercial vehicles) are intensely used vehicles that drive significantly higher mileages. That makes the TCO rather than upfront purchasing price the key decision-making factor for transport operators.

When making a purchase or leasing decision, hauliers take into account all truck-related costs over the vehicle's entire use period. Besides the purchase or leasing costs, this includes energy and

[23] Transport & Environment (2021). Easy Ride: why the EU truck CO2 targets are unfit for the 2020s. Link.
[24] BNEF (2021). Hitting the EV inflection point. Link.

maintenance costs, and in many European jurisdictions tolling costs as well. Once a zero emission alternative is cheaper to own and operate than its diesel counterpart, so-called TCO parity has been reached.

Operational requirements - such as sufficient driving range, no additional time losses due to recharging or refuelling, and similar payload capabilities - are also important conditions for hauliers which need to be met when switching to zero emission trucks. The TNO report therefore also considered the following parameters to analyse the techno-economic feasibility of switching to zero emission trucks:

- Capability to drive the daily distances trucks are used for in Europe today;
- Alignment of charging and refuelling times with the legally required driver breaks;
- Similar payload capacity as diesel for zero emission drivetrains.

If both TCO parity is reached and the operational requirements of transport operators can be fully satisfied, an accelerating market uptake of zero emission trucks can be expected if there is a sufficient supply of these ZEVs.

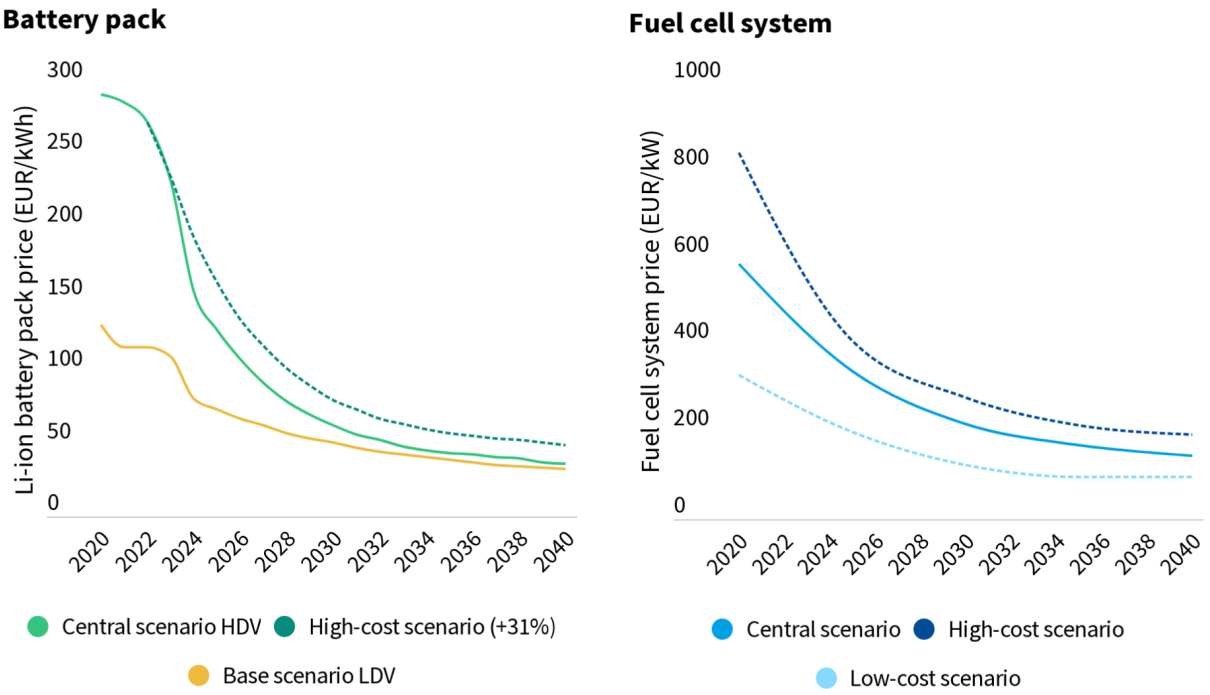
2.4.1. Electric trucks will have lower overall costs than diesel

Some observers still argue that batteries would be too expensive for trucks and would only be suitable for the short-haul segment while fuel cell trucks, or even e-fuels, would excel in the long-haul segment. This is turning out to be a fallacy. The reason why electric trucks will increasingly displace diesel across all segments, and particularly for long-haul, is ultimately down to simple economics.

Main cost assumptions

Key drivers which will help achieve TCO parity of zero emission trucks are the expected technology improvements and the resulting vehicle cost reductions for batteries, fuel cells and hydrogen storage tanks. Battery-powered trucks, whose main cost is their large battery, will benefit from the increasing economies of scale of battery production from the passenger car segment due to strong technology synergies.

TNO's analysis uses battery pack price projections by BloombergNEF for light-duty vehicles (LDVs) and adapts them for the specificities of the heavy-duty segment, including different production volumes and chemistries. A central and high-cost scenario for batteries was analysed. Fuel cell prices are based on a comprehensive literature review and represent a central, high- and low-cost scenario depending on the expected production volume in the future (see Figure 5).



Source: TNO (2022)

Figure 5. Cost assumptions for batteries and fuel cells for HDVs

Future cost advantages of zero emission trucks compared to diesel also depend on the development of energy prices including diesel, electricity and renewable hydrogen, which are notoriously difficult to project for future years. To overcome this uncertainty and look beyond the short-term volatility of energy markets, the analysis by TNO assumes 10-year average diesel and electricity prices and forecasts them based on price projections by the U.S. Energy Information Administration, the International Energy Agency and the EU Reference Scenario. Renewable hydrogen end user prices were taken from the International Council on Clean Transportation based on the assumption that the vast majority of hydrogen refuelling stations will have to rely on grid-connected on-site production over the next two decades to offer the lowest price at the dispenser.[25]

TCO results

While battery electric trucks are more expensive to buy upfront than diesel today, and will likely remain so in the future despite falling battery costs, they will be able to achieve a lower TCO across all freight use cases over time. This is due to the fact that the higher vehicle prices are amortised through consistently lower operating costs for energy and maintenance during the truck's operation.

With trucks being heavily-used capital goods which are running for more than one million kilometres over their lifetime,[26] operating costs such as electricity and fuel as well as maintenance have a

[25] It is expected that decentralised and grid-connected on-site production with a power purchase agreement will likely represent the cheapest production pathway well into the 2030s as it avoids costly transmission and distribution costs without an extensive pipeline infrastructure.

[26] ICCT (2018). European heavy-duty vehicles: Cost-effectiveness of fuel efficiency technologies for long-haul tractor-trailers in the 2025 - 2030 timeframe. Link.

significant impact on the TCO as they scale with increasing mileage. In other words, the longer the distances a truck drives, the more cost-competitive the electric truck becomes compared to its diesel counterpart. This makes BEVs extremely interesting also for long-haul operations and explains why trucks and cars have a similar ZEV uptake potential timeline, even if trucks require bigger batteries than cars.

