Market Readiness Analysis

Expected uptake of alternative fuel heavy-duty vehicles until 2030 and their corresponding infrastructure needs

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ACRONYMS AND ABBREVIATIONS

ACEA. European Automobile Manufacturers' Association

AFIR. Alternative Fuels Infrastructure Regulation

BEV. Battery Electric Vehicle

CCS. Combined Charging System

CIS. Commonwealth of Independent States

CNG. Compressed Natural Gas

CPO. Charge Point Operator

EAFO. European Alternative Fuels Observatory

ECTA. European Clean Trucking Alliance

EEA. European Environmental Agency

ERS. Electric Road System

ETD. Energy Taxation Directive

EU. European Union

FCEV. Fuel-Cell Electric Vehicle

GHG. Greenhouse gases

GTW. Gross Train Weight

GVW. Gross Vehicle Weight

H2ICE. Hydrogen internal Combustion Engine

HDPI. High Pressure Direct Injection

HDV. Heavy-duty vehicle, Heavy-duty vehicles

ICCT. The International Council of Clean Transportation

ICE. Internal Combustion Engine

LH2. Liquid Hydrogen

LNG. Liquefied Natural Gas

LPG. Liquefied Petroleum Gas

MCS. Megawatt Charging System

MS. Member State, Member States

NOES. Non-Oriented Electrical Steel

OEM. Original Equipment Manufacturers

SBTi. Science Based Targets initiative, Science Based Targets initiative

SMR. Steam Methane Reforming

T&E. Transport and Environment

TCO. Total Cost of Ownershipt

TNO. Netherlands Organisation for Applied Scientific Research

TPMLM. Technically Permissible Maximum Laden Mass

YTD. Year To Date

ABSTRACT

This report assesses the market readiness of zero-emission heavy-duty vehicles and the required infrastructure to meet the 45% emission reduction targets set by the revised CO_2 standards by 2030. Achieving these goals requires the widespread adoption of zero-emission vehicles and a robust recharging and hydrogen refuelling infrastructure

Three main aspects are investigated: the market readiness of the vehicles considering both the demand and supply side, the corresponding infrastructure requirements, and the barriers. Building on the inputs of the stakeholders, a 'study scenario' is developed. This scenario shows a concrete picture of what the zero-emission heavy-duty vehicle fleet and its infrastructure requirement could look like by 2030. There are however key barriers that need to be overcome such as high total cost of ownership, limited electricity grid capacity, lengthy permitting processes, and uncertainty in hydrogen availability and pricing. Stakeholders also emphasize the importance of policy drivers such as emissions trading systems and tolling and tax reforms, to stimulate demand.

In conclusion, achieving the 2030 targets demands a coordinated approach involving manufacturers, operators, and policymakers to address infrastructure gaps, market barriers, and policy incentives, ensuring the transition to a zero-emission HDV fleet.

EXECUTIVE SUMMARY

Introduction

This report provides a comprehensive market readiness analysis of zero-emission heavy-duty vehicles (HDVs) and their supporting infrastructure requirements through 2030.

The recent revision of the heavy-duty vehicles CO_2 standards sets new and more ambitious targets for the emissions reductions of the sector. In the revised standards, lorries and coaches should in fact reduce their emissions by 43% by 2030 and by 90% by 2040 (with respect to different baseline years). New city buses are subject to a zero-emission fleet mandate of 90% from 2030, and 100% from 2035. Efficiency improvements of conventional diesel engines, though important, will not be sufficient to achieve these targets. Zero-emission vehicles, such as battery electric vehicles (BEV), fuel cell electric vehicles (FCEV) and H_2 internal combustion engine vehicles (H2ICE), will need to play a major role already by 2030. To support the deployment of these vehicles, the Alternative Fuel Infrastructure Regulation (AFIR), aims to ensure initial deployment of publicly accessible electric recharging infrastructure and hydrogen refuelling stations for heavy-duty vehicles.

Objectives

The purpose of the present report is twofold: (1) set a solid basis for the technology and market-readiness report dedicated to heavy-duty vehicles, which is mandated in Art 24.1 of AFIR and is due by the end of 2024, (2) provide initial inputs for the review of the AFIR itself, which is scheduled for 2026. The development of technologies, both on the supply and demand side, need in fact to be monitored and analysed to understand whether real-world market developments match the assumptions of the European co-legislator at the time when AFIR was agreed. More specifically, this report investigates three aspects: the vehicles market readiness, the infrastructure requirements and the barriers.

Methodology

The analysis was carried out through combining desk research and field research. In particular, the field research allowed to fill some of the gaps of the literature research through the insights provided by the stakeholders. The stakeholders included sector associations, manufacturers, part suppliers, operators and their customers, charge point operators and infrastructure providers. They were reached through over 20 interviews, a preliminary workshop, an extensive online survey, and a final validation workshop. Finally, the information gathered throughout the study, and building on the inputs of the stakeholder, is used to develop a ‘study scenario’ that allows to give a more concrete picture of what the zero-emission heavy-duty vehicle fleet and its energy requirement could look like by 2030 and to assess the corresponding infrastructure needs. It is important to underline that the results are only as solid as the inputs which are subject to high uncertainty. The results are therefore intended to be used as basis for discussion rather than a prognosis both in terms of number of vehicles and energy demand for recharging/refuelling infrastructure.

Zero-emission vehicle market readiness analysis

As said earlier, zero-emission vehicles, such as BEVs, FCEVs and H2ICE vehicles, will need to play a major role already by 2030 to decarbonise the sector.

BEVs are the most efficient heavy duty zero-emission vehicles as they can reduce by half or more the energy demand of their diesel counterparts (depending on operating conditions). Compared to BEVs, hydrogen fuelled vehicles generally allow for longer ranges and shorter refuelling times at the expense of lower efficiencies and higher operational costs as well as, in the case of FCEVs higher purchase costs. Beyond the vehicle efficiency, green hydrogen production, compression and, in case, liquefaction are also energy intensive processes further reducing the source- to- wheel efficiency. H2ICE vehicles generally have higher fuel consumptions than FCEVs, but they could be well-suited for particularly heavy operations and in industries with high vibration and dust-laden air.

According to CALSTART [1], BEVs dominate the zero-emission segments, with, in 2024, 115 models available compared to the 23 FCEV models. In the heavy truck market segment, there are 40 heavy-duty BEV models available with typical ranges from about 250 km to 500 km, whereas their 6 FCEV counter parts reach ranges from 400 to 1000 km, with only a few

FCEVs surpassing the ranges offered by BEVs. Medium trucks count 16 BEV models and one FCEV model. According to European Automobile Manufacturers Association (ACEA) data [2], there are two H2ICE that will soon come to the market in the heavy-duty segment (with up to 44 t, Gross Train Weight (GTW), that is the maximum allowed weight of the truck plus trailer). The offer of zero-emission models for the bus segment represents the largest part in the overall offer of zero-emission models. There are in fact 59 BEV buses available with ranges that reach 700 km and 15 FCEV bus models. The offer in the coach segment remains very limited. Always according to CALSTART data, considering the announcement up to 2027, only three coach models are available, two of which are FCEV. The lack of models available in the long-haul coach segment was also underlined by stakeholders during the consultation.

As the portfolio of zero-emission vehicles available widens, registrations of such vehicles, though still limited, are increasing rapidly. Based on registrations reported by the European Alternative Fuels Observatory (EAFO) [3] up to the 3rd quarter of 2024, BEVs are by far the largest type of zero-emission vehicles registered in the EU and account for up to 2.09% of registration of N2 and N3 vehicles (lorries), compared to the 0.03% of H_2 fuelled vehicles. BEVs make up also the largest type of zero-emission M2-M3 vehicles (coaches and buses) with 14.84 % of registrations compared to 0.11% of H_2 fuelled vehicles. To complement, according to ACEA[4] and ICCT[4] data, the highest shares of BEVs are reported for medium lorries with 5.4%, and urban busses with 40% (to note, the urban buses share refers to the second quarter of 2024 only).

OEMs plan to reach the CO_2 emission reduction targets with one in three new lorries being zero-emission in 2030 and emission reductions obtained through efficiency improvements of about 15%. Their commitment to reach the targets and their own emission reduction ambition is clear, however they provide little official information on the drivetrain mix that will allow them to achieve these objectives. Whereas there are clear targets for manufacturers, operators currently include zero-emission vehicles in their fleet mainly to reach their own voluntary targets or allow their clients, who have also set targets for themselves, to reach them.

The ‘study scenario’ developed in this study, considers that (1) one in three new lorries in 2030 should be zero-emission vehicles, (2) battery electric vehicles will play the predominant role, (3) the contribution of H_2 vehicles is expected to be highest for the long-haul and coach segments, and (4) short-haul will be the first to decarbonize. This results in about 534,000 zero-emission heavy-duty vehicles on the road by 2030 (426,000 lorries and 108,000 buses and coaches) of which 459,000 BEVs (357,000 lorries and 102,000 buses and coaches) and 74,000 H_2 (68,000 lorries and 6,000 buses and coaches). Considering the energy consumptions values (kWh/km) as reported by the ICCT [5], lorries will require 29.9 TWh of electricity and 13.7 TWh of H_2. Buses and coaches will require 6.5 TWh of electricity and 0.8 TWh of H_2. These figures are affected by the uncertainty of the inputs, including the future energy consumption values for the different types of vehicles. A major factor of uncertainty is also the expected contribution of H_2 fuelled vehicles by 2030. The report explores the impacts of the range of energy consumption values obtained from the literature and of theoretical scenarios where only battery electric vehicles contribute to the new zero-emission fleet on the energy needs of the zero-emission vehicles fleet itself.

Infrastructure requirements

Stakeholders have provided key inputs to what the market foresee in terms of need for recharging/refuelling infrastructure now and towards 2030. For BEVs the need for publicly accessible recharging infrastructure is largely determined by the use case. Especially long-haul lorries and coaches will have a high dependency on publicly accessible recharging infrastructure while urban delivery lorries, buses and vocational vehicles will primarily recharge at depots/private recharging infrastructure. Regional lorries may need publicly accessible recharging infrastructure depending on the routes/use case, which may vary.

Stakeholders expect overnight recharging to have utilization rates between 25-50% depending on the operations. There is great uncertainty on utilization rates for the publicly accessible recharging infrastructure as stakeholders expect these to be 2-30%. The actual utilisation rates and power outputs will greatly impact the need for recharging infrastructure.

With longer routes larger outputs (kW) becomes increasingly important. Charge Point Operators (CPOs) expect the market towards 2030 to feature thousands of high-power chargers, including megawatt charging capable stations, strategically placed along key corridors and logistics hubs. This is however often hampered by grid limitations, including slow upgrade processes and insufficient capacity in high-demand areas.

For H_2 vehicles only 5-15% of fleet operators is expected to have private refuelling infrastructure. Instead, the operators will be mostly depending on a publicly accessible infrastructure in their operations. A mix of outputs are expected with a greater emphasis on 700 bar for use cases of longer distance.

Electric Road Systems (ERS) are unlikely to significantly contribute to HDV electrification before 2030 due to the technology's early development stage and the need for extensive infrastructure investment and policy backing.

Understanding vehicle specifications and use cases is essential to designing suitable recharging and refuelling infrastructure in terms of output (kW/bar), locations, and numbers of recharging/refuelling points. Both vehicle specifications and use cases vary between the different vehicle categories (urban, regional, long-haul, bus, coach, or vocational) leading to various recharging/refuelling needs. In general, the driving patterns with longer daily travelled distances of battery electric long-haul lorries and coaches make them more dependent on publicly accessible, high power recharging infrastructure, while other types of BEVs may operate with no or very limited need for publicly accessible infrastructure. For H_2 vehicles, most of the energy is expected to come from publicly accessible refuelling infrastructure.

To calculate the energy demand and infrastructure needs of both BEVs and H_2 vehicles, a line of assumptions, averages and generalizations need to be made. The focus of the analysis is the need for publicly accessible infrastructure which differs between the different vehicle types and propellants. Detailed calculations and a consistent approach led to the results that to serve the HDV fleet as assumed in the scenario, a total of:

- **18,000 recharging points** are needed. These are of various output effects kW but with an emphasis (90%) on chargers above 150 kW.
- **1,100 refuelling points** are needed. Almost ¾ of these are 700 bar.

The results are, however, hugely depending on these assumptions as well as other input data.

The strategic objective of the Alternative Fuels Infrastructure Regulation (AFIR) is to offer extensive infrastructure coverage along the TEN-T road network, as well as in urban centres and designated parking locations. Based on the infrastructure that AFIR mandates, it is anticipated that the energy supply, measured in kWh/kg H_2, will satisfy roughly 50-80% of the electric recharging needs and 50-65% of the hydrogen refuelling requirements. However, these projections do not permit us to draw definitive conclusions about the adequacy of the legal stipulations established by AFIR. The initiative's central policy goal is to ensure a foundational level of infrastructure throughout the entire European Union and along its principal transport corridors. To address areas of heightened demand and regions beyond the scope of the TEN-T network, supplementary investments will be necessary.

Barriers

The barriers to zero-emission HDV adoption differ by stakeholder because each group views the market from its own unique perspective. Stakeholders operate from different standpoints and engage with various other actors, resulting in distinct challenges. These different priorities and interactions between actors create a varied perception of barriers by each group. The inputs for this analysis come from both survey data and interviews, ensuring a comprehensive understanding of each actor’s concerns. By categorizing the outputs according to stakeholder groups, we can better highlight the specific issues they see currently and in the future.

When analysing the responses by the different stakeholder groups, it can be seen that there is a general consensus over what the barriers are that that zero-emission HDV adoption is facing: TCO and the related issues, lack of electricity grid capacity and the length of related administrative processes, lack of public recharging, and green hydrogen price uncertainty.

The stakeholders foresee that the identified barriers will decrease by 2030. This view is based on their expectations on advances in technology, development of the infrastructure, establishment of sufficient production capacities and adequate supply chains for supporting this transition. The NGOs and research institutions, agree with the rest on the existence of the barriers but tend to be more optimistic on them being solved by 2030. Vehicle OEMs, however, don't agree and see substantial barriers in the area of lacking recharging infrastructure today. They forecast this to remain the case also in 2030, while other stakeholders think this will be mitigated by 2030. Survey results show that bus and coach operators perceive the market situation differently from the other respondents. For them, the factors that contribute to vehicle TCO such as the availability of financial incentives and lack of financial tools are important barriers and they expect this to remain so also in 2030. The representatives of hydrogen economy, similarly to other stakeholders see TCO as a major barrier to zero-emission HDV adoption and foresee this to remain the case in 2030.

Conclusions

Vehicles

To meet the 45% CO_2 reduction target by 2030, manufacturers must ensure one in three new registered lorries are zero-emission, a significant leap from the current 2%. Battery electric vehicles (BEVs) are expected to dominate the market, supported by stationary recharging infrastructure, as affirmed by 80% of stakeholders during the final validation workshop. By 2030 there could be 426,000 zero-emission lorries and 108,000 zero-emission buses and coaches requiring a total of 36.4 TWh of electricity and 14.5 TWh of H_2.

All major manufacturers offer diverse models of BEVs across segments and are planning new ones by 2030. Currently BEVs are most suitable for regional and urban deliveries and buses, but both manufacturers and operators anticipate performance improvements across all use cases, including long-haul. To reach the reduction targets it is not enough to decarbonise the regional and urban delivery, the long haul must also transition. FCEV and H2ICE vehicles are emerging, primarily targeting long-haul and demanding operations. Hydrogen vehicles offer complementary solutions for long-haul due to their range and refuelling similarities with diesel but face cost, efficiency, and green hydrogen availability and price barriers.

Under the assumptions of the 'study scenario' by 2030 there will be about 534,000 zero-emission vehicles on the road, of which 426,000 lorries. The share of H_2 vehicles in the zero-emission fleet amounts to 16%. These results are based on the expected market shares as reported by the stakeholders, but given the few models currently available, the very low penetration of H_2 observed in the market, the contribution FCEVs and H2ICE by 2030 need to be underlined as an important source of uncertainty in the results presented in this study.

To conclude, as mentioned by several stakeholders, if on the one hand manufacturers have clear emission reduction targets, on the demand side targets are less clear. Incentives like EU Emission Trading System (ETS2), road tolling revisions, and European Taxation Directive (ETD) reforms are seen as important pieces of the puzzle that, where and when in place, provide an incentive for the demand and use of heavy-duty zero-emission vehicles. The Eurovignette directive, already provides for such incentives, notably in Germany. The Clean Vehicles Directive (CVD), which promotes clean mobility in public procurement tenders, initially kick started the market for zero emission busses. The revision of the Weights and Dimensions Directive also promotes the use of zero-emission vehicles through certain derogations from the maximum authorised weights and dimensions of vehicles.

Infrastructure

In conclusion, stakeholders predict a varied demand for recharging and refuelling infrastructure for different types of electric and hydrogen (H_2) vehicles by 2030. Battery Electric Vehicles (BEVs) such as long-haul lorries and coaches will rely heavily on publicly accessible recharging infrastructure, while vehicles like urban delivery trucks and buses may mostly use private or depot-based facilities. The need for public chargers also applies to regional lorries, depending on their routes. High-power recharging infrastructure investment is ongoing, yet it is often constrained by grid limitations.

For H_2 vehicles, the majority of fleet operators will depend on public refuelling points, with an expected preference for 700 bar refuelling stations for long-distance travel. The analysis based on use cases and overall energy demand indicates a requirement for 18,000 publicly accessible recharging points, primarily with outputs above 150 kW, and 1,100 H_2 refuelling points, with the majority being 700 bar. However, these figures heavily depend on the assumptions and input data used in the calculations.

AFIR sets clear targets to ensure infrastructure coverage along Europe’s main transport network and in urban nodes. The projected energy demand for both BEVs and H_2 vehicles is partially covered by fulfilment of the AFIR targets (around 50-80% for BEVs and 50-65% for H2 vehicles), indicating the necessity for additional publicly accessible infrastructure also beyond the TENT-network to meet vehicle energy needs.

Barriers

We conclude that the primary barrier to deploying a widespread recharging network for HDVs is grid capacity, not the cost or technology of chargers. To accelerate the deployment of zero-emission HDVs, it will be crucial to prepare electricity grids for increased electricity demand at recharging hubs as well as depots, by strengthening the grid and addressing permitting processes to reduce lead times for grid connections. The stakeholders reached through the consultation, are optimistic that technological advancements and market maturity will reduce cost-related barriers by 2030, particularly through economies of scale in vehicle production and energy supply. However, uncertainty remains around hydrogen price competitiveness due to its low energy efficiency and reliance on subsidies.

1. INTRODUCTION

This document forms the Final Report of the study "Market Readiness Analysis: Expected uptake of alternative fuel heavy-duty vehicles until 2030 and their corresponding infrastructure needs".

The **main aim** of this study is to gather evidence and provide analysis to help the European Commission develop a "**technology and market-readiness report dedicated to Heavy-Duty Vehicles** (HDVs)". The European Commission is in fact required to submit this report to the European Parliament and the Council by the end of 2024, as mandated in Art 24.1 of the Alternative Fuels Infrastructure Regulation (AFIR)[6]. This report should provide initial indications on what is happening in the market of HDV and current and short-term technological developments for recharging and refuelling technologies, such as high-power recharging, Electric Road Systems (ERSs) and the use of hydrogen. For this purpose, this study will provide an analysis of the market with respect to the targets and goals set by European Union's (EU) legislation up to 2030. The results of this study will also serve as an input to the review of AFIR itself, which is due in 2026. In essence, this study aims to provide a holistic view of the heavy-duty automotive sector's preparedness, resilience, and progress towards a more sustainable, low-carbon future, including the point of view of Original Equipment Manufacturers (OEMs), transport operators and recharging/refuelling operators)

1.1. BACKGROUND

We are living in a time of extraordinary transformation. On the one hand, we are witnessing how impacts of climate change are unfolding with increasing speed and scope. On the other hand, key enabling technologies, which include batteries, power electronics and alternative fuels, have reached high technological readiness levels and are beginning to penetrate mass markets, leading to substantive technological transformations in the transport sector.

The EU has adopted its climate ambitions in the European Green Deal, which sets the aim to be climate neutral by 2050. According to European Commission's Sustainable and Smart Mobility Strategy, for the transport sector this would mean a 90% emissions reduction by 2050 (compared to 1990 levels). By then, nearly all new heavy-duty vehicles would need to be zero-emission. The intermediate ambition for 2030 is set in the "Fit for 55" package, the urgency of which dramatically increased with Russia's war of aggression against Ukraine and the EU's response in the REPowerEU Plan [7]. To ensure the EU remains on track to achieve climate neutrality the Commission has recently recommended reducing the EU's net greenhouse gas emissions by 90% by 2040 relative to 1990 and has contextually presented its assessment for a 2040 climate target for the EU [8].

HDVs such as lorries (or trucks)[1], city buses and long-distance coaches, are responsible for 28% of GHG emissions from road transport in the EU and account for over 6% of total EU-27 GHG emissions. The previous EU legislation setting CO_2 emission performance standards for new HDVs (Regulation (EU) 2019/1242) set emission reductions targets for new lorries of >16 t to 30% by 2030 relative to the 2019/2020 baseline. The revised standards strengthen these reduction targets by extending the scope of the legislation to lorries of >5 t and buses and coaches of >7.5 t, and by increasing the emission reduction targets. Lorries and coaches should reduce their emissions by 43% by 2030 and up to 90% by 2040. New buses under the new regulation must be zero-emission from 2035. A summary of the legally binding targets set in the new CO_2 standards is presented in Table 1.

[1] To note, 'lorry' and 'trucks' are used as synonyms throughout the text.

Table 1 Brief overview of the targets set in the new HDV CO2 standards, please refer to Table 2 for a more detailed overview and the reference year for the different types of vehicles. To note, for urban busses the target is expressed as a zero-emission vehicle mandate.

<table>
<tr><th>Scope</th><th>Target year</th><th>CO_2 emission reduction target</th></tr>
<tr><td rowspan="3">Fleet wide new vehicles, for lorries > 5 t and coaches > 7.5 t</td><td>2030</td><td>43%</td></tr>
<tr><td>2035</td><td>64%</td></tr>
<tr><td>2040</td><td>90%</td></tr>
<tr><td rowspan="2">Urban buses >7.5 t (ZEV mandate)</td><td>2030</td><td>90% (ZEV mandate)</td></tr>
<tr><td>2035</td><td>100% (ZEV mandate)</td></tr>
</table>

Table 2 gives additional detail by summarising the main vehicles bins and groups included in the new HDV CO_2 standards as adapted from a very clear visualization in a recent report by The International Council of Clean Transportation (ICCT) [10]. The vehicles included in the regulation, correspond (almost completely) to Scope1 of the 2023 CO_2 Standards Impact Assessment , presented on 14/02/2023 in SWD(2023) 88 [11]. Trailers and semi-trailers are not directly addressed in this study.

Table 2 Vehicle bins, their corresponding groups, vehicle characteristics, reduction targets by year and reference baseline year in the new CO_2 standards, adapted from a summary by the ICCT [10]. *The reference period of group 1s is also 2025. Note: the CO_2 standards also include trailers and semi-trailers as well as the primary vehicles of coaches and interurban buses [10]. *The reference period of group 1s is also 2025.

<table>
<tr><th>Vehicle bins</th><th>Vehicle group</th><th>TPMLM (t)</th><th>Axles</th><th>2025</th><th>2030</th><th>2035</th><th>2040</th><th>Baseline year</th></tr>
<tr><td>Heavy lorries ≥ 16 t with 4×2 and 6×4 axle configurations</td><td>4-UD, 4-RD, 4-LH, 5-RD, 5-LH, 5-RD-H, 5-RD-LH</td><td>>16 t</td><td>4×2, 6×4</td><td>15%</td><td>43%</td><td>64%</td><td>90%</td><td>2019</td></tr>
<tr><td>Heavy lorries > 7.4 and <= 16 t</td><td>1s*, 1, 2, 3</td><td>>7.4 t-≤16 t</td><td>4×2</td><td rowspan="6">0%</td><td rowspan="4">43%</td><td rowspan="6">64%</td><td rowspan="6">90%</td><td rowspan="2">2021</td></tr>
<tr><td>Heavy lorries with special axle configuration</td><td>11, 12, 16</td><td>>7.5 t</td><td>6×4, 8×4</td></tr>
<tr><td>Medium lorries</td><td>53, 54</td><td>>5 t-≤7.4 t</td><td>4×2 (rear wheel drive)</td><td rowspan="3">2025</td></tr>
<tr><td>Coaches and interurban buses</td><td>32-UC, 32-CS, 32-CT, 32-4C, 34-DU, 34-CL, 34-DD, 34-IC</td><td>>7.5 t</td><td>2- and 3-axles</td></tr>
<tr><td>Vocational vehicles</td><td>5V, 1V, 3V, 2V, 3V, 10V, 11V, 12V, 16V</td><td>>5 t</td><td>4×2, 6×2, 6x4, 8x4</td><td>0%</td></tr>
<tr><td>Urban buses</td><td>DD-LF, SD-LF, SD-LF3,</td><td>>7.5 t</td><td colspan="2">2- and 3-axles</td><td>90%</td><td>100 %</td><td>100 %</td><td>(ZEV mandate)</td></tr>
</table>

	T3-LF, T3-LE						

The 'vehicle bins' referred to in the Table above refer to the group of vehicles as defined in the legislation for the different targets and baseline years. The vehicle groups are used to characterise vehicles based on their chassis configuration (rigid or tractor), Technically Permissible Maximum Laden Mass (TPMLM), axle configuration, and other relevant characteristics as defined in Regulation (EU) 2017/2400. Each group is associated to specific test cycles (called mission profiles) that are weighted according to the typical usage, this allows to simulate real word operational conditions and consequent CO_2 emissions through the VECTO tool [12]. For example, UD, RD and LH in the Figure above refer to typical driving cycles for Urban Delivery, Regional Delivery and Long-Haul. To note, the TPMLM to which the legislation refers can be different from the Gross Vehicle Weight (GVW). The TPMLM is the maximum weight that a vehicle or vehicle combination (i.e. motor vehicle with trailer or semi-trailer) including its own weight and the weight of the payload, that is permitted by its design and technical specifications and reported in the registration records. The GVW refers to the maximum legally authorised weight of the vehicle or vehicle combination including its own weight and the weight of the payload. These vehicles are the typical workhorse vehicles that make up most of the market in long haul and regional delivery. HDVs are very heterogeneous as they can have very different uses and drive cycles.

To achieve the emission reduction targets set in the new CO_2 standards, efficiency improvements, though important, will not be sufficient. Zero-emission vehicles, such as battery electric vehicles, fuel cell vehicles and H_2 internal combustion engine vehicles will need to play a major role already by 2030. The Alternative Fuels Infrastructure Regulation (AFIR)[6] aims to ensure the deployment of publicly accessible electric recharging infrastructures, hydrogen (as well as liquefied methane) refuelling stations for heavy-duty vehicles along TEN-T road network and in urban nodes. A summary of the recharging and H_2 refuelling infrastructure requirement set in AFIR for 2030 relevant for HDVs, is presented in Table 3.

Table 3 AFIR Capacity requirement by December 31st, 2030. Adapted from a report by The International Council of Clean Transportation (ICCT) [13]

Target year	Scope	Minimum capacity requirements	Minimum distance requirements
2030	TEN-T core	One recharging pool with 3,600 kW of aggregated power with at least two points of min. 350 kW	Every 60 km in each direction of travel
		H2 refuelling stations with minimum 1 tonne per day capacity and equipped with at least a 700 bar dispenser.	Every 200 km
	TEN-T comprehensive	One recharging pool with 1,500 kW of aggregated power with at least one point of min. 350 kW	Every 100 km in each direction of travel
	Urban nodes	1,800 kW of aggregated power provided by recharging stations with a min. of 150 kW	
		One H2 refuelling station for cars and lorries	
	Safe and secure parking	At least four 100 kW recharging stations at all safe and secure parking areas	

This will allow using zero-emission road vehicles throughout the EU and ensure the lack of infrastructure does not hinder new technology adoption.

Additionally, the European Commission recently published the impact assessment on the 2040 climate plan [8] to inform a draft law setting the intermediary 2040 target. This target is halfway between the already-agreed 2030 targets and the net-zero ambition set by 2050.

Beyond AFIR and the revised HDV CO_2 emission standards, other EU legislation is relevant for the decarbonisation of the sector. The main regulatory and non-regulatory instruments interacting with the HDV CO_2 standards are summarized in Table 4, adapted from the corresponding impact assessment [11].

Field	Policy
Overall climate policy	Effort sharing regulation EU ETS Directive Energy and Climate Governance Regulation
Environmental and climate policies	HDV CO_2 emission standards Euro 7 emission standards Batteries directive, will be repealed by the Battery Regulation
Energy and fuel policy	Renewable Energy Directive Fuel Quality Directive Energy Efficiency Directive
Infrastructure policy	Alternative Fuels Infrastructure Regulation (AFIR) TEN-T regulation
Pricing	Energy Taxation Directive (ETD) Eurovignette Directive ETS for buildings, road transport and additional sectors
Other transport related measures	Clean vehicles directive (CVD) Directive on maximum authorized weights and dimensions Initiatives related to multimodal transport Driving time and rest periods
Enabling budgetary framework	R&D Horizon Europe Connecting Europe Facility - Transport Alternative Fuels Infrastructure Facility (AFIF) Next generation EU - Recovery and Resilience Facility (RRF) Social Climate Fund Just Transition Fund European Structural and Investment Funds (ESI Funds)

Table 4 Summary of the EU policy context relevant for HDVs, adapted from the HDV CO2 standards impact assessment.

1.2. OBJECTIVES

The main objective of this study is to set a solid basis for the **technology and market-readiness report dedicated to heavy-duty vehicles**, as mandated in Art 24.1 of the AFIR and due by the end of 2024. The results will also be relevant for the **review of the AFIR** itself, which is scheduled for 2026. This report is required under Art 24.1 of AFIR because markets for alternative fuels and particularly for zero-emission vehicles and their infrastructure are still in an early stage of maturity and are rapidly evolving. The development of technologies and markets, both on the supply and demand side, need to be monitored and analysed to understand whether real-world market developments match the assumptions of the European co-legislator at the time when AFIR was agreed.

Heavy-duty vehicles market readiness

This report provides an analysis of the HDV market readiness, considering the plans up to 2030 of both the suppliers' side (e.g. OEMs and their parts suppliers) and the operators' side (e.g. carriers, shippers). Combining the analysis from the supply and demand side will allow to gain a better understanding of how offer meets demand and how this will evolve in the next few years.

As regards the suppliers side this report particularly looks at:

- what types of zero-emission vehicle models, manufacturers currently offer and are planning to offer up to 2030,
- how they are planning to reach the targets set in HDV CO_2 emissions standards regulation up to 2030,
- the robustness of their planning, financing and value chains.

As regards the operators' side, the objectives of the report are:

- to provide an overview of which zero-emission vehicles operators are planning to include in the fleet, their characteristics, how they are and will be used, and for what purposes, and the speed and scale of fleet transition
- to understand how operators rate the operational performance of zero-emission vehicles available on the market today and how they expect it to evolve for the different use cases,
- to understand what commitments large operators are taking to decarbonize their fleet and reduce their Scope1 and Scope 2, and possibly Scope 3, emissions.

In addition to the views of suppliers and operators, the report also draws on views and information shared by relevant sector associations, NGOs and research organisations.

The final objective, in terms of vehicle market readiness, is to combine the inputs collected to develop a 'study scenario' and estimate a compatible evolution of the fleet and its energy needs. The results will serve as input to the analysis of the recharging and refuelling infrastructure requirements.

Analysis of heavy-duty vehicles recharging and refuelling infrastructure needs for sufficient zero-emission vehicles deployment

The report goes through a series of steps to analyse the need for infrastructure:

Stakeholder inputs on Recharging and Refuelling Infrastructure

The report provides insights in stakeholders' view on future demand for recharging/refuelling infrastructure and the different use cases of vehicles providing basis for the projection of the infrastructure demands. These insights feed into the vehicle specifications, use cases, and the energy demand for each category of vehicles.

Vehicle Specifications and Use Cases

The objective of this part of the report is:

- to provide an overview of vehicle categories by regrouping the vehicles based on driving and recharging/refuelling patterns,
- to provide numbers, technical specifications and use cases for each of the various vehicle categories.

Energy Demand and Recharging and Refuelling Infrastructure in 2030

The report also identifies the expected recharging and refuelling infrastructure demand for heavy-duty vehicles (HDVs) in 2030. The focus is on the demand for *publicly accessible* recharging and refuelling infrastructure. These projections are based on:

- the projected numbers of vehicles in each vehicle category and energy demand derived from the previous sections,
- stakeholders' views on different use cases for each vehicle category,
- assumptions on split between demand for private and publicly accessible recharging/refuelling infrastructure for each vehicle category,
- assumptions on average utilization rates for all publicly accessible recharging/refuelling points.

This leads to the share of energy demand expected to be demanded from publicly accessible recharging/refuelling infrastructure to support a growing fleet of zero-emission HDVs by 2030. The objectives are furthermore to determine the energy demand and number of the different types of recharging/refuelling infrastructure (based on output in kW/bar) needed to meet the demands of different zero-emission HDV use cases, from urban delivery to long-haul operations.

Finally, the report will compare the demand for publicly accessible recharging/refuelling infrastructure with the requirements of AFIR and discuss the geographical aspects of ensuring a cohesive and sufficient public infrastructure to support the shift to zero-emission HDVs.

Identify challenges and barriers for uptake of zero-emission vehicles on the production, user and infrastructure side.

The research aims to identify the barriers to the adoption of zero-emission heavy-duty vehicles and the development of their supporting infrastructure. It seeks to understand the existing challenges from the perspective of three key stakeholder groups: vehicle manufacturers, road transport operators, and infrastructure providers, but also takes into account the views of other stakeholders. The aim is to provide an assessment of how these barriers are likely to evolve between now and 2030.

The analysis is based on inputs from: (1) vehicle manufacturers, who must organise the supply chains, secure investment financing and forecast the demand, (2) road transport operators, who have to invest in purchasing suitable zero-emission vehicles to be included in their daily operational schedules, whilst balancing the added cost of new technologies with their financial sustainability, and (3) infrastructure operators, who have to build the recharging/refuelling networks to meet the infrastructure demands of the industry.

1.3. METHODOLOGY

To carry out this study we applied a methodology based on both desk and field research which was carried out in five main tasks, shown in a high-level overview in

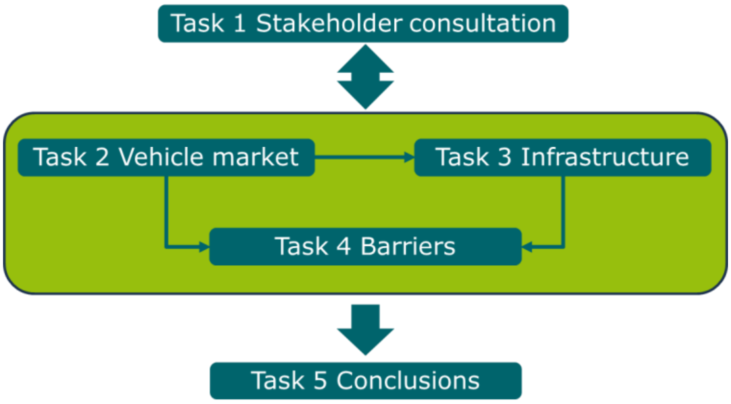


Figure 1. The report is structured on the same lines of the methodology, with each task summarising the findings in the corresponding chapter.

Task 1 established the overall methodology which consisted mainly of the stakeholder **consultation strategy and engagement** throughout the project (Chapter 2). The core tasks were Task 2, concerning the study of the **vehicle market** both from the supply and demand point of views (Chapter 3), Task 3, concerning the requirements for recharging **and refuelling infrastructures** (Chapter 4), and Task 4 identifying **challenges and barriers**. Task 2, Task 3, and Task 4 actively supported the design and, where necessary, adaptation of the methodology by identifying gaps that needed to be filled through stakeholder inputs (Chapter 5). Finally, Task 5, combined the analysis carried out in the previous tasks to draw the overall **conclusions** outlined in the final chapter (Chapter 6).

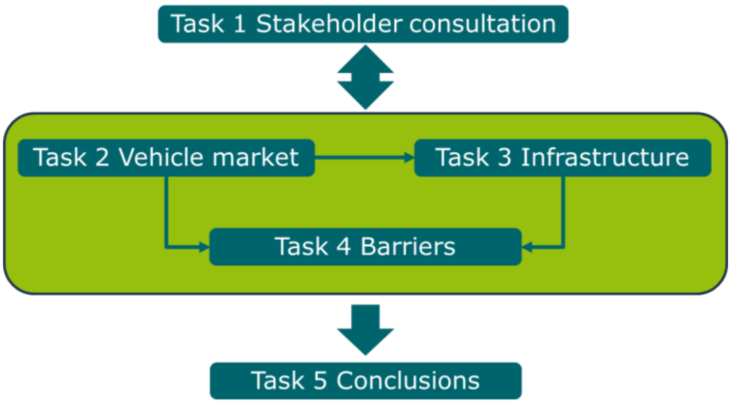


Figure 1: Overview of tasks and their interdependencies.

1.4. SCOPE

This study looks at the developments of the HDV sector **until 2030**. It considers all categories of alternative fuel HDVs, and the expected infrastructure needs with a specific focus on battery-electric and hydrogen fuelled vehicles (hydrogen fuel-cell and internal combustion vehicles powered by hydrogen). The focus is **on the EU-27 market**, and on highlighting, where possible and relevant, differences between Member States (MS) as well as the international context.

1.4.1. VEHICLE MARKET

In terms of **vehicle categories** (vehicle groups) and zero-emission propulsion systems, this study is consistent with the scope reported in the Impact Assessment accompanying the proposal for a review of the HDV CO_2 Regulation, presented on 14/02/2023 in SWD(2023) 88

[11][2], the regulation itself, and the most recent modelling scenario including the impact of the revised CO_2 standards as provided by the Commission for the purpose of this study.Table 5 reports the vehicle categories considered in this study and corresponding aggregation in terms of vehicle groups.

Table 5 Vehicle categories

Medium lorries 5-7.5 t	Groups 53, 54
Heavy lorries 7.5-16 t	Groups 1, 2, 3
Heavy lorries > 16 t (long-haul)	Groups 4, 5, 9, 10 for long-haul
Heavy lorries > 16 t (regional delivery)	Groups 4, 5, 9, 10 for regional delivery
Heavy lorries (special axle) > 16 t	Group 11, 12, 16
Buses	
Coaches	

Whereas manufactures are familiar with the vehicle sub-groups (as they are used in vehicle registration and the monitoring and reporting mechanism), for operators the definition of the use case is more relevant. The **use cases** are the **intended operation** as marketed by manufactures or as the **actual operation** as defined in practice by how the operators use the vehicles. In general, this report considers the following use cases:

- Long haul truck < 500 km daily
- Long haul truck > 500 km daily
- Regional delivery
- Urban delivery
- Vocational vehicles
- Buses
- Coach < 300 km daily
- Coach 300-500 km daily
- Coach > 500 km daily

To note, vocational vehicles are lorries that are not used for the delivery of goods, such as garbage trucks and construction vehicles. They may differ substantially from delivery vehicles and are defined as such according to the digits used to supplement the code for bodywork (rigid lorries) or to their maximum speed (tractors). The group they are allocated to has a ‘v’ in its name. The vocational vehicles included in the agreed text of the revised HDV CO_2 standards are 53v, 1sv, 1v, 2v, 3v, 4v, 5v, 9v, 10v, 11v, 12v, 16v and their emission reduction target is set only for 2035.

Furthermore, there are multiple **vehicle configurations** (e.g. tractor/semi-trailer or truck/trailer with different axle configurations) and **multiple operational conditions** that affect the potential to apply zero emission technology (e.g. actual distance profile: long haul may be half day trips, full day trips, multiday trips; type of routes travelled: TEN-T vs. non TEN-T, which will affect the availability of recharging/refuelling infrastructure, hilly vs. flat: energy recovery potential; climatological conditions: need to use heating/air conditioning; weight-constrained vs. volume-constrained vs. double-constrained vs. unconstrained; the deployment of vehicles in specialised or multiple operations, etc.).

[2] The Impact Assessment for the amendment of the HDV CO2 Regulation, in its Annex 9, presents the results of a modelling exercise for four scenarios (baseline + 3 policy scenarios) each containing a projection of the market share for five drive trains and five vehicle weight categories.

When analysing the new HDV vehicles manufacturers are putting on the market, this report considers several **technical characteristics** such as efficiency (kWh/km), battery capacity (kWh) or hydrogen storage capacity (kg), connector type – e.g. compatibility with Megawatt Charging System (MCS) and/or Combined Charging System (CCS)[3], range (km). As this is connected with infrastructure requirements, these vehicle specifications are elaborated in Section 4.2.

The zero-emission **propulsion systems/drive trains** considered in this study, are:

- Battery Electric Vehicles (BEV)
- Fuel Cell Electric Vehicles (FCEV)
- Hydrogen Internal Combustion Engines (H_2ICE)

Finally, **energy saving technologies** (e.g. aerodynamic devices and aerodynamic cabs), can contribute to the HDV CO_2 standards targets, their importance will be therefore considered when assessing the fleet manufacturers' plans to reach the 2030 targets.

1.4.2. RECHARGING AND REFUELLING INFRASTRUCTURE

To be consistent in the evaluation, the same terms and categories described in the previous section (the **scope** for vehicle market) have been used for the analysis of the recharging and refuelling infrastructure.

The scope of the recharging and refuelling infrastructure includes:

- for BEV, primarily battery recharging, but also encompassing catenary recharging (through ERS). In terms of recharging infrastructure, the report discusses both CCS and MCS and distinguishes the following power outputs:
  - <50 kW
  - 50-150kW
  - 151-350kW
  - 351-600kW
  - >600kW
- for hydrogen-powered vehicles both liquid and gaseous hydrogen energy storage systems and refuelling infrastructure. The following H_2 storage technologies will be considered together with the H_2 purity (e.g. fuel cell grade):
  - Compressed gaseous H_2 350 bar
  - Compressed gaseous H_2 700 bar
  - Liquid Hydrogen

In terms of recharging and refuelling infrastructure, a distinction between the status of the infrastructure is made in terms of availability. The availability is generally given by either Private or Publicly accessible infrastructure, even though semi-publicly accessible infrastructure is also expected to be seen in some sectors/locations. The two types may encompass different locations:

Private Recharging/Refuelling Infrastructure:

- Depot: May be at fleet operators' depots, used primarily for overnight or scheduled downtime recharging/refuelling, suitable for predictable routes and regular returns to a central base.

[3] MCS (Megawatt Charging System) refers to a set of standards for the vehicle, for the cable, the communication, the charger. CCS on the other hand is the technology and standard that was developed for light-duty vehicles; while it is suitable for the heavy-duty ones, it is not considered optimal for this use-case. MCS is suitable to deliver both high (i.e. megawatt) and low power recharging.

- Opportunity: Mid-journey at strategic locations like private logistics hubs or loading/unloading points, allowing HDVs to "top up" during breaks or operational pauses without major route deviation.

Publicly accessible Recharging/Refuelling Infrastructure:

- Stations accessible to all operators, strategically placed along key transport corridors and urban areas to support long-haul and regional HDV operations, especially critical for longer routes or routes which does not start from a depot.

The foreseen demand for private and public recharging and refuelling infrastructure, are determined both by the range of the specific vehicle, the use cases, and the recharging/refuelling technology. The report primarily focuses on the need for publicly accessible recharging/refuelling infrastructure.

2. STAKEHOLDER CONSULTATION

Field research was conducted to collect the opinions of the identified relevant stakeholders. We conducted the following consultation activities:

- Over 20 interviews, including preliminary interviews and follow-up,
- Two stakeholder workshops,
- An online survey.

The stakeholders addressed are HDV manufacturers, components suppliers of HDV (particularly those involved in the development of zero-emission/alternative fuel drivetrain components), HDV fleet owners/operators, and operators of alternative fuel infrastructure. In fact, these are the stakeholders with high interest and knowledge. Most of them will also be affected by the CO_2 emission performance standards for HDV, the zero-emission requirements for buses, and the new regulation on deploying alternative fuel infrastructure. Their views and opinions were gathered through the consultation activities.

The following sections present the key conclusions drawn from each consultation activity. Some elements of the stakeholder consultation strategy have been adjusted throughout the project, to better address the Commission’s needs and address the gaps identified.

2.1. INTERVIEWS

The first step involved organising a total of six interviews with targeted stakeholders to get their views on the principal aspects to consider during the rest of the consultations, as well as to collect views, literature, and contacts for the following activities. To do so, we prepared a preliminary list of questions to guide the interviews, which was then regularly updated based on the replies received.

The following stakeholders were consulted for preliminary interviews:

- European Automobile Manufacturers’ Association (ACEA)
- European Clean Trucking Alliance (ECTA)
- Transport and Environment (T&E)
- E.ON (Electric Utility Company)
- ElaadNL (Researching & testing smart and sustainable recharging
- Milence (Charging infrastructure provider/operator)

We decided to consult these stakeholders because they could provide a first view on the decarbonization of heavy-duty transport. ACEA offered insights into industry trends and regulatory challenges for vehicle manufacturers, while ECTA contributed expertise on sustainable logistics in specialized freight. T&E brought a policy and advocacy perspective on reducing emissions in the sector. E.ON, ElaadNL and Milence added critical knowledge on the electricity grid and infrastructure development for large-scale EV recharging networks. Together these stakeholders could offer a selection of views on the challenges and opportunities in bringing zero-emission HDVs to market.

Among the topics covered in these preliminary interviews, we can mention:

- General outlook on 2030 targets
- Perspectives on the enabling conditions to achieve the new emission targets for HDVs (including recharging and refuelling infrastructure)
- Expected role of key technologies to decarbonise vehicles
- Barriers to the development of ZEV HDV market.
- Follow-up interviews were conducted with several-stakeholders on-line and in, one case, in person. These interviews allowed collecting further information and point of view of stakeholders who did not feel comfortable sharing information in the online survey.

2.2. ONLINE SURVEY

As part of the stakeholder consultation strategy, an online survey was launched. This was our main tool to collect input for the study's tasks. In fact, the questionnaire was designed in close consultation with Tasks 1, 2, 3 and 4. The results of the targeted survey feed into the market readiness analysis work and will be reported in the final report.