This is further illustrated by Figure 6 above which compares the TCO of diesel, BEV and FCEV long-haul trucks in the 2030s depending on the daily distance driven.[27] For example, battery electric long-haul trucks that drive as little as 200 km (or more) per day already will be cost-competitive with diesel from 2030.

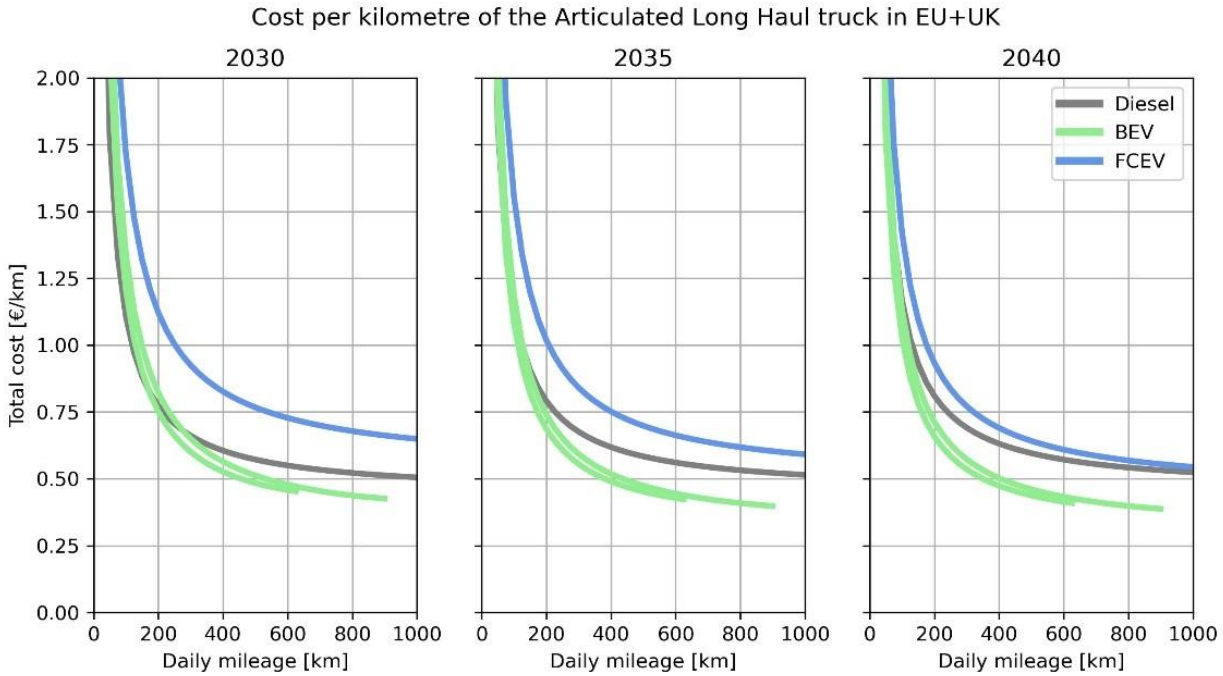


Figure 6. TCO of long-haul trucks in relation to the daily distance driven

2.4.2. Higher battery prices would have minor impact on ZEV uptake potential

Determining the uptake potential of zero emission trucks requires a large number of assumptions which can be prone to considerable uncertainty. The sensitivity analyses undertaken by TNO attempt to mitigate these uncertainties by covering many possible scenarios. The results indicate that the findings on the techno-economic feasibility of zero emission trucks are robust across a wider range of possible developments in the future.

The report includes sensitivities on cost-related parameters which would impact the TCO of BEVs (higher battery prices, higher electricity prices), FCEVs (higher and lower fuel cell prices, lower

[27] For illustrative purposes, the TCO shown is here based on energy prices averaged for the EU + UK. The TNO report uses country-specific energy prices to model the individual ZEV uptake potential in each country.

renewable hydrogen prices) and diesel (lower diesel prices). It also examines range-related sensitivities such as a higher variation in the daily mileage, which would make the rightsizing of batteries more difficult, or a lower annual mileage which would diminish the TCO advantage of zero emission trucks.

Especially the possible scenario where future battery prices would not come down as fast as expected is attracting increased attention these times. However, the TNO analysis shows that even if battery prices would be a third higher compared to the central scenario, this would have little impact on the overall ZEV uptake potential. Figure 7 illustrates how urban delivery trucks would be the least affected segment due to their small battery pack sizes, whereas for regional delivery and long-haul the uptake may be slightly delayed (by less than 3 years).

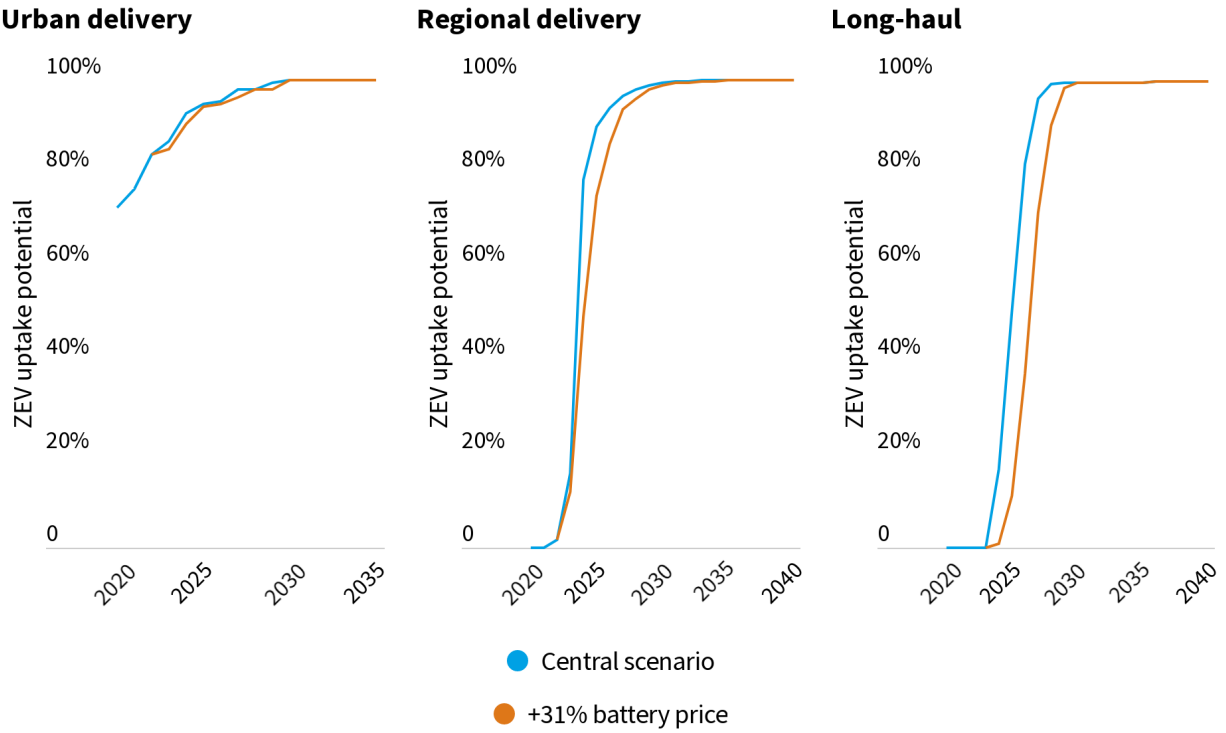


Figure 7. ZEV uptake potential with higher battery prices

Batteries will not become a bottleneck, but policy action is needed

The supply of battery cells and critical raw materials is scaling up quickly, with new plans of ramping up production capacity for electric vehicles being announced every other week. Previous T&E analysis has shown than there will be enough battery cells[28] and critical raw materials[29] to meet the world's electric passenger car needs. Battery demand from cars will continue to dominate overall

[28] Transport & Environment (2021). Weak climate rules put Europe's battery boom at risk. Link.
[29] Transport & Environment (2022). Enough raw metals to make 14 million electric cars globally in 2023 – study. Link.

demand over the coming decade: BNEF's Electric Vehicle Outlook estimates that only 3 - 8% of battery demand in 2025 will come from commercial vehicles, and up to 15% by 2030.[30]

There are genuine concerns about the effect a tight commodities market will have on battery prices. Structurally, a long period of low commodity prices has seen underinvestment in new metal mining, while short-term Covid-induced disruptions in supply chains and the war in Ukraine have added to pressure on prices. But this is not expected to last: mining and recycling companies are already reacting to high prices by announcing expansions, which should lead to prices stabilising in the next few years.

However, Europe's policy-makers must do more to ensure battery supply does not become a bottleneck for the ramp-up of electric truck production. Setting strong HDV CO_2 standards would create volume certainty and signal to the supply chain to scale up the supply of batteries and critical minerals so that there is sufficient supply coming online also for the heavy-duty market.

Although there is no fundamental shortage in battery materials, there is no guarantee that Europe can continue supplying its leading EV market by itself and without disruption. Growing electric vehicle sales in China and the U.S. mean that there is competition for critical raw materials, with both countries introducing measures to ensure access and control of key resources and supply chains.

European policymakers need to beef up diplomacy with fellow democracies and begin discussions with mining companies. A dedicated authority to ensure security of supply of sustainably sourced critical metals at EU level would help to coordinate and streamline efforts to ensure sufficient supply. Funding and financing for refining and processing capacity as well as speeding up sustainable resource extraction in Europe will also be needed.

2.4.3. Electric trucks can meet all operational needs of transport operators

Electric trucks have sufficient range

Although today's diesel trucks often carry large fuel tanks with which they can drive long distances without refuelling, trucks do not need a range of thousands of kilometres to carry out their daily job. According to the TNO report, rigid trucks with a permanently mounted trailer and mostly used for urban and regional delivery drive 286 km per day on average in Europe. Articulated tractor trailers which are most common for regional and long-haul operations drive an average of 530 km per day. The daily mileage distribution also shows that 97% of the European truck fleet drives no more than 800 km per day (see Figure 8).

[30] BNEF (2022). Electric Vehicle Outlook 2022. Link.

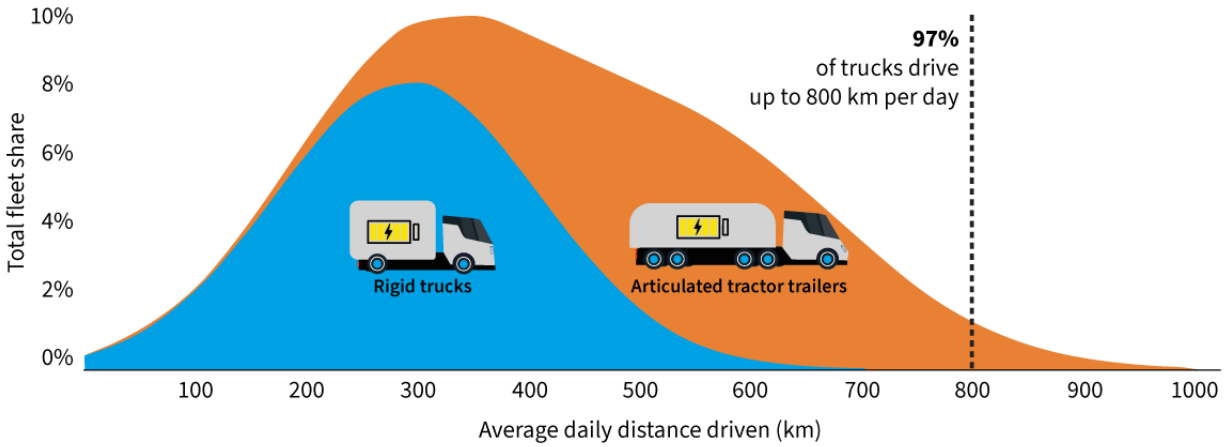


Figure 8. Average daily distances driven by trucks in Europe

All European truck makers are now bringing battery electric trucks into series production which can serve these range requirements,[31] in many use cases even without charging en route.[32] This means that for a lot of truck trips already today, there is only a limited need for public charging infrastructure to be in place immediately. For example, Daimler announced its 500 km range *eActros LongHaul* truck for series production in 2024.[33] MAN will also begin series production of its *eTruck* with a range of around 450 km by 2024.[34] By the same year, Scania will offer battery-powered 40-tonne trucks running four and a half hours between breaks for 560 km.[35] Volvo has already started the series production of its *FH Electric* this year which can drive up to 500 km with a short stop for charging.[36] DAF has announced the series production of the *XD and XF Electric* with a range up to 500 km for 2023.[37] And IVECO aims to enter mass production of the 500 km *Nikola Tre BEV* in 2023.[38]

Charging can take place during the driver breaks

For distances that exceed the range of the newest generation of electric long-haul trucks, the mandatory driver breaks offer the perfect opportunity to recharge. For safety reasons, European regulation[39] requires truck drivers to stop for 45 minutes after every 4.5 hours of driving. After a maximum daily driving period of 9 hours, an 11 hours rest period is required. These breaks and rest periods provide the ideal opportunity to charge the trucks, either fast during the day or longer overnight, allowing them to operate for the same time period per day as their diesel counterpart. Depending on the daily distance to be covered, battery electric trucks will either just charge at

[31] ACEA (2022). Zero and low-emission heavy-duty vehicles. Link.
[32] Electric long-haul trucks will be available with ranges of 800 km and perspectively 1000 km. However, downsizing their batteries for the actual range needs in combination with public fast charging will often be the cheaper TCO option.
[33] Daimler (2022). Mercedes-Benz Trucks presents the eActros LongHaul for long-distance transport. Link.
[34] MAN (2022). MAN and ABB E-mobility rev up for the next phase of electromobility in long-haul trucking. Link.
[35] Scania (2022). The Scania Report 2021. Annual and Sustainability Report. Link.
[36] Volvo (2022). Volvo's heavy-duty electric truck is put to the test: excels in both range and energy efficiency. Link.
[37] DAF (2022). DAF Trucks demonstrates industry leadership at IAA 2022. Link.
[38] IVECO (2022). Iveco Group displays its product milestones towards net zero carbon mobility at IAA 2022. Link.
[39] European Union (2019). Regulation on the harmonisation of certain social legislation relating to road transport. Link.

private charging points at freight depots and logistics hubs or also use public charging pools with high-power opportunity and overnight charging points en route.