The survey was launched on the 11th of July 2024 and remained open until the 13th of September 2024. It was disseminated via Ramboll's proprietary online survey tool SurveyXact (see Figure 2). It includes an analytical module and allows for disaggregating and filtering of the results, as well as export into different formats (xls, csv, word).

Figure 2. Ramboll's proprietary survey software - SurveyXact

SurveyXact was developed by Ramboll in 1999 as an in-house tool that has since grown to become Scandinavia's leading tool for creating questionnaire-based surveys. It is a state-of-the-art product in the category of survey software that aims to support the survey process from data collection to presentation and distribution of results.

The system contains advanced features for data collection regardless of whether the data are retrieved online, through telephone interviewing or with paper questionnaires. Furthermore, the system handles the same questionnaire without difficulty in almost any language. It also allows for full (visual) customisation and complex activation/visibility settings, thus making it possible to fully tailor the questions asked of each respondent based on their profile and/or their answers to preceding questions.

The system has a built-in data analysis toolkit that allows for easy cross-tabulation of results, allowing for filtering based on stakeholder types and/or their responses, thus facilitating descriptive statistical analysis of the results that can be supplemented with a more robust statistical analysis in external programmes.

SurveyXact is fully GDPR-compliant. http://www.surveyxact.com/

The survey was sent to relevant stakeholders, associations and their members. The survey was also shared on the European Alternative Fuels Observatory[4] website of the European Commission.

The survey aimed at collecting insights into the overall readiness of the market to respond to the requirements set out by the CO_2 emission performance standards for HDV and AFIR, and the maturity (technological/economic) in different vehicle market segments and different Member State markets.

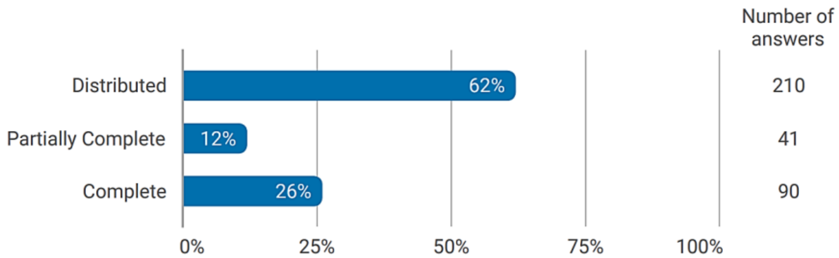
- The survey was articulated around the following sections:
- Section 1 - About you
- Section 2 - Targeted market readiness questions (different for each type of respondent)
- Section 3 - Identification of barriers
- Section 4 - Concluding questions

Section 2 was then divided between the following types of respondents:

- Section 2.1– Original Equipment Manufacturers (OEM), part suppliers and relative associations
- Section 2.2 – Operators – freight and passenger transport operators/authorities
- Section 2.3 – Infrastructure – (CPOs)”

As of the 12th of September, the survey had been sent to 341 actors of the field. 26% of these actors (90) completed the survey and 12% (41) partially completed it. Overall, 38.42% of the actors completed the survey (at least partially). To note, in many cases several people of a same organisation registered to fill out the survey while, as requested, only one survey per organisation/company was finally submitted. The completion rate is therefore higher than the figure below suggests.

Figure 3. Survey completion rate. Note: in many cases several people of a same organisation registered or partially filled in the survey but only one survey was finally submitted.



The analysis of the survey results is thoroughly presented in Sections 3, 4 and 5

2.3. STAKEHOLDER WORKSHOPS

The third stakeholder consultation activity consists of two stakeholder workshops.

The first **stakeholder workshop** was held online on the 27th of June 2024. This workshop introduced the study’s objectives, the proposed methodological approach, and offered a first occasion for a guided discussion with key stakeholders’ associations. Some of the questions

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[4] Survey on the Future of Alternative Fuels for Heavy-Duty Vehicles (2024). Available on https://alternative-fuels-observatory.ec.europa.eu/general-information/news/survey-future-alternative-fuels-heavy-duty-vehicles

that were going to be asked during the online survey were presented and validated by the invited stakeholders (as the survey was launched following the workshop). We also used an online engaging tool (MentiMeter) to feed a discussion on key topics including technologies to decarbonise HDVs, vehicle market supply and demand, and recharging and refuelling infrastructure.

Overall, the purpose of this first guided discussion was to:

- Collect information and opinions about the expected uptake of ZEV HDVs in the near future,
- Check elements of convergence and divergence in opinions/expectations of stakeholders,
- Collect input on potential barriers for the uptake.

The workshop was mainly addressed to sector associations. 43 participants took part, representing stakeholder associations (8), vehicle manufacturers (OEMs) (9), technology suppliers (5), recharging infrastructure operators (3) and energy suppliers (3). Other participants were representatives of the European Commission and the study consortium.

The workshop highlighted the need for a diversified approach to decarbonizing the sector, with battery-electric vehicles leading the way but not being sufficient on their own. Decarbonising long-haul trucking, which accounts for the largest emissions share, is essential to meet 2030 targets, with approximately one-third of truck sales needing to be zero-emission vehicles by then. Public infrastructure is critical for long-haul routes, though infrastructure providers face challenges with land availability and grid readiness, particularly along the TEN-T corridors. A disconnect exists between manufacturers' need for public infrastructure and infrastructure providers' focus on depot recharging, which is more suited for short-distance operators. Additionally, addressing the 'chicken and egg' dilemma—where infrastructure and vehicle affordability must align—is key to driving the uptake of zero-emission trucks. Finally, the high upfront costs of transitioning from diesel to zero-emission vehicles will require coordinated efforts across the value chain, including shippers, consumers, and policymakers, with unpopular but necessary political decisions to spur market development.

The **second stakeholder workshop** took place on the 14th of October and presented the main results of the survey and consultation and introduced the preliminary findings, in order to discuss and collect stakeholders' feedback. The discussions were key to validate the conclusions of the study and to gather suggestions on how to address the identified barriers.

The invitees were the participants of the first workshop, the survey respondents and interview contacts. This workshop was open to anyone interested. About 125 participants attended the workshop of which around 90 responded to the polling questions raised during the workshop. They represented vehicles manufacturers (OEMs), part suppliers and related associations (24), operators of freight and passenger transport (13), technology providers (10), recharging infrastructure operators or associations (6), public authorities/researchers/consultants (19), and other (17). Other participants were representants of the European Commission and the study consortium.

On the basis of the preliminary results of the study, the participants were presented with our preliminary findings (Table 6 below) and were presented related questions to initiate discussion and understand whether they agreed or not with the findings. The workshop fostered a good level of participant engagement, resulting in an interactive and dynamic session.

Table 6. Initial findings presented during the 2nd workshop

Preliminary finding 1	**Current developments of technological maturity and market investment show strong differences for battery-electric and hydrogen-fuel cell and combustion technologies. Based on current market shares and announced vehicle models, the contribution of FCH_2 and H_2 ICE to emission reductions until 2030 will be limited, and OEMs will mostly rely on BEVs for reaching their 2030 targets. It is unlikely that Electric Road Systems (ERS) will play a significant role by 2030. Until 2030, the zero-emission HDV fleet will**

therefore be predominantly represented by BEVs relying on stationary recharging.

The great majority of workshop participants (80%) either agrees or strongly agrees that by 2030 zero-emission vehicles will be predominantly represented by BEVs relying on stationary recharging. There seems therefore to be a broad agreement that BEVs will represent the overwhelmingly predominant ZEV technology at least until 2030. As for the recharging technology, given the short time before 2030, manufacturers underlined that all efforts should be focused on deploying the necessary depot and publicly accessible recharging infrastructure. Some respondents considered that ERS could also be useful for operators to reduce recharging time, and that it could be an excellent solution but only with extremely high utilization of the system and extremely high uptake of this equipment on all the vehicles. But ERS deployment beyond some very limited pilots is very unlikely at least by 2030**.**

A majority of participants (57%) also agrees that the high initial purchase cost represent a key barrier to the adoption of battery-electric HDV. During the workshop the point was raised by one participant that TCO parity may still not be enough. The road freight industry operates on very low margins and a TCO of zero-emission vehicle lower than that of conventional diesel internal combustion engine may be necessary to convince operators to make the technological switch as long as this comes with perceived risks. Finally, voting during the Workshop shows that there are different opinions about the comparable competitiveness of FCEV and H2 ICE with more than 40% not having a clear opinion. One third of respondents agreeing that the TCO of H2 ICE risks being significantly higher than that of FCEV, and one quarter of respondents disagreeing. In any case, without competitive (green) hydrogen prices, none of the hydrogen technologies will be competitive**.**

Preliminary finding 2

Battery electric HDVs will rely on a combination of depot recharging using primarily 100-150 kW chargers, and public recharging using CCS and/or MCS. Wherever possible, operators will maximise the share of depot recharging because of lower cost per kWh.

MCS (Megawatt Charging System) refers to a set of standards for the vehicle, for the cable, the communication, the charger. CCS on the other hand is the technology and standard that was developed for light-duty vehicles; while it is suitable for the heavy-duty ones, it is not considered optimal for this use-case. During the Workshop, some participants noted that the term "MCS" is somewhat misleading as MCS allows recharging both at lower-power levels (e.g. 100 or 200 kW), for example for overnight recharging, and high-power levels of 1 MW or more for fast-charging. Fast charging is a key enabler to decarbonize the long-haul but it should be highlighted that recharging at 'megawatt' speed is not always necessary and that not all MCS recharging points will necessarily provide such high power levels. It should be clarified that MCS refers to the technology and the evolving standard, not to the recharging speed. With this in mind, vehicle manufacturers and recharging point operators indicated that answer to the question of whether MCS will become the primary standard for BEV HDVs recharging is 'definitely yes'; the actual power required and provided by different MCS recharging points may however be lower for many use cases, and more comparable to current recharging speed using CCS

Preliminary finding 3

The current and announced availability of FC H2 and H2 ICE HDV vehicle models is very limited. While AFIR mandates only 700 bar, it is not possible at the moment to conclude that there is a clear convergence of OEMs towards that standard. This raises questions about future refueling requirements and the technologies that should be available at publicly accessible refueling points (700 bar, 350 bar, liquid hydrogen). However, the costs for the deployment of parallel hydrogen refueling infrastructure for these different technologies would be very high, and subject to significant risk of stranded assets.

The availability of the different pressure levels or liquid H2 is not considered the main issue, though during the workshop was mentioned that 350 bar is not sufficient for long-haul. A more pressing issue in the view of participants expressing this view are the requirement set in the AFIR in terms of capacity of the refuelling points along TEN-T (1 tonne per day). These requirements could also be met by refuelling stations offering very long refuelling times, which would completely hinder the advantage of H2 over BEV for the long-haul and that a better indicator would be how many vehicles can refuel in quick succession.

Preliminary finding 4	**The existing H2 refuelling infrastructure is broadly sufficient for the current H2 HDV vehicle fleet; in light of the current market trends and latest announced timeframes for series production of new H2 models by OEMs, the number of H2 HDVs on the market is not expected to reach a level that would require significantly higher capacity before 2030. Beyond 2030, clearer market signals about vehicle availability and greater clarity on the predominant option (350 bar, 700 bar, liquified) will be needed for further infrastructure deployment.** Voting during the Workshop showed more than 40% (less than half) of participants agreed or strongly agreed with the statement that "in light of the current market trends and latest announced timeframes for series production of new H2 models by OEMs, the number of H2 HDVs on the market is not expected to reach a level that would require significantly higher capacity of H_2 refuelling infrastructure than currently installed before 2030." At the same time, 20% of the participants neither agreed nor disagreed with the statement, and 37% disagreed or strongly disagreed. The dispersion of answers highlights the uncertainty around H2.
Preliminary finding 5	**The primary barrier to deploying a widespread recharging network for HDVs is grid capacity, not the cost or technology of chargers. To accelerate the deployment of zero-emission HDVs, it will be crucial to prepare electricity grids for increased electricity demand at recharging hubs as well as depots, by strengthening the grid and addressing permitting processes to reduce lead times for grid connections.** Voting during the Workshop shows that grid capacity is seen by the vast majority of respondents as a major barrier to the deployment of BEV. However, participants discussed that there are also 'lower hanging fruits' related to the electricity grid. It is for example very difficult for charge point operators (CPOs) to know where capacity is available and obtain reliable information. It would be useful therefore to very granular maps that show where capacity is available and where it is likely to be available in the coming years at DSO level. Another aspect concerns pricing, which, for example, in Germany, considers peak power penalizing therefore recharging stations that may require high power only for a short part of the day. Electricity prices in publicly accessible recharging are in general more expensive than the ones for depot recharging at own location. Some more considerations are needed on pricing mechanisms to allow that investment in public recharging infrastructure are recovered and public recharging makes sense for large and small operators alike.

3. VEHICLE MARKET ANALYSIS AND FLEET DEVELOPMENTS

The objective of this section is to **provide an analysis of the HDV market readiness** based on information shared by suppliers and operators on their planning for the transition to 2030, and additional information sources, following the objectives stated in Section 1.2.

The analysis relies both on desk research and the stakeholder consultation carried out through the interviews, workshops and the survey. The results for the supply side are reported in Section 3.1 and for the demand side in Section 3.2. After a brief overview of the global context in Section3.3 the findings of the study are used to build a 'study scenario' describing the corresponding fleet evolution as well as its energy requirements up to 2030. The 'study scenario' is presented in Section 3.4 and will serve as input to determine the infrastructure requirements in the following Chapter.

3.1. SUPPLY SIDE – MANUFACTURERS AND PARTS SUPPLIERS

3.1.1. CURRENT AND FUTURE OFFERING OF ZERO-EMISSION VEHICLE MODELS UP TO 2030

Zero-emission heavy-duty vehicles drive trains – brief overview

With the term **"zero-emission vehicles"**, we refer to BEV, FCEV and H2ICE, consistently with the revised CO_2 standards. In this section we provide a short overview of these different drivetrains and mention, as examples, models that are currently available in Europe.

Battery electric vehicles rely on electric motors that can reach very high efficiencies. A typical value for total drivetrain efficiency is 85% which compares to 40% of a conventional diesel internal combustion engines[5] (ICE) [14]. ICCT reports, for example, a maximum diesel heavy-duty vehicle efficiency of 44.5% (for the 2019-2020 reporting period) [15]. BEV lorries can achieve a source-to-wheel electrical efficiency of 70-80 %, with only one-fourth of the energy that is produced at the source being lost [16]. A typical energy consumption for a heavy-duty 40 t tractor-trailer combination is about 140 kWh per 100 km [17]. Fuel consumption varies depending on the payload and operating conditions. One should also note that batteries can drain faster in particularly hot or cold weather conditions.

Based on modelling results, TNO (Netherlands Organisation for Applied Scientific Research), reports the energy consumption of BEVs with respect to their diesel counter parts for different vehicle configurations, and concludes that BEVs energy consumption can be up to three times lower than that of conventional diesel lorries[18]. Volvo in an actual test , reported that their FH electric lorry, with a gross combination weight of 40 t and average speed of 80 km/h, operated with an energy consumption of 110 kWh per 100 km (or 50% less than its diesel counterpart) leading to a range on a single charge of 345 km [19].

All major European OEMs offer a portfolio of BEV lorries, for different use cases and in different configurations, which are already in series production. Volvo, for example, offers models with typical ranges of about 300 km and, with their FL Electric model, up to 450 km. [20]. In Scania's portfolio of BEV lorries with several wheel and cab configuration options, the 520 kWh battery can offer a range 395 km at 42 t. New options with battery sizes of 520 kWh and 728 kWh will be available for order during 2025 [21].

The portfolio of BEVs for passenger transport is also expanding. A large supplier of BEV buses in the EU is Solaris [22] , which focuses on the production of zero and low-emission vehicles and makes available several models. For example, their Urbino 12 model, allows a maximum of 100 passengers of which 41 seated. With six batteries mounted on the roof, it can rely on a total capacity of over 600 kWh [23]. MAN, which is also a major electric bus supplier in the EU, provides several variants of their Lion's City E bus with battery capacities ranging from 320 kWh to 640 kWh and a range between 300 and 380 km [24].

Fuel Cell Electric vehicles rely on fuel cells as electrochemical power generators that directly power the electric drivetrains. A fuel cell vehicle is an electric vehicle where the fuel cell engine integrates with a battery to form a hybrid powertrain. FCEV have demonstrated

[5] A typical diesel heavy-duty truck consumes approximately 33 litres per 100 km (or 333 kWh per 100 km)

typical drivetrain efficiencies of 48-58% in operation. The typical fuel consumption of heavy-duty fuel cell trucks is 8-10 kgH_2 per 100 km (or 266-333 kWh H_2 per 100 km) [25]. Stakeholders pointed out that refuelling at hydrogen fuel cell electric vehicles will play a role particularly in certain long-distance use cases.

Only a few FCEV models are currently available in the EU or are being announced by manufacturers. Examples are the XCIENT made available by Hyundai with a 400 km range on a single charge of 31 kg H_2 in a 350 bar tank [26] and the IVECO HD FCEV with a range 800 km on a single charge of 70 kg of H_2 at 700 bar. Daimler Trucks, to the best of the authors' knowledge, is the only European OEMs who is pursing the liquid H_2 storage technology. The Mercedes-Benz GenH2 Truck prototype covered, in a record run, 1047 km with 80 kg of cryogenic liquid H_2 stored at -253°C in two 40 kg tanks, fully loaded and with a gross combined vehicle weight of 40 t [27]. Customer testing is expected in the coming years with the introduction of the series planned for the end of this decade [28], [29]. Daimler Trucks also makes available several models of FCEV (and BEV) in the bus segment which are already in series production. The eCitaro FCEV buses offer ranges from 350 to 400 km and passenger capacity up to 128 (in the 4-door, articulated configuration)[30]. In the coach segment, where only a few zero-emission vehicles are available, the recently launched Irizar i6S Efficient offers 1000 km range

H_2 internal combustion is, in several aspects, similar to a conventional diesel combustion engine but development for H2ICE is still ongoing. H2ICE have typical fuel consumption that are higher than FCEV and in the range of 10-12 kgH_2 per 100 km (or 333-400 kWh H_2 per 100 km). Efficiencies are lower, and according to Ballard can be in the 30-40% range [25]. They could be well-suited to retrofit vehicles and in industries with high vibration and dust-laden air and where efficiency is not the primary concern, as for example rescue services and fire trucks [25]. Stakeholders also pointed out their suitability in heavy long-haul transport and the advantages H2ICE can bring in terms of know-how (as it similar to the long-term core business of European OEMs), possibly reduced components costs and reduced supply chain risks. Given the appropriate infrastructure H2ICE would benefit from fast refuelling times, as FCEV [31].

To the best of our knowledge, there are no H2ICE models currently available on the market in series production. MAN Truck & Bus will be the first European truck producer to launch a small series production of H2ICE with their MAN hTGX model, which is planned for 2025. This truck is deemed suitable for special transport tasks that require special axle configuration or where the truck body work does not allow for the space for the battery on the frame. Examples of applications are construction work, tank transportation or timber transport. This model offers high payloads, maximum ranges up-to 600 km, and it is initially offered in both 6x2 and 6x4 axle variants. It relies on 700 bar compressed H_2 in a 56 kg tank [31]. Volvo Trucks will also start testing H2ICE in 2026 and aims for a commercial launch towards the end of this decade. The Volvo H2ICE heavy-duty lorry will feature Westport's High Pressure Direct Injection technology (HDPI) and with 80 kg H_2 stored at 700 bar, reach a range of 800 km. This lorry delivers a power/torque up to 30% higher than traditional diesel engines while offering up to 5% efficiency improvement [32].

For both H2ICE and FCEV, H_2 stored on board the vehicle can be at 350 bar, 700 bar or as liquid hydrogen (LH2). LH2 has far higher energy density than gaseous hydrogen, tanks are therefore much smaller and due to the lower pressure, significantly lighter. This gives the trucks larger cargo space and higher payload weight, which makes them suitable for multi-day, difficult to plan long-haul transport. To note, however, that liquefying H_2 is an energy intensive process which therefore reduces the overall system efficiency [29]. The electricity required for compression for H_2 storage in tanks at 350 or 700 bar ranges from 15% to 30% of the hydrogen energy content, which increase up to 40% for liquefaction [33]. To note, green H_2 production from electrolysis requires about 55 to 60 kWh of electricity per kg of H_2 further lowering the source-to-wheel efficiency [34]. From the consultation, H_2 at 700 bar is best suited for long-haul operations whereas urban buses, as well as lorries for regional delivery, typically rely on H_2 at 350 bar.

Throughout the consultation whereas some stakeholder pointed out the complementarity of H_2 fuelled vehicles to BEV, especially for demanding long-haul operation, others pointed out the lower system efficiency due to H_2 production, storage and transport, safety concerns, the limited availability and potential for truly green H_2, the importance of this energy carrier in other sectors and especially the industry, and the high uncertainty on its price, which as will be shown in Section 5, is considered one of the most important barriers that will still be relevant in 2030. .

Furthermore, because of the high cost of a refuelling station with respect to a charger, the entry barrier given by the limited availability of public infrastructure is higher for H_2 vehicles than for BEVs. Installing an own refuelling point is much more costly and complex than installing a recharging point. Therefore, the lack of public infrastructure is a very high entry barrier for H_2 vehicles. Stakeholders highlighted the importance of the current AFIR targets on refuelling stations to kick-start the market and allow entry to all solutions for fast decarbonisation.

Energy prices are an important component of the total cost of ownership (() of heavy-duty vehicles [35]. For what concerns H_2, according to the European Hydrogen Observatory, in 2023 the levelized cost of H_2 production via electrolysis with a direct connection to a renewable energy source varied from 4.13 to 9.30 Euro/kg (279 Euro/MWh), with an average of 6.61 Euro/kg (198 Euro/MWh) and a median of 6.20 Euro/kg (186 Euro/MWh). For comparison the cost of H_2 production via steam methane reforming () was 3.76 Euro/kg (112 Euro/MWh)[36]. According to Eurostat, average EU electricity prices excluding all taxes for non-household consumers, have been within the 70 to 100 Euro/MWh in the period from going from 2008 to the end of 2021. The post pandemic recovery and Russia's invasion of Ukraine were major factors that pushed prices to a record high of 200 Euro/MWh. Of course, H_2 prices are also affected by electricity prices as, as said earlier, about 55 to 60 kWh of electricity are required per kg of H_2.

Compared to BEVs, the lower efficiencies of FCEV and H2ICE, and, in general the price of green H_2 with respect to the price of green electricity, directly result in higher operating costs of H_2 fuelled vehicles.

To note, the models cited in this sections are only a few examples, the reader is referred to each manufacturers' website for more detailed model characteristics, to the data explorer made available by CALSTART [1] and to ACEA [37] [2].

As will be shown later, throughout the consultation, most stakeholders pointed out that BEVs will play the most important role to reach the targets set by 2030 in the revised CO_2 standards.

BEVs are the most efficient heavy-duty zero-emission vehicles which can reduce by half or more the energy demand of their diesel counterparts (depending on operating conditions).

With respect to BEVs, H_2 fueled vehicles generally allow for longer ranges and shorter refuelling time at the expense of lower efficiencies and higher purchase and operational costs. Beyond the vehicle efficiency, green H_2 production, compression and, in case, liquefaction are also energy intensive processes further reducing the source-to-wheel efficiency. H2ICE vehicles generally have higher fuel consumptions than FECV but they could be well-suited for particularly heavy operations and in industries with high vibration and dust-laden air.

Zero-emission heavy duty vehicles models availability and their range

To explore more in detail, the type of vehicles that are available in Europe currently and in the short-term, we rely on the dataset made available by CALSTART through the Drive to Zero's Zero-Emission Technology Inventory Data Explorer (ZETI)[1] and the overview compiled by ACEA of the current zero-emission vehicles available today or will soon come to the market [2]. The data reported by ACEA concerns all major Europe based manufacturers, whereas ZETI also includes foreign brand, such as Chinese or US based manufacturers.

ACEA reports 52 zero-emission truck models of which the majority are already available in series production and 18 bus models, also mostly already available in series production. The trucks cover all the use cases with Urban/Regional/Municipality/Long haul distribution and delivery. The buses cover Urban and Interurban passenger transport, and one model is reported for Regional passenger transport. Apart from BEV and FCEV, also two H2ICE (with up to 44 t, Gross Train Weight (GTW)) are reported [2].

Based on the data from CALSTART, Figure 4 and Figure 5 give an overview of the BEV and FCEV heavy duty model availability in different market segments.

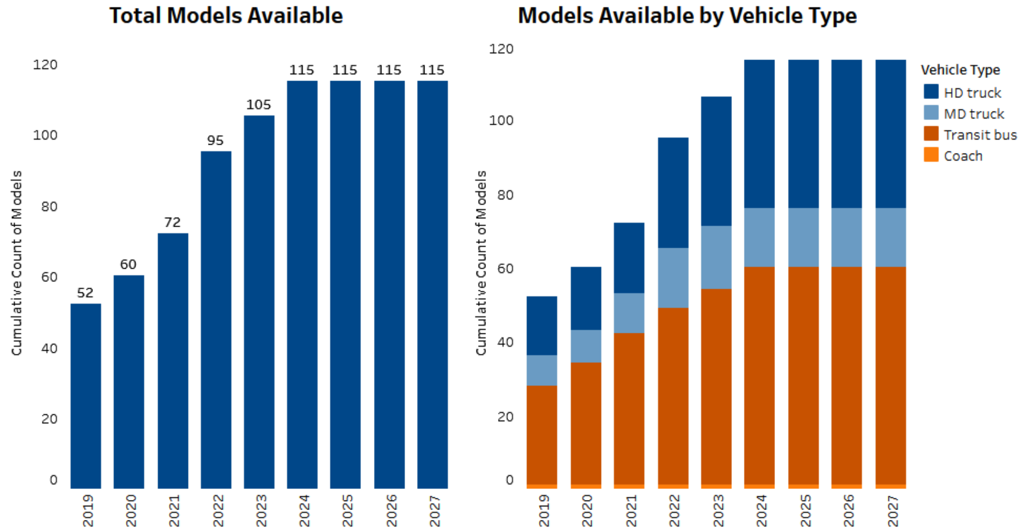


Figure 4 Heavy-duty battery electric vehicle models available in Europe. Source: ZETI, version 3.8, updated Novembre 2024.

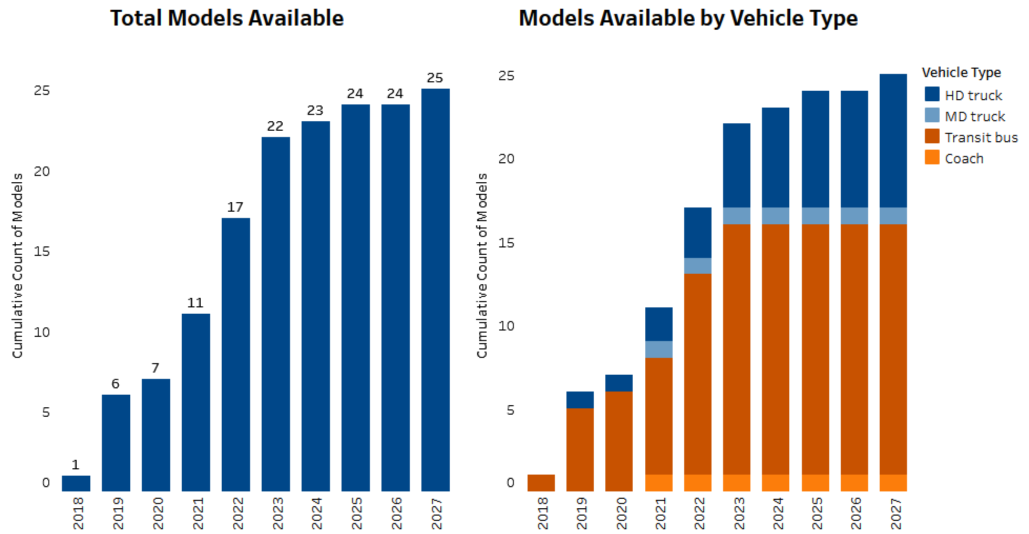


Figure 5 Heavy-duty fuel cell vehicle models available in Europe. Source: ZETI, version 3.8, updated Novembre 2024)

In these figures HD trucks refers to U.S. Class 7 and 8 trucks, that is trucks of more than 11.8 t which therefore corresponds roughly to N3 class (>12 t) vehicles according to the European classification. MD trucks are U.S. Class 3-6., that is trucks of between 4.5 t-11.8 t, with also some 2b vehicles (3.8-4.5 t). Again, this is similar to the European classification of N3 vehicles which includes vehicles between 3.5 t and 12 t[6]. Coaches refer to long distance passenger transport whereas transit buses refer to city busses[7]. BEVs, as the most mature technology, dominates the market for zero-emission vehicles, with, in 2024, 115 models

[6] Personal communication with CALSTART.
[7] This is inferred from the type of vehicles available in the corresponding categories.

available[8] compared to the 23 for fuel cells. Battery electric, as already mentioned, is the drivetrain that is expected to play the major role towards reaching the decarbonisation target at least up to 2030.

Using again information made available by ZETI, Figure 6 and Figure 7 summarise the truck and bus ranges for HDV commercialized in Europe. Although there are only a few H_2 FCEV available some of those have the highest range. The dashboard allows to hover on the points and see to which model each one corresponds. The highest range BEV is the Tesla Semi which even though it is available for purchase it has not yet been deployed in Europe. [38]. The highest range FCEV of over 1,000 km refers to the Nikola truck, however, from more recent information with respect to when the figures were last updated, it appears that the model available in the European market from the joint venture between Iveco and Nikola has a maximum range of 800 km. Heavy-duty BEV models typically reach ranges from about 250 km to 500 km, whereas their few FCEV counter parts reach ranges from 400 to 1000 km. To note, only very few FCEV models offer significant higher ranges than the best-in-class BEVs.

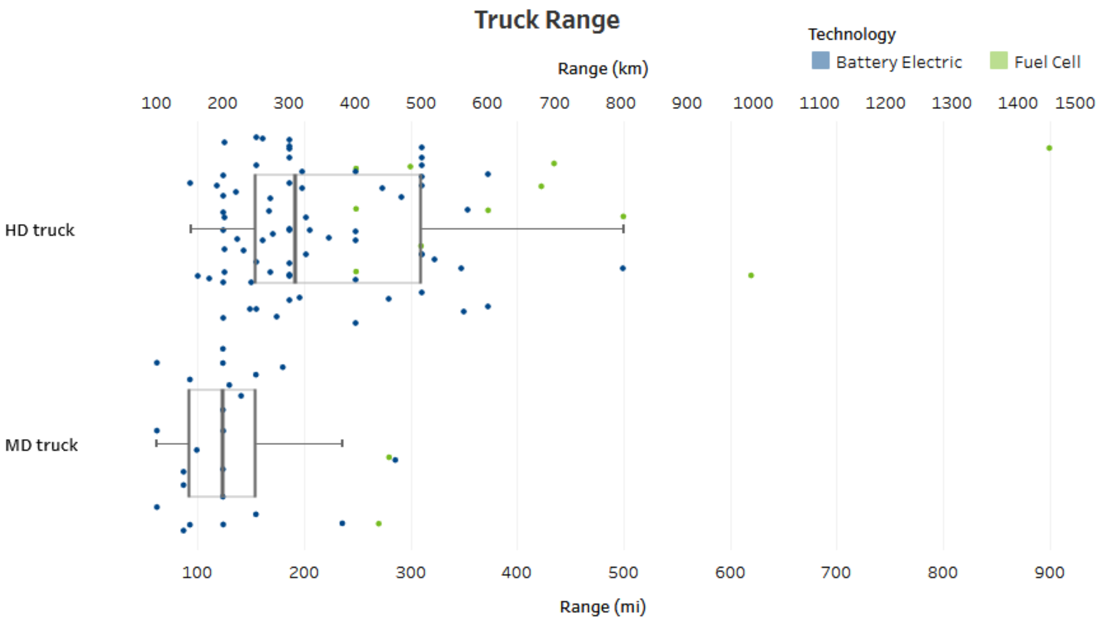


Figure 6 Battery electric and fuel cell heavy-duty and medium-duty truck ranges (models available up to 2027, in Europe) (ZETI, version 3.8, updated Novembre 2024)

[8] 'Available' refers to models that are expected to be available on the market in a given year, given CALSTART's sources.

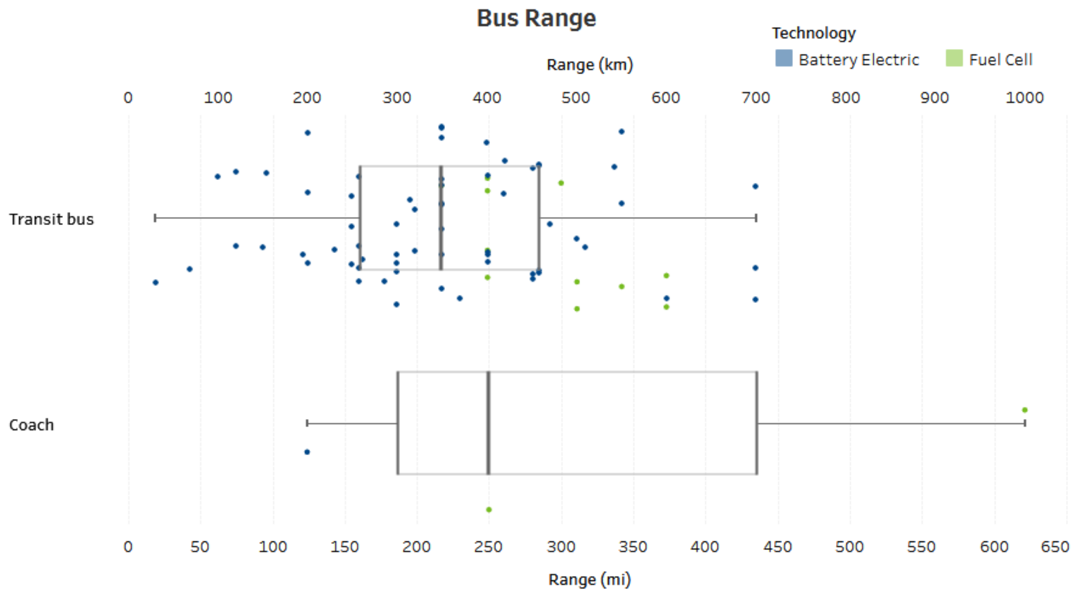


Figure 7 Battery electric and fuel cell heavy-duty buses and coaches ranges (models available up to 2027, in Europe) (ZETI, version 3.8, updated Novembre 2024)

For buses, the highest range of 700 km, is offered by the three different variant of the Ebusco 3.0 electric bus [39]. For coaches, the offer appears very limited, with only three models available or announced up to 2027, two of which are FCEVs. The highest range is offered by the Irizar i6s efficient coach with a maximum range of about 1000 km.

It is important to note, already here, that, even for a long-haulage operations in Europe, the speed and driver rest regulations mean with 4.5 hours of driving, at 85 km/h maximum speed, a lorry can cover maximum 360 km in a single stint [21]. Therefore, if infrastructure is available and can deliver enough power in the drivers' mandatory resting time, very high ranges may not be necessary even for the long-haul use cases. Infrastructure requirements for zero-emission heavy duty vehicle is thoroughly addressed in Chapter 4.

BEVs dominate the market for zero-emission vehicles, with, in 2024, 115 models available compared to the 23 for FCEV.

In the heavy-duty market segments (above 11.8 t) there are 40 BEV models available with typical ranges from about 250 km to 500 km, whereas their 6 FCEV counter parts reach ranges from 400 to 1000 km with only a few FCEVs surpassing the ranges offered by BEV. In the medium-duty market segments (above3.8 t) there are 16 BEV models and one FCEV model.

According to the ACEA data, there are also two H2ICE that will soon come to the market in the heavy-duty lorry segment.

The offer of zero-emission models for the bus segment represents the largest part in the overall offer of zero-emission vehicle models. There are 59 BEV buses available with ranges that reach 700 km and 15 FCEV models.

The offer in the coach segment remains very limited, which was confirmed also during the stakeholder consultation. According to CALSTART data, considering the announcements up to 2027, only three coach models are available, two of which are FCEV. The maximum range reaches 1000 km.

Heavy-duty vehicle registrations

The increase of availability of zero-emission heavy-duty models in recent years is reflected in the new vehicles sales and registrations. In this section, we provide an overview of the heavy-duty vehicle market in the EU-27 by combining information that is obtained by different sources.

The European Environment Agency (EEA), makes available detailed information on the registration of new heavy-duty vehicles in Europe in the context of the Monitoring of CO_2 emissions under Regulation (EU) 2018/956 [40]. This dataset can give us a good understanding of distribution of sales in terms of vehicle groups, manufacturers and member states but, for what concerns the contribution of zero-emission heavy-duty vehicles, given the fast evolution of the market, this data is outdated. The most recent data in fact refer to the reporting period 01/07/2021 to 30/06/2022). Further insight on the more recent evolution of zero-emission vehicles in the new fleet and the consequent penetration in the overall fleet is therefore obtained by the European Alternative Fuels Observatory (EAFO)[11]. EAFO, makes available more recent data on sales of heavy-duty vehicles however, it does not provide information on the contribution of different vehicle groups or weight classes. The data published by the ICCT [41], and ACEA[4], is used to further complement the picture of the registrations. These data do not provide the full split in terms of vehicles groups (as the EEA dataset does) but provide insight on the contribution zero-emission of electrically powered vehicles for of buses vs coaches and heavy vs medium duty lorries.

Looking at the EEA dataset, the following figures provide a summary of new registrations for the 2021/2022 reporting period. The registrations considered here include only the unique records that are 'matched' in the reporting of both member states (MS) and manufacturers.

First, Figure 8 shows the registration per vehicle group and per country. Germany, France, Poland, Italy and Spain are the MS that count the most registrations.

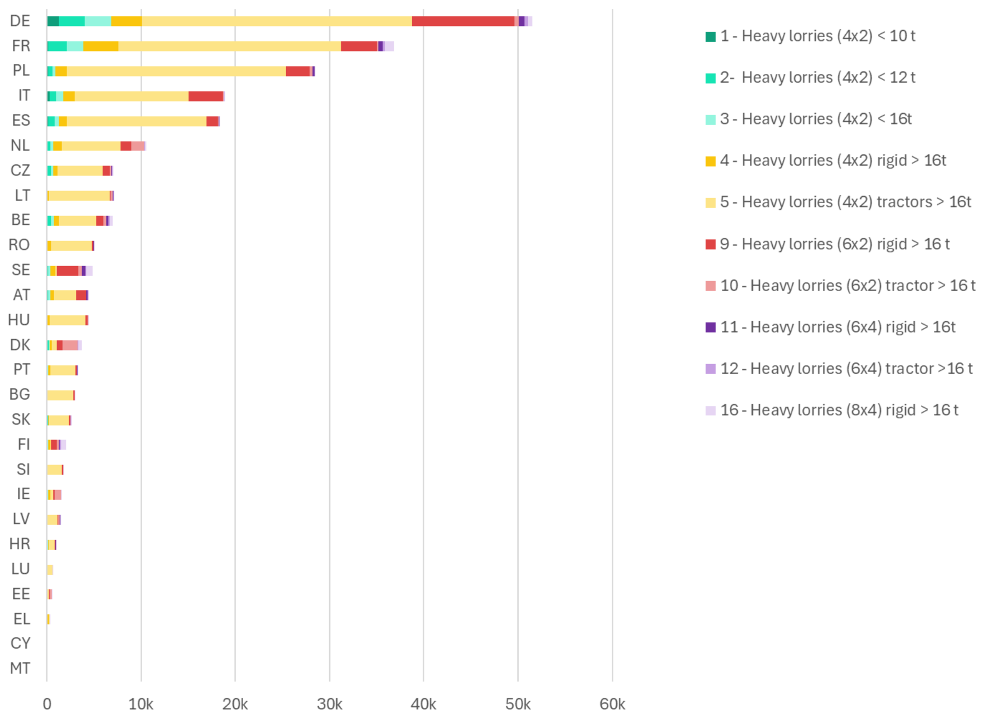


Figure 8 HDV registrations in the EU27 per MS and per group, reporting period 01/07/2021 to 30/06/2022, Source: EEA

Summarising the same information per vehicle group, it becomes evident that the most registered vehicles are group 5 tractors with 4x2 axle configuration for heavy lorries, mostly dedicated to long-haul transport, as reported in Figure 9. In 2023, this category of vehicles represented 65% of heavy-duty vehicle registrations, including vehicles covered under the original CO_2 standards, the newly added vehicles and unregulated vehicles [43].

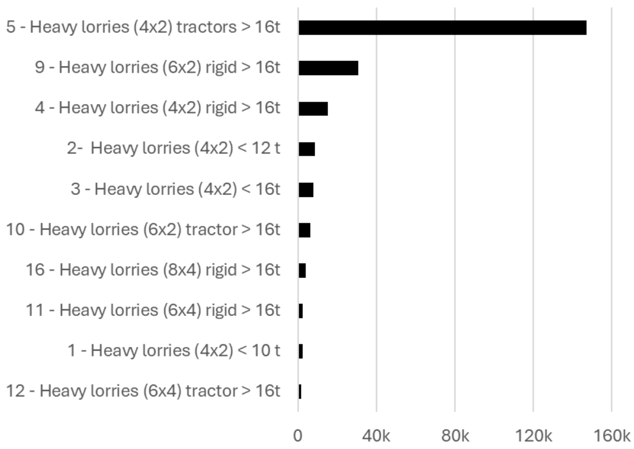


Figure 9 Overall HDV registrations per group in the EU27, reporting period 01/07/2021 to 30/06/2022, Source: EEA.

The corresponding OEMs (vehicle makes) are reported in Figure 10.

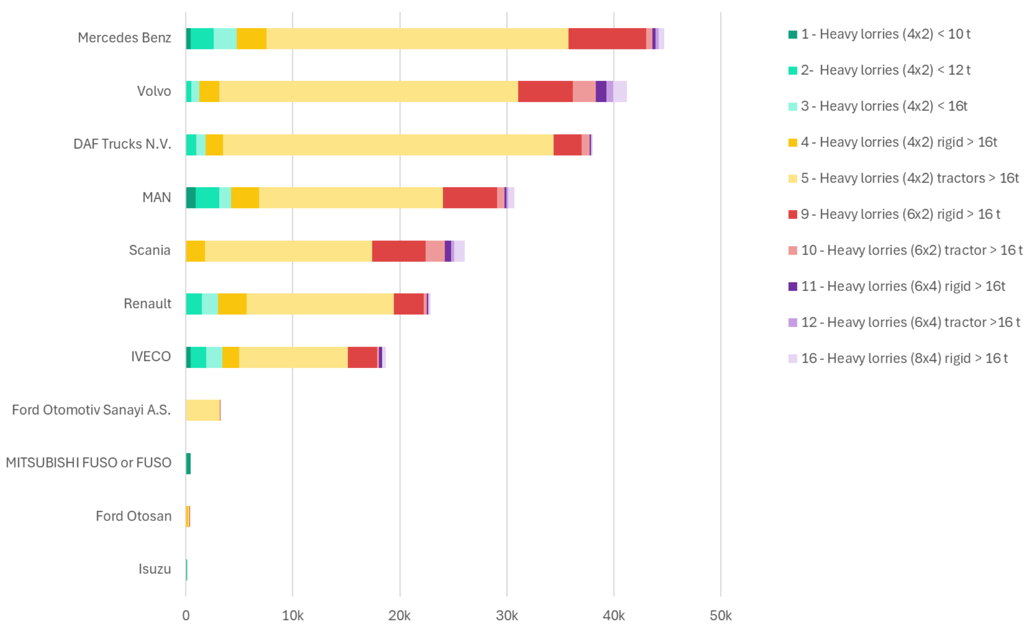


Figure 10 Overall HDV registrations per OEM and per group in the EU27, reporting period 01/07/2021 to 30/06/2022, Source: EEA

Of these vehicles a small number is represented by zero-emission vehicles. For the reporting period considered only 261 zero-emission **matched vehicles** were registered over a total of 226,564 HDV registration (note, also only matched vehicles, and excluding group 0 registrations). Around 400 additional zero-emission vehicles were registered but were not matched by OEM data, as their emissions were not certified. These data however, as said earlier, refer to the 2021/2022 reporting period and, given the speed at which the market evolves it can only give limited information on the status of the market, especially for what concerns ZEV registrations. Preliminary 2022/2023 data show a five-fold increase in number of zero-emission vehicles

EAFO data includes BEV and H_2 powered vehicles but also vehicles fuelled by LNG, CNG and LPG. As shown in Figure 11, in terms of zero-emission vehicles, battery technology currently clearly dominates. The number of BEV (N2&N3) registered in 2024, YTD is 5,210 and the number of H_2 vehicles is 69, this corresponds to 2.09% and 0.03% of market share respectively.

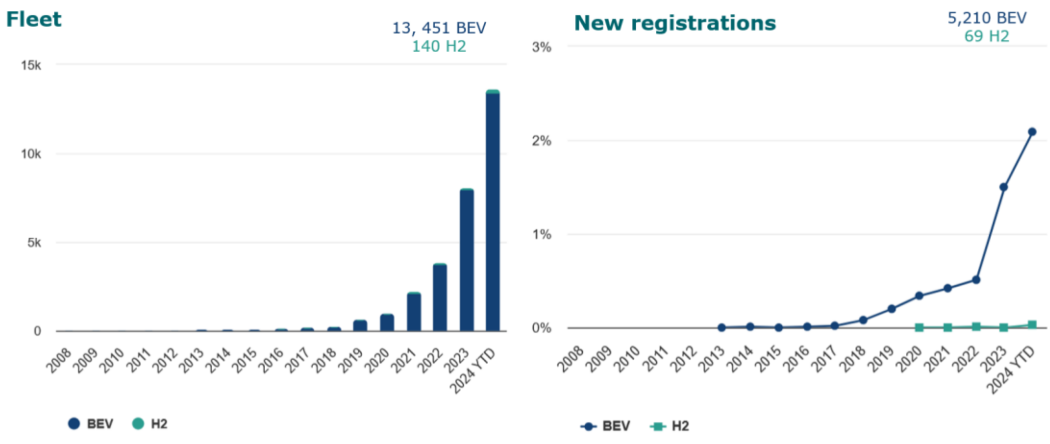


Figure 11 Total number of alternative fuelled BEV and H_2 heavy duty trucks (N2&N3) in the European fleet and corresponding share of new registration. Source: EAFO

In the first half of 2024, Germany alone contributed to 53% of the EU's electrically chargeable truck sales [42].

The same type of data is made available for buses (M2&M3). The total number of alternative fuelled busses is reported in Figure 12

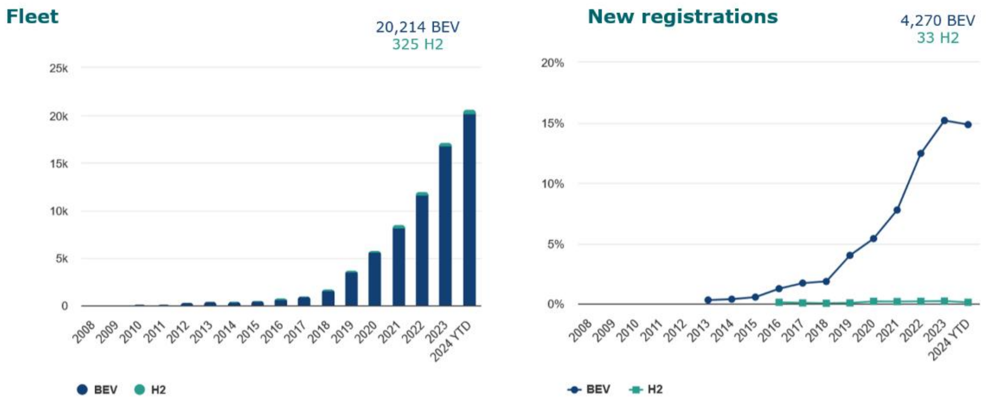


Figure 12 Total number of BEV and H2 busses and coaches (M2&M3) in the European fleet and corresponding share of new registrations. Source: EAFO

The number of BEV buses and coaches (M2 and M3) registered in 2024, YTD is 20,214 which in terms of market share corresponds to 14.84%. The largest market for electric buses is France followed by Germany and Spain [42].

As mentioned earlier, however, in these figures, however, it is not possible to see the further split per vehicle type of weight category. We therefore complement this information with the data made available by ACEA and the ICCT.

For what concerns lorries, data from ACEA relative to the same period (Q1-Q2 of 2024) gives further insight on the contribution of medium lorries (between 3.5 and 16 t) and heavy lorries (of 16 t and over). Electrically chargeable medium lorries accounted for 1,792 registrations (or 5.6% of the total 31,937 medium lorries registrations) and electrically chargeable heavy lorries for 1,707 registrations (or 1.1% of total 151,358 heavy lorries registrations). In total the 3,499 electrically chargeable vehicles accounted for about 1.9% of the total 183,295 registrations. To note, that electrically chargeable vehicles account for both BEV and PHEV, the latter however, as shown earlier, represent only a very small fraction of the newly registered vehicles. H_2 fuelled vehicles are reported together with other gas-powered vehicles, but as shown earlier only have a marginal share in total sales. It is important to underline, that both the reporting periods and scope do not match the ones of the registrations reported from the EEA dataset, and therefore the numbers cannot be directly compared. Furthermore, EAFO data and ACEA report higher numbers of BEVs in the medium lorries category as electric vans that weigh more than 3.5 t are accounted for in this category. More recent data from ACEA, covering Q1-Q3 for 2024 is also available [4].

For what concerns buses and coaches, further insight is provided by the data made available in the market spotlight by the ICCT. The report for Q1-Q2 for 2024 shows that most zero-emission vehicles in the buses and coach segment are in fact electric city buses. Electric city buses accounted for 40% of city bus sales in the second quarter of 2024 (that is 1,616 registered units of the 1,722 ZEV registered in the bus and coach segment), up from 32% registered in the first quarter, see

Figure 13.

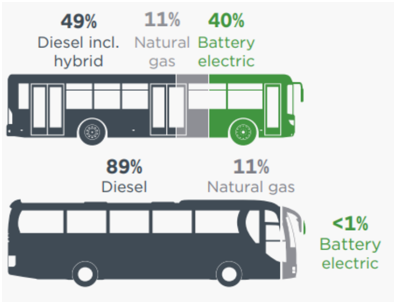


Figure 13 Sales of buses and coaches by powertrain, relative to the Q2 of 2024 [41].

As the portfolio of zero-emission vehicles available on the market widens, registrations of such vehicles are increasing rapidly.

BEVs are by far the largest type of zero-emission vehicles registered in the EU and account for up to 2.09% registration of N2 and N3 vehicles (lorries or trucks), compared to the 0.03% of H_2 fueled vehicles.

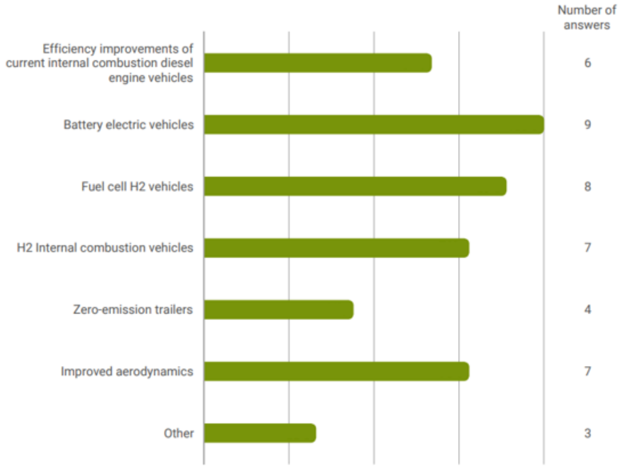
BEVs make up also the largest share of M2-M3 vehicles (coaches and buses) with 14.84 % of registrations compared to 0.11% of H_2 fueled vehicles.

Complementing this information with ACEA and ICCT data to obtain some more detail on the contribution of zero-emission vehicles for different categories shows that the highest shares of BEVs are reported for medium lorries with 5.4%, and urban busses with 40% (to note, the urban bus share refers to the second quarter of 2024 only).

To note that new registrations in the EU-27, overall, are dominated by group 5 tractors which are the typical work force for long-haul transport and represent 48.93% of the emissions of the sector. The decarbonization of group 5 vehicles, and therefore long-haul transport, is essential. The overview of models available today or that soon will come to the market shows that several models of BEVs and FCEVs can be expected to cover 500 km and more on a single charge or tank of fuel.

Zero-emission heavy-duty vehicles performance according to OEMs

During consultation, we specifically asked OEMs and part suppliers which HDV technologies they are offering and developing. Results from the survey show that all zero emission drivetrain options are being considered as well as other technological improvements (engine efficiency, improved aerodynamics, zero-emission trailers, etc.) by both OEMs and their part



suppliers.

Figure 14 shows results for OEMs only whereas Figure 15 shows results for all respondents, that is OEMs and their part suppliers.

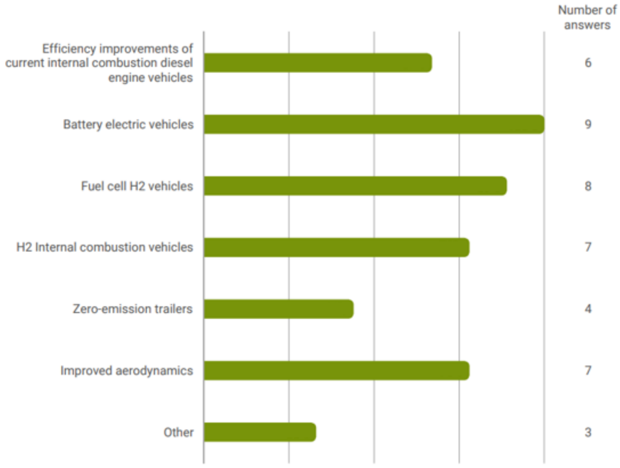


Figure 14 Technologies OEMs are developing or investing in.

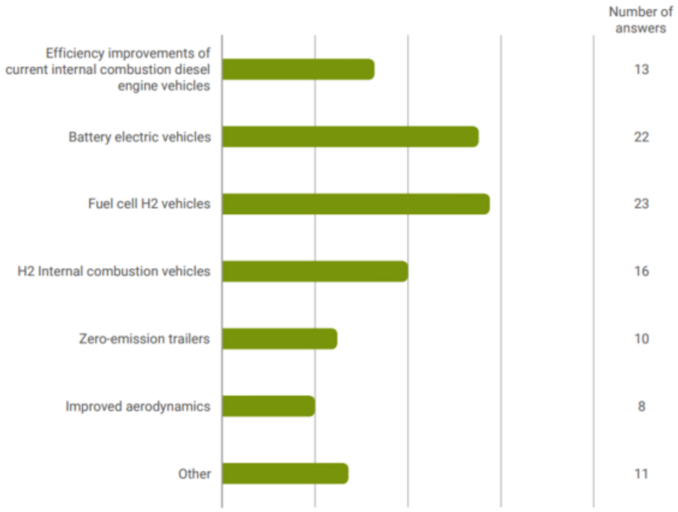


Figure 15 Technologies OEMs and their part suppliers are developing or investing in.

Furthermore, we asked OEMs[9] to rate the suitability of each zero-emission drivetrain per use case in term of vehicles currently available and vehicles that will be put on the market before 2030. As will be shown later, the same question was asked to operators to understand to what extent expectations of the offer and demand sides of the market match.

Figure 16 shows the answers that OEMs gave in terms of the suitability of the BEVs they have on the market today for the different use cases. Results show that the BEVs available on the market today are best suited for regional delivery (<300 km daily), urban delivery, busses and to a certain degree also vocational vehicles. One respondent also reported excellent performance for the long-haul of less than 500 km daily. For the long-haul above 500 km respondents reported performance from very poor to fair. To note is that, at the moment, the OEMs reached through the survey, do not offer vehicles in the long-distance coach segment.

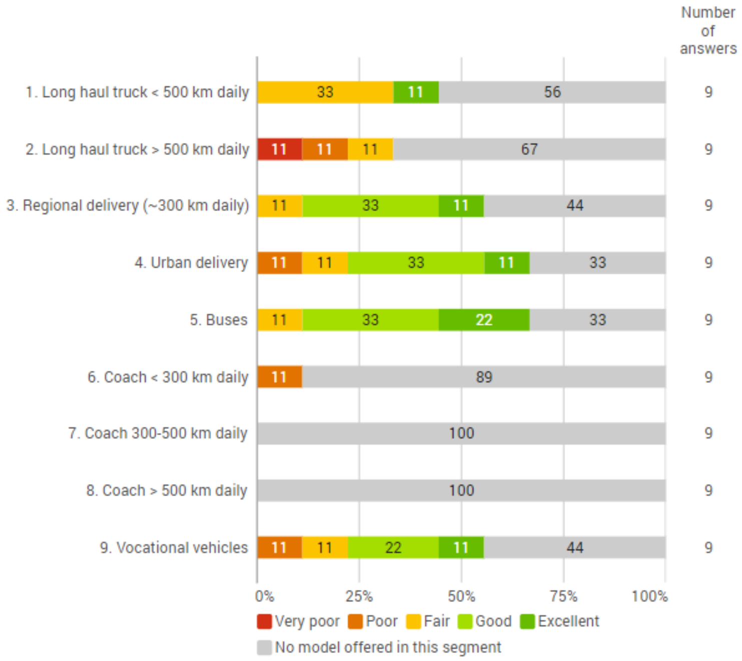


Figure 16 Suitability of BEV on the market today. Answers to the question: "To which extent do you think battery electric heavy-duty vehicles you have on the market today meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

Figure 17 shows the answers that the same OEMs gave in terms of the suitability of the BEVs they plan to have on the market by 2030 for the different use cases. Results show a very positive outlook with performances in all use cases mostly rated between good and excellent.

[9] The answers are filtered to show the results of only the OEMs. Other stakeholders who replied to the questions are therefore not included here.

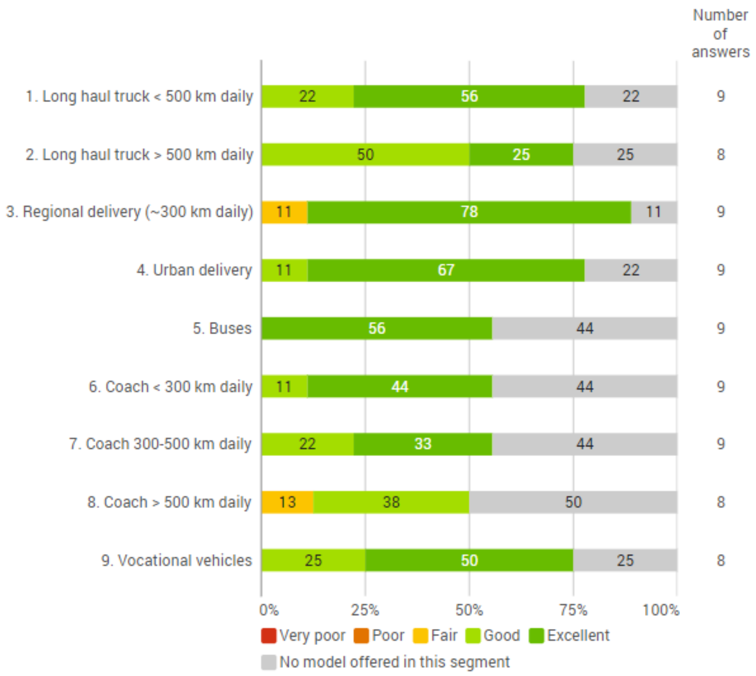


Figure 17 Suitability of BEV expected to be on the market by 2030. Answers to the question: "To which extent do you think battery electric heavy-duty vehicles you plan to put on the market by 2030 will meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

Figure 18 shows the answers that OEMs gave in terms the suitability of the FCEV they have on the market today for the different use cases. As shown earlier, today, there are not many FCEV available on the market. This is reflected in fact that 'no model offered in this segment' is always the most selected answer. Excellent performance is reported by one respondent only in the long-haul segment (both above and below 500 km), for buses and for vocational vehicles. A good performance rating was given by two respondents for the regional and urban delivery, and for the bus segments.

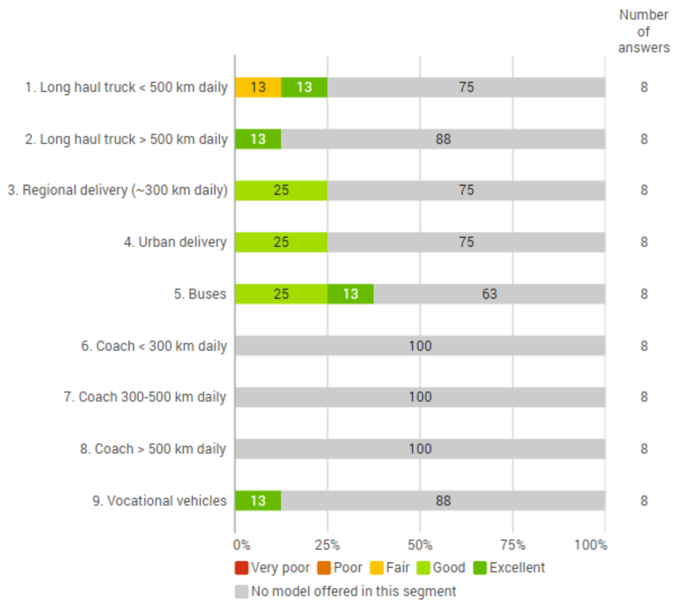


Figure 18 Suitability of FCEV on the market today. Answers to the question: "To which extent do you think fuel cell heavy-duty vehicles you have on the market today meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

The outlook reported by OEMs for 2030 looks positive also for FCEV. Figure 19 shows the answers that OEMs gave in terms of the suitability of the FCEV they plan to put on the market by 2030 for the different use cases. Almost all OEMs reached through the survey reported they will have models available in the long-haul segment (both above and below 500 km daily) and regional delivery with mostly good and excellent performances. For the other use cases the most selected response was 'no model offered in this segment. A few OEMs reported that they will have models available with good and excellent performance also for the other use cases.

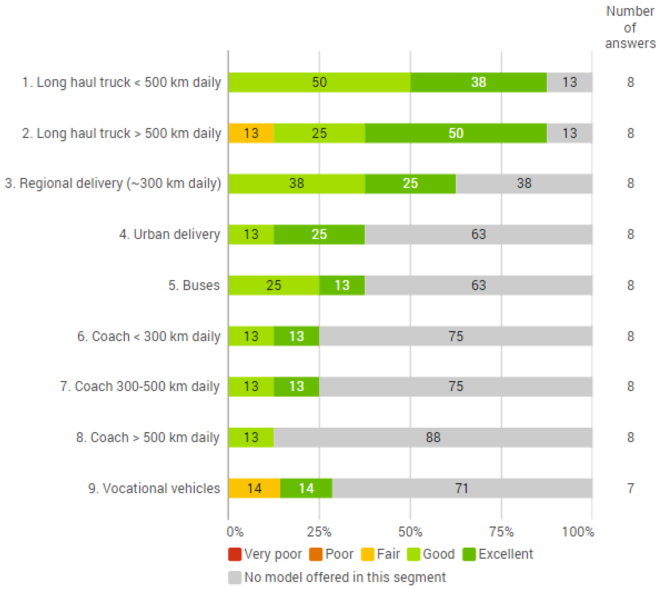


Figure 19 Suitability of FCEV expected to be on the market by 2030. Answers to the question: "To which extent do you think fuel cell heavy-duty vehicles you plan to put on the market by 2030 will meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

The OEMs reached through this consultation are developing and investing in a wide range technologies and drivetrains to decarbonize their fleet.

BEVs are available today for all use cases (the OEMs reached through the survey did not report vehicles available in the coach segment, but a few vehicle models are or will soon be available as shown in the previous sections).

OEMs report that BEVs are most suitable for regional and urban delivery as well as for buses and to a certain extent vocational vehicles. BEV suitable for long-haul operations are also already present in the market with several new models expected in the near term. The outlook for 2030 is positive with good to excellent performance in all use cases.

Very few OEMs report on the performance of FCEV today as only a few models are on the market. By 2030, most OEMs report they will have FCEV available which will be suitable for long-haul and regional delivery, but they also report vehicles with good to excellent performance in all use cases.

3.1.2. HOW ARE MANUFACTURERS PLANNING TO REACH THE TARGETS SET IN HDV CO_2 EMISSIONS STANDARDS REGULATION UP TO 2030

OEMs planning up to 2030

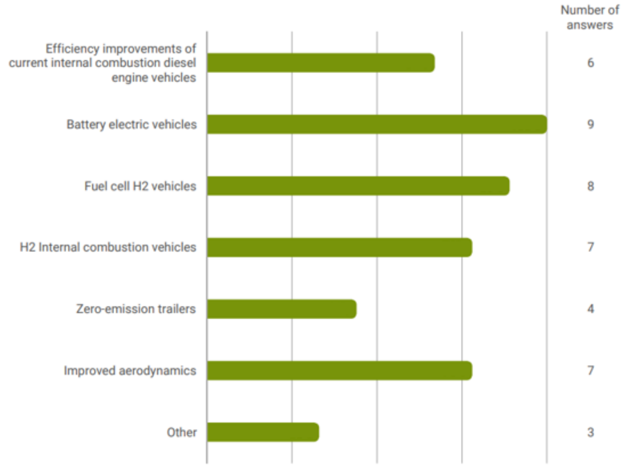
The outcomes of the preliminary interviews and the 1st workshop carried out in this study, show that OEMs reckon that, by 2030, about 1 in 3 of their new vehicle sales, across all market segments, should be zero-emission to comply with the revised standards and avoid sanctions. Whereas short-distance transport will be the first and 'easiest' to decarbonise (i.e. buses and public procurement vehicles in cities, urban and regional delivery vehicles), also the emissions of long-haul trucks need to be tackled to reach the targets, which is more challenging.

Some OEMs have raised the bar making public commitments about their ambition. To note, however, that when OEMs mention 'fossil-free', 'zero-emission', 'net-zero', this can sometimes still include combustion engines running on biofuels and alternative fuels, which is therefore not in line with the definition of zero-emission vehicles in the text of the revised CO_2 standards. The regulation, in fact, includes only battery electric vehicles, fuel-cell and other hydrogen-powered vehicles. During consultation, OEMs underlined that there is no 'silver bullet' technology and various options to decarbonise the sector should be considered, including BEVs, H_2 fuels (in fuel cells and combustion engines) but also sustainable CO_2 neutral fuels (such as synthetic fuels and biofuels). A summary of public commitments is provided in the impact assessment for the revised CO_2 standards [11].

Interestingly, the Clean Room Talks held in 2022 between the German government and the main European truck manufacturers [44] report that, according to manufacturers who participated, about 2 in 3 HDVs will be zero-emission by 2030, well above the 1 in 3 required to meet the targets of the revised CO_2 standards according to the OEMs during this consultation. During the consultation, however, some OEMs warned that the ambitions reported in the Clean Room Talks should already be considered obsolete and, in the meantime, became less optimistic. Also, smaller trucks might be easier to decarbonise but weigh less. In other words, the same target can be higher with more small lorries or with fewer big lorries.

Volvo Truck ambition is to be fossil free by 2040 and reach net-zero emissions by 2050 with intermediate targets of -40% emission reduction per vehicle km by 2030 for both buses and trucks [45] but has not recently made public commitments in terms of zero-emission vehicle share. DAF Trucks is committed to reduce the CO_2 emissions of trucks sold by 45% in 2030, in line with European regulation [46]. MAN aims, by 2030, to produce 1 in 2 trucks equipped with zero-emission power units. The aim for buses is at 90% of the total bus sales delivered with zero-emission power units [47]. Scania has set the goal of 50% of sales being zero-emission by 2030. The ambition of Daimler is to be CO_2 neutral in 2039 in Europe the Us and Japan and globally by 2050. Hyundai is already selling only zero-emission trucks in Europe and Tesla, without having made a formal commitment, should make the Semi truck in the European market by 2027 [48]. These statements show a clear ambition of OEMs to decarbonise their fleets but give little further information on the technology mix they plan to put on the market to achieve their goals.

Survey results on the technologies OEMs and part suppliers are offering, developing or investing in show that BEV and both H_2 FCEV and H_2 ICE technologies are being considered



by manufacturers (see Figure 14). In the survey, we tried asking specifically which drivetrains they are planning to put on the market per vehicle type, however, the small number of responses does not allow a meaningful analysis. An overview of the models available today or that will soon enter the market was presented in section 3.1.1 based on data made available by ACEA and CALSTART.

Manufacturers are also working on various improvements to current technologies which will help, albeit insufficiently, reaching the HDV CO_2 emissions standards targets. The deployment of zero-emission vehicles is in fact essential to reach the targets but the increase of energy efficiency of the vehicles with improvements of aerodynamics in the design of new cabins, cooling airflow, gap to trailer and trailers as well as the development of zero-emission trailers are also factors mentioned as crucial to reduce emissions and increase range. To note, that in the case of 5-LH vehicles over the long-haul mission profile, air drag accounts for 39.6% of energy use, slightly more than rolling resistance which accounts for 37.7%[49]. Other energy losses are due to breaking (12.4%) and to losses in the individual components of the powertrain (the rest, about 10%). ACEA reports that overall energy efficiency improvements between 2000 and 2019 lead to a decrease of energy consumption per tonne-kilometre transported of almost 15%[50].

OEMs plan to reach the CO_2 emission reduction targets with 1 in 3 new vehicles being zero-emission in 2030 and efficiency improvements. Their commitment to reach the targets set out by the revised standards and their own ambition is clear, but they provide little official information on the drivetrain mix that will allow them to achieve their objectives.

As shown in the pervious sections, OEMs are investing in different technologies and developing all zero-emission vehicle drivetrains, which is also evident from the heavy-duty models that are entering the market, with BEVs currently representing the largest share of the models on offer.

To note, throughout the consultation OEMs underlined that, from their point of view, there is no 'silver bullet' technology. To achieve their own objectives in terms of limiting the environmental impacts, they are considering various options to decarbonise the sector, including sustainable CO_2 neutral fuels (such as synthetic fuels and biofuels) at least for specific use cases, even if these are not relevant to reach the targets set out by the new standards.

Financing tools OEMs make available for the purchase of zero-emission HDV

As will be discussed later, TCO is of paramount importance for the uptake potential of zero-emission HDV by transport operators. Financing tools that could help lower the cost barrier for the deployment of ZEV are thoroughly analysed in the report on this subject recently published by ECTA (European Clean Trucking Alliance)[51].

In the context of this study, we asked OEMs and suppliers which financing tools they make available to their customers. Preliminary results show that only outright purchase and rent-to-buy have been selected. Other options were truck as a service, dynamic per mile leasing, battery leasing, leasing with residual value guarantee and collective purchasing or leasing. However, respondents also pointed out that all options should be made available. One respondent mentioned that they are currently exploring the possibility of leasing fuel cells to some OEMs, but the viability of this business model is not proven yet. Another one mentioned that they are currently focusing on purchase only and only once the demand of customers that are willing to pay the price immediately is satisfied, they will start exploring other options. The answers of OEMs can be compared to the ones of operators to the corresponding question: "which financing tools are you using or would like to be available to include zero-emission HDV in your fleet?"

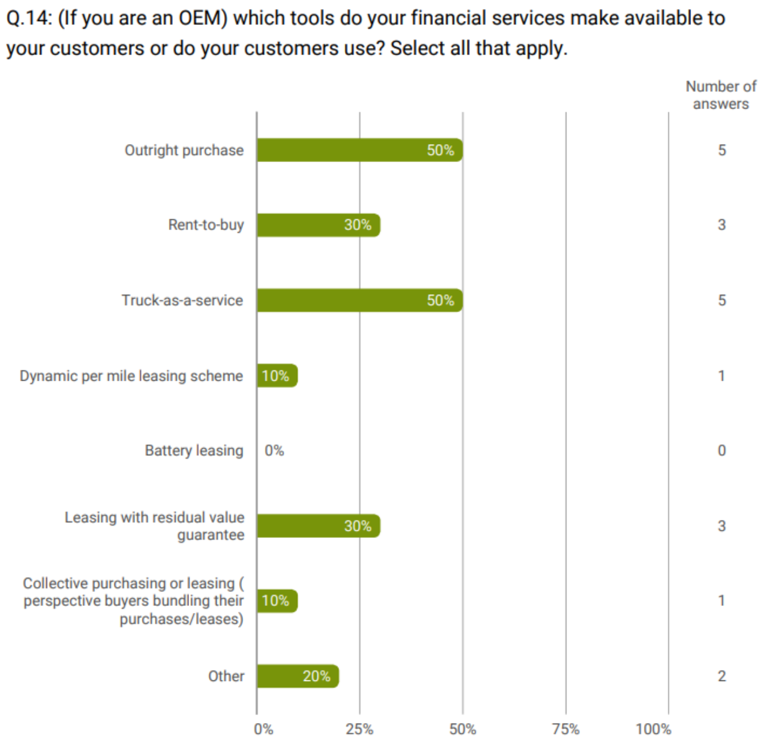


Figure 20 Financial tools made available or that customers use to purchase heavy-duty vehicles (respondents OEMs and their part suppliers)

The high capital investment of zero-emission vehicles requires adequate financial services.

Taking into consideration the uncertainty given by the limited number of answers, the most selected options made available by the supply side are outright purchase and truck-as-a service.

3.1.3. ROBUSTNESS OF MANUFACTURERS AND SUPPLIERS PLANNING, FINANCING AND VALUE CHAINS

Robustness of planning and financing

During the consultation, OEMs showed confidence in their ability to meet the targets and attain the required manufacturing capacity under the condition that certain enabling conditions are met. These enabling conditions are:

- a sufficiently dense network of lorry-suitable recharging and refuelling infrastructure; and
- TCO and cost parity for ZEVs in comparison to conventionally powered vehicles (e.g. through other policies such as ETS2, CO_2-differentiated road user charges and other support and incentive schemes).

Barriers will be thoroughly discussed in Chapter 5.

As previously shown, BEVs are currently dominating the zero-emission HDV fleet. However, in the consultation process, the concern over the uncertainty on the technology pathway preferred by OEMs to reach the targets was raised several times. For example, it was mentioned that the inclusion of H_2ICE as a zero-emission technology has created additional uncertainty in the market, with some OEMs apparently slowing down development of BEVs and FCEVs to redirect resources to H_2ICE vehicles. On the one hand, this uncertainty affects the customers as well as the banks, who lack a comprehensive understanding of ZEVs as well as data on vehicle performance, reliability or residual value. On the other hand, OEMs underline that, for them, it is important to have a "technology neutral" approach to allow diversification and avoid reliance on one technology only. These elements, with other factors, such as the decision of Germany to halt subsidies for electric truck and buses, contribute to the uncertainty in the market both for OEMs and the users. As mentioned earlier the technology neutral approach is dependent on certain conditions being met for all technologies being pursued, which require careful planning and additional investments.

Another factor of uncertainty in the suppliers' planning, is the Commission's review of the effectiveness and impact of the HDV CO_2 standards, planned for 2027. Some OEMs mentioned that they fear this review may affect the targets and, consequently, require a revision of their investment plans.

According to OEMs, they will be able to reach the targets given the 'enabling conditions' are met. These conditions are mainly the availability of a sufficiently dense recharging and refuelling infrastructure and TCO parity of zero-emission vehicles with conventional vehicles.

Robustness of supply chains

Results of the survey show that almost 40% of respondents report issues in their supply chain (respondents for this question are OEMs and their part suppliers), see Figure 21.

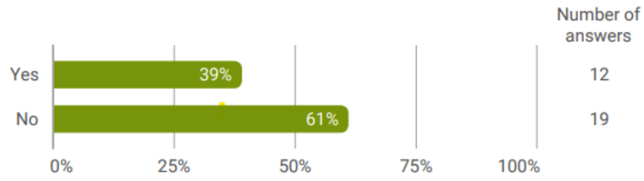


Figure 21 Supply chain issues for OEMs and their parts suppliers (respondents for this question are OEMs and part suppliers).

As shown in Figure 22, the components and material that are mentioned as most critical are batteries, followed by semiconductors, and memory chips with processors and other electronic components.

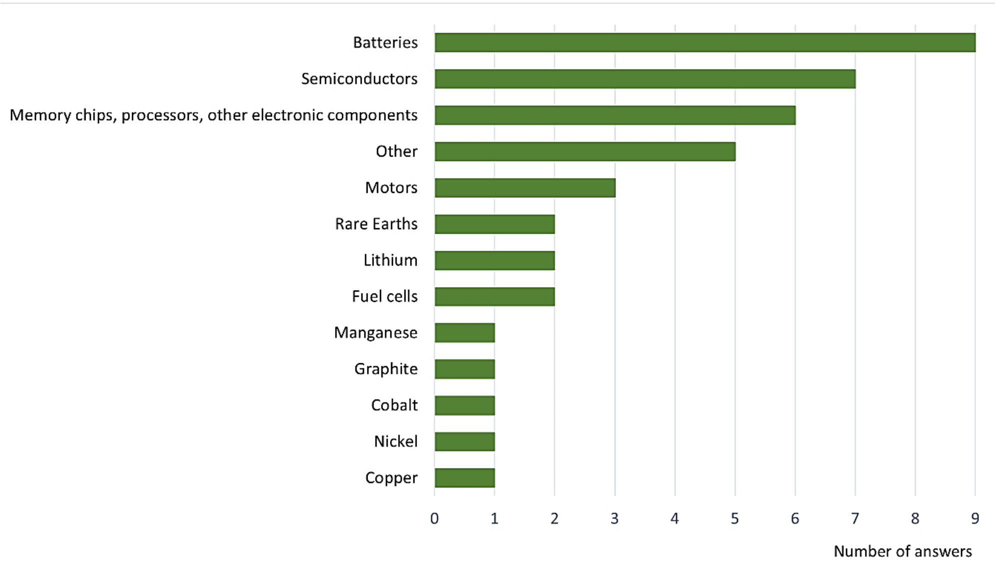


Figure 22 Components and materials for which OEMs and part suppliers are currently experiencing issues (number of answers, respondents for this question are OEMs and part suppliers)

Other refers to carbon fibre for making the H_2 tanks (the material is not scarce, but it is heavily controlled in terms of availability and pricing by the aerospace industry), vessel bosses (which are reinforced attachment points on tanks or vessels under pressure), and other components such as wiring harnesses and power electronics. Respondents also pointed out that the uncertainty is higher for small manufactures who are considered last in line in terms of priority for delivery of materials and components.

To face these supply chain challenges, companies are implementing various strategies to secure the components and materials they need for their manufacturing processes. The respondents of the survey mentioned the following strategies:

- Regional sourcing options
- Multiple suppliers for the same components/materials
- Development of direct relationships with suppliers
- Investments in the development of the components provided by the suppliers
- Increased inventories

OEMs and part suppliers also reported several materials and components that may become critical in the future, such as:

- NOES (Non-Oriented Electrical Steel) , that is a type of steel that is specifically designed for use in electrical motors and other electrical applications.
- Rare Earths, which are difficult not to source from China
- Aluminium and copper
- Silicon Carbide for semi-conductors
- Carbon fibre for pressure vessels
- For fuel-cell systems: membranes, compressors, humidifiers, etc. at automotive / industrial level of quality (too unmature suppliers / not at the right size to invest on their industrialization ramp-up)

According to the respondents of the survey, the EU should address the supply challenges by supporting suppliers and companies who are planning to invest or increase relevant activities, promoting investments in local manufacturing of critical components and re-use and recycling of raw materials inside the EU, supporting global trade, supporting processes for rare earth extraction less harmful to environment, and allowing faster bureaucracy for the mining industry.

Respondents to the survey also brought up that the value chain of H2ICE is similar to the one of CNG/LNG ICE and therefore to the current core business of OEMs, making this technology, from the production point of view “easier to scale at a reasonable cost”. To note, however, that for the demand side, H2ICE are characterised by higher fuel consumption and fuel cost than BEV.

To note that the supply of materials and components is evaluated as a moderate to significant barrier by most stakeholder, as shown in Chapter 5.

Almost 40% of respondents reported that they are currently experiencing issues in their supply chain. The highest concern is for batteries, semiconductors and other electronic components. Components for H2 vehicles are also mentioned, especially for what concerns the manufacturing of the H2 tanks.

3.2. DEMAND SIDE – OPERATORS, SHIPPERS FORWARDERS

3.2.1. WHICH ZERO-EMISSIONS AND CONVENTIONAL VEHICLES OPERATORS ARE PLANNING TO INCLUDE IN THE FLEET, HOW THEY ARE AND WILL BE USED, AND FOR WHAT PURPOSES

This section is based mostly on stakeholder input. First, we asked respondents to describe their operations. As can be seen in Figure 23, the survey reached all the use cases considered in this study, with at least one respondent.

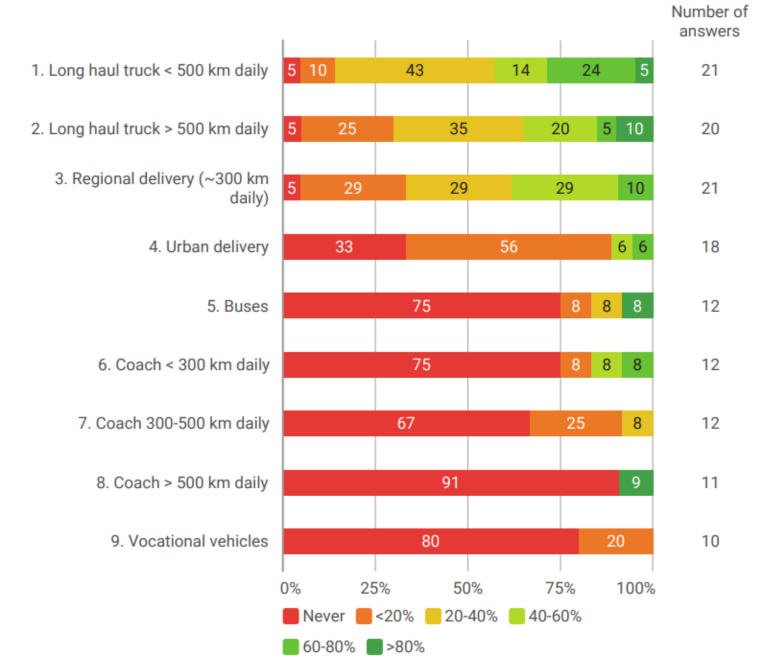


Figure 23 Typical use cases and corresponding turn-over share of the stakeholders reached through the survey: "Which use cases best describe your operations? Please specify the share of your turnover for each use case". To note, empty answers should be considered equivalent to never in this figure (respondents are operators only).

Next, we asked them for which use cases they are currently deploying ZEVs. Figure 24 shows the results for BEVs and Figure 25 for FCEVs. Apart from the long-distance coach segment, BEVs and FCEVs are already being deployed for all use cases with more answers, as can be expected for BEVs. For FCEVs most respondents reported that they are not deploying this type of drive train for any of the use cases.

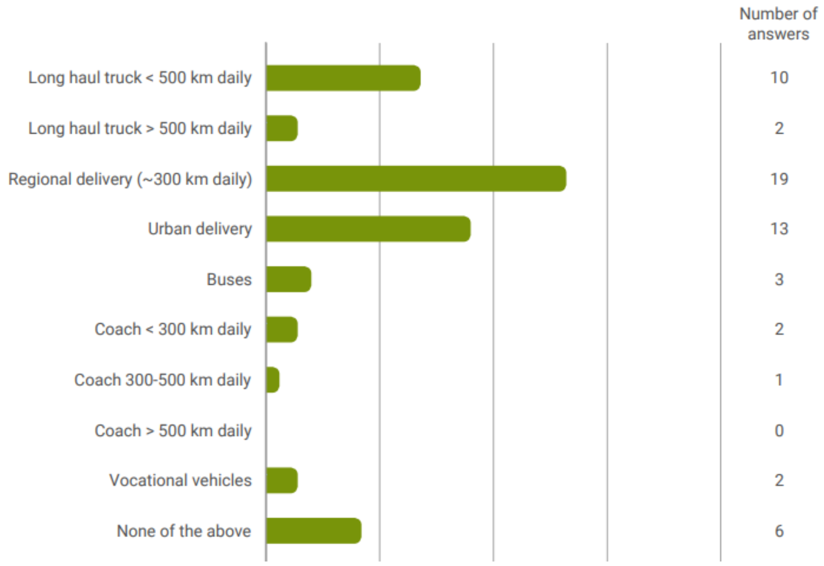


Figure 24 Use case for which the operators reached by the survey are deploying BEVs

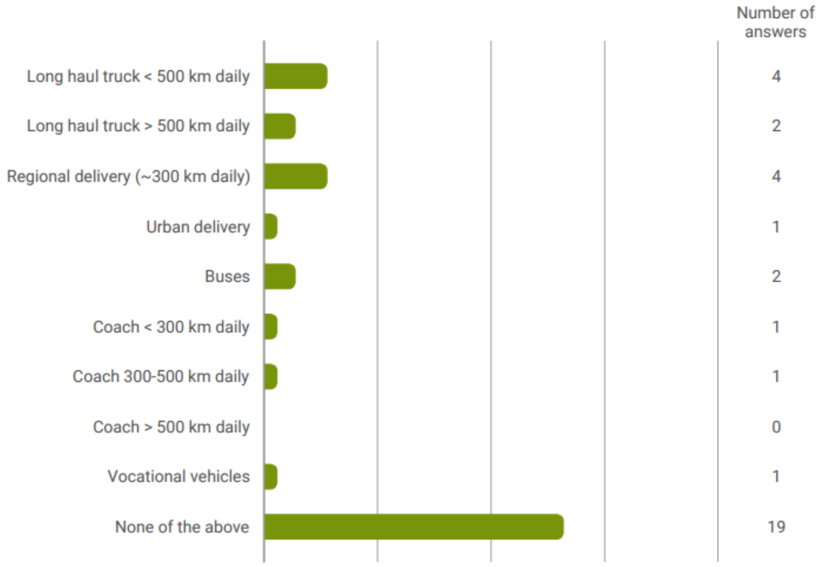


Figure 25 Use cases for which the operators reached by the survey are deploying FCEV

Looking at the future, we asked operators which drivetrains they are planning to purchase and include in their fleet by 2030. Results, reported in

Figure 26, show that on the one hand two or more types of drivetrains are selected for each of the use cases; on the other, for each use case, the option 'None' was selected, meaning that they are not planning to purchase any ZEV for that use case. BEVs are expected to be deployed in all use cases. FCEVs are expected to be deployed for all use cases except urban delivery. H_2ICE are expected to be deployed especially in the long-haul segment. The reply 'other' often refers to the deployment of HVO100 or BioLNG vehicles, although these are not ZEV (see Section 3.1.1). To note that, this Figure, only shows the type of drivetrains operators plan to include in their fleet but does not give an indication of their relative importance. In several cases this information could not be disclosed because of confidentiality reasons. The sample of operators that was reached through this study cannot be considered representative of the whole HDV operators market in the EU, which is extremely varied in terms of, for example, company sizes. The data collected therefore did not allow to estimate in detail and with confidence the proportion of ZEVs that operators are willing to deploy by 2030.

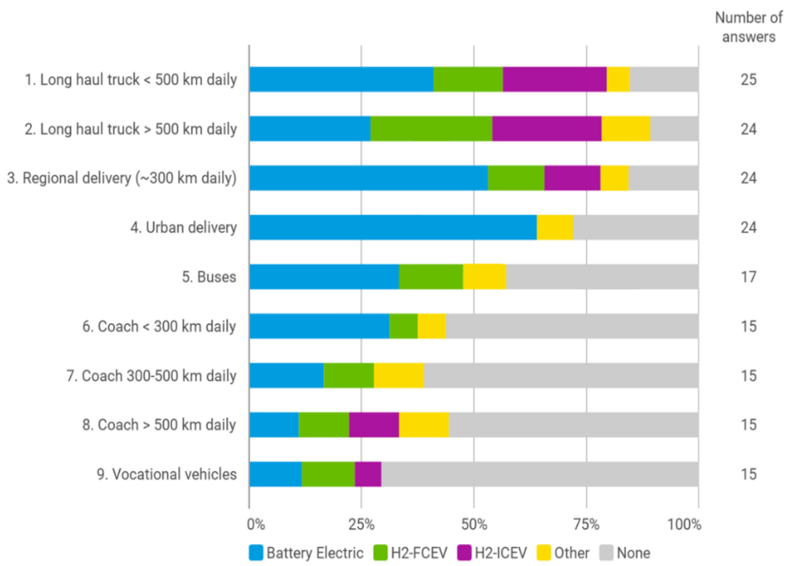


Figure 26 Drivetrains the operators reached through the survey are planning to deploy up to 2030.

Throughout the consultation, and particularly in the targeted interviews, it became clear that BEVs are the most sought-after drivetrain for most use cases. Several stakeholders reported that even though companies deploying zero-emission vehicles are still considered "pioneers" that make this type of vehicles part of their long-term strategy, they are also no longer a "novelty" as they are becoming more and more common, on the contrary, the ones that are not looking into these technologies risk being "left behind". At the moment, there are several benefits that operators expect from including zero-emission vehicles in their fleet that are summarised in Figure 27. Results of the survey show that the most important one is "reaching climate objectives and commitments in terms of CO_2 emission reductions", followed by a greener brand image and a reduced cost of tolls. Several of the stakeholders reached through the survey and consultation have in fact set voluntary CO_2 emission targets through the Science Based Target initiative (SBTi). The SBTi is an initiative that encourages companies from all sectors and of all sizes to set science-based emission reduction targets, that is targets that align with the Paris Agreement goal or limiting global warming to 1.5°C above pre-industrial levels [52]. To note, a reduction in the Total Cost of Ownership (TCO) is selected by some of the respondents as an expected benefit. The TCO is in fact a very important variable operators consider when selecting vehicles for their fleet. As will be shown later, TCO is currently one of the main barriers to zero-emission vehicle adoptions and as discussed in the second workshop (see Section 2.3), TCO parity or even lower TCO compared to conventional vehicles would be necessary to drive adoption.

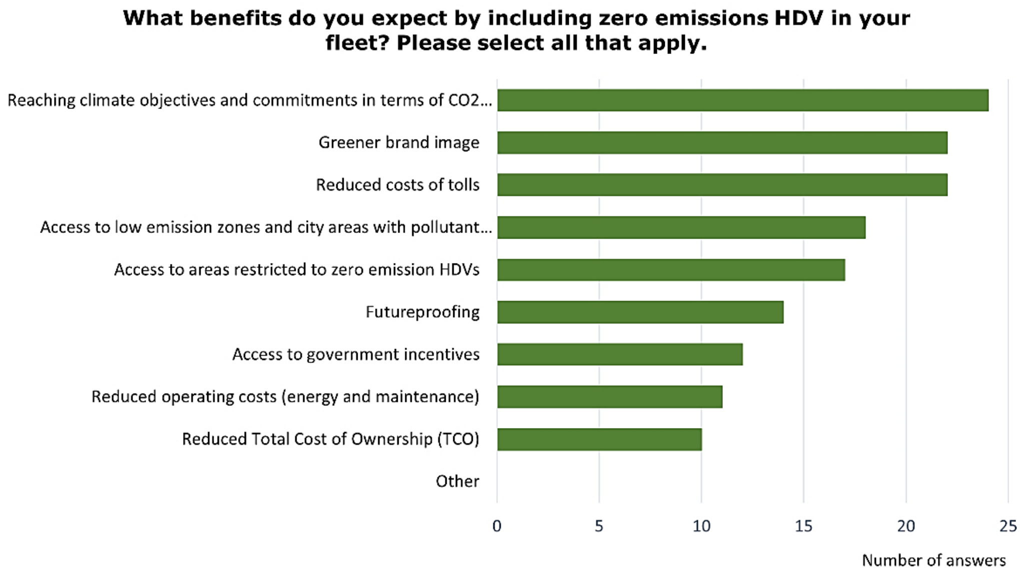


Figure 27 Benefits expected by operators from incorporating ZEVs in their fleet (respondents include operators only)

Most respondents are planning to include BEVs in their fleet by 2030, which overall will be deployed in each of the use cases. FCEV are considered by a few respondents in almost all use cases, whereas H2ICE are considered for the long-haul segments.