The Alternative Fuels Infrastructure Regulation (AFIR) will ensure a sufficient coverage of such public truck charging infrastructure by the time the first electric long-haul trucks are coming to market.[40] As part of the regulation, the European Commission has proposed mandatory targets for a full coverage of high-power charging stations across Europe's main road network by 2025, which will be extended to the whole TEN-T network by 2030.[41] The Council's position on the legislation maintains this timeline and foresees additional targets for 2027, while targets for hydrogen refuelling stations will follow from 2030.[42] The European Parliament significantly increases the ambition of the Commission's proposal in terms of the minimum mandatory power output per charging pool.[43]

Moreover, the market is set to deliver additional infrastructure on top of the targets mandated by AFIR. Already today, plans by the private sector are gearing up to roll out public truck charging infrastructure across the EU. The joint venture by the five major truck brands Daimler, MAN, Scania, Volvo and Renault Trucks plans to install 1,700 public high-power truck charging points across Europe by the second half of the 2020s.[44]

It can be expected that commercial vehicle charging will become a profitable business case for charging point operators (CPOs) once the CO_2 standards have brought sufficient volumes of vehicles on the road. Traffic flows of trucks are also more regular and predictable which makes it easier to plan the charging infrastructure roll-out more cost-effectively and lead to higher utilisation rates.

Figure 9 below illustrates how electric long-haul trucks will be charged during their daily rest periods. The battery can be fully charged overnight, either at the private depot or at public truck parking areas. A single driver can then drive no more than 350 km[45] within the allowed 4.5 hours during the first half of the day until a 45-minute break is required. If the truck needs to drive more than what its single charge allows for, this break can be used to charge the battery at high power levels for the second 4.5 hours of driving time.

[40] ICCT (2022). A review of the AFIR proposal: public infrastructure needs to support the transition to a zero-emission truck fleet in the European Union. Link.
[41] European Commission (2021). Proposal for a regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure. Link.
[42] Council of the EU (2022). General approach on alternative fuels infrastructure (AFIR). Link.
[43] European Parliament (2022). Legislative Observatory. Deployment of alternative fuels infrastructure. Link.
[44] Volvo (2022). The Volvo Group, Daimler Truck and the TRATON GROUP kick off European charging infrastructure joint venture. Link.
[45] Assuming a close to 80 km/h average vehicle speed.

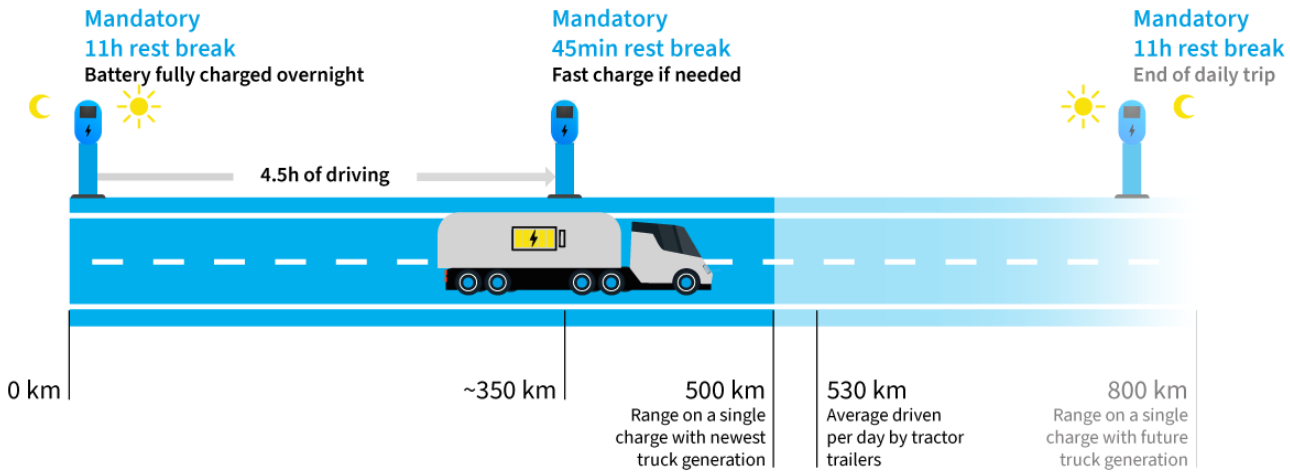


Figure 9. Daily driving patterns of electric long-haul trucks

The Megawatt Charging System (MCS) for HDVs is expected to be commercially available from 2024. CharIN, the industry's standardisation initiative, has finalised the standard which is capable of recharging battery electric trucks during their daily rest breaks of 45 minutes.[46] Research shows that such high-power truck charging stations are technically and economically feasible and would also not pose fundamental challenges when being connected to the electricity grid.[47]

Electric trucks will carry the same payload

Improving vehicle energy efficiency and battery energy density will ensure that most battery electric trucks will be able to carry the same amount of goods as diesel trucks today. Besides technology improvements to the design and performance, the additional weight due to the battery pack is also compensated for by replacing the internal combustion engine with a lighter electric drivetrain and by using the so-called 'ZEV weight allowance' which grants a maximum of two additional tonnes to zero emission trucks driving on European roads.[48]

The TNO analysis indicates that all BEVs in the urban and regional delivery segment would be able to carry the same tonnage than the equivalent diesel vehicles already today. In fact, all battery-powered urban and regional delivery trucks would actually be able to carry even more cargo weight than diesel today and this payload advantage will only grow over time due to improving battery technology.

BEVs with the biggest batteries will temporarily suffer from limited payload losses in the 2020s. The electric long-haul truck with a 500 km range will lose a few hundred kilograms of payload capacity in the early 2020s, while being able to carry increasingly more cargo than its diesel counterpart from

[46] CharIN (2022). CharIN e. V. officially launches the Megawatt Charging System (MCS). Link.
[47] Transport & Environment (2022). Flicking the switch on truck charging. Link.
[48] European Union (2019). Council Directive laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic. Link.

the mid 2020s onwards. The electric long-haul truck with the largest battery for 800 km is estimated to lose around three tonnes of payload capacity if it was designed today, which decreases to 1.5 tonnes by mid decade. This payload loss is fully eliminated by 2030 (see Figure 10). FCEVs will not have any payload losses regardless of the segment, partly due to the ZEV weight allowance.

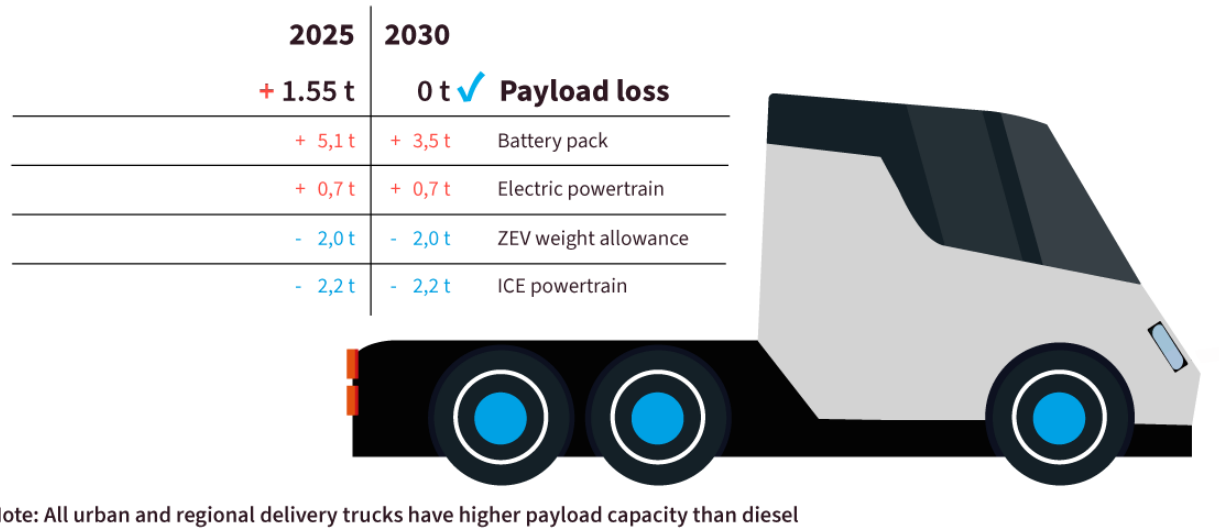


Figure 10. Payload losses of electric long-haul trucks

The small payload losses in the 2020s for the electric long-haul trucks with the biggest batteries are unlikely to have an adverse impact on their usability for real-world haulage operations. This is because the majority of road freight shipments in Europe are volume- and not weight-constrained, that is the volume limit of the trailer is often reached earlier than the maximum vehicle weight.

As an effect, many trucks in Europe drive around only partially loaded and sometimes even completely empty. Statistics by the UK's Department of Transport estimate that 30% of long haul trucks are driving empty while the average loading factor is 63% of the maximum payload capacity.[49] A study for the European Commission has estimated that the share of long haul truck mileage in the EU, which is constrained by weight limitations, is between 10% and 19.5%, with the average loading factor being estimated at 56% of the total payload capacity.[50]

3. Implications for the review of the truck CO_2 standards

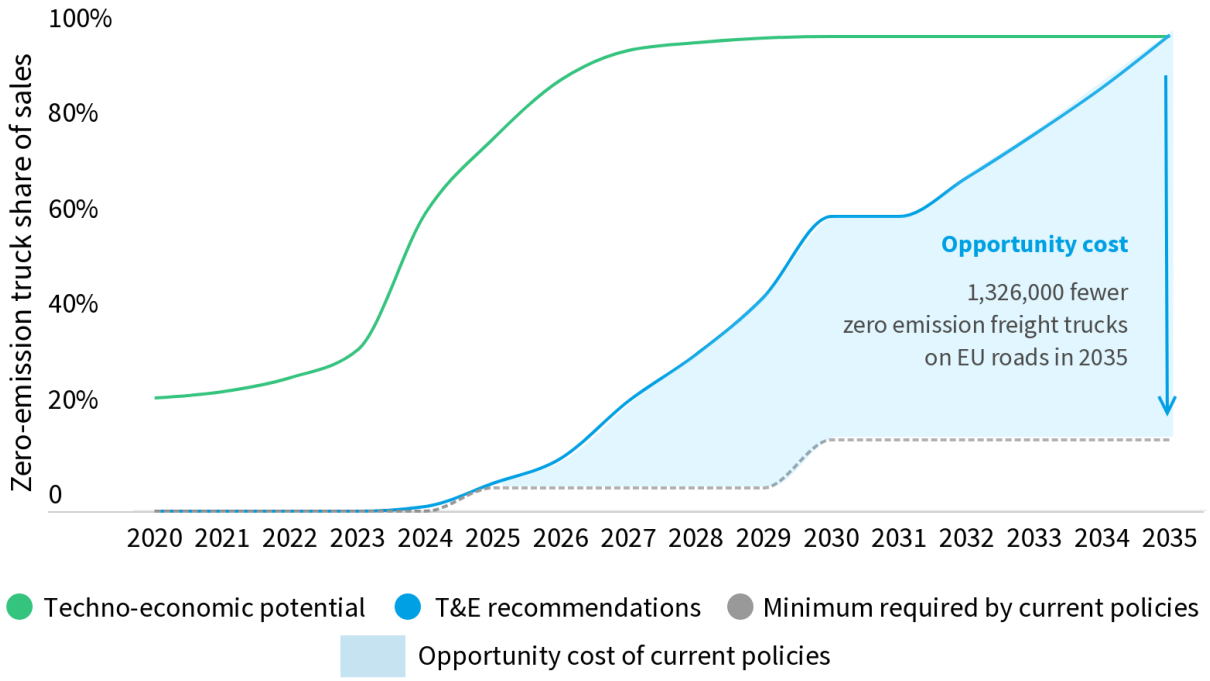
The forthcoming review of the HDV CO_2 standards is the opportunity to put the European HDV sector on a trajectory in line with climate neutrality.[51] The evidence clearly shows that this is not only feasible, but would also bring massive economic benefits for the industry and society as a whole.

[49] Department of Transport (2022). Data about the road freight domestic activity. Link.
[50] European Commission (2015). Light weighting as a means of improving Heavy Duty Vehicles' energy efficiency and overall CO2 emissions. Link.
[51] Transport & Environment (2022). Truck CO2: Europe's chance to lead. Link.

While the technology costs of ZEVs are expected to drop once their production scales up and infrastructure is being rolled out, transport companies who want to go zero emission already today are struggling with a lack of supply of ZEVs.[52] The techno-economic feasibility of zero emission trucking is by itself thus not enough to enable the market ramp-up. Without strong supply-side policy in the form of ambitious CO_2 standards, the ZEV uptake potential identified by TNO would be merely hypothetical and fail to materialise in reality. This would deprive transport operators from benefiting from the rapidly increasing cost advantage of transitioning to electric trucks.

3.1. Set a trajectory to 100% new zero emission freight trucks by 2035

The aggregated ZEV uptake potential for all urban, regional delivery and long-haul trucks reaches 99.6% in 2030 and 99.8% by 2035. This means that virtually all new freight trucks including small, medium and heavy lorries will be able to switch to zero emissions from a cost and operational perspective already by 2035.



Note: Assumes ZEV uptake across all freight trucks, including currently regulated and unregulated vehicle groups

Figure 11. ZEV uptake potential compared to current policies and recommendations

However, under the current CO_2 reduction targets, truck makers would only need to sell a low share of ZEVs, a huge gap compared to what is already technically and economically feasible in the 2020s (see Figure 11). The current 2030 CO_2 target would only deliver about 15% ZEV sales across the small, medium and heavy lorries segments. Without significantly higher CO_2 targets, truck manufacturers

[52] European Clean Trucking Alliance (2020). Position paper. Make zero-emission trucks an offer you can't refuse. Link.

will have no incentive to sell more ZEVs than what they currently need for complying with the regulation.