Operators expect several benefits from the deployment of zero-emission vehicles, first and foremost, fulfilling their climate objectives and commitments, secondly, they aim at greener brand image and reducing their toll costs.

3.2.2. CURRENT AND EXPECTED PERFORMANCE OF ZERO-EMISSION VEHICLES

Preliminary survey results show that there can be several operational characteristics that can be specific to certain transport company and may impact the deployment of zero-emission vehicles, see results in Figure 28.

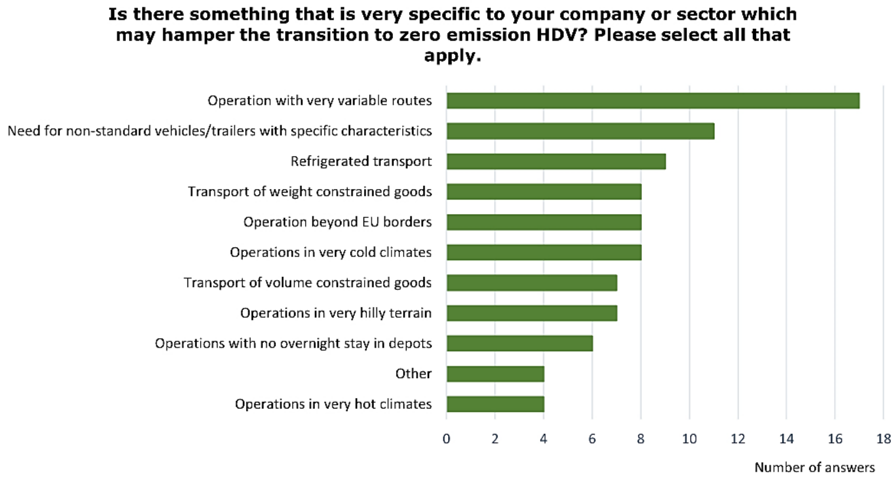


Figure 28 Specific operating conditions that may hamper the transition to ZEVs

The most selected characteristic is the operation with very variable routes. This type of operation is strongly reliant on the availability of infrastructure and requires thorough planning of logistics taking into account when and where recharging or refuelling is possible (more detail in the next chapter).

The next selected challenge is the need for non-standard vehicles/trailers with specific characteristics. One example is the transport of bulk liquid chemical products in tankers, which can consist of hazardous goods with restrictions on circulation, routes, and loading. Another example is specific trailers which may not fit with trucks given the size and shape of the batteries of a zero-emission truck. Respondents also mention that redesigned trailers that could allow for more cargo and still comply with the EU Weights and Dimensions Directive[10] are more expensive than other trailers.

Other issues refer to cross-border differences regarding maximum payload and round-the-clock operations which do not allow long times for recharging.

In the previous section we reported the answer that OEMs gave when asked to rate the performance of the zero-emission vehicles they have on the market today and the one of the vehicles they expect to put on the market by 2030. In this section we report the answer that operators gave on the same question according to their experience and expectation. Despite being overall less positive they provided similar answers.

Currently, operators, like OEMs, report the best performances for BEVs for regional and urban delivery and also some positive, although limited, experiences for the other use cases. The most challenging use cases are clearly the long-haul and the coaches.

[10] Council Directive 96/53/EC of 25 July 1996 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. OJ L 235, 17.9.1996, p. 59

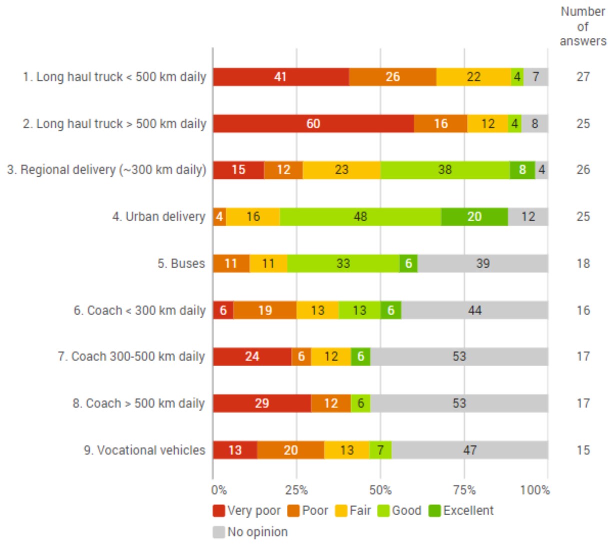


Figure 29 Suitability of BEV on the market today. Answers to the question: "To which extent do you think battery electric heavy-duty vehicles available on the market today meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

The outlook to 2030, also in this case is optimistic, with a clear expectation of improvements for all use cases. The most challenging use case remains the very long-haul with over 500 km daily.

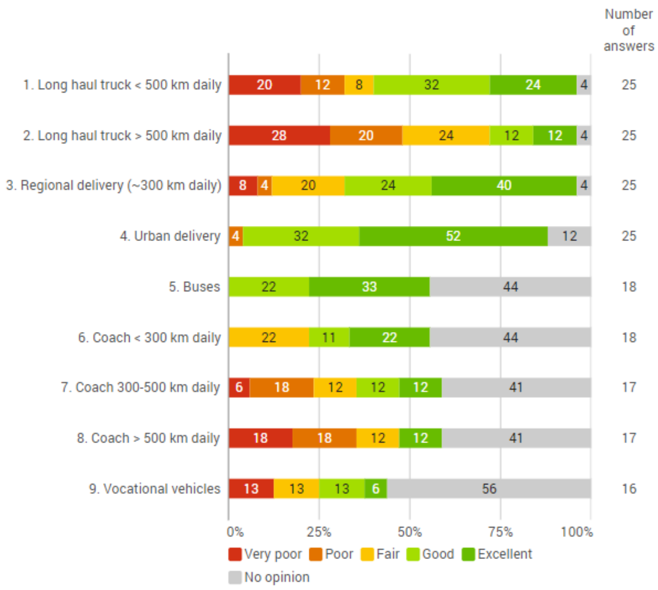


Figure 30 Suitability of BEV on the market by 2030. Answers to the question: "To which extent do you think battery electric heavy-duty vehicles available on the market by 2030 will meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

In general, the performance of FCEV today is seen as poorer with respect to BEVs with the best performances reported for buses and regional/urban delivery. The outlook for 2030 is more positive and significant improvements are expected for all use cases.

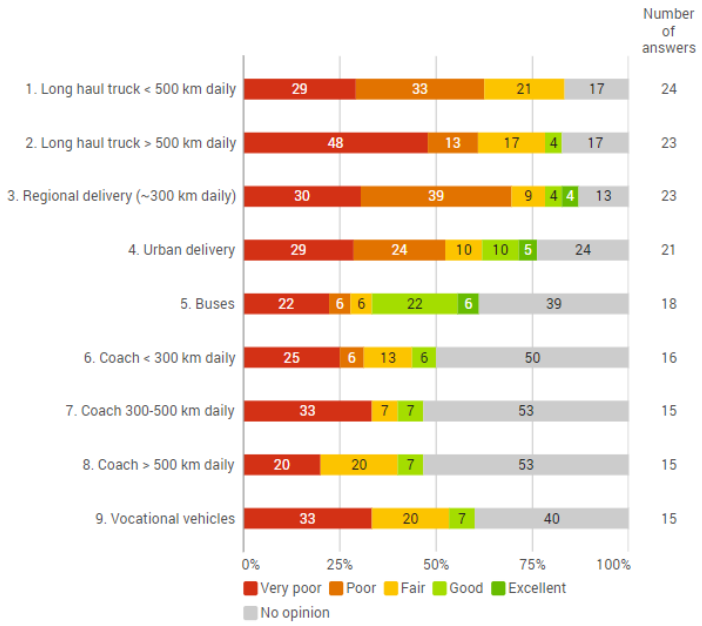


Figure 31 Suitability of FCEV on the market today. Answers to the question: "To which extent do you think FCEV heavy-duty vehicles available on the market today meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

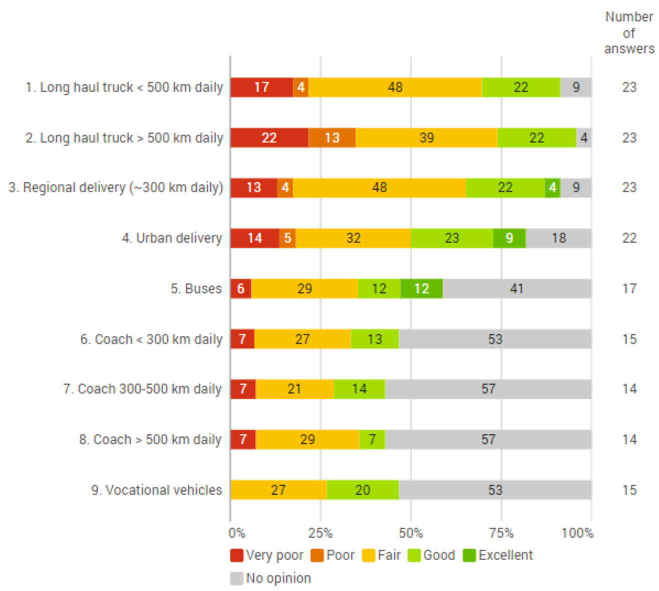


Figure 32 Suitability of FCEV on the market by 2030. Answers to the question: "To which extent do you think FCEV heavy-duty vehicles available on the market by 2030 will meet the operational requirements (performance, range, etc.) for the following specific intended use cases?"

On the demand side, the key operational challenges are variable routes, specialized vehicles, and cross-border operational constraints. Despite these challenges, there is optimism for improved BEV and FCEV performance across all use cases by 2030, with very long-haul transport (above 500 km daily) remaining the most difficult to address. BEV are currently best rated for Regional and Urban delivery and for busses. The outlook to 2030 is particularly positive for BEVs for all use cases with daily distances below 500 km. FCEVs currently receive the highest rating in the bus segment. Their outlook looks less positive than that of BEVs, with best performances from fair to good or excellent in the long-haul truck and urban delivery segment.

3.2.3. FINANCING OF ZERO-EMISSION VEHICLES

During consultation we asked operators which financial tool they are using or would like to use. Preliminary answers are displayed in **Error! Reference source not found.** and show t hat all options are considered by operators with the most selected option being "outright purchase" and "leasing with residual value guarantee". Several stakeholders point out that they often do not own the vehicles themselves and logistic operations are partly or completely outsourced to third-party logistics (3PLs) with whom they have to coordinate to find solutions to include zero-emission vehicles.

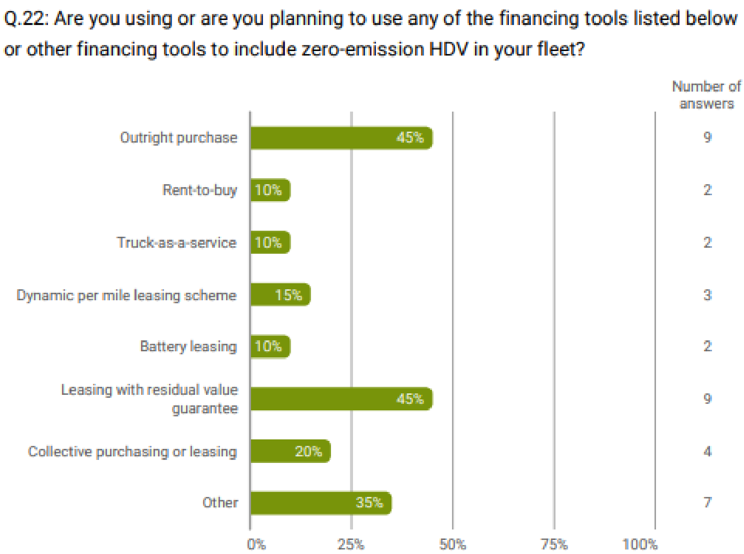


Figure 33 Financing tools operators are using. "Are you using or are you planning to use any of the financing tools listed to include zero-emission vehicles in your fleet"?

The high capital investment of zero-emission vehicles requires adequate financial services.

Taking into consideration the uncertainty given by the limited number of answers, the preferred options from the demand side are outright purchase and leasing with residual value guaranteed.

During the consultation, several operators highlighted the uncertainty of the residual value of zero-emission vehicles and its importance in the TCO equation.

3.2.4. WHAT COMMITMENTS LARGE OPERATORS ARE TAKING TO DECARBONIZE THEIR FLEET AND REDUCE THEIR SCOPE 1 AND

SCOPE 2, AND POSSIBLY SCOPE 3, EMISSIONS

To have an overview of the commitment of large operators to decarbonise their fleet and reduce their overall emissions, we referred first of all to the Science Based Target initiative (SBTi).

Several transport and retail companies take part to this initiative and are therefore visible in the SBTi dashboard [53]. Here it is possible to see the companies that have 'committed' to reduce their emissions and the ones that have 'target sets' either in the near-term and/or on the long-term according to science-based criteria and guidelines developed by the SBTi. These targets are in general also the ones announced by companies in their own environmental reports.

During the consultation we asked companies how they are planning to reduce their emissions and in particular emissions related to transport operations. Depending on the type of company the emissions related to transport can belong to their scope 1 (direct emissions), scope 2 (indirect emissions from energy purchasing) or scope 3 emissions (value chain)[11]. Respondents have mentioned the use of biofuels at least in the short-term and electrification of the fleet. They have also mentioned modal shift to trains and short sea shipping for the longer routes and fleet electrification for the shorter ones.

Several operators also mentioned that carriers use the vehicles provided by the manufacturers to satisfy the services required by their clients with very thin profit margins. Therefore, they feel their influence in the decarbonization of the supply chain is limited. Clients who have set their emission reduction commitments through, for example, the SBTi, are willing to go the extra mile to decarbonise their supply chain but, for most, it does not make economic sense. At the moment, with the revised CO_2 standards there are clear targets set for the OEMs but there is an imbalance as, on the operators' side, there is not clear mandate. In particular, the upcoming ETS2, road tolling and the revision of the Energy Taxation Directive (ETD) are expected to give a clear signal also on the demand side, on top of the existing legislation such as the revision of Weights and Dimensions Directive and the Clean Vehicle Directive

Large operators who take part to the Science Base Targets initiative voluntary commit to decarbonize their fleets, primarily through biofuels, electrification, and modal shifts. However, from the policy point of view, whereas OEMs have clear targets, operators and their clients have little incentive to decarbonize. ETS2, road tolling and the revision of the ETD are often mentioned as policies that will help give a clear signal also on the demand side.

3.3. GLOBAL CONTEXT

Europe, according to the most recent ACEA pocket guide (2023-2024) [54], 'manufactures less than one-fifth of the world's commercial vehicles, trailing China and North America' Europe here includes Turkey and the Commonwealth of Independent States (CIS)[12][55] The share to the global commercial vehicle production (including buses) per region of origin is reported in Figure 34.

Even though the European market is currently dominated by European OEM's new players are entering the market especially for the zero-emission vehicle drivetrains. See ICCT for the shares by powertrain and manufacturer for different vehicles segments [41].

[11] For a detailed definition of the 'Scopes' please refer to relevant literature, as for example: https://ghgprotocol.org/standards-guidance

[12] Former soviet republics that chose to collaborate on economic, political and military matters.

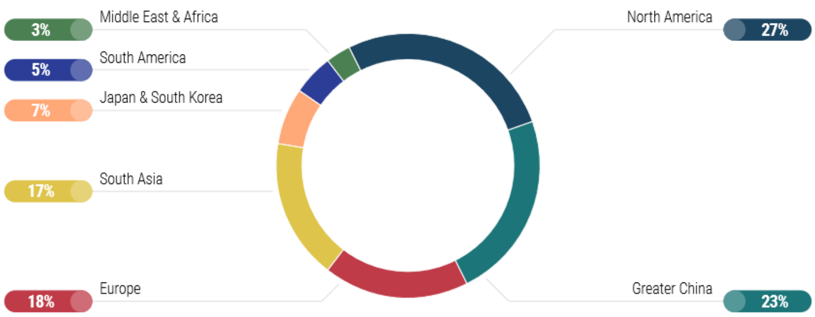


Figure 34 Global commercial vehicle production, % share in 2022 [54]

In the consultation we specifically asked stakeholder to provide their viewpoint on the global context of the HDV market including their prognostic on the competition that will/may arise from other large markets, such as China and the US. Also, in this case there were contrasting points of view that will be analysed and summarised at the consultation process.

Some OEMs and operators report that, for BEV drivetrains, it is well-acknowledged that China is further ahead in the technology and supply chain race. Especially for the supply chain, this is creating clear dependencies from China. Several stakeholders mentioned that the Chinese domination of the entire battery value chain means that it is very expensive and difficult to build up an EU-domestic supply chain. On the other hand, for FCEV and H2ICE, while Europe, US and Japan led for long time the race; China is advancing very fast and driving the technology cost down. Stakeholders also pointed out that supporting the FCEV market in Europe will help the European industry maintaining the edge in the technology for exports in other markets. While the complete industry will profit from economies of scale also in the markets abroad, it is important to avoid for H_2 technologies the dependencies we see for BEVs as well as reduce these dependencies.

OEMs acknowledge that there is a risk that European industry will be challenged with imports from outside the EU in a similar manner as the passenger car industry is experiencing. One stakeholder raised the point that European manufacturers are lagging, notably for the coach segment. Duty fees on Chinese vehicles would lead to a price increase that could make, de facto, that no technology is available for this market segment.

During the consultation several operators welcomed competition to lower prices. For them, the big entry barrier for vehicles produced by OEMs outside the EU is the after-sale service in terms of maintenance, repairs in case of damage, and fast availability of spare parts. This barrier will likely be addressed through partnerships and independent services.

Other stakeholders focused on the possibility of collaborations between European companies and those in China or the U.S.A. that could facilitate the transfer of critical technologies. For example, European firms could partner with U.S.A. companies for advanced hydrogen fuel cell technologies or with Chinese firms for affordable battery technology. These partnerships can help European manufacturers overcome some of the technological and cost barriers associated with zero-emission HDVs.

The European market of heavy-duty vehicles is dominated by European based manufacturers but, with respect to zero-emission heavy-duty vehicles, new players from abroad, namely from China and the U.S.A., are entering the market.

It is acknowledged that China is leading the technology and supply chain race, which is creating dependencies especially for what concerns batteries.

Creating a domestic supply chain remains a challenge for the EU. In terms of vehicles, the highest entry barrier for manufacturers outside the EU is currently the after-sale service for vehicles maintenance and spare parts. But once this barrier is addressed, the vehicles will come to the market.

Competition, apart from lowering prices, also brings the potential for partnerships and collaborations which are already a reality for several manufacturers.

3.4. FLEET EVOLUTION UP TO 2030

The inputs collected throughout this study and summarised in the previous sections are here combined to develop a 'study scenario' and estimate a compatible evolution of the fleet and its energy needs up to 2030. The results will serve as input to the analysis of the recharging and refuelling infrastructure requirements, which will be addressed in the next Chapter.

It is important to underline that the results presented in this Chapter should not be considered as the outcome of a full-fledged demand driven or fleet evolution modelling exercise, such as the ones carried out for an Impact Assessment, which is beyond the scope of this study. This exercise is rather a **simplified assessment** that, by building on the results of the most recent scenario provided by the Commission for the purpose of this study and information available in the literature, incorporates, as far as possible, the insights gained from the market readiness analysis and, in particular, from the stakeholders. Results presented in this section will not provide insight, for example on the cost optimal technology mix in 2030. Instead, they will provide an estimate of the evolution of the fleet composition and corresponding energy needs in the transition period up to 2030, given the expected new vehicle registrations (market shares) of the different zero-emission drivetrains in 2030. **It is important to underline that the results are only as solid as the inputs which are subject to high uncertainty. The results are therefore intended to be used as basis for discussion rather than a prognosis.** This 'study scenario' aims to reflect the consultation results, which clearly show that the market is evolving quickly and BEVs are expected to play the predominant role, at least by 2030. However, there is still a lot of **uncertainty** on what the market of heavy-duty vehicles will look like in detail for the different market segments.

3.4.1. APPROACH AND DATA SOURCES

To estimate the evolution of the zero-emission fleet, including all regulated lorries, as well as busses and coaches, and the corresponding energy requirements, we rely on the most recent scenario provided by the European Commission for the purpose of this study, which is complemented with information made available by the ICCT in their white paper "The European heavy-duty vehicle market until 2040: analysis of decarbonisation pathways" [5] and the supplementary information of the impact assessment of the 2040 climate target plan [56].

The scenario provided by the European Commission for the purpose of this study is used to set the trends in terms of overall new vehicle sales[13], and fleet turnover as well as the

[13] Except for buses for which registration data is considered. For 2020 new sales of buses and coaches amounted to about 30,000 vehicles (with about a 50%-50% share in the two segments). In 2025, the pre-Covid-19 value of 40,000 registrations of buses and coaches is considered. To note, these data for buses and coaches include also non-regulated vehicles that are below 7.5 t. At the moment of writing, it was not possible to obtain a reliable estimate of the share of regulated vehicles within these market segments.

starting point, that is the fleet composition in 2020. The European Commission scenario provides values in 5 years intervals so the values for the intermediate years are simply obtained through linear interpolation.

In the new lorry fleet, the share of vehicles per group is matched to the one reported in the ICCT white paper cited above. Based on the information on reference CO_2 emission (g/tkm) and payloads provided in the same study and typical mileages reported in the revised CO_2 standards, Figure 35 shows the contribution to overall sales and to CO_2 emissions of the different vehicle groups in the lorry segments, which underlines the overwhelming contribution of Group 5 -LH, both in terms of sales and fleet emissions.

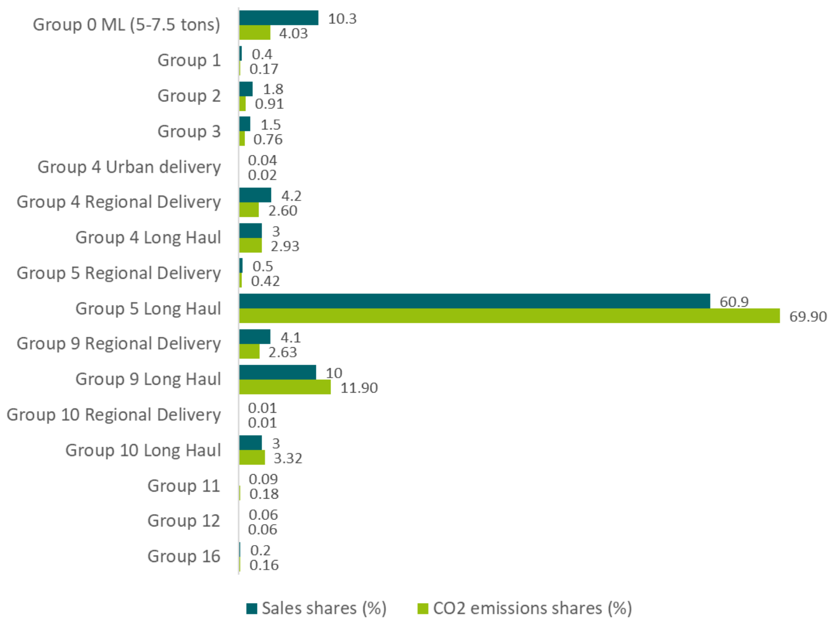


Figure 35 Contribution (in %) to new fleet share and corresponding CO_2 emissions per vehicle group, based on ICCT [5].

The market shares of zero-emission vehicles in 2020 are considered negligible except for buses. For this market segment the market share of BEVs reported in the Commission scenario is taken as reference. Section 3.4.2 summarises the zero-emissions market shares considered for the years 2024 and 2030. For the year 2024, BEV and FCEV market shares are set based on the most recent information on registrations whereas the expected market shares in 2030 per drivetrain and group are set based on both **quantitative and qualitative information** collected during this study. Because the great majority of zero-emission vehicles in 2030 can be considered rather new, with less than 5 years of operation, the typical mileage of the zero-emission vehicles per group reported in the revised CO_2 standards is assumed representative.

The energy consumption per vehicle group and drivetrain and its evolution over the years is an important parameter that greatly affects energy needs and consequently infrastructure requirements. The literature proposes a wide range of values. The ICCT report cited above estimates for group 5-LH lorries in 2030 an electric energy consumption of 0.91 kWh/km by 2030. As mentioned earlier in this study, Volvo reports an electricity consumption of 1.1 kWh/km for BEV for a fully loaded 40 t truck. The ICCT, in a report looking at real-world energy consumption of BEV trucks in China [57], reports 1.1. kWh/km as nominal electricity consumption but 1.5 kWh/km under real driving conditions for tractor trailer combinations. TNO, in a report commissioned by T&E, models battery electric articulated long-haul trucks consuming between 1.05 and 1.07 kWh/km in 2030 [18]. Shoman et al., after a review of the literature which shows the variability of reported energy consumption, finally considers 1.8 kWh/km for highway operations (1.2 kWh/km in urban areas) for long-haul trucks [58]. This value is similar to the reference values reported in the in the supplementary information of the impact assessment of the 2040 Climate Target Plan, which for group 5-LH lorries BEV considers a reference values of 1.65 kWh/km [56].

In Section 3.4.3 the results of the 'study scenario' are presented in terms of the composition of the zero-emission fleet per drivetrain and vehicle type, and the corresponding energy needs. The energy needs estimated in the 'study scenario', unless otherwise specified, rely on the '**low**' energy consumption values as reported by the ICCT. The choice of using ICCT values for the 'study scenario' stems from the consideration that these values take into account expected efficiency improvements and provide a coherent picture across all vehicle groups. Because the assumptions on the energy consumption values per vehicle have a considerable impact on the overall energy needs of the zero-emission vehicle fleet, results are presented also considering the '**high**' energy consumptions reported in the 2040 Climate Target Plan both for FCEVs and BEVs, which are used as reference and do not take into account efficiency improvements. The infrastructure requirements presented in Chapter 6 rely, unless otherwise specified, on the 'low' energy consumption values.

3.4.2. EVOLUTION OF ZERO-EMISSION VEHICLES MARKET SHARES

Keeping the **uncertainty** in mind, based on the information collected in this study and especially during the stakeholder consultation, a 'study scenario' is proposed considering the evolution of new zero-emission vehicles market shares between 2020 and 2024, with a projection to 2030.

The best estimates of the 2030 market shares for this scenario, for the different vehicle types and drivetrains are summarised in Table 7. The information supporting the values provided in this table, are, as said earlier, both of qualitative and quantitative nature and will be presented in detail in the next sections. To note, that H2ICE drivetrains are not explicitly considered as, as will be explained later, their contribution by 2030, in a rapidly evolving market is highly uncertain. H2 fuelled vehicles overall are considered, without splitting FCEV and H2ICE[14].

Table 7 Market shares (new vehicle registrations) in 2030 for the 'study scenario'.

	BEV (%)	H_2 (%)	Total ZE (%)
Medium lorries, 5-7.5 t *(Groups 53, 54)*	32	1	33
Heavy lorries 7.5-16 t *(Groups 1, 2, 3)*	48	2	50
Heavy lorries > 16 t *(Groups 4, 5, 9, 10 for Long Haul)*	24.5	7	31.5
(Groups 4, 5, 9, 10 for Regional Delivery)	49	1	50
Heavy lorries (special axle) > 16 t *(Group 11, 12, 16)*	32	1	33
Buses	88	2	90
Coaches	25	8	33

In terms of zero-emission vehicles market shares by 2030, the values assumed in this study are compatible with the revised EU fleet-wide targets outlined in the revised CO_2 standards. Looking at the impact assessment, the zero-emission vehicles market shares reported in the table correspond to a scenario in between the medium and high target levels, with, however, as will be shown later, a considerably smaller contribution of H_2.

[14] For simplicity, the fuel consumption of FCEVs is considered to represent H2 vehicle.

For comparison, in 2020, the market shares of zero-emission vehicles were negligible for all segments of lorries with, in the N2 and N3 categories, only 0.32% of BEV registrations. For what concerns buses and coaches, EAFO reports that in 2020, BEVs already accounted for 5.39% of registrations (M2 and M3 categories). In the 'study scenario', for 2020, only zero-emission vehicle buses are considered. The market share and the corresponding fleet are taken from the Commission scenario.

In 2024 (year to date), for what concerns lorries, H_2 powered vehicles represent only a very marginal share of the total sales with only 0.03% of vehicles sold in the N2 and N3 categories. BEVs represent a higher share, with 2.09% of sales in the same categories (EAFO). More detailed data reported by ACEA shows that BEVs represent 5.6 % of sales of medium lorries (3.5-7.5 t) and 1.1. % of heavy lorries (>16 t). However, one should note that, as explained earlier, BEV vans that weigh more than 3.5 t, and are outside the scope of the regulation, are also accounted for in EAFO data and in the medium lorries market segment of ACEA. As it was not possible at this stage to collect more detailed data, as a conservative assumption, in 2024, the market share of BEVs for all lorries is set to 1.1% and for FCEV is set to 0.03%.

For what concerns buses and coaches (M2 and M3 categories), EAFO reports, always for 2024 (year to date), a market share of 14.84% for BEVs (down from 15.18% in 2023) and 0.11% for H_2 powered vehicles (down from 0.21% in 2023). ICCT reports that most of BEV registrations in these categories are in fact electric city buses, with 40% and 32% of new city buses being electric in the first and second quarters of 2024 respectively. The BEV market share for coaches is reported to be less than 1%. Following up on these considerations, in 2024, the market share of FCEV for both buses and coaches is set to 0.15%. The BEV market share for buses is set to 35%, a value in between the first and second quarter, and for coaches to 0.5%.

The following paragraphs explain the rationale, the qualitative and quantitative assumptions behind the values reported in Table 7.

Assumptions on the overall share of zero-emission vehicles:

The first element considered is that by 2030, according to the OEMs at least 1 in 3 of the new heavy-duty vehicles sold needs to be zero-emission for manufacturers to meet the 43% emission reduction targets of the revised CO_2 standards and avoid penalties. This estimate already considers a 15% emission reduction that can be achieved through efficiency improvements[15].

The HDV demand side of the market, is starting to adopt zero-emission vehicles, which for certain use cases, can already reach TCO parity with conventional ICE ones. As shown in the survey results, manufacturers are confident that zero-emission vehicles, both BEV and FCEV will meet the operational requirements for all use cases. Operators also expect significant improvements in terms of performance. Already today, they often rated the performance of BEVs for the short-haul market segment such as regional delivery, urban delivery and buses "good" to "excellent".

For medium lorries, the 43% emission reduction of the target is set with respect to reference year 2025. The typical use cases for this type of lorries, considering the corresponding mission profiles in the revised CO_2 standards, are in the shorter-haul segments for regional and urban delivery which are expected to be easier to decarbonise. Likewise, heavy lorries of over 16 t with special axle configuration have typical use cases in the regional delivery, and the corresponding vocational vehicles have typical use cases in construction (vocational vehicles are outside to 2030 emission reduction scope). However, without more specific information, new sales in this segment for 2030 are set, as a minimum, to the overall average of 1 in 3 new zero-emission vehicles.

[15] The 33% market share manufacturers state is needed to achieve a 43% emission reduction target given a 15% efficiency improvement can be explained by expressing the specific emission target, e_t, as follows:

$$e_t = e_r(1-0.43) = e_r(1-0.15)(1-x)$$

Where e_r represents the emissions in the reference year and x the fraction of zero-emission vehicle in new sales necessary to achieve the target, which under these assumptions is 0.33.

Heavy lorries in the 7.5-16 t weight class, have typical use cases in the regional and urban delivery whereas heavy lorries of over 16 t have typical use cases both in the short-haul and in the long-haul. To reach the targets, however decarbonising short-haul lorries in these categories is not enough. Considering, the CO2 contribution reported in Figure 35, long-haul lorries (group 4,5,9,10 -LH) account for about 88% of the CO_2 emissions of all regulated heavy goods (trucks or lorries) vehicles sales. Considering only the lorries in the 7.5-16 t weight class (1, 2, 3) and in the over 16 t weight class (4, 5, 9, 10) the contribution of 4,5,9,10 -LH reaches 92%. This means that, in order to achieve a 43% emissions reduction, taking into account that 15% can be achieved through efficiency improvements, even with 50% of new zero-emission vehicles in all non-long-haul segments, about 31.5% of the long-haul lorries in the 7.5-16 t and over 16 t weight classes would still need to be zero-emission[16]. To note, one stakeholder estimated that 50% of the lorries affected by the revised CO_2 standards are so called "demanding long-haul" which need to rely on public recharging infrastructure.

The main assumptions underlying the overall zero-emission vehicle share presented in Table 7 are:

- For heavy goods vehicles as a whole, about 33% of new vehicles, overall, need to be zero-emission to achieve a 43% emission reduction given a 15% efficiency improvement, as stated by manufacturers.
- For medium lorries and heavy good lorries (special axle and over 16 t), zero-emission vehicles new sales are set to the minimum of 33%
- For the rest of the heavy goods vehicles, the market share of zero-emission vehicles for the long-haul is set to 31.5% and for all other segments to 50%.
- For (urban) buses, the revised CO_2 standards regulation, mandates a 90% share of zero-emission buses. New sales of zero-emissions buses are therefore set to 90%.
- For coaches (and interurban buses), 33% of new vehicles, overall, are set to be zero-emission, following the same general reasoning applied heavy-duty vehicles overall.

Assumption on the split of BEV, FCEV, and H2ICE in the market share

BEVs are set to become the predominant option in the decarbonization of heavy-duty vehicles. The consultation however highlighted conditions for which BEVs could struggle to meet some use cases operational requirements. Examples included extremely cold weather conditions, extreme heat, operation in very hilly terrain, and demanding long-haul operation. Long and very long-haul trips with heaviest duty vehicles arise as the use case where FCEV could best complement BEVs, with their, in general, longer ranges (newer models reaching up to 1,500 km, with the Nikola Two FCEV, although, to the best of our knowledge not yet operating in Europe), and refuelling times and payload almost equivalent to those of conventional diesel engines [59]. As an indication, stakeholders reported that their expectation is for the FCEV market to cover 15-25% of the zero-emission vehicle market in 2030 for busses, coaches, and the heavy-duty long-haul segment. This is the main assumption we consider estimating the future market share of FCEV. For what concerns H2ICE, with only models available in small series production or with trials that are set to start in the future (ACEA), their contribution by 2030, is very uncertain. H2ICE are therefore not directly included in the analysis and H_2 vehicles are included considering the fuel consumption of FCEV. The H_2 infrastructure necessary to support FCEV could be used also for H2ICE.

[16] The share of vehicles in the long-haul fleet, x_{LH}, needed to reach the emission reduction target of 43%, given a 15% emissions reduction through efficiency improvement, when as much as 50% of the regional delivery vehicles are zero-emission vehicles, can be calculate as follows:

$$x_{LH} = 1 - \frac{(1-0.43) - {E_{RD}}/{E_{fleet}}\,(1-0.5)(1-0.15)}{E_{LH}(1-0.15)}$$

Where the emissions of the fleet in the scope of the emission reductions considered, $\boldsymbol{E_{fleet}}$, the emission of the long-haul fleet $\boldsymbol{E_{LH}}$ and the emissions of the regional delivery fleet, $\boldsymbol{E_{RD}}$, are computed considering payloads, mileages and reference emissions. As official numbers are not publicly accessible, as far as to the authors knowledge, the values reported in Figure 35 are taken as reference.

In general, in the impact assessment of the revised CO_2 standards, in 2030, hydrogen powered vehicles have a higher contribution to new sales than what is considered in the 'study scenario'. For example, in the heavy lorry segment (>16 t), in the impact assessment, H_2 powered vehicles contribute 13% and 18% in the medium and high target level scenarios respectively, whereas in the proposed 'study scenario' they contribute for a maximum of 7% for the long-haul segment only.

The main assumptions underlying the split per drivetrain reported in Table 7 are:

- For the long-haul segment, the market share of FCEV is set to about 20% of the zero-emission vehicles market share, which as explained earlier is set to 30%. This results in 7% of the new long-haul lorries being set to FCEV.
- For coaches the share of FCEV is set to 8%, which is also the share in the baseline scenario of the impact assessment and corresponds to almost 25% of the market share of zero emissions vehicles in this segment.
- The contribution of FCEV for all other segments is set to 1-2%, as in the baseline scenario of the new CO_2 standards impact assessment.
- All other new zero-emission vehicles are BEVs.

3.4.3. 'STUDY SCENARIO' – FLEET EVOLUTION AND ENERGY NEEDS

This section summarises the results in terms of zero-emission fleet and corresponding energy needs resulting from the 'study scenario' as described in the previous sections, and in particular, considering the market shares of Table 7.

The evolution of the zero-emission fleet is reported in Figure 36, differentiating freight transport (darker colours) from passenger transport (lighter colours). Note, the vehicle uptake in the sales is a simple linear interpolation.

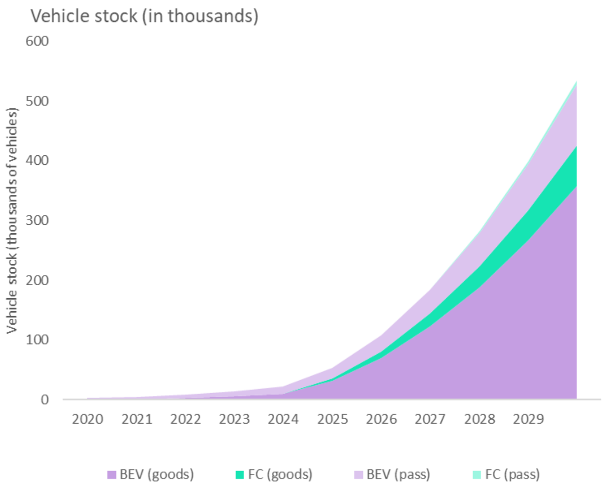


Figure 36 Evolution of the zero-emission vehicles stock according to the 'study scenario'.

Specifically for 2030, The number of BEVs and H_2 vehicles are reported in Figure 37 and, in tabular form, in Table 8.

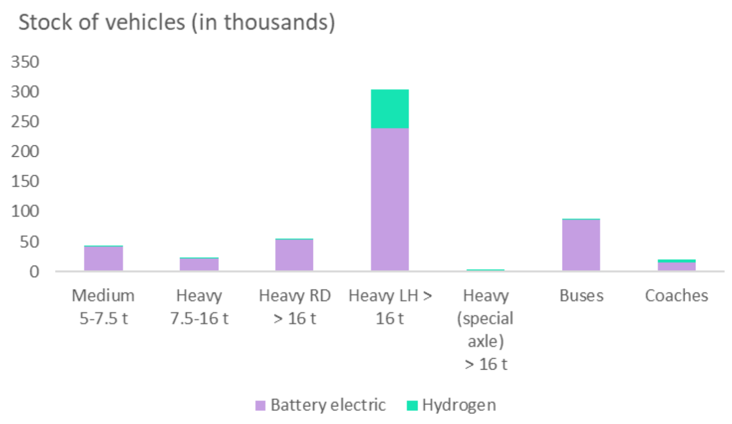


Figure 37 Fleet composition of zero-emission vehicles per segment in 2030

Table 8 Zero-emission heavy-duty vehicles fleet in thousands of vehicles estimated in the 'study scenario' for 2030.

	BEVs (thousands)	**FCEVs** (thousands)	**ZEVs** (thousands)
Medium lorries, 5-7.5 t	41	1.3	43
(Groups 53, 54)			
Heavy lorries 7.5-16 t	22	0.9	23
(Groups 1, 2, 3)			
Heavy lorries > 16 t			
(Groups 4, 5, 9, 10 for Regional Delivery)	54	1.1	55
(Groups 4, 5, 9, 10 for Long Haul)	239	65	304
Heavy lorries (special axle) > 16 t			
(Group 11, 12, 16)	1.4	0.04	1.45
Total lorries	***357***	***68***	***426***
Buses	87	1	89
Coaches	15	5	20
Total buses and coaches	***102***	***6***	***108***
Total heavy-duty vehicles	***459***	***74***	***534***

These numbers show well the importance of the decarbonisation of the long-haul trucks, which by 2030, with 304,000 vehicles, should account for the segment with the largest number of zero emission vehicles.

According to the 'study scenario', by 2030 there will be almost 534,000 zero-emission medium and heavy-duty vehicles on the road in the EU27; 357,000 of them will be medium and heavy-duty lorries and 108,000 buses and coaches. Of the zero-emission vehicles, 459,000 will be BEVs and 74,000 will be FCEV.

Results can be roughly compared to the outcomes of other studies. Namely, ACEA estimates that to reach a 45% emission reduction target by 2030, as set in the revised CO_2 standards, the minimum number of heavy-duty trucks on EU-27 roads needs to be about 400,000, with about 330,000 BEVs and 70,000 H_2 powered vehicles [60]. In the 'study scenario' the total number of heavy-duty trucks is estimated at 426,000 of which 357,000 BEVs and 68,000 H_2 powered vehicles.

The ICCT, in their analysis of the proposal for the revised CO_2 standards[17], estimated that in 2030 there would be a total of 675,000 zero-emission heavy-duty vehicles on the road, compared to the 534,000 estimated in this study. In the ICCT study the fleet is composed of 220 000 medium lorries (3.5 t – 16 t), 215,000 heavy lorries (over 16 t) and 240,000 coaches and buses [43]. In the 'study scenario' the number of vehicles below 5 t is not taken into consideration as it is outside the scope of the regulation. In similar weight classes the 'study scenario' counts 66,000 lorries (5 t – 16 t), 294,000 lorries (over 16 t) and 108,000 coaches and buses.

The energy consumption per market segment is reported in Figure 38 for the 'low' consumption scenario taken as a reference in this study. Because of the predominance of heavy LH vehicles in the new sales and the lower energy efficiency of H_2 drivetrains translate into relatively high H_2 needs.

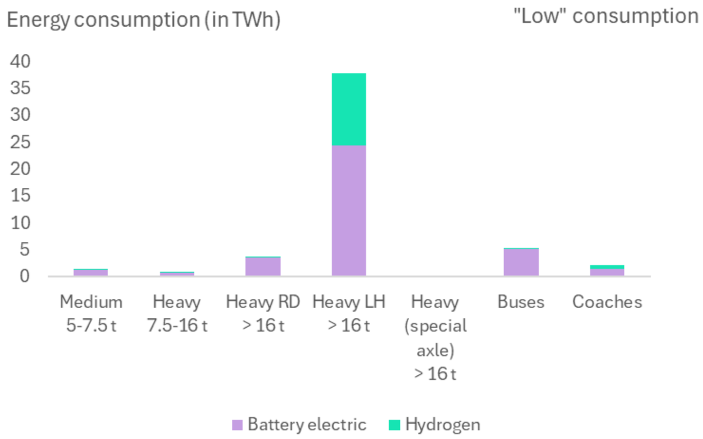


Figure 38 Energy needs of zero-emission vehicles in the 'study scenario' per segment in 2030

To underline the effect of the assumptions of the energy consumption on the energy needs, Figure 39, shows the results for the two scenarios: the 'high' energy consumption referring to the reference values reported in the 2040 Climate Target plan and the 'low' energy consumption one, referring to the values reported by the ICCT.

[17] In the proposal, the target for buses was set to 100% already in 2030, instead of 90%.

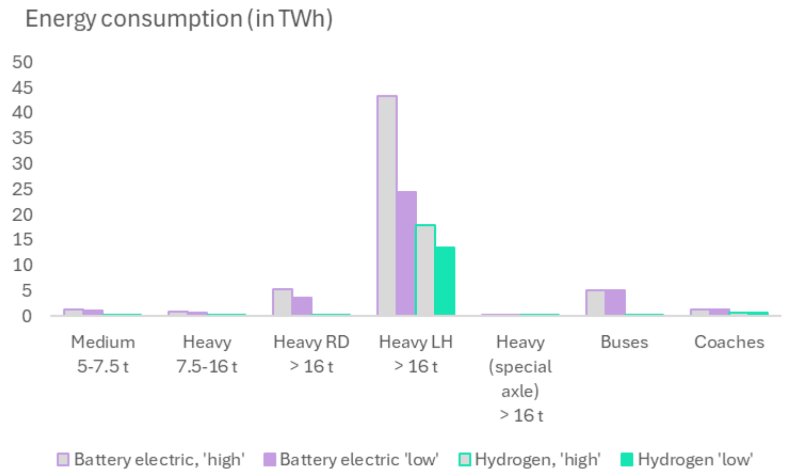


Figure 39 Comparison of energy needs in 2030 for the 'study scenario', taking as reference the 'low' energy consumption values as reported by the ICCT or the 'high' ones as reported in the 2040 Climate Target Plan Impact Assessment.

For a more detailed overview, the energy needs of the zero-emission vehicle fleet by 2030 are also summarised in Table 9, in TWh.

Table 9 Zero-emissions heavy-duty vehicle fleet energy need in 2030 (in TWh) in a 'low' and a 'high' energy consumption scenario.

	'Low'			'High'		
	BEV (TWh)	**FCEV (TWh)**	**ZEV (TWh)**	**BEV (TWh)**	**FCEV (TWh)**	**ZEV (TWh)**
Medium lorries, 5-7.5 t						
(Groups 53, 54)	1.15	0.06	1.21	1.34	0.06	1.41
Heavy lorries 7.5-16 t						
(Groups 1, 2, 3)	0.74	0.05	0.80	0.97	0.06	1.04
Heavy lorries > 16 t						
(Groups 4, 5, 9, 10 Regional Delivery)	3.60	0.11	3.71	5.35	0.16	5.51
(Groups 4, 5, 9, 10 Long Haul)	24.4	13.5	37.8	43.4	18.0	61.4
Heavy lorries (special axle) > 16 t						
(Group 11, 12, 16)	0.07	0.00	0.07	0.12	0.01	0.13

Total lorries		***29.9***	***13.7***	***43.6***	***51.2***	***18.3***	***69.5***
Buses		5.08	0.16	5.24	5.08	0.16	5.24
Coaches		1.39	0.68	2.07	1.39	0.68	2.07
Total buses and coaches		***6.47***	***0.84***	***7.31***	***6.47***	***0.84***	***7.31***
Total heavy-duty vehicles		***36.4***	***14.5***	***50.9***	***57.7***	***19.1***	***76.8***

In the 'low' consumption scenario, which is considered as a reference for this study, the total energy consumption of the zero-emission heavy-duty vehicles fleet in 2030, is of 50.9 TWh. The corresponding electricity demand amounts to 36.4 TWh and H_2 demand to 14.5 TWh. Lorries alone account for 29.9 TWh of electricity consumption and 13.7 TWh of hydrogen consumption. Passenger transport, with buses and coaches, accounts for 7.31 TWh, of which 6.47 TWh of electricity. The electricity consumption we obtain for trucks and buses of 30.3 TWh (for heavy-duty vehicles overall of 36.4) can be compared to the 28.1 TWh reported by T&E for the same scope (including trucks and buses)[18].

In the 'high' consumption scenario, the total energy demand increases from 50.9 to 76.8 TWh. Looking only at lorries, the increase is from 43.6 to 69.5 TWh.

To give further insight on how the assumptions impact energy demand, if all new zero-emission vehicles in the 'study scenario' were battery-electric vehicles, in the 'low' consumption scenario the total energy demand would decrease from 50.9 TWh (36.4 TWh of electricity and 14.5 TWh of hydrogen) to 43.65 TWh (electricity), and in the 'high' scenario from 76.8 (57.5 TWh electricity and 19.13 TWh hydrogen) to 70.24 TWh (electricity).

Figure 40 summarises these results for lorries alone. If all the new zero-emission lorries in the 'study scenario' were battery electric, energy consumption would decrease from 43.6 TWh (electricity and hydrogen) to 36.67 TWh (electricity only) in the 'low' consumption scenario and from 69.5 TWh (electricity and hydrogen) to 63.15 TWh (electricity only) in the 'high' consumption scenario

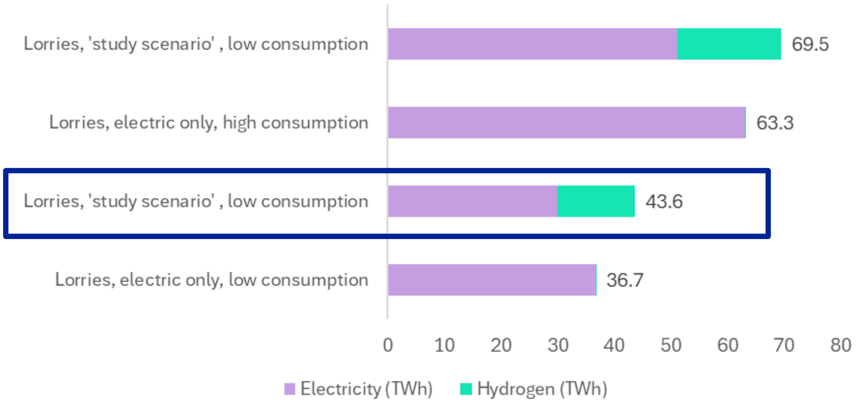


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Figure 40 Comparison of energy needs in TWh, under low and high consumption assumptions for the 'study scenario' and equivalent theoretical scenario where all new zero-emission vehicles are battery electric. In the box, the scenario considered for this study.

One should note that, in these theoretical scenarios, the additional electricity needs between the 'study scenario' and the 'electric only' ones, are more than compensated by the avoided H_2 production. In the case of Green H_2 produced from electrolysis, generally requires over

[18] The estimate by T&E is based on a step-wise introduction of HDVs dependent on the announcements by manufactures ant the targets, in contrast to the simplified linear uptake modelled in this study. The number of BEV by 2030 estimated by T&E is lower but with a slightly higher energy consumption.

1.5 kWh of electricity per kWh of H_2 (without accounting for transport and compression/liquefaction). These numbers serve the purpose of giving an idea of the impact of uncertainty, which is still evident both in terms of the contribution of H_2 fuelled vehicles and efficiency, on the possible composition of the fleet and the corresponding energy needs implied by the revised CO_2 standards.

Considering the inputs collected throughout the consultation, in the 'study scenario', BEVs are expected to play the dominant role in the decarbonization of heavy-duty vehicles, with H_2 contributing mainly for part of the long-haul both for goods and coaches. This results in about 534,000 zero-emission vehicles on the road by 2030 (426,000 lorries and 108,000 buses and coaches) of which 459,000 BEVs (357,000 lorries and 102,000 buses and coaches) and 74,000 hydrogen vehicles (68,000 lorries and 6,000 buses and coaches). Lorries will require 29.9 TWh of electricity and 13.7 TWh of H_2, and 6.5 TWh of electricity and 0.8 TWh of H_2 for buses and coaches.

Under the assumptions of the 'study scenario' by 2030, the share of H_2 vehicles in the zero-emission fleet amounts to 16% and their energy requirement to 28.5%. These results are based on the expected market shares as reported by the stakeholders, but given the few models currently available, the low penetration of H_2 vehicles currently observed in the market, the contribution FCEVs and H2ICE by 2030 should be underlined as an important source of uncertainty in the results presented of this study.

These numbers are estimated through a simplified assessment that builds on the most recent scenario provided by the Commission for the purpose of this study, literature data, and relies on several simplifying assumptions (such as a linear market uptake). It is therefore important to underline that the results are only as solid as the inputs which are subject to high uncertainty. The results are therefore intended to be used as basis for discussion rather than a prognosis.

4. INFRASTRUCTURE REQUIREMENTS

In this section the demand for public available recharging infrastructure is calculated and subsequently compared to the requirements for eHDV recharging infrastructure in AFIR. To estimate the demand for infrastructure, the section goes through a series of steps as illustrated by Figure 41.

First, it is paramount to project the expected numbers of eHDVs in the future and the different technologies and technical specification of the vehicles. For this we will use the projection year of 2030 which corresponds to the final deadline for fulfillment of requirements in AFIR for infrastructure dedicated to HDV. The number of vehicles per type as well as their energy demand are provided in the previous section.

Moreover, it is important to understand the various use cases (expected typical driving and recharging/refuelling patterns depending on vehicle type and propellant) to assess the need for public recharging/refuelling infrastructure. The different vehicle types will have different use cases and hence needs for publicly accessible infrastructure. With an understanding of the use cases, it is possible to assess the split between private and publicly accessible recharging/refuelling infrastructure and project the demand in 2030. Finally, we will compare the projected demand with the requirements of AFIR and discuss the requirements in their role as to facilitate a sufficient backbone of recharging and refuelling infrastructure in Europe.

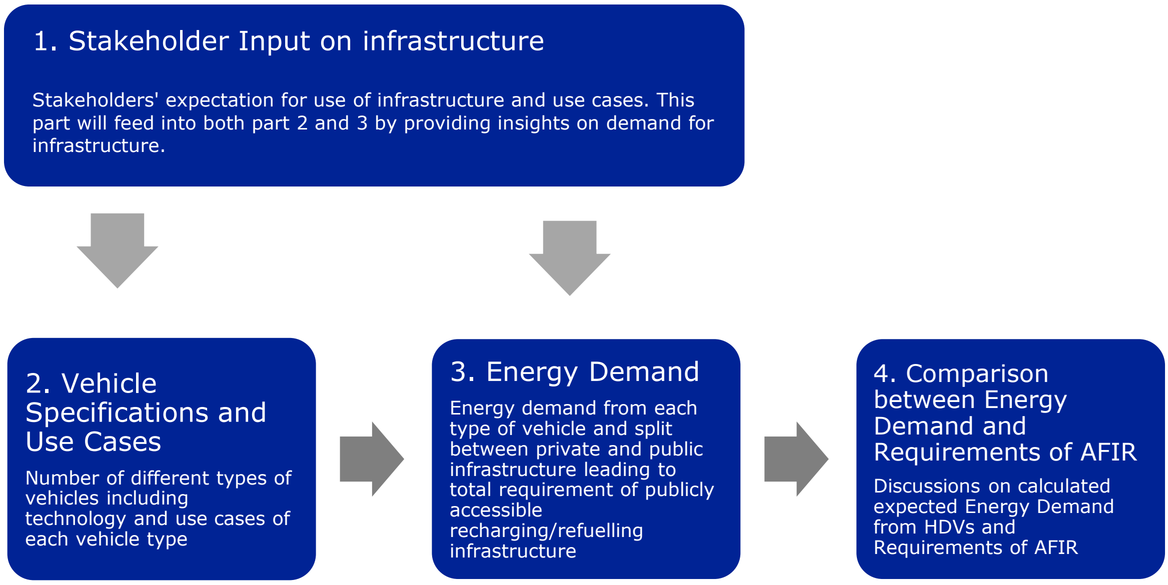

Figure 41. The section goes through four steps to compare the energy demand with the requirements of AFIR.

4.1. STAKEHOLDER INPUT ON INFRASTRUCTURE

4.1.1. STAKEHOLDERS ON RECHARGING INFRASTRUCTURE

In this section Stakeholders input on recharging infrastructure will be presented. The section will primarily focus on inputs from stakeholder interviews, workshops and surveys performed in this study.

Stakeholders on Private versus Public Recharging

Stakeholders point out that depot recharging is preferred due to its cost-effectiveness, reliability, and ability to integrate seamlessly with operations. Depot recharging allows operators greater control over energy costs and scheduling, which is particularly important for managing fleet operations efficiently. Several stakeholders emphasize that depot recharging is significantly cheaper than public recharging and helps optimize downtime while lorries are being loaded or unloaded. Similarly, stakeholders within urban and regional transport anticipate that 90% of recharging will occur at private recharging locations. This is due to most of the driving being depot to depot driving. Stakeholders specify that the planning advantages and cost savings for recharging are key factors for deciding to invest in private recharging.

Especially for regional transport private opportunity recharging at depots or at private logistics terminals during loading and unloading is also considered as a supplement for operational efficiency. Stakeholders note that utilizing these periods for recharging maximizes vehicle utilization and reduces idle time. When looking at results from the survey it can be seen in Figure 42 that the respondents in general consider recharging at private depots as being the most used form of recharging.

Stakeholders did also agree with the preliminary finding presented to them in the 2nd workshop which stated "*Battery electric HDVs will rely on a combination of depot recharging using primarily 100-150 kW chargers, and public recharging using CCS and/or MCS. Wherever possible, operators will maximise the share of depot recharging because of lower cost per kWh"* which further indicates that the market agrees on this being the pathway we will see towards 2030. Stakeholders have also emphasized that they are willing to let subcontractors or operators who have an errand at the logistic hub or terminal use the available recharging infrastructure, further eliminating the need for public recharging for this group.

Some stakeholders advocate for mixed infrastructure models where public rechargers complement private depot networks, particularly in areas with high demand variability. They suggest that shared infrastructure models can provide flexibility and meet the needs of fleet operators who may not have access to private depots or who operate across regions with varying infrastructure availability. Transport & Environment (T&E) emphasizes that while a significant portion of recharging is expected to happen privately, public recharging infrastructure is crucial to ensure that lorries can complete their routes reliably.

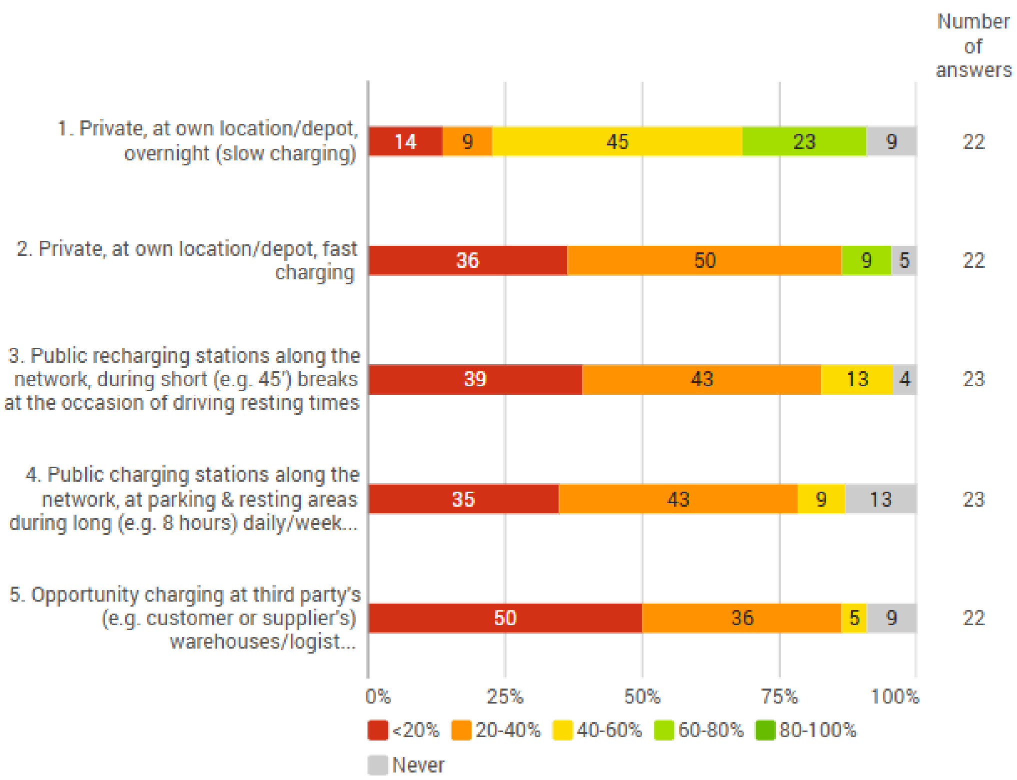

Figure 42. Survey results for the question: "How do you foresee the split in recharging for heavy-duty vehicles in 2030 overall in the market? Please estimate the share for each type"

Public recharging is primarily viewed as a supplement for long-haul routes, with stakeholders highlighting the increasing demand for strategically located high-power recharging station along major freight corridors. For long-distance operations where depot recharging is insufficient, public infrastructure becomes essential. Stakeholders estimate that most of long-haul lorries driving will rely on public recharging with estimates ranging between 40-65%. Stakeholders emphasize the importance of public lorries stops equipped with secured recharging hubs to facilitate overnight stays and range extension. Coach operators indicate a clear need for recharging near the end of routes, such as bus stops, not just along highways, to support their operational needs.

For urban buses, stakeholders anticipate that the vast majority, if not all, recharging will occur at private depots. Given their fixed schedules and predictable overnight downtime, urban buses are well-suited to fully private recharging infrastructure, reducing the need for public recharging options entirely.

For coaches, the split between public and private recharging is expected to be more evenly split due to their varied operational requirements. While private depot recharging is important for operators with centralized hubs, particularly for overnight recharging at the start and end of routes, public recharging is essential for supporting longer journeys and providing flexibility during intercity and international operations. Stakeholders highlight that public recharging infrastructure at transit hubs and rest stops is critical for range extension on routes where private recharging is unavailable or impractical.

The reliance on public recharging for coaches is closely linked with the geographical spread of their operations, which often spans multiple regions or countries. Stakeholders agree that a strong public recharging network is vital to ensure route reliability and to support operators who lack access to private depot.

Expected Demand for Outputs (kW) by Vehicle Type

General Overview

Stakeholders widely expect most recharging for urban delivery, regional delivery lorries, buses, and vocational vehicles to occur at local depots, supported by outputs between 40 and 150 kW. This lower-power recharging approach aligns with predictable schedules and overnight recharging requirements. A smaller portion of depot recharging may require outputs in the 150–350 kW range for cases where more rapid recharging is needed due to unexpected delays or tighter schedules.

Stakeholders also anticipate that public recharging infrastructure will primarily serve regional and long-haul lorries as well as coaches, as these groups face longer routes and less access to private depot facilities. For urban delivery and vocational vehicles, the minimal public recharging needs could potentially be supplemented by existing passenger vehicle recharging infrastructure as some of the vehicles may be able to fit in terms of size into this existing infrastructure which is relatively well-developed compared to existing recharging infrastructure for larger HDVs.

For vocational vehicles, such as bin lorries or construction vehicles, stakeholders highlight that private depot recharging will dominate for fixed-route or centralized operations, such as municipal waste collection. Vehicles with less predictable routes, like those in construction, may rely more on public recharging infrastructure to supplement depot recharging. However, given the limited adoption of BEV vocational vehicles currently, stakeholder insights remain sparse, and projections for their public-private recharging split are uncertain. Stakeholders agree that developing infrastructure for these vehicles will need to align with their operational diversity and range requirements.

Regional Delivery Lorries

Primary Recharging Needs

Stakeholders highlight that most recharging for regional delivery lorries will occur at depots, with outputs between 150-350 kW sufficient to meet their schedules. Depot recharging offers logistical advantages and cost efficiency, ensuring that lorries are ready for daily operations.

Supplementary Public Recharging

For non-routine routes or extended trips, public recharging infrastructure will serve as an essential complement to depot recharging solutions. Stakeholders expect 150–350 kW chargers to dominate public recharging for regional lorries, providing flexibility without the higher costs of ultra-high-power recharging points. When looking at results from the survey in Figure 44, it can be seen that the stakeholders expect that most public recharging for regional delivery lorries will take place at an output of above 350 kW. Quite a few also find 150-350 kW fairly relevant. This relates to public recharging for regional delivery, which will mainly be for range extending purposes and therefore higher output chargers will be most relevant for this group.

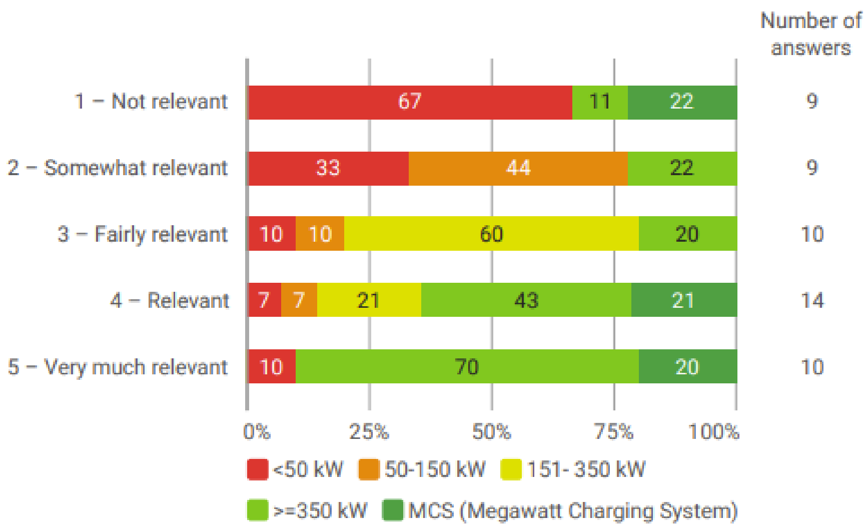

Figure 43 Survey results for the question: " Which recharging power outputs (kW) do you use/plan to use at public recharging stations for your operations? Please rate power outputs from not relevant to very much relevant for the regional user case"

An estimation of the answers from the stakeholders would put around 70-75% of the recharging need at above 350 kW with 20-25% in the range of 150-350 kW. A small amount of around 5% would probably also take place at below 150 kW. This tracks well with the answers that were received during the interviews as well.

Long-Haul Transport Lorries

Primary Recharging Needs

Stakeholders emphasize that while depot recharging will remain relevant for pre-journey readiness or overnight recharging at logistics hubs, long-haul transport lorries will heavily rely on public recharging infrastructure for their operational needs. Depot recharging for this group is expected to involve 150–350 kW outputs, catering to instances when vehicles return to base. Depot charging will be relevant for all long-haul operation all the way from 400km to 800km+ in the beginning of each journey and depending on the destination it can also be in the beginning of the return leg of the journey. The length of the trip will influence how much of the journey can be covered by depot charging. For operations between 400-500km which starts from the depot it can be almost the entire demand, while for trips starting from non-depot areas will need to rely on public charging for all of their recharging demand. Trips which have a length of 500km+ will have varying degrees of needs for recharging infrastructure with the need increasing as the trips gets longer.

Public Recharging

For long-haul operations, public recharging infrastructure will be essential to support range extension during mandatory driver rest breaks and other en-route requirements. Stakeholders expect high-power chargers above 350 kW to dominate, as these outputs align with the need for rapid energy replenishment during rest periods. Figure 45 from the survey responses shows that stakeholders, to a great extent, prioritize chargers exceeding 350 kW for long-haul lorries, as time constraints necessitate minimizing downtime.

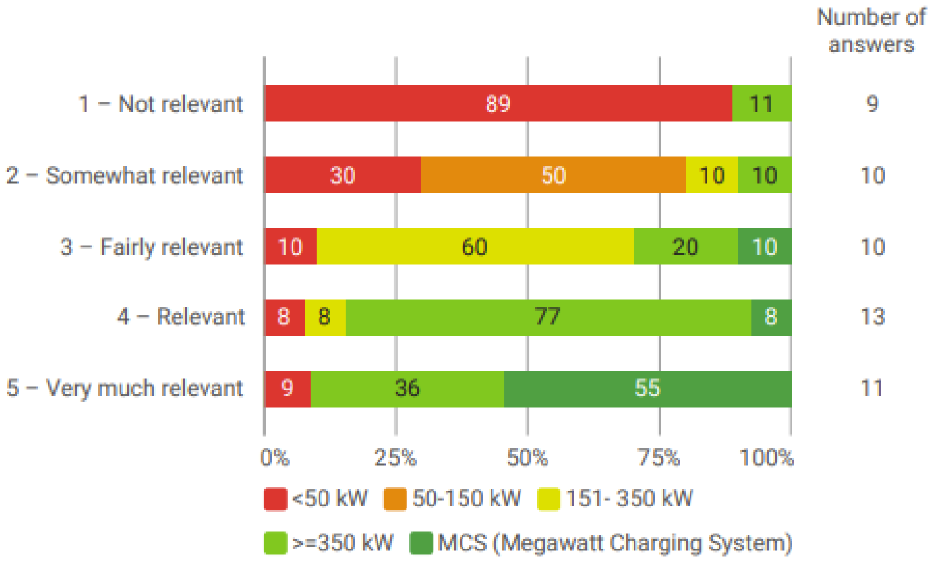

Figure 44 Survey results for the question " Which recharging power outputs (kW) do you use/plan to use at public recharging stations for your operations? Please select all that apply. Please rate power outputs from not relevant to very much relevant for the international user cases

Estimates derived from survey results and interview responses suggest that approximately 70% of public recharging needs for long-haul transport will be met by ultra-high-power chargers. A smaller portion, around 20-25%, of public recharging events may occur at mid-range 150-350 kW outputs, catering to situations where operational constraints are less pressing where a small range extension of 100-200 km might be what is needed or for overnight recharging on very long-distance journeys. The need for public recharging below 150 kW is expected to be low, around 5-10%, for long-haul vehicles, as it does not meet the requirements for quick turnaround times but could be relevant at overnight recharging in some specific cases.

Coaches

Primary Recharging Needs

Stakeholders note that both depot recharging and public recharging will play a significant role in supporting coaches, particularly for overnight recharging or during layovers at depots. Outputs of 150-350 kW are generally considered sufficient for these purposes, as they align well with typical operational schedules and allow for recharging during planned downtimes.

Public Recharging

For intercity and long-distance operations, public recharging infrastructure will be crucial to meet the needs of coaches, especially on routes where depot recharging is unavailable or impractical. Stakeholders expect public recharging for coaches to focus on high-power chargers above 350 kW, as these are essential to ensure efficient energy replenishment during scheduled stops, such as at bus terminals or rest areas.

Estimates derived from survey results and interview responses suggest that approximately 75-80% of public recharging needs for coaches will be met by ultra-high-power chargers with outputs above 350 kW. These chargers are seen as essential for minimizing downtime during short layovers or scheduled stops, particularly on long-distance routes. A smaller portion, around 15-20%, of public recharging events is expected to occur at mid-range outputs of 150-350 kW, overnight stops or shorter routes where such power levels are sufficient. This is a smaller percentage than for long-haul transport and is due to long-distance coaches often have two drivers, so they can drive several 4.5 hour stretches in a row and therefore is less dependent on overnight recharging. Public recharging below 150 kW is anticipated to account for less than 5% of recharging needs for coaches, as these outputs are generally inadequate for the rapid energy replenishment required, though they may be used in specific low-priority cases.

Stakeholders on expected Utilization Rates for Recharging Infrastructure

Stakeholders emphasize the importance of achieving high utilization rates across both private and public recharging infrastructure. For depot and opportunity recharging, stakeholders aim to maximize efficiency, with some estimating utilization rates of up to 70% for opportunity recharging. Depot recharging, particularly at lower outputs, is expected to see utilization rates between 25-50%, reflecting its role in supporting overnight and pre-journey recharging needs. For a description of opportunity charging se section 1.4.2.

For public recharging infrastructure, utilization rates are harder to predict, as most stakeholders provided only rough estimates for 2030. The expected range for lower-output public chargers is around 25-40%, while stakeholders state that higher-output public chargers may achieve utilization rates between 5-25%. These figures remain speculative, with stakeholders acknowledging significant uncertainties.

Some stakeholders pointed out that higher utilization rates for public recharging of lorries should be achievable, as lorry recharging is more predictable and easier to plan compared to car recharging. They also emphasized that selecting the right locations for recharging infrastructure can increase utilization and, consequently, reduce the overall infrastructure required. Additionally, stakeholders highlighted the possibility of booking infrastructure in advance as an important factor in maintaining high utilization rates. Installing less recharging infrastructure but strategically placing it at optimal locations could further support higher utilization. Charge Point Operators (CPOs) also stressed the need for high utilization rates to establish a viable business model for publicly accessible recharging infrastructure. The existing literature on the topic also varies greatly with some sources estimating a utilization rate of 4-5 hours per day for high-power rechargers equivalent to 16-20% and others has it as low as 2% in their estimations.[61] Other sources are somewhere in the middle of these estimates [50], [61], [62], [63]. Further literature also expects a utilization rate for lower output which is a bit higher at around 30%.[61]. The higher estimates are more in accordance with what has been expressed by stakeholders. It has been difficult to uncover any concrete data on current or projected utilization rates of the actual publicly accessible recharging infrastructure. This means that utilization rates are highly theoretical or at best estimations as pointed out by some stakeholders.

When calculating the need for infrastructure, utilization rates are a key input that significantly affects the projections. For example, a drop in the utilization rate from 20% to 10% could double the projected need for recharging infrastructure. However, lower utilization rates do not necessarily imply the need for a proportional increase in recharging infrastructure.

For public recharging, the utilization rate ideally reflects a well-optimized network where infrastructure is placed at strategically chosen, high-demand locations. In practice, however, utilization rates can vary greatly between locations. Public infrastructure may still be required in areas with lower utilization rates to ensure a coherent, accessible, and relatively fine-meshed network that serves all regions effectively.

For private recharging, the utilization rate often depends on the specific operations and scheduling of the fleet or individual vehicles. These private systems are usually tailored to meet predictable needs, making their utilization rates inherently different from those of public infrastructure. It is also worth noting that how utilization is measured—whether based on hours of use, energy delivered, or other metrics—can influence the interpretation of these rates and their implications for infrastructure needs.

4.1.2. STAKEHOLDERS ON REFUELLING INFRASTRUCTURE

In this section Stakeholders' input on refuelling infrastructure will be presented. The section will primarily focus on inputs from stakeholder interviews, workshops and surveys performed in this study.

Stakeholders on Private versus Public hydrogen Refuelling Infrastructure

Private Refuelling

Stakeholders generally view private refuelling infrastructure as a niche solution, expected to play a limited role in the broader deployment of hydrogen-powered fleets. Its primary use is anticipated among specific fleet operators with predictable routes and high utilization rates, such as larger bus operators or regional delivery fleets. Stakeholders highlight that private hydrogen refuelling solutions can provide cost control and reliability, but the high capital costs and operational complexities make them feasible only for a small percentage of the market.

Some stakeholders point out that private stations may be relevant for 5-15% of the fleet, primarily for operators with centralized depots, such as regional delivery fleets or dedicated bus systems. For example, larger companies with a high density of vehicles and repetitive operations might invest in private refuelling infrastructure to ensure reliability and manage costs. However, the majority of fleets, particularly those with diverse or less predictable routes, are unlikely to adopt this model. When looking at the results in Figure 45 from the survey conducted in relation to this study, few expect a large part of their refuelling to happen privately with very few expecting more than 40% of their refuelling to happen at private refuelling depots. As a relatively large portion of respondents answers 'Never', it must be expected that these include both stakeholders who never expect to use hydrogen vehicles and stakeholders who never expect to use that specific type of refuelling. From the background data it is estimated that survey respondents expect around 20% of the refuelling to happen privately.

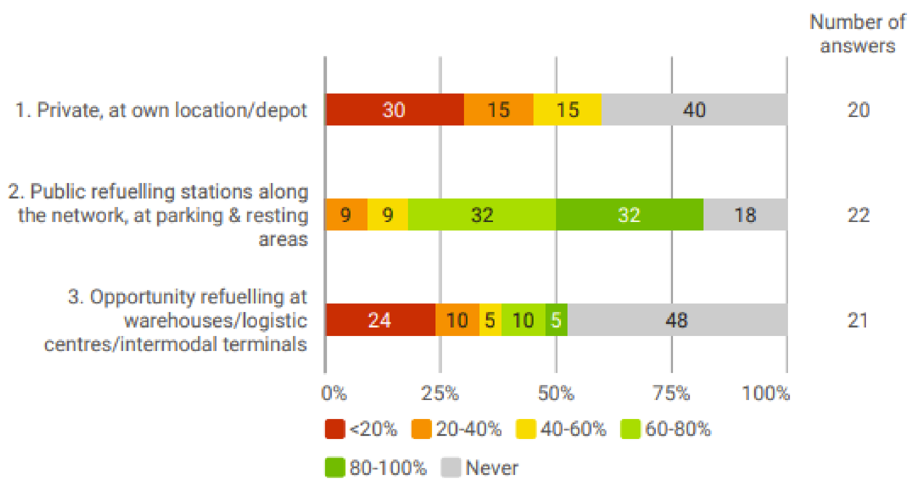

Figure 45 Survey results for the question "Where do you foresee to refuel your hydrogen vehicles most frequently in 2030? Please estimate the share of the different locations

Publicly accessible Refuelling Infrastructure

Most hydrogen refueling needs are expected to be met through publicly accessible refuelling infrastructure, with stakeholders estimating this to account for 85-95% of the total demand. Public refueling is expected to be the norm for hydrogen, as it supports the flexibility required by long-haul vehicles, coaches, and other applications that rely on access to a geographically dispersed network of refueling points. The current deployment rate is low but so is the availability and uptake of hydrogen vehicles, and stakeholders note that achieving the necessary coverage will require coordinated efforts between private companies and public authorities. Despite these challenges, publicly accessible refuelling infrastructure is expected to form the backbone of the hydrogen ecosystem, catering to nearly all long-haul lorries, most coaches, and a significant portion of regional delivery vehicles. From the survey results in Figure 45 it is estimated that around 65% of hydrogen refuelling will occur at publicly accessible stations and approximately 25% through what is referred to as "opportunity refuelling." In this context, opportunity refuelling refers to publicly accessible refuelling infrastructure located at or near warehouses or logistics hubs, similar to the current diesel infrastructure for HDVs. Unlike private infrastructure, these pumps are open for public use and support flexible operations for various fleets.

This setup mirrors the existing diesel refuelling model, where refuelling often takes place at publicly accessible stations within warehouse and logistics areas. For hydrogen, stakeholders anticipate that around 20% of refuelling opportunities will occur at these types of locations but remain publicly accessible. This brings the total share of hydrogen refuelling met by publicly accessible infrastructure to around 90%, as indicated by the survey respondents.

It is important to note that the definition of "opportunity refuelling" for hydrogen differs from the concept of "opportunity charging" used for electric vehicles. For hydrogen, the focus remains on public refuelling infrastructure, with private hydrogen refuelling stations expected to play only a minor role in very specific use cases.

In summary, while private refuelling solutions will cater to a small subset of fleets with specific needs, stakeholders expect publicly accessible refuelling infrastructure to handle the vast majority of hydrogen refuelling requirements. Publicly accessible refuelling stations are seen as essential for enabling the transition to hydrogen-powered transportation on a large scale, accommodating a wide range of vehicle types and operational demands.

Expected Outputs (350 bar, 700 bar, Liquid Hydrogen) by Vehicle Type

In Figure 46 the survey results indicating the stakeholders view on which hydrogen refuelling types that are relevant for the different use cases of heavy-duty vehicles.

Urban Delivery and Vocational Vehicles

Stakeholders indicate that urban delivery vehicles and vocational vehicles will primarily rely on 350 bar refuelling infrastructure, which is sufficient to meet their shorter range and lower energy requirements. These vehicles typically operate within predictable routes and/or shorter distances, making high-output hydrogen refuelling unnecessary.

Regional Lorries

For regional lorries, 350 bar solutions are expected to dominate due to their compatibility with moderate range requirements. However, stakeholders note that 700 bar refuelling may become relevant for more intensive regional operations where higher energy storage is needed to support longer or more demanding routes.

Long-Haul Lorries

Long-haul lorries are expected to rely heavily on 700 bar refuelling infrastructure. This output level is necessary to support the extended ranges required for long-distance freight transport. Stakeholders emphasize that 700 bar systems provide the energy density and refuelling speed needed to minimize downtime during long-haul operations.

Buses and Coaches

Stakeholders foresee a split in refuelling requirements for buses and coaches. Urban buses are expected to utilize 350 bar refuelling, aligning with their shorter, intra-city routes. For long-distance coaches, however, both 700 bar and liquid hydrogen may be relevant, as these vehicles require higher energy densities to cover extended routes efficiently. That said, the adoption of liquid hydrogen remains uncertain and is likely to be limited to specific use cases or will simply not be used in the market. A few interviewed stakeholders mentioned liquid as something they saw as viable. Furthermore, only a single OEM is currently going to bring a liquid H2 HDV to market as per Section 3.1.

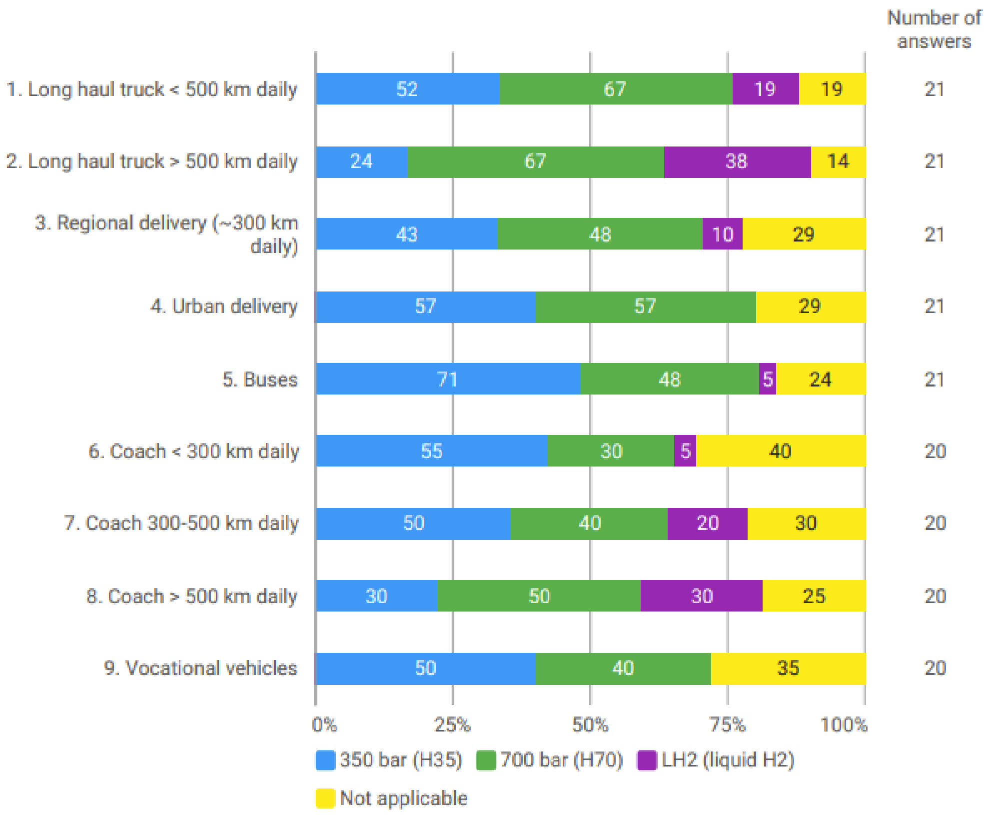

Figure 46. Survey results for the question "Which hydrogen refuelling types are relevant for the different use cases of heavy-duty vehicles?"

4.1.3. CHARGE POINT OPERATORS ON THE EXISTING RECHARGING MARKET

CPOs are integral to the electrification of eHDVs navigating current challenges while preparing for future growth. The deployment of high-power recharging infrastructure remains costly, with grid connectivity limitations and lengthy permitting processes adding to the complexity. According to stakeholders and EAFO existing recharging infrastructure is largely centered around 350 kW chargers, with a growing focus on higher-capacity solutions such as 600 kW and beyond, particularly in Western Europe along freight corridors and logistics hubs although these are still at an experimental level [16], [64], [65].

CPOs do according to the involved stakeholders recognize this period as both an opportunity and a challenge. The anticipated growth in eHDV adoption requires scaling infrastructure to meet 2030 targets, but high costs, regulatory barriers, and grid capacity constraints continue to slow progress. To address these challenges, many CPOs are advocating for public-private partnerships and government incentives to support and accelerate deployment.

To accommodate growing demand, CPOs are focusing on deploying high-power chargers (350–1,000 kW) at strategic locations such as TEN-T corridors, logistics hubs, and rest areas frequently used by HDVs. These locations are carefully selected to maximize utilization by aligning with established freight routes and operational patterns of logistics fleets. However, finding suitable land for these installations presents significant challenges.

Many CPOs are turning to greenfield developments where they can build infrastructure from the ground up. This approach allows them to design sites optimized for HDV operations, including space for large vehicles, high-capacity chargers, and amenities for drivers. In addition, some CPOs are incorporating secure parking facilities into these developments, addressing the growing demand for safe and secure rest areas. These parking areas often include features like fencing, CCTV, and driver amenities, enhancing both security and usability.

Conversely, retrofitting existing locations poses greater challenges. Stakeholders note that implementing the necessary upgrades – such as space for high-power chargers, grid connections, and enhanced security features – can be significantly more complex and costly at brownfield sites. Existing land use, limited space, and regulatory hurdles further complicate these projects, making greenfield development an increasingly attractive option for CPOs.

Operators and logistics companies want to ensure that recharging infrastructure aligns with operational requirements. Flexible business models, including subscription-based and pay-per-use options as well as booking options help address varying demand levels. Additionally, integrating renewable energy and on-site storage solutions is a priority, as these measures reduce strain on the grid, enable recharging during off-peak hours, and facilitate deployment in areas with limited grid capacity.

4.1.4. CHARGING POINT OPERATORS' RECHARGING MARKET OUTLOOK TOWARDS 2030

By 2030, the demand for high-power recharging infrastructure is expected to grow significantly as more fleets transition to electric heavy-duty vehicles (HDVs). According to CPOs and other stakeholders, a gradual shift toward higher-capacity chargers, particularly those using Megawatt Charging System (MCS) technology, is anticipated to support long-haul operations. However, the Combined Charging System (CCS) is expected to remain relevant in applications such as regional logistics, urban logistics, and depot recharging. Reports suggest that the market will continue to include a mix of both standards, reflecting the diverse needs of fleet operators and operational scenarios.

Stakeholders indicate that the roll-out of MCS is seen as pivotal for enabling HDVs to recharge efficiently during mandatory rest breaks, making it well-suited to long-haul fleets. However, they emphasize that widespread deployment will depend on significant investments and coordinated standardization efforts. This is specifically to ensure to MCS becomes the one dominating standard and that communication protocols such as ISO 15188-20 also becomes standard across the market.[66]

CPOs report efforts to integrate renewable energy sources as well as battery energy storage systems (BESS) into their infrastructure. This approach, they argue, will help mitigate grid constraints, enhance sustainability, and make high-power recharging more feasible, even in areas with limited grid capacity.

Regulatory frameworks, such as AFIR, are frequently highlighted by stakeholders as critical drivers of investment in both CCS and MCS technologies. These regulations set clear requirements for the deployment of high-power chargers along key freight corridors, ensuring comprehensive network coverage. However, some stakeholders caution that deployment timelines could fall short without increased government incentives and streamlined permitting processes for sites as well and faster delivery of the requested power from the grid connection.

Despite these optimistic expectations, stakeholders also point to significant challenges. Grid limitations, including slow upgrade processes and insufficient capacity in high-demand areas, are cited as ongoing bottlenecks. Additionally, deploying chargers in rural or low-traffic regions is viewed as economically challenging, prompting calls for targeted subsidies and policy interventions to ensure uniform infrastructure coverage across Europe.

Looking ahead, stakeholders expect the market to feature thousands of high-power chargers, including MCS-capable stations, strategically placed along key corridors and logistics hubs. Reports emphasize that standardization and interoperability will be critical for ensuring compatibility across networks, while innovations such as automation and smart grid integration are likely to enhance efficiency and reliability. Achieving this vision, however, is seen as contingent on continued collaboration among industry stakeholders, governments, and energy providers to address challenges and build a robust, equitable recharging infrastructure.

CCS vs. MCS for Heavy-Duty Vehicle Recharging Standards

CCS remains the predominant recharging standard for HDVs today, particularly for regional and urban delivery lorries. Its power delivery, typically up to 350 kW, suits fleets with predictable routes and less time-sensitive operations. However, its limitations in power output and recharging speed mean it may become less practical for demanding use cases, such as long-haul freight transport, as the market evolves [67].

MCS, on the other hand, is expected to increasingly cater to high-power applications, including long-haul lorries. Unlike CCS, MCS is not restricted to extremely high-power recharging but supports a flexible range of power outputs, from lower levels like 100 or 200 kW, suitable for overnight recharging, to high-power levels of up to 3.5 MW for fast recharging. This adaptability is crucial for diverse use cases, as fast recharging enables substantial energy replenishment during legally mandated driver rest breaks, a key factor for maintaining fleet efficiency [68], [69].

CPOs and vehicle manufacturers have identified MCS as the likely future primary standard for BEV HDVs. Although the system can theoretically deliver up to 3.5 MW, most operators agree that outputs between 700 kW and 1.2 MW are sufficient for most operational needs. Moreover, the operational flexibility of MCS aligns with the diverse demands of HDVs, ensuring minimized downtime and the ability to handle significant energy requirements.

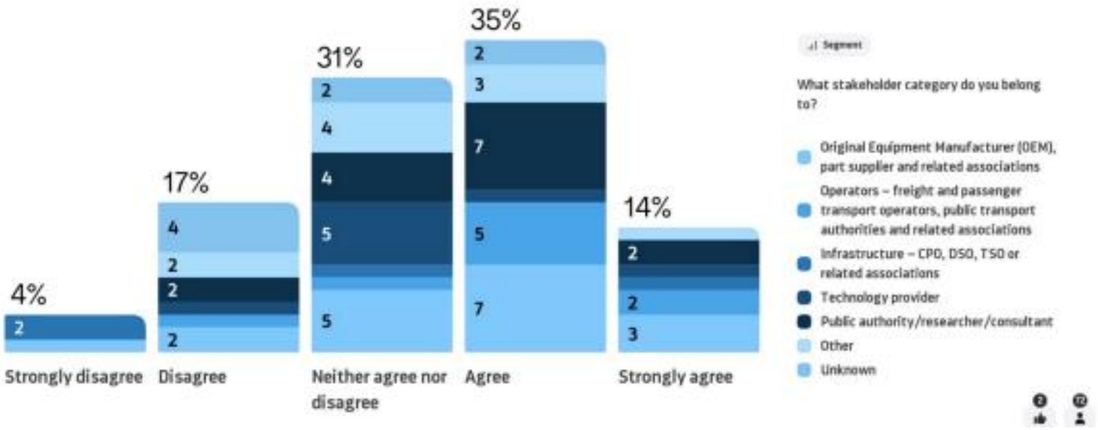

Figure 47. Stakeholders answer to whether they agree with the following statement: "The operational requirements of the vast majority of use cases can be met with CCS, but MCS offers both operational advantages and greater safety, so it can be expected to become the primary technology for BEV HDVs over time".

In Figure 47, a survey highlights stakeholder perceptions of MCS versus CCS, showing agreement that MCS offers operational advantages and greater safety over CCS, making it the preferred long-term technology for BEV HDVs.

4.1.5. CHARGING POINT OPERATORS' PERSPECTIVES ON REQUIRED OUTPUTS

CPOs generally regard 1.2 MW as the upper limit necessary to meet long-haul HDV recharging needs during mandatory driver rest breaks. This level allows vehicles to gain substantial range – more than sufficient for the remaining part of a daily route. Nevertheless, this high output will only be needed in extreme cases and most recharging would be done by lower output. Some CPOs state that this high output will be needed in very few cases, and it consequently might not be economically viable to use this output at any but a few recharging stations.

For most use cases, outputs between 350 kW and 700 kW are considered adequate. These levels provide a good balance, enabling meaningful range extensions during rest breaks while remaining more economical and easier to deploy than higher-capacity systems. Stakeholders emphasize that these outputs align well with fleet operational patterns and are less demanding on the grid.

For overnight recharging scenarios, where vehicles are parked for extended periods, outputs between 100 kW and 250 kW are often seen as sufficient. This is also the level of output seen at most public recharging hubs today and CPOs expect to continue adding chargers in this range.

While MCS is expected to play a critical role in addressing the high-power recharging needs of long-haul logistics, the CCS is likely to retain relevance in several key segments due to its established infrastructure and suitability for less demanding applications.

In regional and urban logistics, CCS remains an economical and widely adopted solution. These operations often have less stringent recharging speed requirements, allowing CCS chargers – typically delivering up to 350 kW – to efficiently meet fleet needs. The lower power requirements of these applications make CCS a practical and cost-effective choice.

In depot recharging scenarios, where vehicles have extended downtime, CCS is particularly well-suited. Fleets can rely on slower, overnight recharging to replenish battery levels without requiring the faster speeds of MCS. This approach minimizes infrastructure costs while providing sufficient energy to support daily operations, making CCS an integral part of fleet recharging strategies.

As the market evolves, CPOs are carefully balancing investments in both CCS and MCS technologies. This dual approach ensures they can meet the diverse needs of fleets, providing effective solutions for long-haul applications while continuing to serve regional, urban, and depot recharging requirements. By doing so, CPOs position themselves to support the wider adoption of MCS while maintaining the flexibility to address various operational demands.