While from a techno-economic point of view an even faster transition would be possible, switching to 100% zero emission sales in all freight segments by 2035 would ensure sufficient lead time to roll out the necessary infrastructure and convert European vehicle production lines to a fully zero emissions lineup. It will give the necessary technology clarity and investment certainty to the industry to move full steam ahead and take global leadership of zero emission technology.

To translate this in the HDV CO_2 standards legislation, a CO_2 target of -100% should be set for heavy lorries (above 16 tonnes) by 2035. Medium lorries (7.4 - 16 tonnes) should be regulated via the same common CO_2 reduction target as heavy lorries. A ZEV sales target of 100% should apply to small lorries (3.5 - 7.4 tonnes) in 2035 and to vocational vehicles in 2040 (see Section 3.3.).

Reaching 100% zero emission sales in 2035 for small, medium and heavy lorries would deliver 1,679,000 zero emission trucks on the road, close to five times more than what can be expected under the current regulation. In terms of cumulative emissions, this would save an additional 3 gigatons of CO_2e until 2050 compared to what is required under the current targets.[53]

3.2. Enable a faster ramp-up until 2030

To get to 100% new zero emission freight trucks in a cost-effective and socially just manner, investments into the transition and production needs to start in the 2020s already, with a massive ramp up towards 2030 to follow the typical S-curve in which technology adoption takes place. Failing to prepare and scale up sales until 2030 would entail disruption in the following decade in terms of workforce upskilling, infrastructure roll-out and battery supply.

If Europe moves too late, it also risks losing its market leadership to emerging competitors from the U.S. and China who are already massively investing into zero emission trucks today bolstered by strong policy action by their governments. For example, the tax credits introduced by the U.S.'s *Inflation Reduction Act* could help electric freight trucks reach TCO parity in America already in the early 2020s.[54]

By 2030, most small, medium and heavy lorry sales can already transition to zero emissions as the TNO analysis shows. Already in 2027 the vast majority of new electric freight trucks would be cheaper to own and run and match the capabilities of diesel trucks if ambitious supply-side policies are put in place. This supports the argument to scale up much faster until 2030 than what the current regulation requires.

[53] Transport & Environment (2022). Addressing the heavy-duty climate problem. Link.
[54] RMI (2022). The Inflation Reduction Act Will Help Electrify Heavy-Duty Trucking. Link.

This is especially the case for 2030. The TNO report finds a ZEV uptake potential of 99.6% for all urban, regional delivery and long-haul trucks by 2030 already. This shows there is huge cost-effective potential to scale up ZEVs much faster than currently foreseen by the legislation. The current CO_2 targets until 2030 are too weak to ramp up ZEV production at the pace and volume needed to exploit the techno-economic potential.

The CO_2 targets for medium and heavy lorries therefore need to increase to -65% in 2030 and a new intermediate target of -30% should be introduced for 2027. T&E analysis shows that a CO_2 target of -65% for medium and heavy lorries would deliver 659,000 ZEVs in total on EU+UK roads by 2030 (see Figure 12). This amounts to just 7% more ZEVs than what truck makers have already announced publicly for the end of the decade, while still being significantly below the techno-economic potential. For small lorries, a ZEV sales target of 35% should be introduced in 2027 and increased to 70% by 2030 reflecting their already high ZEV uptake potential in those years.

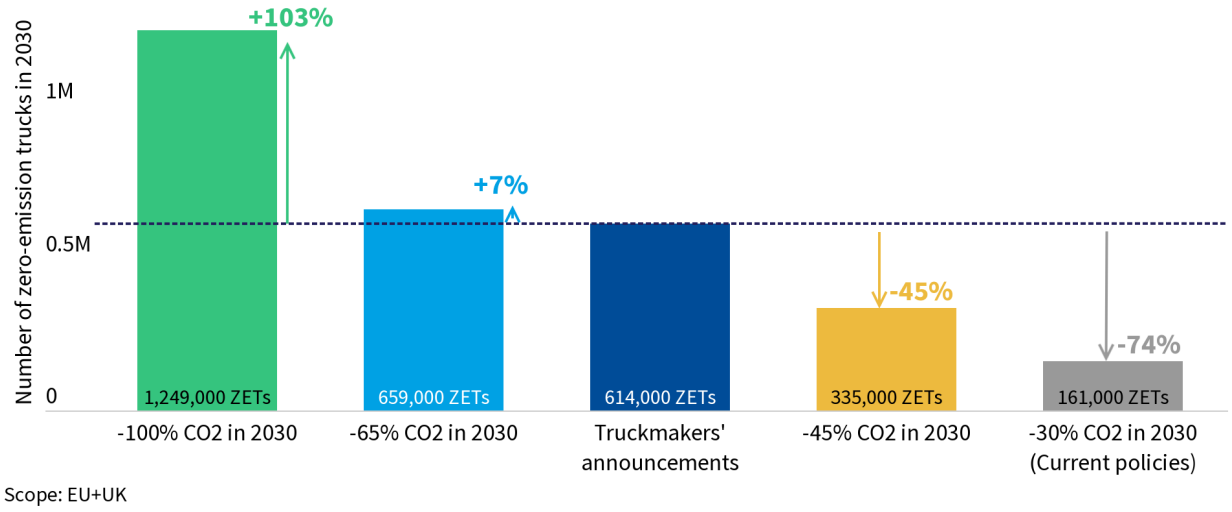


Figure 12. Zero emission truck fleet in 2030 depending on the CO_2 targets

3.3. Regulate all truck types

The CO_2 standards currently only regulate heavy lorries which are responsible for 64% of all emissions from HDVs (see Figure 1). This analysis highlights that the regulation can and must be extended to all categories, including small and medium lorries, but also vocational trucks as well as trailers.

Small and medium lorries, which are responsible for 28% of CO_2 emissions from new HDVs, offer a great emissions savings potential but also just represent a great business case. The techno-economic feasibility to transition all sales to ZEVs in these segments is already reached by 2030. As suggested above, currently unregulated medium lorries should be regulated via the same common CO_2 reduction target as heavy lorries. Small lorries, which are (partly) not certified under the Vehicle

Energy Consumption Calculation Tool (VECTO), should be regulated by a ZEV sales target as they cannot be regulated by a CO_2 reduction target.

Vocational vehicles such as construction or special purpose trucks are currently not regulated under the CO_2 standards. Given that the majority of vocational trucks will not be certified under VECTO, a ZEV sales target should also be applied to those. Vocational vehicles may have more challenging operational requirements in terms of onboard energy storage, running time or infrastructure. Since some of them also run lower mileage, they might also need more time to achieve TCO parity compared to long-haul trucks. While the TNO report indicates that these issues do not apply to construction trucks, they may apply in other vocational use cases. A first ZEV sales target of 15% should apply in 2027. Subsequent targets should be set for 2030 (30%) and 2035 (80%). A 100% ZEV sales target should be set for 2040.

3.4. Give no role to fuels in regulating new sales

Using e-fuels in the road freight sector is inefficient and unnecessary as zero emission alternatives exist. E-fuels would be the most costly compliance option for truck makers, transport operators and society as a whole. Trucks are heavily used capital goods that run for more than one million kilometres over their lifetime. This means that energy and fuel costs dominate the TCO, rendering combustion trucks running on e-diesel uncompetitive. Previous T&E analysis has shown that the TCO of internal combustion trucks running on e-fuels could not be able to compete with battery electric or hydrogen fuel cell trucks, not even if those e-fuels were being produced overseas under favourable conditions like in North Africa and imported to Europe.[55]

A crediting system for so-called 'renewable and low-carbon' fuels, including advanced biofuels and e-fuels, could also not help reduce emissions from HDVs due to sustainability and scalability issues. Food- and crop-based biofuels are associated with significant indirect climate emissions, often causing higher GHGs than their fossil counterpart.[56] Synthetically produced fuels, such as e-fuels, would not be able to reduce air pollutant emissions in any meaningful way.[57]

While advanced biofuels and e-fuels can technically be produced sustainably, advanced biomass feedstocks are limited in supply. This is less of an issue for e-fuels but scaling up renewables, electrolyser and e-fuel production facilities will take time and larger e-fuel quantities would likely not be available before 2040.[58] The limited quantities which will be available by 2030 need to be prioritised to decarbonise hard-to-abate sectors where electrification is not an option such as

[55] Transport & Environment (2021). How to decarbonise long-haul trucking in Germany. Link.
[56] ICCT (2017). Potential greenhouse gas savings from a 2030 greenhouse gas reduction target with indirect emissions accounting for the European Union. Link.
[57] Transport & Environment (2021). Magic green fuels: Why synthetic fuels in cars will not solve Europe's pollution problems. Link.
[58] Odenweller et al. (2022). Probabilistic feasibility space of scaling up green hydrogen supply. Link.

aviation, maritime shipping and parts of industry.[59] These sectors will also have a higher willingness to pay for these fuels due to the lack of other decarbonisation alternatives which would make it even more challenging to provide any substantial volumes to road transport.

A fuel crediting system should not be included in the HDV CO_2 standards as this would also risk creating regulatory loopholes. Fuel credits would mix well-to-tank (fuels and electricity) and tank-to-wheel (vehicle tailpipe emissions) regulations which would lead to incoherent and, in the worst case, unenforceable legislation. Truck makers cannot control what fuel will effectively be used in their trucks over their lifetime, so should not benefit from fuel credits when complying with the CO_2 standards. Decarbonising fuels is important, but, instead of doing this through a complex crediting system, fuels should be governed by separate legislation including the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD).

4. Demand-side policies can accelerate ZEV uptake until 2030

While strong supply-side policy in the form of ambitious CO_2 standards is needed to leverage the techno-economic potential of zero emission trucks, demand-side policies can support to accelerate the ZEV market uptake in the 2020s. The TNO report also looked at an alternative scenario where existing and announced demand-side policies such as national vehicle purchase incentives in seven European countries, CO_2-based road tolls and a European emissions trading system (ETS) for road transport fuels are taken into account.

For the existing purchase subsidies for trucks, it was assumed that they would apply until 2024 after which it can be expected that they will be phased out. For CO_2-based road tolls, national implementation according to the Eurovignette directive for the affected EU countries was assumed, with toll reductions for ZEVs being gradually cut back again from 2030 onwards. The ETS for road transport fuels follows the policy positions recently adopted in the European Parliament and Council.

Figure 13 illustrates how these three demand-side policies would accelerate the ZEV market uptake already in the first half of the 2020s. For urban delivery trucks, the ZEV uptake potential would already be over 80% today and increase faster than in the central scenario until it aligns from the second half of the decade. The ZEV uptake potential of regional delivery trucks would be more than 50% today and reach close to 90% before mid decade. Long-haul trucks would already achieve an uptake potential of almost 30% today and reach close to 100% slightly earlier compared to the central scenario. The impact on the overall ZEV uptake potential in the mid- and long-term would be negligible as two out of the three demand-side policies are assumed to be phased out before 2035.

[59] Transport & Environment (2020). E-fuel would be wasted on cars while it's badly needed to decarbonise planes and ships. Link.

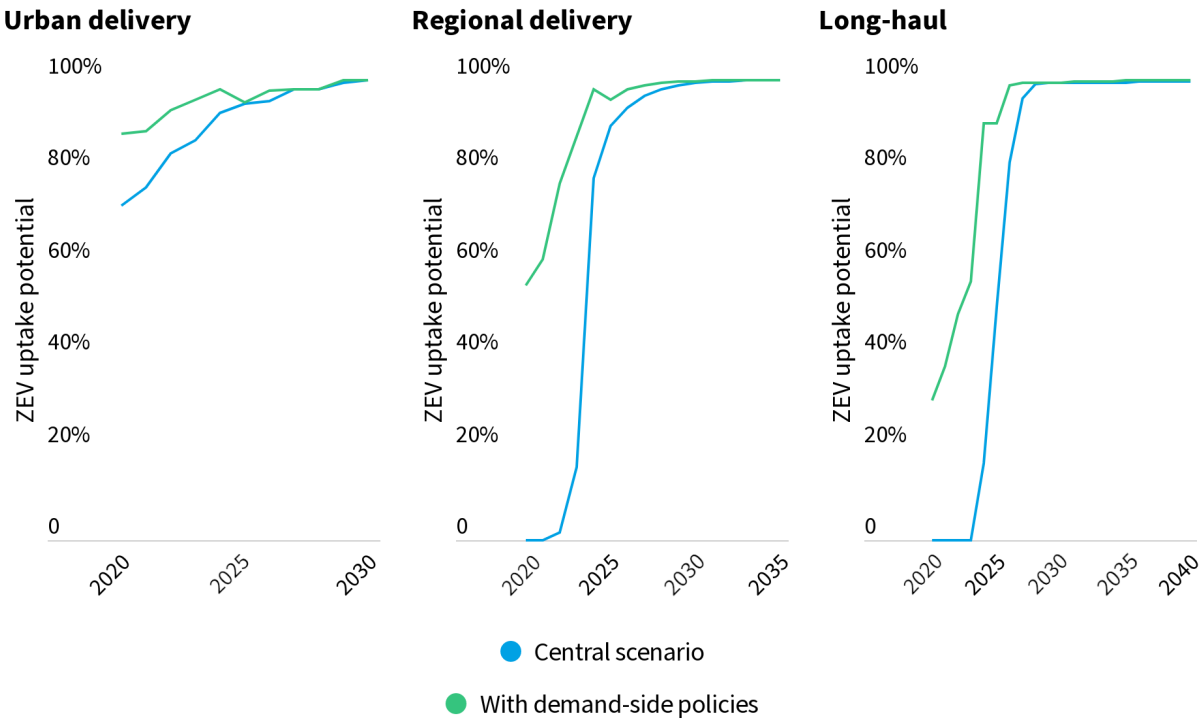


Figure 13. ZEV uptake potential with demand-side policies

5. Conclusions

Heavy-duty trucks are responsible for 26% of greenhouse gas (GHG) emissions from road transport in Europe, while only accounting for 2% of the vehicles on the road. To reduce the EU's GHG emissions and reach climate neutrality by 2050, heavy-duty vehicles (HDVs) need to be entirely decarbonised.