4.1.6. HYDROGEN REFUELLING STATION (HRS) OPERATORS ON THE MARKET

HRS Operators on Current Market Perspective

HRS Operators view the current market for hydrogen with cautious optimism. Stakeholders indicate that the regulatory framework provided by AFIR sets a foundational structure for development.

However, challenges such as high capital costs for stations and uncertain demand continue to hinder expansion. Operators face a chicken-and-egg dilemma: whether to pre-emptively expand infrastructure or wait for stronger signals of fleet adoption from logistics companies and original equipment manufacturers (OEMs). Many OEMs and fleet operators remain hesitant to invest in hydrogen-powered fleets until the infrastructure becomes more widely accessible, delaying broader market adoption.

HRS operators also note that current demand is unevenly distributed. A significant portion of the demand is concentrated in Germany and northwestern Europe, driven by progressive policies and early adoption in these regions [70]. In contrast, demand in other countries primarily comes from public buses, which are often refuelled at dedicated facilities rather than public stations [71]. This creates challenges for scaling infrastructure, as private investment in low-traffic regions is financially unfeasible without public subsidies or co-investment mechanisms [72].

Future HRS Market Outlook Towards 2030

Looking ahead to 2030, HRS operators anticipate growth in network density, but the pace will depend on public funding and targeted policies to mitigate financial risks in low-demand areas. While AFIR mandates hydrogen refuelling stations every 200 km along the TEN-T core network, stakeholders caution that achieving this will require substantial public subsidies. Some Operators emphasize the necessity of minimal national targets for hydrogen refuelling infrastructure beyond AFIR to ensure a dense and accessible network capable of supporting zero-emission vehicles. The industry also calls for high ambition in deploying both hydrogen and electric recharging infrastructure, stressing that these technologies are complementary and critical to achieving EU emission reduction targets [73], [74].

Operators foresee a mix of hydrogen delivery methods and outputs:

- **350-bar dispensers** will likely remain relevant for regional and urban delivery lorries.
- **700-bar dispensers** are expected to dominate long-haul lorry applications due to their alignment with operational needs such as range and refuelling speed.
- **Liquid hydrogen** could serve niche applications where higher energy density is critical, although its infrastructure is less mature and will require further investment and development.

Operators highlight the importance of timely decision-making and policy support, emphasizing that transitioning from legislation to deployment takes significant time and investment. Without sufficient infrastructure density by 2030, the commercialization and adoption of hydrogen-powered heavy-duty vehicles will face significant hurdles.

4.1.7. STAKEHOLDERS ON ELECTRIC ROAD SYSTEMS (ERS)

An Electric Road System (ERS) supplies electric power to vehicles traveling on it, enabling dynamic recharging while in motion. This technology reduces the reliance on large onboard batteries and minimizes downtime for recharging. ERS implementations fall into three main categories:

(1) **Conductive Overhead Lines:** Vehicles draw power from overhead wires using pantographs, much like trolleybuses.

(2) **Conductive Rails**: Power is delivered through rails embedded in or on the road surface, accessed via current collectors.

(3) **Wireless Inductive Recharging**: Power is transferred wirelessly through electromagnetic fields using coils embedded in the road [75].

Stakeholders hold a range of views on ERS as a potential solution for the electrification of HDVs. While some stakeholders see ERS as a promising technology for specific applications, others express concerns about its scalability and funding challenges.

One key issue raised by some stakeholders is the limited access to funding for ERS, particularly when compared to stationary recharging. The lack of access to funding creates an additional hurdle for ERS projects, which require substantial investment in infrastructure along highways. Some stakeholders have expressed the need for more dedicated financial support to develop ERS networks, especially in the initial phases.

In terms of viability, certain logistics companies and large fleet operators see ERS as a viable option for long-haul freight transport, particularly on heavily trafficked corridors like the TEN-T network. ERS offers the potential to reduce vehicle battery size and reliance on stationary recharging infrastructure, thus potentially lowering costs. However, there are also significant disadvantages noted by stakeholders, particularly regarding the high costs of installation, as well as the need for retrofitting vehicles with pantograph systems to access overhead or in-road recharging infrastructure.

Some stakeholders, particularly infrastructure providers, point to the technical readiness of ERS, with pilot projects in countries like Sweden[76] and Germany [77]demonstrating the technology's capability in real-world conditions. The ELISA project in Germany, for instance, has shown positive results in terms of energy efficiency and integration with existing road networks[78]. However, there are still concerns about the broader scalability of ERS across Europe. The Swedish test has recently concluded that it would be too costly for Sweden to be a first mover in regard to ERS due to it dependency of other countries. They do still however wish to follow the development of the technology.

The complexity of integrating ERS into existing infrastructure, combined with funding challenges and the need for further technological refinement, are seen as significant barriers to widespread adoption in the short term. Furthermore, ERS is not expected to play a significant role in the electrification of heavy-duty vehicles at least before 2030, as the technology is still in its developmental phase and requires substantial infrastructure investment and policy support to scale up.

Stakeholders have provided key inputs to what the market foresee in terms of need for recharging/refuelling infrastructure now and towards 2030.

For BEVs the need for publicly accessible recharging infrastructure is largely determined by the use case where especially long-haul and coaches will have a high dependency on publicly accessible recharging infrastructure while urban delivery lorries, buses and vocational vehicles will primarily recharge at depots/private recharging infrastructure. Regional lorries may need publicly accessible recharging infrastructure depending on the routes/use case which may vary.

With longer routes larger outputs (kW) becomes increasingly important. Stakeholders expect overnight charging to have utilization rates between 25-50% depending on the operations. There is great uncertainty on utilization rates for the publicly accessible recharging infrastructure as stakeholders expect these to be 2-30%. This will greatly impact the need for recharging infrastructure.

CPOs do investment in both CCS and MCS technologies and expect the market towards 2030 to feature thousands of high-power chargers, including MCS-capable stations, strategically placed along key corridors and logistics hubs. This is however often hampered by grid limitations, including slow upgrade processes and insufficient capacity in high-demand areas, are cited as ongoing bottlenecks.

For H2 vehicles a minority of fleet operators is expected to have private refuelling infrastructure. Instead, the operators will be mostly depending on a publicly accessible infrastructure in their operations. A mix of outputs are expected with a greater emphasis on 700 bar for use cases of longer distance.

Electric Road Systems (ERS) are unlikely to significantly contribute to HDV electrification before 2030 due to the technology's early development stage and the need for extensive infrastructure investment and policy backing.

4.2. VEHICLE SPECIFICATIONS AND USE CASES

Dividing vehicles into categories based on their driving and recharging patterns is essential for understanding their specific recharging and refuelling infrastructure needs. Different driving styles, such as urban delivery, regional transport, long-haul operations, and vocational use, impose distinct demands on vehicle range, recharging/refuelling speeds, and infrastructure locations. For example, BEV urban delivery lorries typically operate on short, predictable routes and can rely on lower-output depot recharging, while BEV long-haul lorries require high-power public infrastructure to enable rapid recharging during extended journeys. Similarly, the unique operational patterns of buses, coaches, and vocational vehicles necessitate tailored infrastructure solutions to optimize their efficiency.

Table 10 Overview of groupings used in the use case and energy demand section the different EU groups of vehicles are divided into different categories based on their expected driving and recharging/refuelling patterns. Categorizing vehicles in this way allows stakeholders to align infrastructure development with the real-world demands of each vehicle type, ensuring effective support for zero-emission transport transitions.

Table 10 Overview of groupings used in the use case and energy demand section.

Category depending on driving and recharging/refuelling patterns	Corresponding to:
Urban Delivery Lorries	EU Groups 53, 54 (Urban Delivery lorries, 5–7.5 t) and Groups 1, 2, 3 (heavy lorries, 7.5–16 t)
Regional Lorries	EU Groups 4RD, 5RD, 9RD, and 10RD.
Long-Haul Lorries	EU Groups 4LH, 5LH, 9LH, and 10LH
Buses	M3 category - defined within the scope of Regulation (EU) 2024/1610
Coach	M2 Long-distance passenger transport, operating on fixed or semi-fixed routes with fewer stops compared to urban buses
Vocational Vehicles	EU groups 11, 12, 16, special axle configuration vehicles

It is important to note that the definition of vocational vehicles in this section differs from the legal definition provided in Section 3.4.1. This variation arises from the data available for this study. While Regulation (EU) 2024/1610 specifies some uses of special axle configuration vehicles as regional delivery, the lack of detailed data on the split between different mission profiles has led to all vehicles in Groups 11, 12, and 16 being categorized as vocational vehicles in this analysis.

Additionally, it is clear that vocational vehicles exist within other groups, such as 53v, 1sv, 1v, 2v, 3v, 4v, 5v, 9v, and 10v. However, these vehicles have also not explicitly modelled as vocational vehicles in this study due to the same data limitations. Likewise, not all vehicles registered as 11, 12 and 16 are vocational vehicles, that is 11v, 12v, 16v.

This grouping, which includes only around 1,400 ZEVs projected for 2030, has a minimal impact on the overall findings of this study. However, it is important to keep these distinctions in mind when reviewing the use case and energy demand sections of this report.

Further research focusing specifically on vocational vehicles across all relevant groups would be necessary to better understand their mission profiles and recharging needs.

4.2.1. VEHICLE SPECIFICATIONS AND USE CASES OF URBAN DELIVERY LORRIES

Urban delivery vehicles, categorized under EU Groups 53, 54 (Urban Delivery lorries, 5–7.5 t) and Groups 1, 2, 3 (heavy lorries, 7.5–16 t), are specifically designed for short-range, frequent-stop operations in dense urban environments. These vehicles are integral to the logistics chain, performing localized delivery and distribution tasks that require efficient energy use and flexibility.

Battery electric vehicles for urban delivery are expected to drive ranges of approximately 150 to 300 km on a full charge, which, based on the expected evolution in vehicle offerings described in section 5 of this report, aligns well with the operational demands of urban logistics, where daily driving distances typically fall between 100 and 250 km. BEVs for urban delivery predominantly rely on depot recharging, ensuring the vehicle begins the day fully charged. For routes that exceed a single battery cycle or involve multiple loops, opportunity recharging is often used. This supplemental recharging, usually conducted at logistics centers or during breaks on the route or during mandatory breaks needed for driver rest time, allows BEVs to extend their operational range. Publicly accessible recharging infrastructure, with power outputs of up to 350 kW, can also serve as a contingency option, though it is less commonly utilized in well-planned delivery operations.

H2 electric vehicles used for urban delivery provide ranges of 300 to 500 km, which should also be feasible based on the expected evolution in vehicle offerings described in section 5 of this report. H2s are refuelled mainly at public refuelling stations or integrated logistics hubs equipped with refuelling infrastructure. A single refuelling session, which takes approximately 5 to 15 minutes, is sufficient for a full day of operation, covering typical urban delivery routes. This rapid refuelling capability allows H2s to handle longer routes or more extensive delivery loops without significant downtime. Public hydrogen refuelling stations, where available, can support operational flexibility but are not typically the primary refuelling point for well-established delivery networks.

The table below lists the total number of local delivery vehicles both in group 53+54 and group 1+2+3 and their distribution by propulsion type (Battery Electric Vehicles, Hydrogen, and Other Types) as calculated for the study scenario in 2030.

In Table 11 below the expected number of Urban Delivery Lorries in 2030 can be found split according to propellants, while

Table 12 show the vehicle specifications for this category of HDVs.

Table 11. Numbers of Urban Delivery Lorries and split into BEV, H2 and other types of propellants.

Urban Delivery Lorries	Group 1+2+3 in 2030	Group 53+54 in 2030	Total Urban Delivery Lorries in 2030	% of Total
Total number	876,562	967,195	1,843,757	100%
Battery Electric (BEV)	21,951	41,294	63,245	3%
H2 Vehicles	906	1,284	2,190	0%
Other types of vehicles[19]	853,705	924,617	1,778,322	96%

Table 12. Vehicle specification of Urban Delivery Lorries

Urban Delivery Lorries	Average km/day from scenario	Expected range in km
Battery Electric	160	150-300
H2	160	300-400

In the text boxes a typical use case for a BEV and a H2 Urban Delivery Lorry, respectively, is presented. Understanding of these typical use cases provide fundamental info on the reliance on publicly accessible recharging/refuelling infrastructure and the types of

[19] Diesel, LPG and CNG/LNG, PHEV, Hydrogen ICE

recharging/refuelling points (kW/bar) needed. The use cases are primarily based on stakeholders' accounts.

Use Case of Battery Electric Urban Delivery Lorries

A typical urban delivery day for a BEV begins with a fully charged battery, achieved through overnight depot charging. The first route of the day covers 50 to 100 km, with frequent stops averaging 5 to 15 minutes. These stops often coincide with delivery points and involve unloading or administrative tasks. After completing the initial loop, the vehicle may return to a depot or logistics center for an opportunity charge, typically lasting 30 to 60 minutes. This recharging session allows the vehicle to prepare for the afternoon loop, which spans another 50 to 100 km. At the end of the day, the vehicle returns to the depot, where it is plugged in for overnight recharging in preparation for the next day.

Use Case of H2 Urban Delivery Lorries

H2 Urban Delivery Lorries typically begin their day with a full hydrogen tank, refueled either the previous evening or the same morning at a logistics hub or hydrogen station. The first delivery loop generally covers 100 to 150 km, with stops lasting 5 to 15 minutes at each delivery point. Depending on the distance covered, the vehicle may refuel midday at a hydrogen station, a process that takes only 5 to 15 minutes. After refuelling, the vehicle embarks on a second delivery loop, extending the day's total distance to 200 to 300 km. The vehicle is refueled again at the end of the day/the next morning, ensuring it is ready for the following day's operations.

4.2.2. VEHICLE SPECIFICATIONS AND USE CASES OF REGIONAL DELIVERY LORRIES

Regional delivery vehicles are categorized under EU Groups 4RD, 5RD, 9RD, and 10RD. These vehicles are designed to transport goods between regional hubs, distribution centers, and warehouses, often over medium-range distances that range between 200 and 500 km per day. Regional delivery operations prioritize consistent uptime, energy efficiency, and the ability to carry larger payloads than their urban counterparts. Their routes often include moderate stops for loading or unloading and extended driving periods on suburban and regional roads.

Battery electric vehicles (BEVs) for regional delivery are expected to achieve ranges of 300 to 500 km per charge, which, based on the expected evolution in vehicle offerings described in section 5 of this report, aligns well with the demands of regional logistics. BEVs predominantly rely on depot recharging as their primary energy source, often using high-power recharging infrastructure during overnight stops. Opportunity recharging at logistics hubs is also mentioned by stakeholders as critical for vehicles operating near the upper end of their range or undertaking multiple trips in a day. These sessions, lasting 1–2 hours at 150–350 kW, ensure sufficient energy for the remaining part of the day. Public recharging infrastructure is less commonly used but can serve as a fallback for unforeseen route changes or delays. Additionally, some stakeholders highlight that these vehicles might be utilized by multiple drivers throughout the day to improve the total cost of ownership (TCO), which could increase the demand for high-output chargers to ensure quick turnaround times.

Hydrogen vehicles (H2) for regional delivery are expected to achieve ranges of 400 to 800 km per refuelling, which is well-suited for routes requiring greater flexibility in range and payload handling. H2 vehicles will primarily rely on public hydrogen refuelling infrastructure, typically located near or at logistics hubs or along major freight corridors. These stations ensure operational flexibility and allow vehicles to maintain high uptime. A single refuelling session, lasting 10 to 20 minutes, is sufficient to support an entire day of regional delivery operations. The rapid refuelling process makes H2 vehicles particularly suitable for operations that require high uptime and quick turnaround between trips. However, some major operators may choose to invest in private hydrogen infrastructure if it aligns with their operational needs, offering greater control over refuelling logistics and costs. The table lists the total number of regional delivery lorries and their distribution by propulsion type (Battery Electric Vehicles, Hydrogen, and Other Types) as calculated for the study scenario in 2030.

In Table 13 below the expected number of Regional Delivery Lorries in 2030 can be found split according to propellants, while Table 13. Numbers of Regional Lorries and split into BEV, H2 and other types of propellants. show the vehicle specifications for this category of HDVs.

Table 13. Numbers of Regional Lorries and split into BEV, H2 and other types of propellants.

Regional Delivery Lorries	2030	%
Total number	571,166	100%
Battery Electric (BEV)	53,568	9%
H2 Vehicles	1,103	0%
Other types of vehicles[20]	516,495	90%

Table 14. Vehicle specification of Regional Lorries.

Regional Delivery	Average km/day from scenario	Expected range in km
Battery Electric	207	300-500
H2	207	400-800

In the text boxes a typical use case for a BEV and a H2 Regional Delivery Lorry, respectively, is presented. Understanding of these typical use cases provide fundamental info on the reliance on publicly accessible recharging/refuelling infrastructure and the types of recharging/refuelling points (kW/bar) needed. The use cases are primarily based on stakeholders' accounts.

Use case of Battery Electric Regional Delivery Lorry

A typical day for a regional delivery BEV starts with a fully charged battery, prepared via overnight depot charging. The first leg of the route covers 150 to 250 km, with occasional stops lasting 15 to 30 minutes for unloading or loading goods. If the total daily distance exceeds the vehicle's range, an opportunity charging session at a logistics hub is scheduled during a mandatory driver break. These charging sessions, lasting 1–2 hours at a power output of 150-350 kW, replenish enough energy to complete the second leg of the route, covering another 150 to 250 km. At the end of the day, the vehicle returns to the depot for overnight recharging.

[20] Diesel, LPG and CNG/LNG, PHEV, Hydrogen ICE

Use case of H2 Regional Delivery Lorry

A typical day for an H2 vehicle begins with a full hydrogen tank, refueled either the previous evening or early in the morning at a logistics hub or hydrogen station. The vehicle embarks on its first delivery loop, typically covering 150 to 250 km, with stops lasting 15 to 30 minutes at distribution centers or regional warehouses. After completing this loop, the vehicle may refuel at a nearby hydrogen station for 10 to 15 minutes, allowing it to undertake a second loop of 150-250 km. H2 vehicles generally complete their day with sufficient hydrogen to return to the depot or the nearest refuelling station.

4.2.3. VEHICLE SPECIFICATIONS AND USE CASES OF LONG-HAUL LORRIES

Long-haul lorries, categorized under EU Groups 4LH, 5LH, 9LH, and 10LH, are designed to meet the demands of extended freight transport across interstate or international routes. These vehicles prioritize high range, payload capacity, and uptime, as they typically transport goods over distances exceeding 500 km per day. Long-haul operations involve minimal stops, higher average speeds, and the need for reliable, zero-emission solutions.

Battery electric long-haul vehicles are expected to achieve ranges of 400 to 600 km per charge, depending on road conditions, payload, and driving patterns. BEVs for long-haul transport heavily rely on public recharging infrastructure on top of depot recharging, which supports their extensive operational requirements.

Given a typical driving cycle, Eurostat data indicates that the average journey length for international freight in Europe is approximately 611 km [79]. However, apart from this average use cases there are several different opportunities which are described in Use cases box below. This implies that long-haul BEVs running international freight routes will require a recharge mid-route to complete their journeys. For example, during a mandatory driver rest break of 45-60 minutes, a high-capacity charger with an output of 700 kW can provide a substantial range boost of approximately 200–300 km, depending on the vehicle's energy consumption. Overnight stops typically utilize lower-power chargers of 125–150 kW, enabling a full recharge of a within 8 hours.

Hydrogen-powered long-haul lorries are well-suited for routes requiring extended ranges of 400 to 800 km or higher uptime demands. These vehicles rely primarily on public hydrogen refuelling stations, strategically located along major freight corridors and near logistics hubs. Public refuelling infrastructure supports the flexibility needed for varied and unpredictable routes, while some major operators may invest in private refuelling infrastructure if it aligns with their specific operational needs.

A single refuelling session for hydrogen vehicles, typically lasting 10–20 minutes, provides enough fuel for a full day of operations, covering typical long-haul distances. Hydrogen’s rapid refuelling capability, combined with its higher energy density, makes it particularly suitable for long-haul transport, where minimizing downtime is critical.. This aligns with the expectations of stakeholders who anticipate a growing reliance on publicly accessible hydrogen stations to support the transition to zero-emission long-haul transport. Table 15 below lists the total number of heavy-duty lorries and their distribution by propulsion type (Battery Electric Vehicles, Hydrogen, and Other Types) as calculated for the study scenario in 2030 while Table 15. Numbers of Long-Haul Lorries and split into BEV, H2 and other types of propellants. show the vehicle specifications for this category of HDVs.

Long-Haul Lorries	2030	%
Total number	3,449,619	100%
Battery Electric (BEV)	238,970	7%
H2 Vehicles	65,053	2%

Other types of vehicles[21]	3,145,596	91%

Table 15. Numbers of Long-Haul Lorries and split into BEV, H2 and other types of propellants.

Long haul lorries	Average km/day from scenario	Expected range in km
Battery Electric	312	400-600
H2	312	400-800

Table 16. Vehicle specification of Long-Haul Lorries

In the text boxes a typical use case for a BEV and a H2 Long-Haul Lorry, respectively, is presented. Understanding of these typical use cases provide fundamental info on the reliance on publicly accessible recharging/refuelling infrastructure and the types of recharging/refuelling points (kW/bar) needed. The use cases are primarily based on stakeholders' accounts and eurostat[79].

[21] Diesel, LPG and CNG/LNG, PHEV, Hydrogen ICE

Use case of Battery Electric Long-Haul Lorry

A typical day for a long-haul BEV begins with a fully recharged battery, prepared overnight using a 125–150 kW charger at a depot. This ensures the vehicle starts the day with a full range, enabling it to cover approximately 380 km during the first 4.5 hours of driving. At this point, the vehicle typically has around 120 km of remaining range. During the mandatory driver rest period, recharging takes place at a publicly accessible station equipped with a high-capacity charger, typically ranging from 320 to 700 kW.

For an average second leg of 240 km, the vehicle requires around 240 kWh of energy, which can be replenished in 45–60 minutes with a 320 kW charger. For longer second legs of up to 380 km, up to 260 kWh of energy may be needed, requiring approximately 30–45 minutes with a 700 kW charger. At the end of the day, the vehicle returns to a rest stop or depot for overnight charging, ensuring full readiness for the next day's operations.

However, long-haul BEVs operate in diverse scenarios, reflecting the varied nature of logistics across Europe:

Depot-to-Depot Operations:
For structured logistics chains, the vehicle may travel directly between two depots, relying on private depot charging for both overnight and midday charging. In such cases, public charging may play a minimal role, as operations are designed to maximize efficiency within predictable routes.

Mixed Use Cases (Depot and Public Charging):
Some long-haul operations involve a mix of depot charging for the first leg and public charging during the driver's rest break. These scenarios are common when vehicles start at a depot but must continue beyond its range before returning. Public recharging infrastructure becomes essential for supporting the flexibility required for longer routes.

Non-Depot Starts:
In certain cases, long-haul journeys may begin at locations without access to private charging infrastructure, such as at customer sites, warehouses, or other third-party premises. Here, the vehicle starts with a partially charged battery and relies heavily on public recharging stations along the route to complete its journey.

High-Flexibility Operations:
Some use cases involve unpredictable routes or last-minute changes, requiring frequent reliance on a network of public high-power charging stations. For example, logistics companies operating in just-in-time delivery systems may require recharging at multiple public stations to maintain operational flexibility.

Extended Operating Hours:
For vehicles running beyond typical working hours or covering extended distances of up to 800 km in a single day, multiple recharging stops may be necessary. In such cases, high-capacity public chargers (e.g., 700 kW) play a critical role in minimizing downtime and enabling operations to continue seamlessly. This requires two drivers to share the same lorry in order to live up to driver rest time regulations

Use case of H2 Long-Haul Lorry

H2H2 vehicles for long-haul delivery begin the day fully refueled, typically at a depot or nearby hydrogen station. The vehicle's first leg covers 300-400km, with minimal stops except for driver breaks or minor adjustments at logistics hubs. If the route exceeds the vehicle's maximum range, a mid-route refuelling session is conducted at a hydrogen station along the highway, taking 10–15 minutes. After refuelling, the vehicle continues with its second leg, completing another 300 to 400 km. At the end of the day, the vehicle refuels at a logistics hub or hydrogen station to prepare for the next day's operations, ensuring no interruptions in availability.

4.2.4. VEHICLE SPECIFICATIONS AND USE CASES OF BUSES

Urban buses, defined under Regulation (EU) 2024/1610, fall into the M3 category, designed for passenger transport on fixed routes within cities and suburban areas. These buses are required to meet strict zero-emission targets, including a 90% zero-emission share by 2030 and 100% by 2035. Their daily operational ranges typically span 150–300 km, depending on route lengths, stop frequency, and schedules.

Battery electric buses (BEBs) are expected to achieve ranges of 200–300 km per charge, which, based on the expected vehicle selection described in Section 5 of this report, aligns with the operational needs of urban transit systems. BEBs primarily rely on depot recharging during overnight layovers, ensuring they are fully charged for daily operations. For routes exceeding this range, opportunity recharging at transit hubs or terminals during 15–30 minutes layovers is crucial. Public recharging infrastructure is less commonly used but remains a contingency for unexpected delays or route changes.

H2 Busses offer ranges of 300–500 km per refuelling, which, as outlined in Section 5, is achievable with the expected vehicles available by 2030. These ranges typically enable a full day of service on a single refuel. FCEBs refuel at dedicated hydrogen stations, typically located at depots or central transit hubs, with sessions lasting 10–20 minutes to minimize downtime. Public hydrogen stations are available in some areas but are generally not relied upon for urban operations.

Table 17 lists the total number of buses and their distribution by propulsion type (Battery Electric Vehicles, Hydrogen, and Other Types) as calculated for the study scenario in 2030, while Table 17. Numbers of Buses and split into BEV, H2 and other types of propellants. show the vehicle specifications for this category of HDVs.

Buses	**2030**	**%**
Total number	382,246	100%
Battery Electric (BEV)	87,247	23%
H2 Vehicles	1,269	0%
Other types of vehicles[22]	293,730	77%

Table 17. Numbers of Buses and split into BEV, H2 and other types of propellants.

Buses	**Average km/day from scenario**	**Expected range in km**
Battery Electric	164	200-300
H2	164	300-500

[22] Diesel, LPG and CNG/LNG, PHEV, Hydrogen ICE

Table 18. Vehicle specification of Battery Electric Buses.

In the text boxes a typical use case for a BEV and a H2 Bus, respectively, is presented. Understanding of these typical use cases provide fundamental info on the reliance on publicly accessible recharging/refuelling infrastructure and the types of recharging/refuelling points (kW/bar) needed. The use cases are primarily based on stakeholders' accounts.

Use case of Battery Electric Bus

A typical day for a BEV Bus starts with a fully charged battery from overnight depot charging. The bus operates on its first service block, covering 100–150 km over 4–5 hours with frequent stops of 2–5 minutes at each station. For longer routes, the bus may return to a transit hub during a scheduled layover for opportunity charging, replenishing sufficient energy in 15–30 minutes to complete the second service block. At the end of the day, the bus returns to the depot for overnight charging, ensuring full readiness for the next day.

Use case of H2 Bus

H2 buses begin the day fully refueled with hydrogen from the depot or a nearby hydrogen station. They operate continuously on their service route, covering 300–500 km over 12–16 hours, with frequent stops at transit stations. Due to their extended range, H2 buses typically do not require midday refuelling, completing their full schedule on a single tank. At the end of the day or the next morning, the bus refuels at the depot or hydrogen station, ensuring it is ready for the next day's operations.

4.2.5. VEHICLE SPECIFICATIONS AND USE CASES OF COACHES

Coaches are designed for long-distance passenger transport, operating on fixed or semi-fixed routes with fewer stops compared to urban buses. These vehicles typically travel 300–800 km per day, with operational patterns driven by schedules, passenger demand, and the need to minimize downtime.

Battery Electric Coaches (BECs) are expected to achieve ranges of 300–500 km per charge, which, based on the expected vehicle selection described in Section 5 of this report, aligns well with the requirements of long-distance operations. BECs rely on depot recharging during overnight layovers to ensure a full charge for the next day. For routes exceeding this range, opportunity recharging at transit hubs or rest areas during scheduled breaks is critical. High-power chargers, typically 350–700 kW, allow coaches to recharge enough energy in 45–60 minutes to complete their remaining journey. Public recharging infrastructure is essential for supporting longer trips where depot recharging alone is insufficient and not available.

H2 coaches utilize hydrogen tanks with capacities of 30–50 kg, providing ranges of 500–1000 km per refuelling. Hydrogen consumption averages 8–12 kg per 100 km, depending on route conditions and passenger loads. This extended range makes H2 coaches particularly well-suited for intercity and international routes requiring minimal downtime.

H2 coaches refuel at dedicated hydrogen stations, usually located at depots or transit hubs, with refuelling sessions lasting approximately 10–20 minutes. This quick refuelling capability makes H2 coaches particularly well-suited for intercity and international routes that require minimal downtime and high operational flexibility. Public hydrogen stations further support operations, especially for routes where depot-based refuelling is impractical or unavailable.

Making H2 ideal for long-distance routes where quick turnaround is essential. Publicly accessible hydrogen stations can also support operations on less predictable routes or in areas without established refuelling infrastructure.

In Table 19 below the expected number of Coaches in 2030 can be found split according to propellants, while Table 19. Numbers of Coaches and split into BEV, H2 and other types of propellants.

show the vehicle specifications for this category of HDVs.

Coaches	2030	%
Total number	415,048	100%
Battery Electric (BEV)	14,946	4%
H2 Vehicles	4,670	1%
Other types of vehicles[23]	395,433	95%

Table 19. Numbers of Coaches and split into BEV, H2 and other types of propellants.

Coaches	Average km/day from scenario	Range in km
Battery Electric	263	300–500
H2	263	500-800

Table 20. Vehicle specification of Coaches.

In the text boxes a typical use case for a BEV and a H2 Coach, respectively, is presented. Understanding of these typical use cases provide fundamental info on the reliance on publicly accessible recharging/refuelling infrastructure and the types of recharging/refuelling points (kW/bar) needed. The use cases are primarily based on stakeholders' accounts.

Use case of Battery Electric Coach

A typical day for a Battery Electric Coach starts with a fully charged battery from overnight depot charging or overnight public charging. The coach embarks on its first service block, covering 300-400 km over 4–5 hours, aligning with the first driver's shift. During the mandatory driver break, typically lasting 45–60 minutes, the coach utilizes a high-power charger at a transit hub or rest area to recharge, restoring sufficient energy for the next leg of the journey. If a second driver is onboard, the coach continues its operation seamlessly, covering an additional 300-400 km, with minimal delays for charging. At the end of the day, the coach returns to the depot for overnight charging, ensuring readiness for the next day.

Use case of H2 Coach

CECs begin the day fully refueled with hydrogen from a depot or nearby hydrogen station. The coach operates continuously on long-distance routes, covering 500–800 km over 8–12 hours. With two drivers alternating during mandated breaks, the coach minimizes downtime, allowing continuous operations. The extended range of FCECs enables them to complete the day's schedule without the need for additional refuelling. At the end of the day, the coach refuels at the depot or transit hub, ensuring it is fully prepared for the next day's service.

4.2.6. VEHICLE SPECIFICATIONS AND USE CASES OF VOCATIONAL

[23] Diesel, LPG and CNG/LNG, PHEV, Hydrogen ICE

VEHICLES

Vocational vehicles, as defined in Annex I of Regulation (EU) 2019/1242 encompass a wide range of specialized heavy-duty applications, including construction (e.g., tippers, concrete mixers), waste management (e.g., refuse collection), emergency services, and other industrial or municipal tasks. These vehicles are highly diverse in design and operation, tailored to meet the unique demands of their specific use cases. Daily operational patterns vary widely, with some vehicles focusing on short, repetitive tasks, while others require moderate-range capabilities and prolonged stationary operation for equipment use.

Under the Alternative Fuels Infrastructure Regulation (AFIR), vocational vehicles are not subject to infrastructure standards in 2030 unless they are zero-emission vehicles (ZEVs). This reflects their unique operational patterns and use cases, which differ significantly from standard long-haul heavy-duty vehicles. For ZEV vocational vehicles, infrastructure standards will apply to ensure alignment with EU decarbonization goals.

It is important to note again that for this study vocational vehicles will encompass all vehicles in the groups 11, 12, 16 and not specifically the legal definition of vocational vehicle. The reasoning is described in section 6.2.

Battery electric vocational vehicles typically feature large battery capacities ranging from 300 to 600 kWh, depending on the specific application. These vehicles achieve ranges of 150–300 km per recharge, sufficient for urban and regional operations where frequent stops and low-speed maneuvering are common.

They primarily rely on depot recharging overnight to ensure a full battery at the start of the day. For tasks with extended operating hours, opportunity recharging at central hubs or job sites may be required, particularly for vehicles with high auxiliary energy demands.

H2 vocational vehicles are not projected to be present in any significant number by 2030. Therefore, their typical use case is not covered in this study.

In Table 21 below the expected number of Vocational Vehicles in 2030 can be found split according to propellants, while Table 21. Numbers of Vocational Vehicles and split into BEV, H2 and other types of propellants.

Vocational	2030	%
Total number	339,847	100%
Battery Electric (BEV)	1,403	0%
H2 Vehicles	44	0%
Other types of vehicles	338,400	100%

Table 22 show the vehicle specifications for this category of HDVs.

Table 21. Numbers of Vocational Vehicles and split into BEV, H2 and other types of propellants.

Vocational	2030	%
Total number	339,847	100%
Battery Electric (BEV)	1,403	0%
H2 Vehicles	44	0%

Other types of vehicles[24]	338,400	100%

Table 22. Vehicle specification of Vocational Vehicles.

Vocational vehicles	Average km/day from scenario	Range in km
Battery Electric	171	150–300
H2	-	-

In the text box a typical use case for a BEV is presented. Understanding of these typical use cases provide fundamental info on the reliance on publicly accessible recharging infrastructure and the types of recharging points (kW/bar) needed. The use case is primarily based on stakeholders' accounts.

Use case of Battery Electric Vocational Vehicle

A typical BEV vocational vehicle starts the day fully charged from overnight depot charging. Operations vary widely, depending on the use case: a refuse lorry may travel 100–150 km while making frequent stops to collect waste, using significant auxiliary power for compaction; a construction tipper might operate within a 50 km radius of a job site, repeatedly moving materials over short distances. In some scenarios, opportunity charging is used during driver breaks or job site downtime to extend operational capacity. At the end of the day, the vehicle returns to the depot for recharging.

Understanding vehicle specifications and use cases is essential to designing suitable recharging and refuelling infrastructure in terms of output effects (kW/bar), locations, and numbers of recharging/refuelling points. For this reason, a regrouping is made to better describe how the vehicles as expected to be driven and recharged/refueled.

Both vehicle specifications and use cases vary between the different vehicle categories (urban, regional, long-haul, bus, coach, or vocational) leading to various recharging/refuelling needs. In general, the driving patterns with longer daily travelled distances of battery electric long-haul lorries and coaches make them more dependent on publicly accessible recharging infrastructure, while other types of BEVs may operate with no or very limited need for publicly accessible infrastructure. For H2 vehicles, most of the energy is expected to come from publicly accessible refuelling infrastructure.

[24] Diesel, LPG and CNG/LNG, PHEV, Hydrogen ICE

4.3. ENERGY DEMAND AND DEMAND FOR INFRASTRUCTURE

The energy demand based on energy consumption is deduced using technology specific efficiency factors as described in section 3.4.3.

4.3.1. BASIS OF ASSUMPTIONS IN ENERGY DEMAND

As described in the section above there are several ways to recharge/refuel a vehicle. Which infrastructure is relevant depends on the use cases. To evaluate the need for publicly accessible infrastructure, it is important to distinguish between private and publicly accessible infrastructure and have clear definitions of both:

Private recharging or refuelling

- Depot-based recharging or refuelling points located at company-operated facilities.
  - Assumed not to be publicly accessible, but some companies may open their infrastructure to other e.g. at certain operating hours to improve TCO, but this share is expected to be low and not meeting a significant share of demand for energy.
- Recharging or refuelling points at logistic centers or warehouses accessible only to vehicles engaged in business with those facilities.
  - Like for infrastructure at depots, this infrastructure is assumed not to be publicly accessible, even though some companies may open their infrastructure to the public. This is expected to be more prevalent compared to depots being open to others. But it is still considered private recharging.

Publicly accessible recharging or refuelling

On the other hand, public recharging or refuelling is defined as infrastructure that is publicly accessible to any vehicle operator, regardless of their business affiliation. Publicly accessible chargers and refuelling stations are typically installed along major transport routes, at urban nodes, or in publicly accessible logistics hubs. They are designed to cater to a wide range of users, including vehicles that are not directly tied to a specific company's operations. This includes:

- Stations installed along the TEN-T core network or other major corridors that are accessible to all HDVs.
- Recharging/refuelling points located at lorry stops, rest areas, and urban hubs where access is open to any vehicle operator.
- Publicly funded or privately owned infrastructure that allows unrestricted access, equipped with standardized payment systems to accommodate diverse users.

Utilization rates of recharging points

For the estimation of utilization rates of recharging infrastructure, we consider three categories based on the primary use cases of the chargers: those used for overnight recharging, those used during driver rest breaks, and ultra-fast chargers. These utilization rates are reflective of expected operational patterns and practical usage scenarios.

For chargers primarily used for overnight recharging, we estimate a utilization rate of 40%. This corresponds to a usage of just under 10 hours per day, which aligns well with the daily rest requirements for drivers as mandated by regulations. This utilization rate equates to slightly more than one vehicle per charger per day. While most of the usage will occur during nighttime hours, it is also possible that some long rest periods will be taken during the day, further increasing utilization. The combination of predictable usage patterns and extended recharging durations makes this 40% assumption a strong fit for this type of infrastructure.

For chargers used during driver rest breaks during the day, we estimate a utilization rate of 20%. This is based on the shorter recharging durations during breaks, which typically last between 45 minutes and 1.5 hours.[80] Considering the variability in route planning and the scheduling of rest breaks, these chargers are less likely to achieve continuous utilization throughout the day. However, their placement at key transit hubs ensures they are sufficiently utilized by vehicles on long-haul or regional routes.

For ultra-fast chargers of more than 600 kW, we assume a slightly lower utilization rate of 15%. These chargers are designed for both rapid top-ups during operational windows and recharging during driver rest breaks, with recharging sessions often lasting under 30 minutes. While they are critical for enabling flexibility and minimizing downtime, their shorter usage durations, and the need for strategic placement along key routes limit their overall utilization. Overall, these utilization rates are grounded in the specific use cases and expected operational patterns of each type of recharging infrastructure. In Table 23 the utilization rates are summarized. While actual utilization rates in 2030 will vary across Europe based on regional demand and infrastructure deployment, these assumptions provide a reasonable framework for calculating the capacity requirements and network efficiency of recharging infrastructure.

These utilization rate assumptions align well with estimations from other sources, which suggest similar patterns based on recharging behavior and infrastructure usage.[50], [61]

Table 23. Utilization rates depending on output (kW) of recharging point.

Utilization rates depending on type of publicly accessible charger (output in kW)					
Utilization rate	< 50 kW	50-150 kW	151-350 kW	351-600 kW	> 600 kW
Utilization rate	40%	40%	20%	20%	15%

Given the different assumed outputs the recharging points, the expected average kilowatt hours delivered per recharging point per day can be calculated (see Table 24 below) which can be used in the estimation of the number of recharging points needed to meet the total energy demand from Battery Electric HDVs to be provided by publicly accessible recharging points.

Table 24. Average kWh per day that a recharging point can deliver based on the given output levels and utilization rates from Table 23.

Average kWh per day per recharging point of publicly accessible recharging points[25]					
	< 50 kW *– assumed to be 50 kW*	50-150 kW *– assumed to be 100 kW*	151-350 kW *– assumed to be 250 kW*	351-600 kW *– assumed to be 475 kW*	> 600 kW *– assumed to be 700 kW*
Average kWh delivered per recharging point per day	480 kWh	960 kWh	1,200 kWh	2,280 kWh	2,520 kWh

Hydrogen Refuelling Station Capacity

Stakeholders provide differing estimates for the expected daily hydrogen capacity at refuelling stations in 2030. ACEA projects that hydrogen refuelling stations (HRS) along the TEN-T core network will have an average capacity of 2 t per day, emphasizing the need for stations to support the growing hydrogen-powered HDV fleet efficiently. This capacity aligns with the projected demand from long-haul freight operations and the high traffic expected along key corridors.

[25] It should be noted that the calculations take point of departure in recharging points and the energy that one recharging point can deliver. However, in many cases the recharger will have two recharging points and split the energy between the two if both recharging points are in use. This makes it harder to calculate the number of recharging points needed. Furthermore, it may pose a problem for the fleet operator as it will prolong the recharging session and make the operational planning process more complex.

T&E offers a more conservative estimate, assuming an effective daily output of 1.4 t per station, factoring in a 70% utilization rate. This projection accounts for potential underutilization in low-traffic regions or areas with slower hydrogen adoption rates. Meanwhile, AFIR mandates a minimum daily capacity of 1 t of hydrogen per station, setting the baseline for refuelling infrastructure but not necessarily reflecting the higher capacities projected by stakeholders to be needed at high demand road segments where market forces should provide for the additional capacity. These varying estimates highlight the challenges of forecasting a standardized capacity across stations, given the differing regional demands and adoption rates.

For this study, we assume each hydrogen refuelling station supplying an average of 1.4 t of hydrogen per day. This figure accounts for variability in station utilization, with some areas experiencing underutilization while others operate at or near full capacity. This is used by T&E in their calculation in their report 'Fully charged for 2030'.[61]

However, it is important to emphasize that this estimate is highly uncertain, as station capacities in the real world are likely to vary significantly. Capacities could range from the regulatory minimum of 1 tonne per day to as high as 6 t, as noted in another ACEA report, which highlights the need for higher capacities in specific high-traffic corridors to support intensive HDV operations.[50] This variability reflects the diversity of demand profiles across different regions and vehicle use cases, underscoring the importance of adaptive infrastructure planning.

One HRS should have the ability to allow rapid refuelling of lorries during peak hours. Therefore, it is important to note that each station should have more outlets where trucks can refuel similarly to how it is at diesel refuelling stations today. This ensures that there will be no time wasted waiting for the ability to refuel. This report will not state how many there should be at each as it will depend greatly on the expected traffic flow at each individual stop. That level of detail is not the goal of this report.

Average Hydrogen delivered from publicly accessible refuelling points per day.			
	350 bar	700 bar	LH2 (liquid H2)
Average kg delivered per refuelling point per day	1,400 kg		

Table 25. Average Hydrogen that a publicly accessible refuelling point is expected to deliver per day.

4.3.2. ENERGY DEMAND OF URBAN DELIVERY LORRIES AND DEMAND FOR INFRASTRUCTURE

Based on input from stakeholders as described in paragraph 4.1.1 and the use case of urban delivery lorries described in 4.2.1 it is assessed for BEVs that the split between private and publicly accessible recharging can be expected to be around 95% for private recharging and 5% publicly accessible recharging. The use case indicates never exceeds and rarely comes close to 300 km and with frequent stops which could be used for top-up at private opportunity chargers. The demand for 5% publicly accessible recharging is expected to come from smaller fleet operators who do not have their own recharging infrastructure and from top-up recharging in rarer situations. Table 26 show the overall energy demand from Battery Electric Urban Delivery Lorries.

		Energy MWh/year in split between	
	Energy MWh/day	Private recharging	Publicly accessible recharging
		95%	5%
2030	1,892,283 MWh	1,797,669 MWh	94,614 MWh

Table 26. Energy Demand from Battery Electric Urban Delivery Lorries.

Public Recharging Infrastructure and Energy Demand for Urban Delivery Lorries

For the 5% of energy demand fulfilled by public infrastructure, the expected split by output is mainly based on stakeholder input from the survey but corrected according to inputs from stakeholder interviews and use cases. The survey estimated a very high relevance for recharging above 350 kW, but most use cases for urban delivery indicate that this high output will not be needed. Therefore, we estimate that more of the expected power demand is in the range of 151-350 kW than the survey suggests. The split looks as follows:

- **10%** at outputs **below 50 kW**, expected for vehicles parked outside depots for overnight/long stay recharging.
- **20%** at outputs between **50–150 kW**, expected for vehicles parked outside depots for overnight/long duration recharging.
- **30%** at outputs **between 151–350 kW**, the most common for top up recharging during shorter layovers or route transitions. Fits with the theoretical charge speed needed for this use case.
- **20%** at outputs between **351–600 kW**, addressing higher power needs for rapid recharging.
- **20%** at outputs above **600 kW**, for scenarios requiring extremely fast energy replenishment.

In Table 27 the split between different types of publicly accessible recharging points as well as the energy demand for Battery Electric Urban Delivery Lorries can be found.

Table 27. Split between and Energy Demand from different types of Publicly accessible Recharging Points for Battery Electric Urban Delivery Lorries.

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	> 600 kW
Split	100%	10%	20%	30%	20%	20%
2030	94,614 MWh	9,461 MWh	18,923 MWh	28,384 MWh	18,923 MWh	18,923 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 28), we can now calculate the total number over recharging points needed.

Table 28. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric Urban Delivery Lorries

	Types of Rechargers depending on effect in kW				
Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	> 600 kW
195	57	45	45	25	22

Public Refuelling Infrastructure and Energy Demand for Urban Delivery Lorries

The Energy Demand from H2 is calculated based on the assumptions outlined in paragraph 4.3.1. In general, for this group, it is expected that most of their energy need will come from public refuelling with some coming from private refuelling as this group as stated in paragraph 4.2.1 often start and end their day in the same spot. This could be a use case where some operators might install their own refuelling infrastructure. However, there is great uncertainty about this as the market is not very mature for any of the use cases. For this group the assumption is that in average the split will be 80% of the energy demand be met by publicly accessible refuelling infrastructure and 20% will be covered by private infrastructure. Table 29 show the overall energy demand from H2 Urban Delivery Lorries.

Table 29. Energy Demand from H2 Urban Delivery Lorries.

Hydrogen		Energy kg H2/year in split between	
Urban Delivery Lorries	Energy kg H2/year	Private refuelling	Publicly accessible refuelling
		20%	80%
2030	3433409 kg H2	686682 kg H2	2746727 kg H2

Due to their relatively short ranges and the higher efficiency of lower bare refuelling pressure described in section 5.1 of the vehicle section it is expected that almost all the hydrogen for this use case will come from 350 bar refuelling.