Both amongst regulators and industry stakeholders, there is growing consensus that zero emission trucks - battery electric (BEVs) and fuel cell electric vehicles (FCEVs) - are the optimal way to decarbonise the road freight sector.

The TNO report shows that it is possible to fully transition all new freight trucks to zero emission cost-effectively and in time to meet Europe's climate targets. All new urban, regional and long-haul trucks can be zero emission by 2035 across all European markets, with some national markets such as in Northern Europe expected to go even faster. All new sales in those segments will have a lower TCO compared to diesel while delivering the same capabilities in terms of range, payload and driving times.

Aggregating all urban, regional delivery and long-haul trucks, ZEV uptake potential reaches 99.6% in 2030 and 99.8% by 2035. This means that virtually all new freight trucks could switch to zero emission from a cost and operational perspective already by 2030. Only a tiny fraction of long-haul

truck sales with use cases for extremely high daily distances remain favourable for diesel in 2035. However, simply adding an extra stop to charge during the day would flip the balance towards BEVs also in those use cases, while still being cheaper than diesel.

But the techno-economic feasibility of zero emission trucking is by itself not enough to enable the market ramp-up. Without strong supply-side policy in the form of ambitious CO_2 standards, the ZEV uptake potential identified by TNO would be merely hypothetical and fail to materialise in reality.

The CO_2 standards currently only regulate heavy lorries which are responsible for 64% of all emissions from HDVs. This analysis highlights that the regulation can and must be extended to all and cover small and medium lorries, but also to all vocational trucks as well as trailers.

By 2035, a CO_2 reduction target of -100% should apply to heavy lorries (above 16 tonnes). Medium lorries (7.4 - 16 tonnes) should be regulated via the same common CO_2 reduction target as heavy lorries. A ZEV sales target of 100% should apply to small lorries (3.5 - 7.4 tonnes) in 2035 and to vocational vehicles in 2040. Given that the majority of small and vocational trucks will not be certified under VECTO, a ZEV sales target should be applied to those.

The CO_2 targets for medium and heavy lorries need to increase to -65% in 2030 and a new intermediate target of -30% should be introduced for 2027. For small lorries, a ZEV sales target of 35% should be introduced in 2027 and increased to 70% by 2030 reflecting their already high ZEV uptake potential in those years.

Using e-fuels in the road freight sector is inefficient and unnecessary as zero emission alternatives exist. E-fuels would be the most costly compliance option for truck makers, transport operators and society as a whole. Trucks are heavily used capital goods that run for more than one million kilometres over their lifetime. This means that energy and fuel costs dominate the TCO, rendering combustion trucks running on e-diesel uncompetitive.

If European policy-makers do not agree on more ambitious CO_2 standards as part of the upcoming review, including a target to reduce CO_2 emissions from new freight trucks by 100%, they would fail to send the necessary market signal and create investment certainty for Europe's industry.

Failing to do so would put Europe's technological edge in the heavy-duty segment at risk just as the U.S. is joining China in the race to industrial leadership following the passage of the Inflation Reduction Act. In the worst case, it could lead to Europe's domestic automotive and supplier industry falling behind and losing its global leadership to the growing competition from overseas.

Further information

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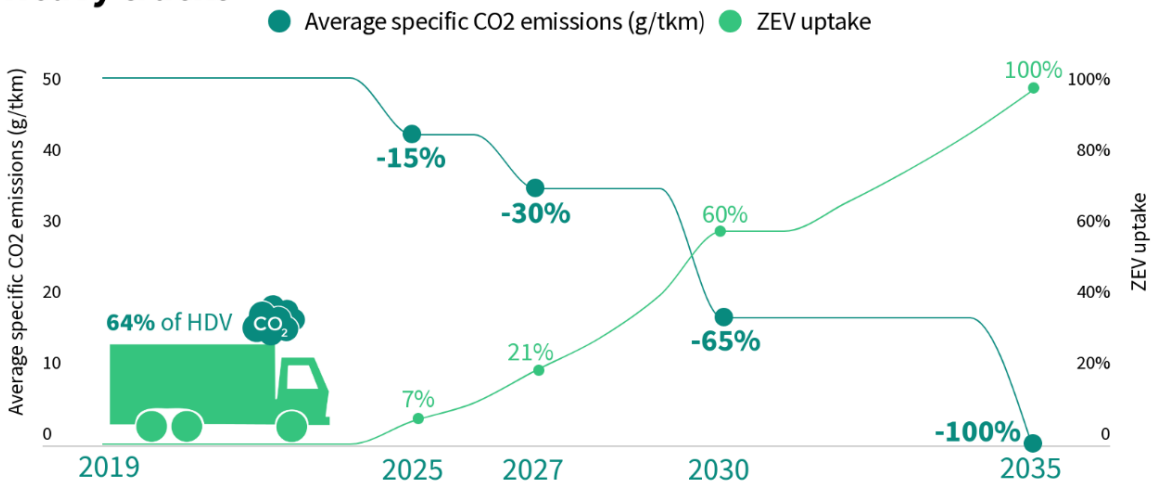
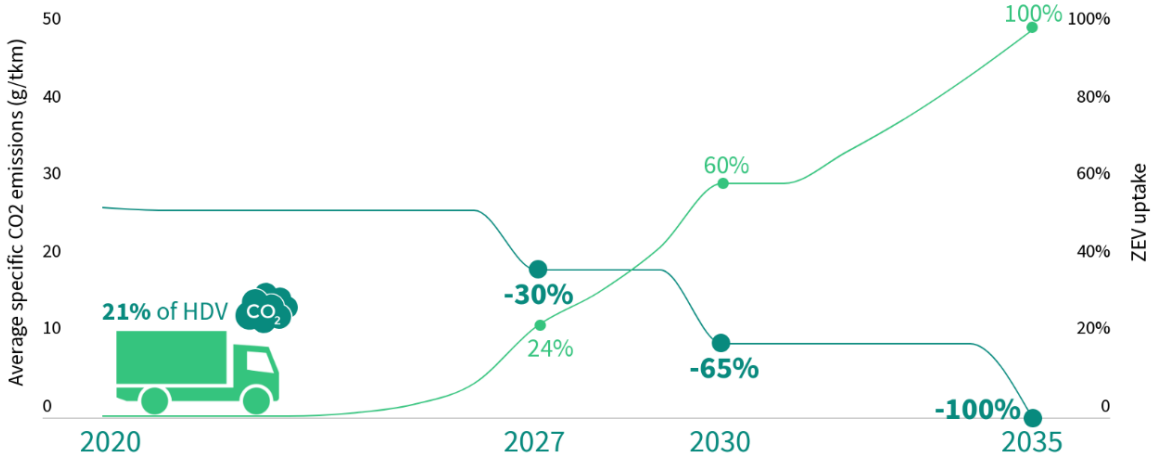
Annex. Targets to reach 100% zero emission freight sales

Heavy trucks



Medium trucks



Small trucks