In Table 30 the split between different types of publicly accessible refuelling points as well as the kg demand for H2 Urban Delivery Lorries can be found.

Table 30. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 Urban Delivery Lorries

		Types of Refuelling Points		
	Total kg H2	350 bar	700 bar	LH2 (liquid H2)
Split	100%	85%	15%	0%
2030	2,746,727 kg H2	2,334,718 kg H2	412,009 kg H2	0 kg H2

Based on the amount of kg that each of the refuelling points will be able to deliver (see Table 25), we can now calculate the total number over refuelling points needed – see Table 31.

Table 31. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 Urban Delivery Lorries

		Types of Refuelling Points		
	Total number of refuelling points	350 bar	700 bar	LH2 (liquid H2)
2030	8	7	1	0

4.3.3. ENERGY DEMAND OF REGIONAL LORRIES AND DEMAND FOR INFRASTRUCTURE

Public Recharging Infrastructure and Energy Demand for Regional Lorries

Based on stakeholder input and the use cases for regional lorries (EU Groups 4RD, 5RD, 9RD, and 10RD) described in paragraph 4.1 and 4.2.2, it is expected that 90% of the energy demand will be met through private depot recharging infrastructure, with the remaining 10% requiring public recharging infrastructure – see Table 32. These vehicles typically cover distances of 200-450 km daily, aligning well with the operational needs of depot-based recharging while utilizing public recharging for non-routine or extended routes.

Table 32. Energy Demand from Battery Electric Regional Lorries.

		Energy MWh/year in split between

	Energy MWh/year	Private recharging	Publicly accessible recharging
		90%	10%
2030	3,601,655 MWh	3,241,490 MWh	360,166 MWh

For the **10% of energy demand** fulfilled by public infrastructure, the split is based on the input from stakeholders and the described use case for the vehicles. This group can be one where driver rest times becomes relevant however not a lot of overnight recharging outside depots is expected therefore most of the recharging will be covered by high output chargers, but the use case does not need outputs of over 600 kW as the trip length involved simply does not constitute a need for top up at public recharging which would require this. Therefore, most of the expected power will be supplied between 151-600 kW with an equal split between them.

See the split assumed below which is also summarized in Table 33:

- **0%** at outputs below **50 kW**
- **15%** at outputs between **50–150 kW**, suitable overnight recharging scenarios.
- **30%** at outputs between **151–350 kW**, aligning with the predominant need for rapid recharging during operational stops. Possibly where the lorries disconnect from trailer and drives to a public recharging.
- **30%** at outputs between **351–600 kW**, offering higher power for quicker replenishment in operationally critical scenarios. This would be enough for any potential range extension needed for this use case of driving where only a small amount of extra power would be needed to reach the final destination.
- **15%** at outputs above **600 kW**, used sparingly if this is the one available at the recharging station. Not many use cases for this group will need this charger. But might be the one available to use or may be used for a shorter period than a full driver rest stop which there often are some in in the Regional delivery Use case[80]

Table 33. Split between and Energy Demand from different Types of Publicly accessible Recharging Points for Battery Electric Regional Lorries

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	> 600 kW
Split	100%	0%	15%	35%	35%	15%
2030	360,166 MWh	0 MWh	54,024 MWh	126,057 MWh	126,057 MWh	54,024 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 24), we can now calculate the total number over recharging points needed for Battery Electric Regional Lorries.

Table 34. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric Regional Lorries

		Types of Rechargers depending on effect in kW				
	Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
2030	596	0	130	202	168	62

Public Refuelling Infrastructure and Energy Demand for Regional Lorries

Energy Demand from H2 is calculated based on the assumptions outlined in paragraph 4.3.1. In general, for all groups it is expected that most of their energy need will come from public refuelling with some coming from private refuelling as this group as stated in paragraph 4.2.2 often start and end their day in the same spot. This could be a use case where some operators might install their own refuelling infrastructure. However, there is great uncertainty about this as the market is not very mature for any of the use cases. There will for this group be calculated with the average of 80% public and 20% private refuelling as shown in Table 35.

Table 35. Energy Demand from H2 Regional Lorries

Hydrogen		Energy kg H2/year in split between	
Regional Lorries	Energy kg H2/year	Private recharging	Publicly accessible refuelling
		20%	80%
2030	3,178,066 kg H2	635,613 kg H2	2,542,453 kg H2

Hydrogen-powered regional delivery lorries will primarily rely on **public hydrogen refuelling stations**, as private depot-based hydrogen refuelling infrastructure is less widespread. Based on use cases and stakeholder input from paragraph 4.1 and 4.2.2, it is estimated that:

- **70% of the hydrogen demand** will be met through **350-bar stations**, aligning with medium-range requirements and is the most efficient for conversion of energy to H2-
- **30% of the hydrogen demand** will utilize **700-bar stations**, suitable for extended range or higher payload flexibility.

Table 36. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 Regional Lorries

		Types of Refuelling Points		
	Total kg	350 bar	700 bar	LH2 (liquid H2)
Split	100%	70%	30%	0%
2030	2,542,453 kg H2	1,779,717 kg H2	762,736 kg H2	0 kg H2

Using assumptions on utilization rates from Section 6.3.1 (see Table 25), the total number of refuelling points required is calculated – see Table 37. These estimates ensure alignment with operational patterns, reflecting the expected throughput per refuelling point.

Table 37. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 Regional Lorries

		Types of Refuelling Points		
	Total number of refuelling points	350 bar	700 bar	LH2 (liquid H2)
2030	7	5	2	0

4.3.4. ENERGY DEMAND OF LONG-HAUL LORRIES AND DEMAND FOR INFRASTRUCTURE

Public Recharging Infrastructure and Energy Demand for Long-Haul Lorries

Based on the use cases for long-haul lorries (EU Groups 4LH, 5LH, 9LH, and 10LH) described in paragraphs 6.1 and 6.2.3, it is estimated that 45% of the energy demand will be met through public recharging infrastructure, while 55% will rely on private depot recharging. These vehicles typically cover distances exceeding 500 km daily but may require a combination of depot recharging for overnight stops and public high-power recharging during operational breaks.

This estimation considers the evolution in possible driving ranges expected by 2030, as outlined in paragraph 5.2.2, which suggests that a greater portion of energy demand will be met through private depot recharging than previously anticipated. The improved driving range, combined with the fact that 97% of HDV journeys in Europe are under 800 kilometres [82], implies that in the vast majority of cases, lorries will only need to recharge enough to cover less than 400 kilometres of range during their journeys. This means that most trips will require, at most, a single recharge on publicly accessible infrastructure.

The use cases for long-haul lorries in Europe also highlight the diversity in operational patterns, which directly influence recharging requirements. While many lorries may begin their trips fully charged from a depot, not all operations follow a depot-to-depot model. Some journeys start or end at locations without private recharging infrastructure, necessitating reliance on public recharging stations. On average, lorries may require recharging to cover distances of 200-250 kilometres between stops, but operational needs and rest requirements create variations.

This variability translates into different recharging needs depending on the trip profile. For example, if a lorry only needs to recharge 150 kWh during a 45-minute mandatory rest break, it can rely on a 350 kW charger, as this is sufficient to meet the energy demand within the allotted time. Explicitly considering such scenarios allows for more tailored infrastructure planning, ensuring that both high-power and lower-power chargers are strategically deployed to meet demand efficiently. Table 38 show the overall energy demand from Battery Electric Long-Haul Lorries.

Table 38. Energy Demand from Battery Electric Long-Haul Lorries

		Energy MWh/year in split between	
	Energy MWh/year	Private recharging	Publicly accessible recharging
		55%	45%
2030	24,369,706 MWh	13,403,338 MWh	10,966,368 MWh

Long-haul transport represents the use case with the highest energy consumption and the greatest reliance on public recharging infrastructure. As a result, it is also the segment with the most detailed estimations for energy demand and charger distribution. While other reports suggest that a majority of public recharging for long-haul lorries will require ultra-high-power chargers (700–1200 kW or more), this study finds that such high outputs may not be necessary to the same extent.

Based on stakeholder input (Section 5.1.) and the use case analysis (Section 5.3), the estimated need for 700–800 kW chargers is significantly lower. Only 35% of long-haul stops are expected to last 30–60 minutes, while 25% are between 1–3 hours, and the majority of remaining stops are overnight, lasting 8–23 hours.[80] Given these patterns, and considering that the average HDV travels 530 km per day[79], much of the required public infrastructure could consist of overnight chargers or chargers with outputs between 350–600 kW, rather than predominantly relying on ultra-high-power chargers.

For the **45% of energy demand** fulfilled by public infrastructure, the expected split by output is:

- **0%** at outputs below **50 kW**, used in limited overnight scenarios.
- **10%** at outputs between **50–150 kW**, primarily for less time-sensitive recharging needs. Not mentioned by many CPOs as something they will put up.

- **30%** at outputs between **151–350 kW**, suitable for moderate replenishment during rest breaks and also for overnight 350-400chargers with two charge points is expected to be used based on stakeholder inputs.
- **30%** at outputs between **351–600 kW**, aligning with the demand for efficient range replenishment and the one which fits with most long-haul trips which needs about 150-200km of extra range.
- **30%** at outputs above **600 kW**, used for rapid energy replenishment during mandatory driver rest breaks for the long-haul trips where a full range after the driver rest stop.

The table below outlines the energy demand split for public recharging by output type in 2030, as derived from stakeholder feedback in paragraph 4.1 and 4.2.3.

Table 39. Split between and Energy Demand from different Types of Publicly accessible Recharging Points for Battery Electric Long-Haul Lorries

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
Split	100%	0%	10%	30%	35%	25%
2030	10,966,368 MWh	0 MWh	1,096,637 MWh	3,289,910 MWh	3,838,229 MWh	2,741,592 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 24), we can now calculate the total number over recharging points needed as shown by Table 40.

Table 40. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric Long-Haul Lorries

		Types of Rechargers depending on effect in kW				
	Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
2030	16,169	0	2,636	5,271	5,125	3,138

Public Refuelling Infrastructure and Energy Demand for Long-Haul Lorries

The total estimated energy demand for hydrogen-powered long-haul lorries is 403,932 t H2/year, based on the study scenario. This is expected to be met with an estimated split of 90% public refuelling and 10% private refuelling as shown by Table 41. This split is expected based on stakeholder input and the fact that most use cases for long haul lorries will be starting routes from other places than their depot and therefor there will not be many operators who will invest in private depot recharging.

Table 41. Energy Demand from H2 Long-Haul Lorries

Hydrogen		Energy kg H2/year in split between	
Long-Haul Lorries	Energy kg H2/year	Private recharging	Publicly accessible refuelling
		10%	90%
2030	403,932,344 kg H2	40,393,234 kg H2	363,539,109 kg H2

Based on operational requirements outlined in Sections 6.1.2 and 6.2.3, it is estimated that:

- **70% of the hydrogen demand** will be met through **700-bar stations**, aligning with the need for extended range and rapid refuelling.
- **25% of the hydrogen demand** will utilize **350-bar stations**, particularly for shorter-range long-haul operations.
- **5% of the hydrogen demand** may utilize **liquid hydrogen refuelling**, which can support niche applications requiring ultra-long range or higher energy density. As stated in section 2.1 there is only currently one OEM who is betting on liquid storage for long haul operations.

The total estimated energy demand for hydrogen-powered long-haul lorries is **353,539 t H2/Year**, based on stakeholder inputs and expected vehicle specifications. Based on the above the split between the different types of publicly accessible refuelling points for H2 Long-Haul Lorries as well as the Energy Demand can be found.

Table 42. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 Long-Haul Lorries

		Types of Refuelling Points		
	Total kg	350 bar	700 bar	LH2 (liquid H2)
Split	100%	20%	75%	5%
2030	363,539,109 kg H2	72,707,822 kg H2	272,654,332 kg H2	18,176,955 kg H2

Using assumptions on capacity (see Table 25), the total number of H2 refuelling points required is calculated in Table 43. These calculations ensure alignment with operational patterns and the throughput per refuelling point.

Table 43. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 Long-Haul Lorries

		Types of Refuelling Points		
	Total number of refuelling points	350 bar	700 bar	LH2 (liquid H2)
2030	1048	210	786	52

4.3.5. ENERGY DEMAND OF BUSES AND DEMAND FOR INFRASTRUCTURE

Public Recharging Infrastructure and Energy Demand for Buses

Based on the use cases for urban and intercity buses described in sections 4.1 and 4.2.4 it is estimated that 100% of the energy demand will be met through private depot recharging infrastructure, with the remaining 0% requiring public recharging infrastructure. Buses typically operate on fixed routes with daily distances ranging from 150 to 300 km, aligning well with overnight depot recharging and some opportunity recharging during operational stops. With this section primarily being city buses it must be expected that most if not all of their recharging needs will be met at private depots. [81]

Therefor there is not calculated with any part of this use case needing public recharging. There might be niche cases where there would arise a need for public recharging, but it has not been mentioned by stakeholders nor found in literature.

Table 44. Energy Demand from Battery Electric Buses

		Energy MWh/year in split between

	Energy MWh/year	Private recharging	Publicly accessible recharging
		100%	0%
2030	5,080,283 MWh	5,080,283 MWh	0 MWh

Public Refuelling Infrastructure and Energy Demand for Buses

Based on input from stakeholders, as described in paragraph 4.1 and 4.2.4, it is estimated that hydrogen refuelling for buses will be split approximately 70% private refuelling and 30% public refuelling. This estimation reflects the varied approaches observed in existing hydrogen refuelling projects, where some prioritize private infrastructure while others rely on public refuelling. Given this diversity, the assumption of a 70/30 split aligns with stakeholder expectations and the trends identified in current projects studied during this analysis. [71], [82], [83].

Table 45. Energy Demand from H2 Buses

Hydrogen		Energy kg H2/year in split between	
Buses	Energy kg H2/year	Private Refuelling	Publicly accessible refuelling
		30%	70%
2030	4,907,239	1,472,172	3,435,067

For this study, there will be assumed a 70% split for 350 bar public refuelling and 30% for 700 bar public refuelling for city buses. This allocation reflects the primary use case of city buses, which predominantly utilize 350 bar systems due to their compatibility with larger hydrogen tanks and the lower compression energy required. The 30% allocation for 700 bar refuelling ensures flexibility for vehicles that may require higher energy density, such as buses with extended range needs or lighter hydrogen vehicles using shared infrastructure. This split aligns with the expected operational requirements of city buses and supports a balanced development of public hydrogen refuelling infrastructure. Table 46 shows the split between different types of publicly accessible refuelling points for H2 buses.

Table 46. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 Buses

		Types of Refuelling Points		
	Total kg	350 bar, kg H2	700 bar, kg H2	LH2 (liquid H2), kg H2
Split	100%	70%	30%	0%
2030	3,435,067	2,404,547	1,030,520	0

Based on capacity and the amount of kg that each of the refuelling points will be able to deliver (see Table 25), we can now calculate the total number over refuelling points needed for H2 Buses. The results are shown by Table 47.

Table 47. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 Buses

		Types of Refuelling Points		
	Total number of	350 bar	700 bar	LH2 (liquid H2)

	refuelling points			
2030	10	7	3	0

4.3.6. ENERGY DEMAND OF COACHES AND DEMAND FOR INFRASTRUCTURE

Public Recharging Infrastructure and Energy Demand for Coaches

Based on the use cases for coaches described in Sections 4.1.1 and 4.2.6, it is estimated that 50% of the energy demand will be met through private depot recharging infrastructure, while the remaining 50% will rely on public recharging infrastructure. Coaches typically operate on long-distance routes ranging from 300 to 800 km daily, with predictable schedules that allow for a mix of overnight depot recharging and public recharging during mandatory breaks or layovers. However, stakeholder pointed out that coaches often start their trip from other places than their depot meaning a slightly higher par should be covered by public refuelling compared to long-haul lorrying which might else resemble the same driving pattern.

Table 48 show the overall energy demand from Battery Electric Coaches.

Table 48. Energy Demand from Battery Electric Coaches

		Energy MWh/year in split between	
	Energy MWh/year	Private recharging	Publicly accessible recharging
		50%	50%
2030	1,392,460 MWh	696,230 MWh	696,230 MWh

The proposed split for public recharging infrastructure for coaches reflects their diverse operational needs, balancing requirements for overnight recharging, range extension during breaks, and rapid recharging for time-sensitive routes. This allocation, based on use cases and stakeholder feedback, ensures efficient and practical infrastructure deployment.

Chargers below 50 kW are excluded due to impractically long recharging times for long-distance operations. 20% of the infrastructure is allocated to 50–150 kW chargers, ideal for overnight recharging during extended rest periods, particularly at depots or designated parking areas. 30% is allocated to 151–350 kW chargers, which serve both as overnight recharging solutions and for range extension during mandatory driver breaks, offering sufficient flexibility for routes exceeding initial battery ranges.

High-power chargers in the 351-600 kW range account for 25% of the infrastructure. These chargers are essential for quickly replenishing energy during shorter breaks, ensuring coaches can continue their routes with minimal downtime while adhering to rest regulations. The remaining 25% is allocated to >600 kW chargers, indispensable for ultra-fast recharging to support extended trips or high-frequency routes where operational schedules are tight. The expected split by output is:

- **0% for <50 kW**: Unsuitable for coach operations due to excessive recharging times.
- **20% for 50–150 kW**: Primarily for overnight recharging in less time-sensitive scenarios.

- **30% for 151–350 kW**: Suitable for overnight recharging and limited use during driver breaks.
- **25% for 351–600 kW**: Supports rapid recharging during shorter breaks to maintain tight schedules.
- **25% for >600 kW**: Ensures minimal downtime for time-critical and long-distance operations.

In Table 49 the split between different types of publicly accessible recharging points as well as the energy demand for Battery Electric Coaches can be found.

Table 49. Split between and Energy Demand from different Types of Publicly accessible Recharging Points for Battery Electric Coaches

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
Split	100%	0%	20%	30%	25%	25%
2030	696,230 MWh	0 MWh	139,245 MWh	208,868 MWh	174,057 MWh	174,057 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 24), we can now calculate the total number over recharging points needed. The results can found in Table 50 below.

Table 50. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric Coaches

		Types of Rechargers depending on effect in kW				
	Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
2030	1101	0	335	335	232	199

Public Refuelling Infrastructure and Energy Demand for Coaches

Based in input from stakeholders as described in paragraph 4.1 a split of 10% private and 90% publicly accessible refuelling infrastructure for hydrogen-powered coaches is proposed – see Table 51. This reflects the operational realities and stakeholder feedback. Stakeholders have not expressed any desire to invest in private refuelling infrastructure, emphasizing instead the need for widespread and strategically located public stations.

Table 51. Energy Demand from H2 Coaches

		Energy kg H2/year in split between	
	Energy kg H2/year	Private refuelling	Publicly accessible refuelling
		10%	90%
2030	20,261,083 kg H2	2,026,108 kg H2	18,234,975 kg H2

A **90% public refuelling allocation** ensures access to refuelling along major routes, at transit hubs, and near bus stops, supporting the flexible and geographically dispersed operations of coach fleets. The **10% private refuelling allocation** accounts for limited cases where operators with fixed routes or centralized operations may establish depot-based refuelling, though this remains rare due to the high costs of private infrastructure.

The proposed split for public hydrogen refuelling - 20% for 350-bar stations, 75% for 700-bar stations, and 5% for liquid hydrogen (LH2) - aligns with the operational needs of hydrogen-powered coaches, based on stakeholder input and industry trends. This is shown by Table 52.

700-bar stations (75%) are the primary choice, supporting long-distance operations with their higher energy density and rapid refuelling capabilities. This aligns with most OEMs' focus and the need for flexible, reliable infrastructure for intercity and international routes. 350-bar stations (20%) complement this by serving shorter-range applications and predictable city-to-city routes, where extended range is less critical and infrastructure costs are lower. Liquid hydrogen (LH2) (5%) addresses niche applications requiring ultra-long ranges or higher energy density, ensuring flexibility for specialized operations as LH2 technology develops.

Table 52. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 Coaches

		Types of Refuelling Points		
	Total kg	350 bar	700 bar	LH2 (liquid H2)
Split	100%	20%	75%	5%
2030	16,208,867 kg H2	3,241,773 kg H2	12,156,650 kg H2	810,443 kg H2

Based on capacity and the amount of kg that each of the refuelling points will be able to deliver (see Table 25), we can now calculate the total number over refuelling points needed for H2 Coaches as shown by Table 53.

Table 53. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 Coaches

		Types of Refuelling Points		
	Total number of refuelling points	350 bar	700 bar	LH2 (liquid H2)
2030	47	9	35	2

4.3.7. ENERGY DEMAND OF VOCATIONAL VEHICLES AND DEMAND FOR INFRASTRUCTURE

Public Recharging Infrastructure and Energy Demand for Vocational Vehicles

Based in input from stakeholders as described in paragraph 4.1 it is assessed for Battery Electric Vocational Vehicles that the expected split between public and private recharging infrastructure for vocational vehicles is estimated to be 50%-50% split, reflecting the varied operational needs of these vehicles – see Table 54. However, there is significant uncertainty in this projection due to the diversity of vocational vehicle applications and their infrastructure requirements.

Currently, it is evident that some types of vocational vehicles, such as garbage collection lorries, will primarily rely on private depot Refuelling. These vehicles operate on fixed, predictable routes with overnight downtime, making depot-based infrastructure the most efficient and practical solution. [85] On the other hand, the refuelling needs for construction vehicles are less clear.

Table 54. Energy Demand from Battery Electric Vocational Vehicles

		Energy MWh/year in split between

	Energy MWh/year	Private recharging	Publicly accessible recharging
		50%	50%
2030	68,142 MWh	34,071 MWh	34,071 MWh

The proposed split for public recharging infrastructure for vocational vehicles - **15% for <50 kW**, **25% for 50–150 kW**, **30% for 151–350 kW**, **15% for 351–600 kW**, and **15% for >600 kW -** reflects the diverse operational needs of this group. Given the lack of market maturity and limited stakeholder input on vocational vehicles, this varied distribution is chosen to address the wide range of potential recharging requirements:

- **15% for <50 kW**: Low-power chargers serve vehicles with predictable, low-energy-demand operations, such as municipal tasks with long idle periods or auxiliary equipment usage. These chargers are cost-effective but limited to applications with longer recharging windows.
- **25% for 50–150 kW**: This category primarily supports overnight recharging for vehicles like garbage lorries or other fleet-operated vehicles that return to depots regularly. It offers a balance between cost and recharging time for operations with less urgency.
- **30% for 151–350 kW**: Serving as the backbone of the split, this category addresses a wide range of needs, including moderate-duration opportunity recharging at job sites or during breaks. It reflects the mid-range recharging requirements of most vocational vehicles operating in urban or regional settings.
- **15% for 351–600 kW**: High-power chargers cater to vehicles requiring rapid top-ups, such as those in construction or emergency services, where prolonged downtime is not feasible. These chargers also serve operations in remote locations where quicker recharging is necessary to maintain efficiency.
- **15% for >600 kW**: Ultra-high-power chargers are allocated for vehicles with high energy consumption and demanding schedules, such as construction vehicles or those requiring rapid energy replenishment in time-critical operations.

In Table 55 the split between different types of publicly accessible recharging points as well as the energy demand for Battery Electric Vocational Vehicles can be found.

Table 55. Split between and Energy Demand from different Types of Publicly accessible Recharging Points for Battery Electric Vocational Vehicles

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
Split	100%	15%	25%	30%	15%	15%
2030	34,071 MWh	5,139 MWh	8,509 MWh	10,202 MWh	5,111 MWh	5,111 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 24), we can now calculate the total number over recharging points needed – see Table 56 below.

Table 56. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric Vocational Vehicles

		Types of Rechargers depending on effect in kW				
	Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW

2030	80	31	20	16	7	6

Public Refuelling Infrastructure and Energy Demand for Vocational Vehicles

In the study scenario, the projected demand for hydrogen from vocational vehicles is estimated to be so low that it does not provide a sufficient basis for making reliable estimates regarding the split between public and private refuelling infrastructure or the preferred refuelling pressure. The limited adoption of hydrogen in this segment, combined with the diversity of vocational vehicle applications and a lack of concrete stakeholder feedback, introduces significant uncertainty. As a result, no specific assumptions about the distribution of refuelling infrastructure or pressure requirements are made for vocational vehicles in this analysis.

4.3.8. TOTAL ENERGY DEMAND AND DEMAND FOR INFRASTRUCTURE

Based on sections 6.3.1-6.3.7 the total energy demand as well as the infrastructure requirements can be calculated. For HDVs infrastructure may be designed for specific vehicle types and not all facilities may be accessible to all vehicles depending on sizes and turning movements. In this section the total number of recharging/refuelling points will however not take this into consideration. Moreover, all of the calculations above are based on assumptions on the number of vehicles, their efficiency and infrastructure utilization rates/capacity which are all associated with a great level of uncertainty.

The output of this section will hence be a general projection which provides an overall basis for discussion and must not be seen as explicit results. To further illustrate this point, we will provide two overall projections of the need for energy and infrastructure based on different assumption on the assumed energy consumption/efficiency of the vehicles, as explained in 3.4.3:

(1) **Low scenario**: Takes as reference the electricity/fuel consumption per km of vehicles as reported in the white paper of The International Council of Clean Transportation (ICCT): "The European heavy-duty vehicle market until 2040: analysis of decarbonisation pathways"

(2) **High scenario**: Takes as reference the electricity/fuel consumption per km of vehicles as reported in the 2040 Climate Target Plan

Total Demand for Public Recharging Infrastructure based on low scenario

The total yearly energy demand (MWh) of all battery electric HDVs, as well as buses and coaches can be seen from Table 57. The total of approximately 36,400,000 MWh is a bit higher than the by T&E described 'Policy scenario' but way under the 'Industry plans' described by the same source [63].

Another result worthwhile mentioning is the overall split between private recharging and publicly accessible recharging. With almost 70% of the energy coming from private recharging infrastructure it will affect the overall business case of establishing recharging infrastructure especially in more rural and remote areas further away from the main corridors of the Union like the TEN-T network. Here the utilization rate can be expected to be lower. This is further discussed in section 4.4.2

Table 57. Total Energy Demand from Battery Electric HDVs, busses, coaches and vocational vehicles – low scenario

		Energy MWh/year in split between	
	Energy MWh/year	Private recharging	Publicly accessible recharging
		69%	31%

Low scenario 2030	36,404,528 MWh	24,253,080 MWh	12,151,448 MWH

Of the total energy demand for publicly accessible recharging infrastructure an overall split between the different recharging points based on output effect (kW) can be seen from Table 58. As shown only a small portion of the energy is expected to come from chargers with an output of 150 kW or below. Almost 90% of all energy is hence expected to be delivered by recharging infrastructure of an effect of 151 kW or above.

Table 58. Split between and Energy Demand from different Types of Publicly accessible Recharging Points for Battery Electric HDVs, busses, coaches and vocational vehicles – low scenario

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
Split	100%	≈0%	11%	30%	34%	25%
Low scenario 2030	12,151,448 MWh	14,599 MWh	1,317,339 MWh	3,663,423 MWh	4,162,377 MWh	2,993,707 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 24), we can now calculate the total number of recharging points needed for all Battery Electric HDVs, busses, coaches and vocational vehicles – see Table 59 below.

Table 59. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric HDVs, busses, coaches and vocational vehicles – low scenario

		Types of Rechargers depending on effect in kW				
	Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
Low scenario 2030	18,107	88	3,166	5,869	5,557	3,426

Total Demand for Public Recharging Infrastructure based on high scenario

To compare the numbers above with the energy and recharging infrastructure demand in the high scenarios Table 60 gives an overview of the energy demand in MWh per year and the split between private and publicly accessible recharging. In this scenario, there is a small increase (from 31 to 36%) in the demand for publicly accessible recharging infrastructure which is in line with the increased demand from a larger number of battery electric long-haul lorries which in general are one of the categories of vehicles in most need for publicly accessible recharging infrastructure. However, the most conspicuous is the general rise in energy demand from 36,404,528 MWh/year to 57,677,372 MWh equivalent to an almost 60% increase.

Table 60. Energy Demand from Battery Electric HDVs, busses and coaches and Vocational Vehicles – high scenario

		Energy MWh/year in split between	
	Energy MWh/year	Private recharging	Publicly accessible recharging

		64%	36%
High scenario 2030	57,677,372 MWh	36,731,820 MWh	20,945,551 MWh

In Table 61 the split between different types of publicly accessible recharging points as well as the energy demand for Battery Electric HDVs, busses and coaches can be found. Again, only charger with output effects of above 150 kW play a major role in the recharging of BEVs.

Table 61. Split between and Energy Demand from different Types of Publicly accessible Recharging Points for Battery Electric HDVs, busses and coaches and Vocational Vehicles – high scenario

		Types of Rechargers depending on effect in kW				
	Total MWh	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
Split	100%	0%	11%	30%	35%	25%
High scenario 2030	20,945,551 MWh	20,582 MWh	2,211,464 MWh	6,310,400 MWh	7,232,015 MWh	5,171,088 MWh

Based on utilization rate and the amount of kWh that each of the recharging point will be able to deliver (see Table 24), we can calculate the total number over recharging points needed for all Battery Electric HDVs, busses, coaches and vocational vehicles in the high scenario – see Table 62 below.

Table 62. Number of Publicly accessible Recharging Points of different Types of Chargers for Recharging Battery Electric HDVs, busses and coaches and Vocational Vehicles – high scenario

		Types of Rechargers depending on effect in kW				
	Total number of recharging points	< 50 kW	50-150 kW	151-350 kW	351-600 kW	>600 kW
High scenario 2030	31,122	124	5,315	10,110	9,656	5,918

Comparing the low and high scenarios **an increase of 73% in the demand for publicly accessible recharging infrastructure** is seen. This highlights the sensitiveness of the calculations regarding i.a. the input data.

It is important to note that the private/publicly accessible split and the split between output effects (kW) has not been changed in the high scenario compared to the low scenario. However, a lower energy efficiency would significantly influence the recharging infrastructure, as it would require recharging more kW within the same amount of time. This would necessitate a shift in the output split, with a higher percentage of high-output chargers to accommodate the increased energy demand. It is crucial to highlight that the primary analysis of the required recharging infrastructure has been done based on the low scenario and this part is only for comparison and to highlight sensitivity.

Total Demand for Public Refuelling Infrastructure based on low scenario

Looking at the total energy demand from H2 vehicles (HDVs, buses and coaches), Table 63 show the need for kg H2 per year and the split between private and private available refuelling infrastructure. As indicated in paragraph 4.1 and 4.2 most (90%) of the refuelling demand will be met by publicly accessible infrastructure. The projected total public kg H2 demand of 390,500 t or 0.390 mega tonnes (Mt) per year equals numbers seen in other studies/literature. [61]

Table 63. Energy Demand from H2 HDVs, H2 buses and coaches – low scenario

		kg H2/year in split between	
	kg H2/year	Private refuelling	Publicly accessible refuelling
		10%	90%
Low scenario 2030	435,822,403	45,246,888	390,575,515

In Table 64 the split between different types of publicly accessible refuelling points as well as the energy demand for H2 HDVs, busses and coaches can be found. Even though the stakeholders see the need for both 350 and 700 bar the overriding need for refuelling infrastructure with 74% seem to be for 700 bar refuelling points.

Table 64. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 HDVs, H2 buses and H2 coaches – low scenario.

		Types of Refuelling Points		
	Total kg	350 bar	700 bar	LH2 (liquid H2)
Split	100%	21%	74%	5%
Low scenario 2030	390,575,515	82,919,251	288,567,559	19,088,704

Based on the amount of kg that each of the refuelling points is expected to be able to deliver (see Table 25), we can now calculate the total number of publicly accessible refuelling points needed for H2 vehicles. The result is illustrated by Table 65.

Table 65. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 HDVs, H2 buses and H2 coaches – low scenario.

		Types of Refuelling Points		
	Total number of refuelling points	350 bar	700 bar	LH2 (liquid H2)
Low scenario 2030	1,126	239	832	55

Total Demand for Public Refuelling Infrastructure based on high scenario

Comparing the low scenario for demand for publicly accessible refuelling infrastructure with the high scenario, first of all a higher (approximately +32%) energy need is seen in the increase of kg H2 needed per year. Above all this is due to a decrease the energy efficiency of the vehicles. This is also described in more detail in section 3.4.3.

Table 66. Energy Demand from H2 HDVs, busses and coaches - high scenario

		Energy kg H2/year in split between	
	Energy kg H2/year	Private refuelling	Publicly accessible refuelling
		10%	90%
High scenario 2030	573,898,079	59,269,709	514,628,370

In Table 67 the split between different types of publicly accessible refuelling points as well as the energy demand for H2 HDVs, busses and coaches in the high scenario can be found. As in the low scenario the overriding need for refuelling infrastructure with 74% seem to be for 700 bar refuelling points.

Table 67. Split between and Energy Demand from different Types of Publicly accessible Refuelling Points for H2 HDVs, busses and coaches - high scenario.

		Types of Refuelling Points		
	Total kg	350 bar	700 bar	LH2 (liquid H2)
Split	100%	21%	74%	5%
High scenario 2030	514,628,370	108,617,464	380,803,302	25,207,604

Based on the amount of kg that each of the refuelling points will be able to deliver per day (see Table 25), we can now calculate the total number over refuelling points needed for H2 vehicles.

Table 68. Number of Publicly accessible Refuelling Points of different Types of Refuelling Dispensers for H2 HDVs, busses and coaches – high scenario.

		Types of Refuelling Points		
	Total number of refuelling points	350 bar	700 bar	LH2 (liquid H2)
High scenario 2030	1,484	313	1,098	73

As shown the energy demand from H2 vehicles differs greatly depending i.a. on the input data. From the low and high scenarios, we see **an increase in energy demand of 32%** varying only slightly between the different types of refuelling points. Again, this highlights the sensitiveness of the calculations regarding i.a. the input data.

It is important to note that the split between private/public available infrastructure and the split of the refuelling type (bar) has not been changed in the high scenario compared to the low scenario. A lower energy efficiency will not have a big influence on theses splits if the vehicles still maintain their expected ranges as it would in the BEV part of the study. However, this would mean a need for larger tanks on the vehicles. It is important to note that the main study of the needed refuelling infrastructure has been done based on the low scenario and therefor this part mainly serves as a comparison to highlight sensitivity.

To calculate the energy demand and infrastructure needs of both BEVs and H2 vehicles a line of assumptions, averages and generalizations need to be made. The focus of the analysis is the need for publicly accessible infrastructure so a split between the two kinds of infrastructure had to be done. This differs between the different vehicle types and propellants as described in paragraph 4.1 (stakeholder input) and 4.2 (technical specifications and use cases). Detailed calculations and a consistent approach lead to the results that a total of:

- **18,000 recharging points are needed. These are of various output effects kW but with an emphasis (90%) on chargers above 150 kW.**
- **1,100 refuelling points are needed. Almost ¾ of these are 700 bar.**

The results are, however, hugely depending on these assumptions as well as the input data. Using another high scenario based on the 2040 Climate Target Plan the energy demand increases by 73% and 32%, respectively, and the demand for infrastructure increases similarly in the high scenario:

- **31,000 recharging points are needed.**
- **1,500 refuelling points are needed.**

4.4. COMPARISON BETWEEN ENERGY DEMAND AND TARGETS OF AFIR

In this paragraph the Energy Demand and subsequently publicly accessible infrastructure for zero-emission vehicles are compared with the infrastructure targets stated in the Alternative Fuels Infrastructure Regulation. Furthermore, the need for recharging and refuelling infrastructure is discussed relating this to the geographical aspects which has not been considered in the projection of infrastructure demand.

4.4.1. TARGETS OF AFIR AND ENERGY PROVIDED AS RESULT

AFIR establishes mandatory national targets for the member states leading to the deployment of alternative fuels infrastructure in the Union for i.e. road vehicles, including dedicated recharging infrastructure for HDVs. Given a timely deployment of recharging/refuelling infrastructure, this is expected to meet a substantial share of the total demand for infrastructure by 2030. An overview of the targets of AFIR for recharging and refuelling infrastructure can be found in Table 69 and Table 70, respectively.

Table 69. Targets for recharging infrastructure dedicated to heavy-duty electric vehicles, Article 4 in AFIR.

Applies to	Deadlines		
	31 December 2025	31 December 2027	31 December 2030
Core network	Power output of ≥1400 kW on 15% of network and at least 1 recharging point of ≥350 kW	Power output of ≥2800 kW on 50% of network and at least 2 recharging point of ≥350 kW	Power output of ≥3600 kW on 100% of network and at least 2 recharging point of ≥350 kW at least every 60 km
Comprehensive network		Power output of ≥1400 kW on 50% of network and at least 1 recharging point of ≥350 kW	Power output of ≥1500 kW on 100% of network and at least 1 recharging point of ≥350 kW at least every 100 km
Safe and secure parking areas	NA	≥2 recharging point of ≥100 kW	≥4 recharging point of ≥100 kW
Urban nodes	Power output of ≥900 kW and ≥150 kW per recharging point	NA	Power output of ≥1800 kW and ≥150 kW per recharging point

Table 70. Targets for hydrogen refuelling infrastructure of road vehicles, Article 6 in AFIR.

Applies to	Deadlines	
	2027	31 December 2030
Core network	Member states to set clear indicative target for 2027 in their national policy frameworks based on linear trajectory towards meeting the 2030 targets.	Output of ≥1 tonne/day and at least 700 bar dispenser at least every 200 km
Urban nodes		≥1 publicly accessible hydrogen refuelling station with location based on analyses

Derived minimum outputs (kWh/MWh) as a result of AFIR

To calculate how this infrastructure is expected to meet the overall projected energy demand, the average utilization rates of recharging infrastructure and capacity of refuelling infrastructure as described in paragraph 4.3.1 are used. An average utilization rate of 20%

between the different publicly accessible chargers is assumed. Along the TEN-T network high-power recharging infrastructure is expected as the most appropriate recharging infrastructure given the use cases of especially long-haul lorries and coaches with a high focus on minimizing recharging time.

In Table 71 and Table 72 the minimum kWh/day expected to be delivered by the mandated recharging infrastructure along the TEN-T network and at parking areas and urban nodes are presented. This assumes that only the bare minimum requirements of the targets are applied.

Table 71. Network: Minimum amount of energy provided for BEV HDVs by recharging pools as set in Targets of AFIR.

Applies to	Targets of 31 December 2030	Approximate length in kilometers [26]	Number of recharging pools	Minimum kWh/day with a utilization rate of 20%
Core network	≥3600 kW at least every 60 km	49 700	829	14 325 120
Comprehensive network excl. core network	≥1500 kW at least every 100 km	87 000	870	6 264 000
Total	-	136 700	1 699	20 589 120

Table 72. Areas and nodes: Minimum amount of energy provided for BEV HDVs by recharging pools as set in Targets of AFIR

Applies to	Targets of 31 December 2030	Number of areas/nodes	Number of recharging pools	Minimum kWh/day with a utilization rate of 20%
Safe and secure parking areas	and ≥4 recharging points of ≥100 kW	1 367	1 367	2 624 640
Urban nodes	Aggregated Power output of ≥1800 kW and ≥150 kW per recharging point	431[27]	431	3 723 840
Total	-	1 798	1 798	6 348 480

If AFIR's targets are met this means that a total minimum of 26,937,600 kWh/day will be delivered at the TEN-T network (core + comprehensive network) and at urban nodes and parking areas. This is equivalent to a minimum of 9,832,224 MWh/year.

As derived in paragraph 4.3.8 the calculated total energy demand from publicly accessible recharging infrastructure is 12,151,448 MWh/year in the low scenario and 20,945,551 MWh/year in the high scenario. This means that the minimum requirements of AFIR can be expected to cover 47-81% of the calculated total energy demand from publicly accessible recharging infrastructure.

In paragraph 4.4.2 the numbers are further discussed.

[26] https://op.europa.eu/webpub/eca/special-reports/core-road-network-9-2020/en/
[27] https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/revised-ten-t-regulation-adopted-sustainable-and-resilient-transport-network-bringing-europe-closer-2024-06-25_en

Derived minimum outputs (kg H2) as a result of AFIR

In Table 73 the expected result of minimum requirements of AFIR is shown. Along the core network and at urban nodes 680 refuelling stations is expected to be found by the end of 2030. If each of these are presumed to deliver an output of 1 tonne per day, the total output of the refuelling stations will be 680 kg H2/day, equivalent to 248,200 kg H2/year.

Table 73. Minimum amount of energy (kg H2) provided for H2 HDVs by refuelling stations as set in Targets of AFIR

Applies to	Approximate length in kilometers / No. of Urban nodes	Targets of 31 December 2030	Number of refuelling stations	Minimum tonne/day
Core network	49 700	Output of ≥1 tonne/day and at least 700 bar dispenser at least every 200 km	249	249
Urban nodes	431	≥1 publicly accessible hydrogen refuelling station based on analysis	431	431 *Presumed that each refuelling station provide output of 1 tonne/day*
Total	-	-	680	680

As derived in paragraph 4.3.8 the calculated total H2 demand from publicly accessible refuelling infrastructure is 390,576 t/year in the low scenario and 514,628 t/year in the high scenario. This means that the minimum requirements of AFIR can be expected to cover 48-64% of the calculated total energy demand from publicly accessible refuelling infrastructure.

In paragraph 4.4.2 the numbers are further discussed.

4.4.2. DISCUSSIONS ON CALCULATED EXPECTED ENERGY DEMAND FROM HDVS AND REQUIREMENTS OF AFIR

Above in paragraph 4.3.8 the expected overall energy demand was provided for both BEVs and H2 vehicles and the need for energy in MWh/year and t H2/year from publicly accessible infrastructure was presented. In paragraph 4.4.1 the expected energy provided as results of AFIR was further calculated and compared with the projected energy demand. The overall conclusions are that a fulfilment of the AFIR targets at a minimum will provide the following shares of the projected demand for energy:

- 47%-81% for recharging depending on the scenario for development in especially long-haul lorries
- 48%-64% for refuelling depending on the scenario for development

However, the regulation only covers the TEN-T network and some predefined urban nodes and parking spaces. The TEN-T network only accounts for a small percentage (approximately 3% depending on sources, as the TEN-T roads represent approximately 136,700 km of the total European road network of approximately 5 mill. km) of the European road network. [84], [85] At the same time, it represents the most critical and heavily used roadways across Europe, facilitating key connections between EU member states and neighbouring countries. While small in proportion, the network handles a disproportionately high share of freight and passenger traffic due to its strategic importance and hence a large share of the publicly accessible infrastructure should be found along the TEN-T network. The projected demand for infrastructure in paragraph 4.3 provides a theoretical estimate of the overall energy demand and the number of recharging/refuelling points required. However, this estimate does not account for the spatial distribution of infrastructure, which is crucial for ensuring a geographically comprehensive network. To achieve sufficient coverage, it is essential to consider the physical placement and accessibility of infrastructure, ensuring that recharging and refuelling points are located strategically across different regions to support seamless operations.

To provide a coherent, fine-meshed, and appropriate infrastructure that encourages fleet operators to invest in zero emission vehicles, one has to look beyond the TEN-T network. To establish the confidence for fleet owners that operations with ZEVs can proceed without interruptions or delays and that recharging/refuelling opportunities will be available in all operational geographies, the infrastructure may have to exceed the projected demand for publicly accessible infrastructure. The best business cases in recharging/refuelling infrastructure are generally found along heavily used roads, while more secluded areas often lack infrastructure if not the public sector supports. To ensure infrastructure wherever HDVs might need to recharge/refuel may require public funding, grants and/or Public-Private-Partnerships.

The overall targets of AFIR lead to a good coverage of infrastructure along the TEN-T road network and at urban nodes and parking areas due to the distance requirement. The recharging infrastructure provided due to the AFIR targets is expected to meet as a minimum 47-81% of the projected energy demand (kWh) from Battery Electric vehicles, depending on the scenario of development in especially long-haul vehicles. For H2 vehicles, a fulfillment of the AFIR targets is expected to provide 48-64% of the energy demand (kg H2) from refuelling infrastructure, depending on scenario.

When assessing the need for additional publicly accessible infrastructure besides what is mandated by AFIR, it is necessary also to include the need for publicly accessible infrastructure beyond the TEN-T network. Geographical aspects furthermore should be taken into consideration to provide a coherent fine-meshed, and appropriate infrastructure that encourages fleet operators to invest in zero emission vehicles.

5. BARRIERS TO THE UPTAKE OF VEHICLES AND THE DEPLOYMENT OF INFRASTRUCTURE

An important aim of this analysis was to understand what the barriers to the uptake of zero-emission HDVs and the deployment of the corresponding infrastructure are , and what the expectation is on their importance in 2030. This chapter of the report describes the main identified barriers to the uptake of zero emission HDVs and their infrastructure based on the outputs of stakeholder interviews, workshop with stakeholders, and the survey results.

To identify which barriers are important, the survey respondents were asked to rate the barriers on Likert scale from 1 – not a barrier at all, to 5 – a major barrier. The results allow identification of four major groups of barriers to zero-emission technology uptake:

(1) The first group of barriers is the **total cost of ownership**, or TCO, of vehicles in their planned operational patterns that depend on their use. The TCO includes cost components like purchase cost, costs of vehicle daily operations (maintenance, energy, labour, etc.) and also any financial incentives or subsidies that the vehicle operator might receive from the government. Although the TCO is currently considered an important barrier, the expectation, according to survey respondents, is that by 2030 the cost-related issues will be largely mitigated . The solutions are likely to come from maturity of the market in both, the recharging market and the vehicles. For example, as the scale of the production of zero-emission HDVs will increase, the unit cost of the vehicles will decrease. Similarly, for the recharging market, with maturing of the market, larger scale of recharging equipment manufacturing and the reduction of risks associated with uncertainties of the future

market demand, the costs to supply energy to the vehicles per kWh supplied will decrease, assuming that grid fees as well as electricity generation costs and taxes remain largely stable.

(2) The second group of identified barriers relates to the availability of **electricity grid** capacity and the associated administrative processes for obtaining grid connections.

The grid connection capacity that is available for recharging location development often limits the maximum size of the recharging pool that could be built, even if the operator would have preferred to build a bigger one due to the demand that needs to be served.

The administrative processes that relate to obtaining all the required documentation for connection substantially increase infrastructure development lead times, therefore increasing the overall cost of infrastructure development.

(3) The third group of barriers relates to the lack of **public recharging** along the motorway network on the main axes travelled by HDVs. This relates to recharging locations designed for both, the short 45-minute breaks and longer daily or weekly rest periods. This is currently a substantial issue, but the expectation according to the respondents is that this will be much less of an issue by 2030 due to the development of dedicated HDV recharging networks in line with AFIR mandatory deployment targets.

(4) And last, the fourth group of barriers relates to the green **hydrogen price** uncertainty. The hydrogen price currently is very high, and it is uncertain if it can be reduced dramatically in a sustainable way without never-ending subsidies to be cost-competitive with the alternatives. According to respondents, this is unlikely to occur in the near future by 2030.

Reaching the price parity with the alternatives is undermined by the low green electricity-to-wheel efficiency of the hydrogen fuel cell vehicles of 19-23% and even lower efficiencies for H2ICE, compared to that of alternatives, e.g. the efficiency for battery electric vehicles is 69% [86].

Figure 48 below summarises the responses to the survey questions on the barriers to zero-emission HDV adoption and infrastructure development.

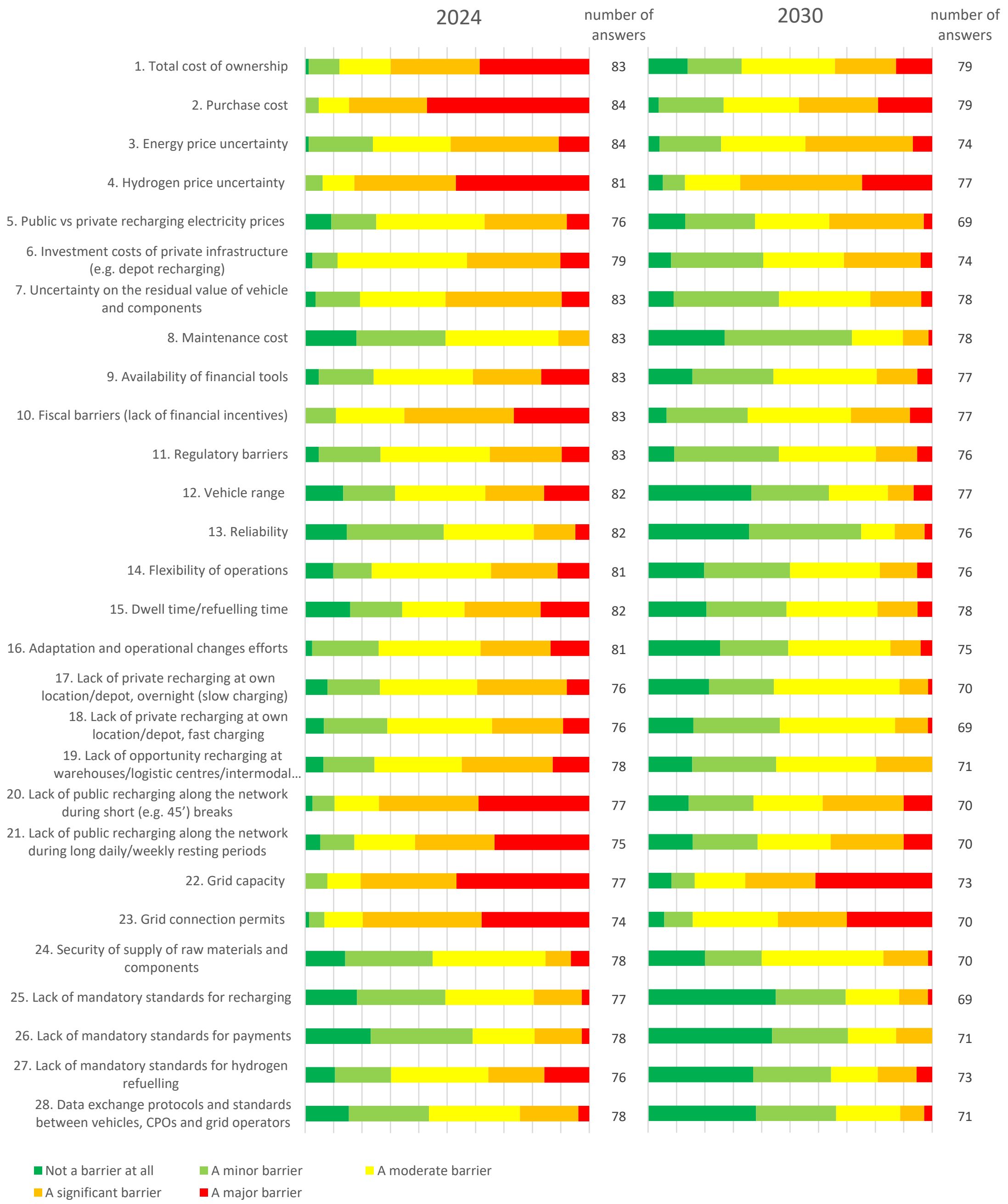

Figure 48: The importance of barriers today and in 2030, all respondents

To understand why certain stakeholders are giving the responses they do to the questions in the survey, interviews with stakeholders were held before, in parallel and after running the survey. Amongst the interviewees, the three biggest categories were intentionally the vehicle manufacturers, the road transport operators and the infrastructure operators.

The identified barriers from the interviews with those three stakeholders are summarised in Table 74 in columns by stakeholder. The barriers in the table are listed in the order of importance, with those most mentioned/stressed by the stakeholders on top. Clearly, the barriers in the table corroborate the barriers that were identified in the survey, while allowing to gain more detailed insight into the conditions surrounding those.

Table 74: Summary of barriers

Vehicle manufacturers	**Road transport operators**	**Infrastructure operators**
	TCO worse than for Diesel	
		Grid connection administrative process / infrastructure development lead times
Availability of raw materials and components		
	Financial challenges of low-margin business, particularly for SMEs	
		Electricity grid capacity
	Lack of recharging stations for HDVs (currently)	
	High leasing payments due to uncertain residual value	
	Availability of vehicles (different types)	
	Lack of data exchange ecosystem	
	Conservative mindset of truckers	
		Land availability for recharging locations
	Vehicle technical limitations (range, payload, reliability & performance, weigh and axle load limits) that limit vehicle use cases	
Technology immaturity (for hydrogen)		
	Energy price uncertainty (hydrogen)	
	Level playing field	
Competition from outside the EU		
		Standardisation (electric & hydrogen)
		Investing into unknown - high risk
		Grid flexibility: connecting to close by renewables

The next section discusses the barriers that were identified by each of the stakeholder groups in further detail. The stakeholder grouping is retained to present a disaggregated discussion of the barriers to the adoption of zero-emission HDVs.

5.1. BARRIERS BY STAKEHOLDER GROUP

The barriers to zero-emission HDV adoption differ by stakeholder because each group views the market from its own unique perspective. Stakeholders operate from different standpoints and engage with various other actors, resulting in distinct challenges. These different priorities and interactions between actors create a varied perception of barriers by each group.

To effectively identify the barriers as observed by each stakeholder, we have summarized our findings based on stakeholder groups. The inputs for this analysis come from both survey data and interviews, ensuring a comprehensive understanding of each actor’s concerns. By categorizing the outputs according to those groups, we can better highlight the specific issues they see currently and in the future.

In this sub-section, the focus is on the three main stakeholder groups: vehicle manufacturers, road transport operators and infrastructure operators, as defined by the scope of the investigation, but the full summary of results is presented in the next sub-section.

5.1.1. VEHICLE MANUFACTURERS

Vehicle manufacturers are responsible for organising the supply chain and production for meeting the uncertain demand of the zero emission HDVs in the market.

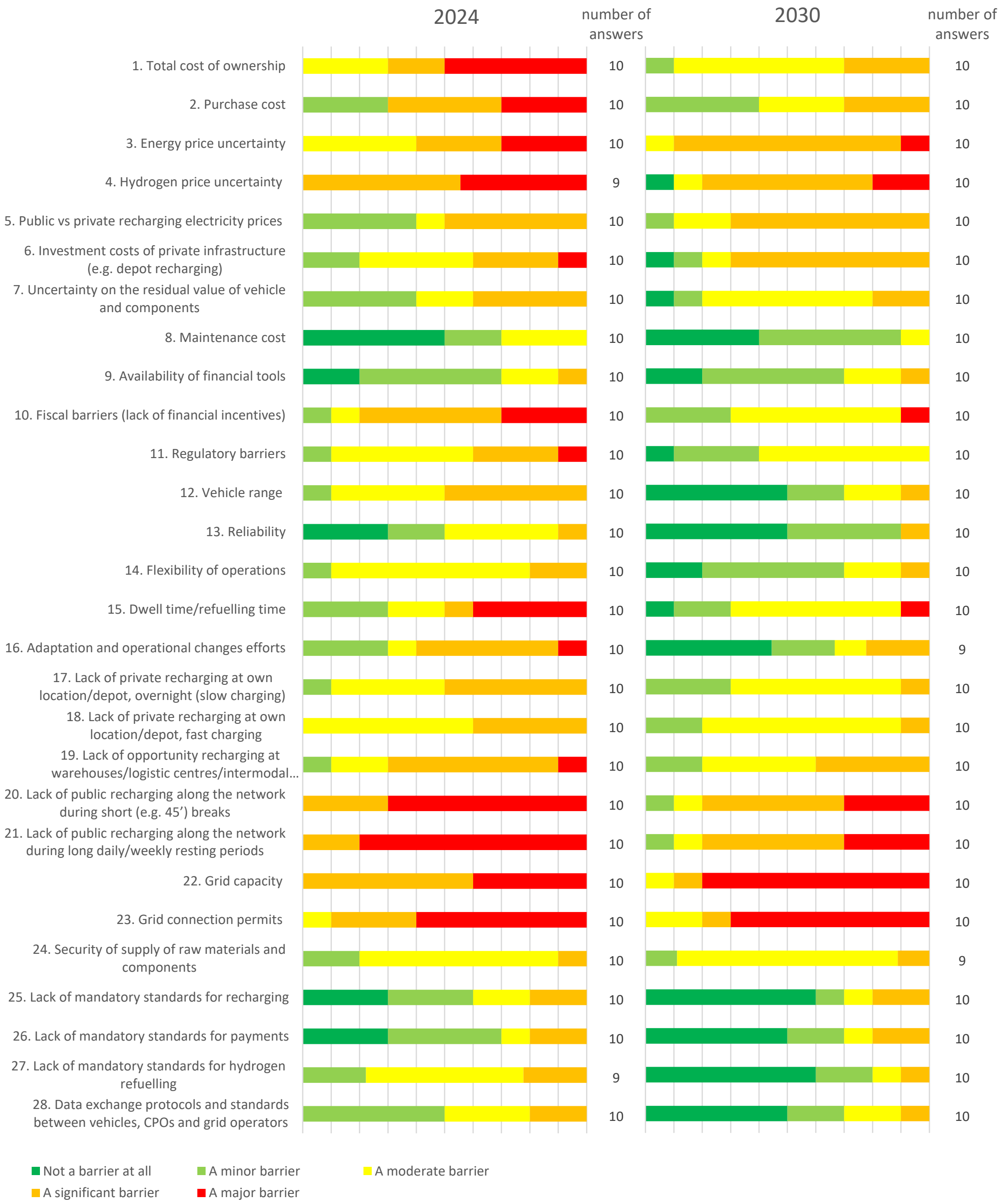

Figure 49: The importance of barriers today and in 2030, responses of vehicle manufacturers

According to survey responses, shown in

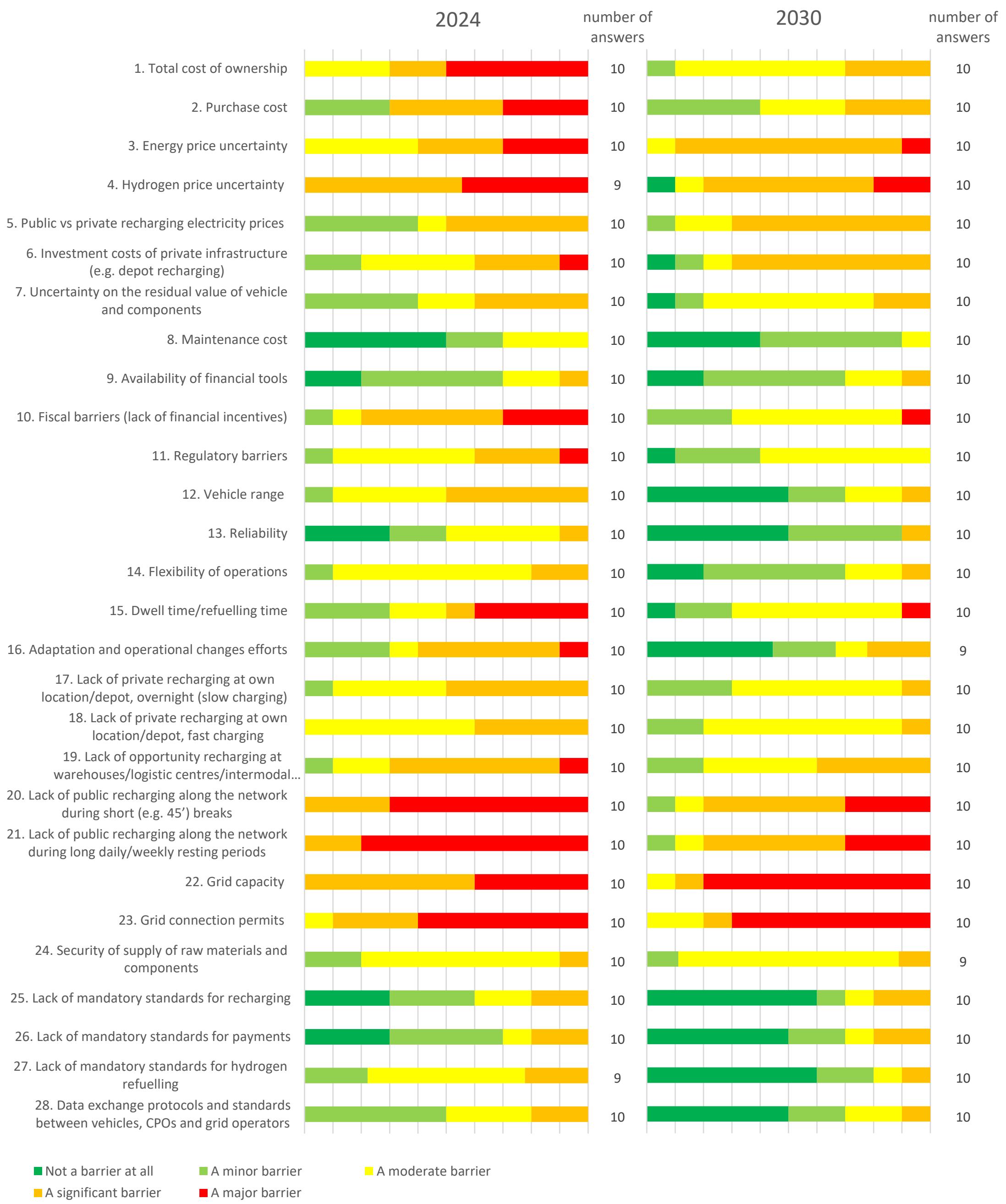

Figure 49, vehicle manufacturers see the same four groups of barriers to the zero-emission HDV adoption as the rest of the stakeholders. Those relate to the four groups described above – TCO, electricity grid capacity and the administrative processes to get an adequate grid connection, lack of public recharging and hydrogen price uncertainty. Vehicle manufacturers are, however, more optimistic about their own ability to bring the purchase price of zero-emission HDVs down than their parts suppliers, HDV operators and shippers of the goods.

During the interviews, some vehicle manufacturers also mentioned issues they face in availability of raw materials and components that are inputs in the vehicle assembly. Others clearly stated that this is not an issue for them at all and they do not think this could become an issue in the near future. In the survey the availability of raw materials was not confirmed to be a substantial issue.

[87]For hydrogen technologies, their technical immaturity that relates to their performance in extreme temperatures, as well as certain atmospheric conditions (e.g. salty/wet air) was mentioned. Specifically, it was noted during the interviews that already in moderately cold

winter conditions the vehicle efficiency drops significantly. In coastal regions with salty air sodium chloride poisoning will significantly deteriorate the performance of the hydrogen fuel cells. And the refuelling nozzles of hydrogen stations are prone to freezing in warm and humid conditions.

5.1.2. ROAD TRANSPORT OPERATORS

Road transport operators are directly facing the different barriers related to zero emission HDV adoption. The group, however, is not uniform and includes two types of operators that work in different markets: freight and passenger transport.

In their survey responses, road transport operators see the same four groups of barriers to the zero-emission vehicle adoption as the other stakeholders. TCO, lack of public recharging, hydrogen price uncertainty, and electricity grid capacity and permitting issues. The permitting issues, however, were not recognised as barriers by the passenger transport operators, probably due to their differing experiences in the areas they operate in.

The issue that the overwhelming majority of the transport operators mentioned, and which is probably the most important barrier for zero emission HDV adoption, is the TCO of the vehicles, which is currently worse compared to traditional diesel-fuelled vehicles. There is, however, expectation expressed by some of the interviewees that with manufacturing scale increases and use of those vehicles at scale with the help of certain taxation policies, which could be unpopular, this barrier can be overcome.

Road transport is a business where it is normal for operators to work with very low margins. Although optimal from the socio-economic point of view, this presents a substantial financial challenge for the operators to accumulate the means required for investing. This problem is most pronounced amongst small operators with 2-3 vehicles. Interviews revealed that the high leasing payments for zero emission HDVs, which have to compensate for the uncertainty of the residual value of the vehicles at the end of the leasing period, result in increased vehicle TCO. In a more mature market, like currently with diesel vehicles, this uncertainty does not exist. For zero emission HDVs, it could be mitigated with policies that could provide residual value guarantees.

For bus operators, for whom the survey responses are shown in

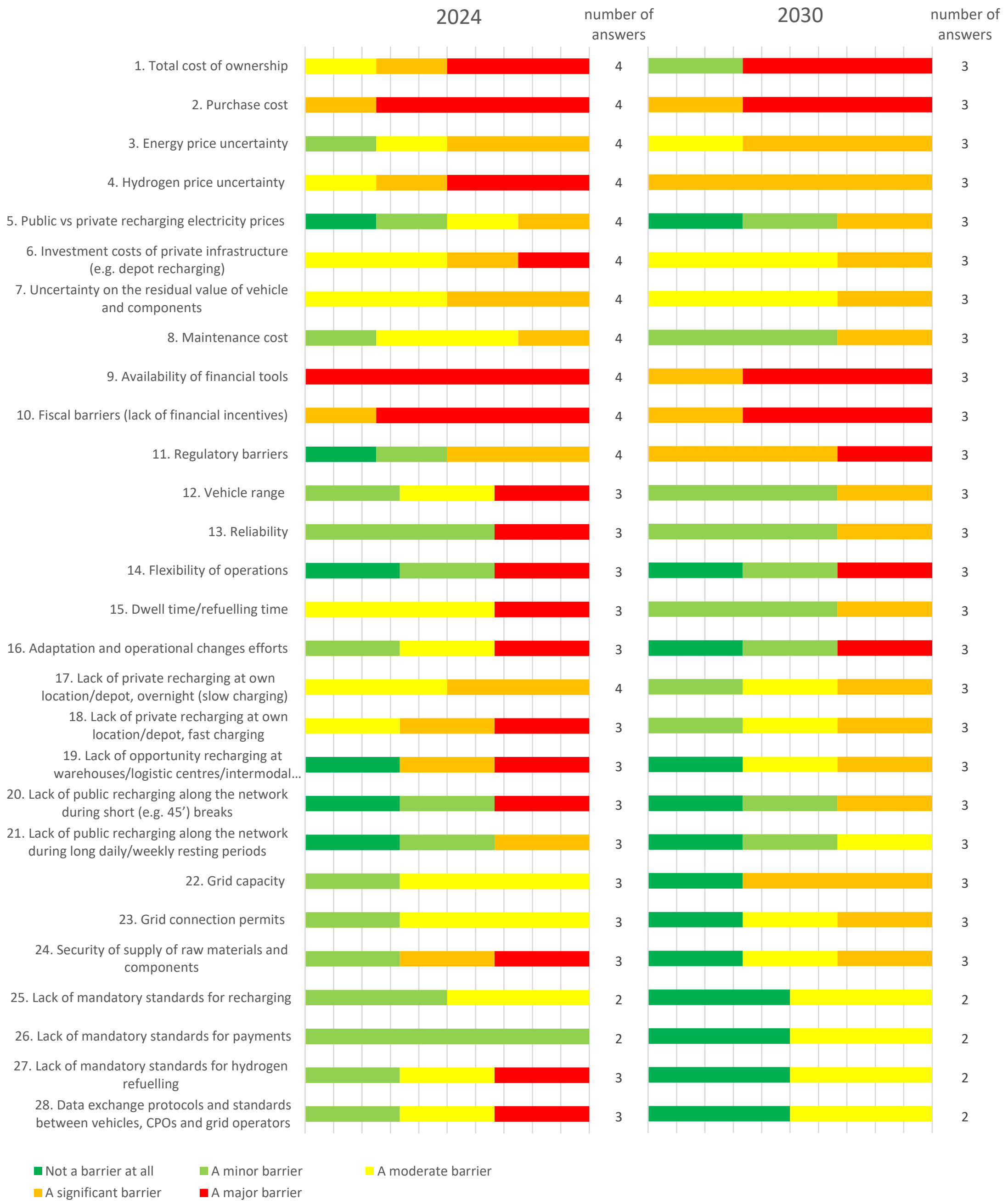

Figure 50, the lack of financial tools and financial incentives from the government to improve TCO is an important barrier today. They foresee this issue to persist also in 2030, with continued challenges in securing the necessary funding and support to fleet modernisation with zero-emission technologies.

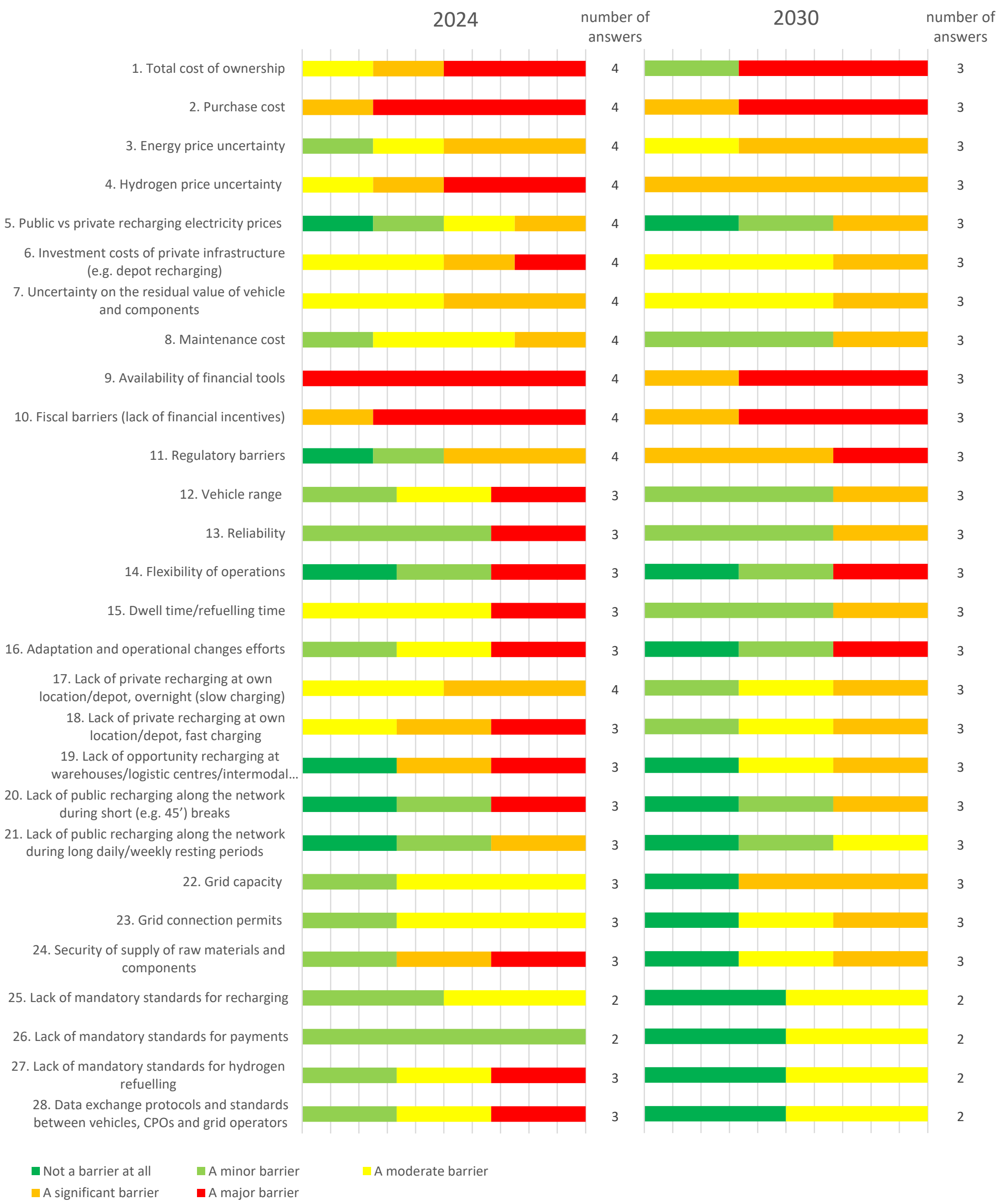

Figure 50: The importance of barriers today and in 2030, responses of passenger transport operators

Unlike other respondents, freight transport operators specifically identified vehicle range as a significant barrier to adoption, whereas this was not a concern for the bus operators. The truck operators believe that advances in technology and/or infrastructure will likely resolve this issue by 2030.

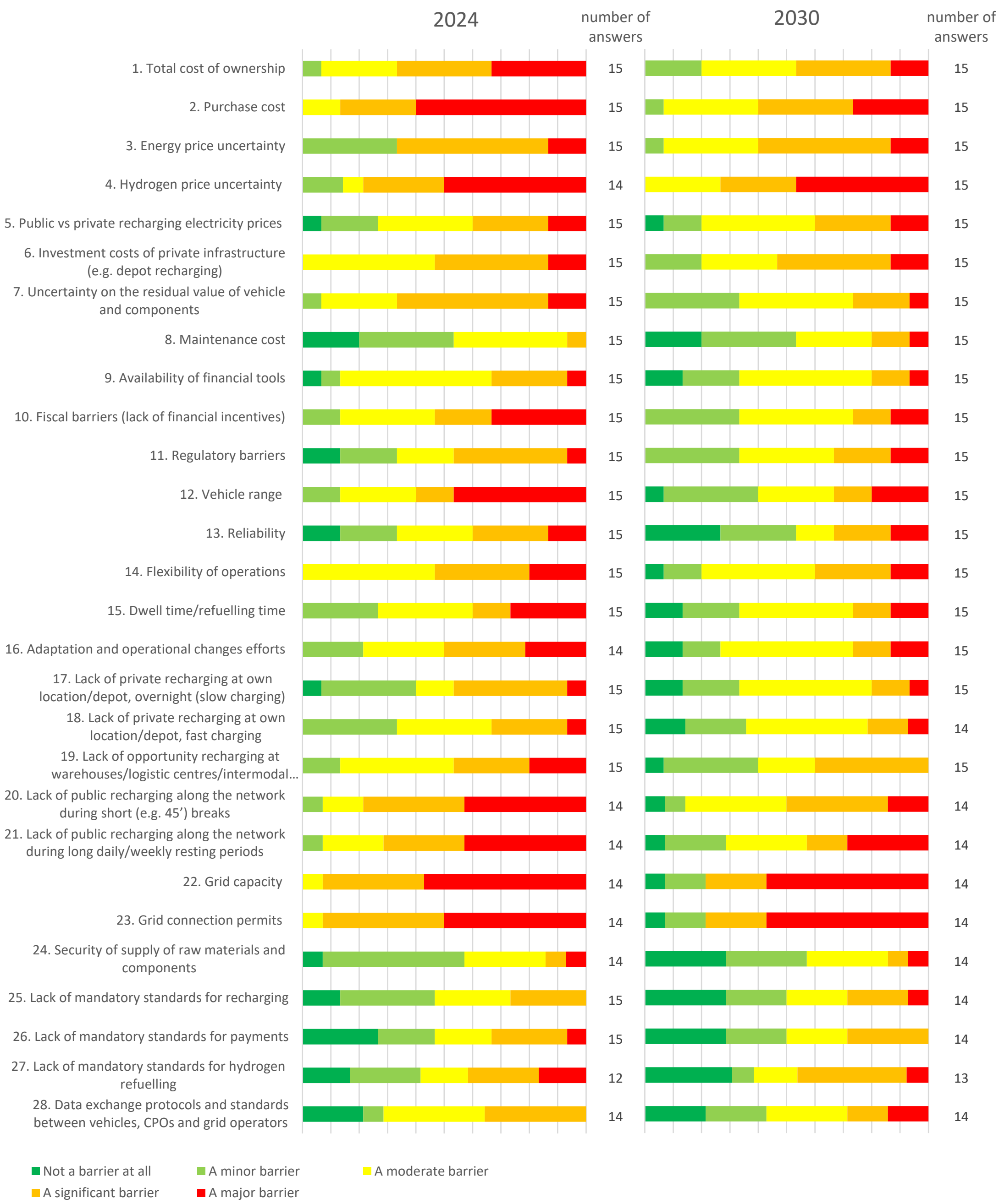

Figure 51: The importance of barriers today and in 2030, responses of freight transport operators

Lack of recharging stations that are specifically designed for heavy duty vehicles is another barrier that a substantial part of the respondents mentioned. The consensus is that the problem is temporary, and this would not be a significant issue in most of the EU by the end of the decade. Interestingly, the lack of public recharging infrastructure was seen as a lesser issue by the bus operators, while still important to the coach operators, likely due to their different operational patterns.

Less frequently mentioned barriers include the different technical limitations of vehicles, the uncertainty of energy prices (especially for hydrogen) and the need for a level playing field in the introduction of the zero emission vehicles. Some transport operators also identified the lack of specific vehicle types. Some vehicle types, e.g. car carriers, are currently still not available in zero emission vehicle versions. The respondents also highlighted the conservative mindset of the road transport operators as a barrier, noting that these operators are generally not accustomed to managing risks and tend to prefer relying on proven technologies.

5.1.3. INFRASTRUCTURE OPERATORS

For the infrastructure operators, as mentioned during the almost all communications with stakeholders, the **administrative processes** that relate to obtaining all the required documentation for grid connection is a major barrier that substantially increases infrastructure development lead times and increases the overall cost of infrastructure development.

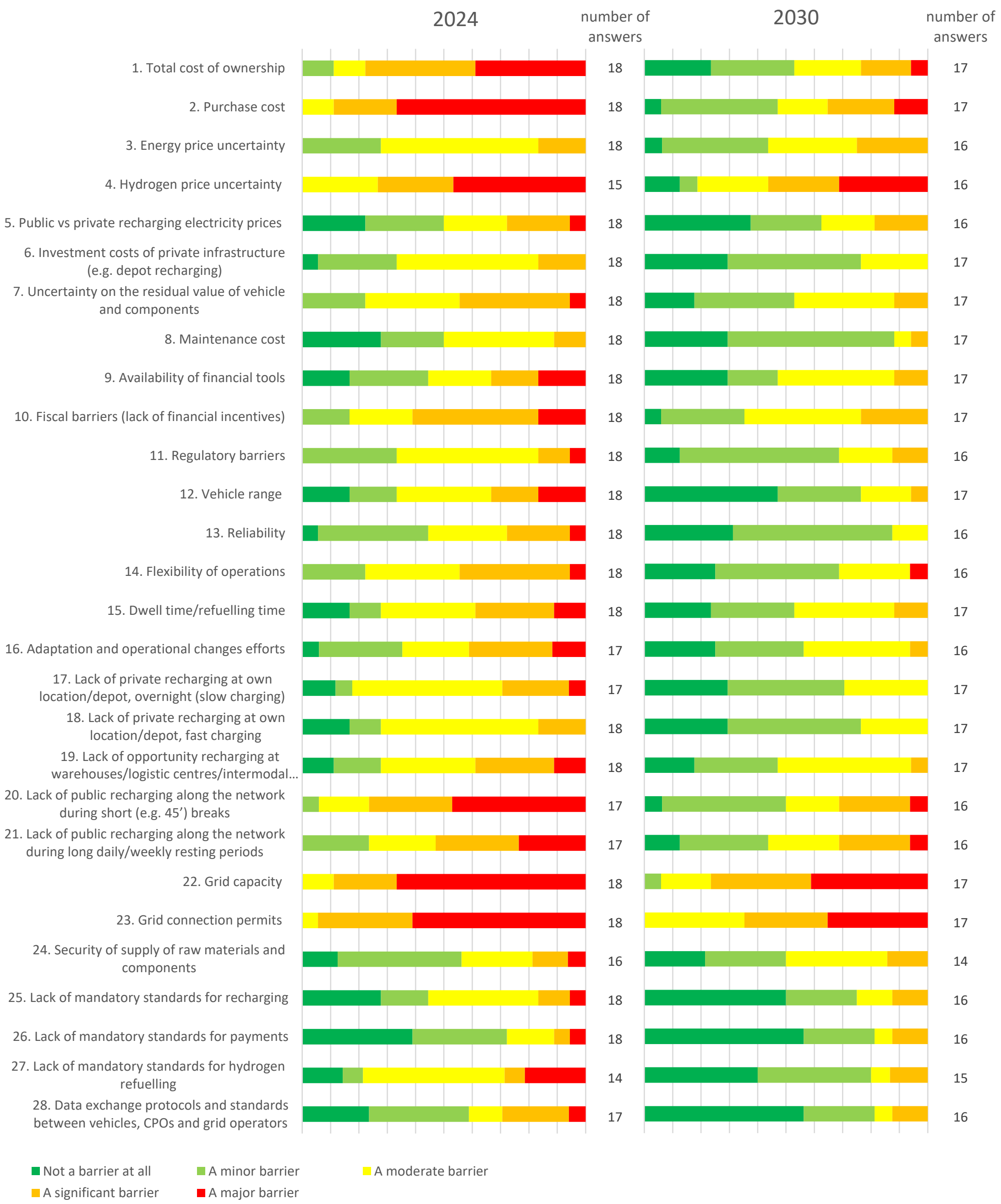

Figure 52: The importance of barriers today and in 2030, responses of infrastructure operators

Another important barrier for infrastructure operators is the **electricity grid capacity** that is accessible at the available locations for recharging station development. It limits the maximum size of the recharging station at a specific location, even if the operator would have preferred to build a bigger one. In practice this means that charge point operators are forced into a financially sub-optimal pattern of building a larger number of smaller stations, although they would have preferred to build a smaller number of bigger stations.

For optimisation of infrastructure use and to guarantee that HDVs can be served in a way that suits their operational needs, a **data exchange ecosystem** is required. This would allow reliable booking for road transport operators and provide knowledge of the battery state and recharging requirements to the charge point operators.

Infrastructure operators, especially in the more densely populated parts of the EU, are struggling to find **land** that meets the requirements for construction of HDV recharging stations. The land has to be of sufficient size, close to the motorway network and have electricity grid connections of sufficient capacity.

Amongst other issues that were mentioned are the **standardisation** (for sharing real-time and forecast recharging infrastructure availability and other operational data) which is lagging behind the market, **high-risk** environment into which recharging infrastructure operators are investing and the **energy market requirements** that do not allow direct peer-to-peer connections to nearby renewable electricity sources.

5.2. BARRIER SUMMARY

A summary of the barriers that shows the survey responses of all stakeholders for 2024 and 2030 is shown in Table 75 and Table 76. The tables show the average ranking[28] that each of the stakeholder groups assigns to each of the barriers. The left column of values shows the average for all stakeholders. The colours for both tables are normalised on the same scale so that tables are comparable.

When analysing the responses by the different stakeholder groups, it can be seen that there is a general consensus over what the barriers are that that zero-emission HDV adoption is facing.

The four major groups of barriers that zero-emission HDV adoption is facing are TCO and the related issues, lack of electricity grid capacity and the length of related administrative processes, lack of public recharging, and green hydrogen price uncertainty.

The stakeholders foresee that the identified barriers in general will decrease by 2030, which relates to their expectations on advances in technology, development of the infrastructure, establishment of sufficient production capacities and adequate supply chains for supporting this transition.

The NGOs and research institutions, agree with the rest on the existence of the barriers but tend to be more optimistic on them being solved by 2030.

Vehicle OEMs, however, don’t agree and see substantial barriers in the area of lacking recharging infrastructure today. They forecast this to remain the case also in 2030, while other stakeholders think this will be mitigated by 2030.

[28] Although the averages for discrete responses given on Likert scale are not entirely representative, they are shown here to facilitate the summary comparison. The frequency of responses is already shown above in this section in figures describing the responses of the main stakeholders.

Table 75: The importance of barriers today, responses by stakeholder group

	all	Vehicle OEMs	Part suppliers	Freight carriers	Shippers	Bus/coach operators	NGOs	Researcher/academic institution	DSOs /TSOs	CPOs	Technology providers	Electricity suppliers	Hydrogen
1. Purchase cost	4.4	3.7	4.3	4.5	4.8	4.8	4.3	4.5	4.8	4.5	4.3	4.8	4.6
2. Hydrogen price uncertainty	4.2	4.4	4.6	4.1	4.4	4.3	3.7	4.2	4.3	4.1	4.4	4.3	4.0
3. Grid capacity	4.2	4.4	4.3	4.5	4.7	2.7	3.3	3.2	4.3	4.7	4.2	4.3	4.2
4. Total cost of ownership	4.0	4.2	4.5	3.9	4.0	4.3	3.3	3.0	4.0	4.1	3.7	4.8	4.7
5. Grid connection permits	4.1	4.5	4.1	4.4	4.6	2.7	3.0	3.2	3.8	4.7	4.4	4.7	3.6
6. Lack of public recharging along the network during short (e.g. 45’) breaks	4.0	4.7	4.2	4.1	4.2	2.7	3.5	4.5	4.3	4.2	4.3	3.7	3.3
7. Lack of financial incentives	3.8	4.0	3.7	3.7	3.9	4.8	3.7	3.3	3.8	3.7	3.7	3.8	4.9
8. Lack of public recharging along the network during long daily/weekly resting periods	3.7	4.8	4.0	4.1	3.8	2.3	3.5	4.2	3.3	3.6	3.8	3.0	2.7
9. Availability of financial tools	3.3	2.2	3.5	3.2	2.9	5.0	3.8	3.5	3.5	2.9	3.2	3.3	4.0
10. Uncertainty on the residual value of vehicle and components	3.4	3.0	3.2	3.7	4.1	3.5	2.2	3.7	3.3	3.3	3.5	3.3	3.7
11. Investment costs of private infrastructure (e.g. depot recharging)	3.4	3.3	3.2	3.7	3.6	3.8	3.2	3.7	3.5	2.6	2.9	3.5	3.2
12. Energy price uncertainty	3.3	3.9	3.8	3.5	3.6	3.3	3.0	3.0	2.8	2.9	3.3	3.0	3.6
13. Adaptation and operational changes efforts	3.2	3.4	3.0	3.5	3.8	3.3	3.0	3.2	2.8	3.1	3.1	3.8	3.1
14. Lack of opportunity recharging at warehouses/logistic centres/intermodal terminals (e.g. during loading/unloading)	3.3	3.7	3.4	3.5	3.5	3.3	3.3	3.3	2.8	3.1	3.2	3.3	2.3
15. Flexibility of operations	3.1	3.1	3.2	3.7	4.0	2.7	2.2	3.0	2.8	3.4	3.0	3.5	2.7
16. Dwell time/refuelling time	3.1	3.6	2.9	3.4	3.7	3.7	2.7	3.2	2.3	3.1	2.7	3.3	2.6
17. Lack of private recharging at own location/depot, overnight (slow charging)	3.1	3.4	3.4	3.1	3.1	3.5	3.2	2.8	2.8	3.0	2.8	3.7	2.2
18. Lack of mandatory standards for hydrogen refuelling	3.1	3.0	3.3	3.0	3.2	3.3	3.3	3.0	3.0	3.1	3.1	3.0	2.6
19. Regulatory barriers	3.1	3.4	2.7	3.1	2.8	2.8	3.8	3.0	2.8	2.9	3.0	2.8	3.6
20. Vehicle range	3.1	3.4	3.1	3.9	3.5	3.3	1.8	3.0	2.3	3.1	2.9	3.5	2.3
21. Public vs private recharging electricity prices	3.1	3.1	3.6	3.2	3.8	2.5	3.5	3.5	2.3	2.6	3.2	2.3	2.3
22. Lack of private recharging at own location/depot, fast charging	3.1	3.4	3.1	3.1	3.2	4.0	2.7	3.5	2.5	2.7	2.9	2.7	2.0
23. Data exchange protocols and standards between vehicles, CPOs and grid operators	2.7	2.7	2.8	2.9	3.0	3.3	2.5	2.7	2.5	2.5	2.9	2.0	2.7
24. Reliability	2.6	2.3	2.7	3.1	2.9	3.0	1.5	2.0	3.0	2.9	2.7	3.5	2.9
25. Security of supply of raw materials and components	2.6	2.9	3.0	2.6	2.5	3.7	2.8	2.2	2.3	2.6	2.6	2.3	2.6
26. Lack of mandatory standards for recharging	2.5	2.3	2.8	2.7	2.5	2.5	2.7	2.2	2.0	2.6	2.7	2.7	2.2
27. Maintenance cost	2.4	1.8	2.5	2.3	2.4	3.0	2.2	2.0	2.5	2.3	2.4	2.8	3.0
28. Lack of mandatory standards for payments	2.4	2.2	3.1	2.7	2.8	2.0	2.7	2.2	1.8	2.1	2.2	1.8	1.8

Survey results show that bus and coach operators perceive the market situation differently from the other respondents. For them, the factors that contribute to vehicle TCO such as the availability of financial incentives and lack of financial tools are important barriers and they expect this to remain so also in 2030.

The representatives of hydrogen economy, similarly to other stakeholders see TCO as a major barrier to zero-emission HDV adoption, and foresee this to remain the case in 2030.

Table 76: The importance of barriers in 2030, responses by stakeholder group

	all	Vehicle OEMs	Part suppliers	Freight carriers	Shippers	Bus/coach operators	NGOs	Researcher/academic institution	DSOs /TSOs	CPOs	Technology providers	Electricity suppliers	Hydrogen
1. Grid capacity	3.8	4.7	4.1	4.1	4.6	3.0	2.7	2.5	3.0	4.3	3.9	3.3	4.0
2. Hydrogen price uncertainty	3.7	3.8	4.1	4.2	4.1	4.0	2.8	3.5	3.7	3.4	3.6	3.3	3.6
3. Grid connection permits	3.6	4.5	3.7	4.1	4.2	2.7	2.3	2.7	3.0	4.1	3.8	3.3	3.6
4. Purchase cost	3.4	2.9	3.8	3.8	3.9	4.7	2.8	2.5	3.0	3.0	3.4	3.5	3.8
5. Energy price uncertainty	3.2	4.0	3.8	3.7	3.6	3.7	2.3	2.0	2.3	2.9	3.1	3.0	3.8
6. Total cost of ownership	3.0	3.2	3.5	3.4	3.1	4.0	2.3	1.7	2.0	2.7	2.9	3.3	3.8
7. Lack of financial incentives	2.9	2.9	3.5	3.1	2.9	4.7	1.8	2.5	2.7	2.9	3.2	2.0	3.6
8. Lack of public recharging along the network during short (e.g. 45') breaks	3.0	4.0	3.6	3.4	3.4	2.3	1.7	2.7	2.0	2.9	3.1	3.3	1.8
9. Lack of public recharging along the network during long daily/weekly resting periods	2.9	4.0	3.4	3.4	3.4	2.0	1.7	2.7	2.3	2.9	3.0	3.0	1.8
10. Availability of financial tools	2.6	2.2	2.9	2.8	2.6	4.7	2.7	1.8	2.3	2.4	2.6	2.3	3.3
11. Uncertainty on the residual value of vehicle and components	2.7	2.9	2.9	3.0	3.2	3.3	1.8	2.2	2.0	2.5	3.0	2.5	3.1
12. Investment costs of private infrastructure (e.g. depot recharging)	2.9	3.4	3.1	3.5	3.2	3.3	2.5	2.7	2.3	1.8	2.5	1.7	2.2
13. Public vs private recharging electricity prices	2.9	3.6	3.3	3.3	3.4	2.3	2.5	2.7	1.7	2.2	2.8	2.0	2.0
14. Regulatory barriers	2.7	2.5	2.6	3.1	2.6	4.3	2.0	2.3	2.0	2.4	2.6	2.0	3.0
15. Lack of opportunity recharging at warehouses/logistic centres/intermodal terminals (e.g. during loading/unloading)	2.6	3.2	3.0	2.9	2.9	2.7	1.8	2.0	2.3	2.4	2.6	2.7	2.0
16. Security of supply of raw materials and components	2.6	3.0	3.0	2.4	2.9	2.7	2.2	2.2	1.3	2.7	3.1	2.3	2.8
17. Lack of private recharging at own location/depot, fast charging	2.5	2.9	2.9	2.8	3.1	3.0	2.0	2.0	2.3	1.9	2.3	1.7	2.0
18. Flexibility of operations	2.5	2.2	2.6	3.3	3.5	2.7	1.7	2.3	1.7	2.3	2.2	2.5	1.9
19. Adaptation and operational changes efforts	2.4	2.1	2.4	3.0	3.5	2.7	1.8	2.0	2.0	2.2	2.4	2.8	1.9
20. Lack of private recharging at own location/depot, overnight (slow charging)	2.5	2.8	2.9	2.8	3.1	3.0	2.0	1.7	2.3	1.9	2.3	2.0	2.0
21. Dwell time/refuelling time	2.6	2.8	2.4	2.9	3.4	2.7	1.5	2.3	1.3	2.5	2.5	2.5	1.9
22. Lack of mandatory standards for hydrogen refuelling	2.2	1.7	2.5	2.8	2.8	2.0	2.0	1.7	1.7	1.9	2.4	2.0	2.0
23. Vehicle range	2.2	1.9	2.2	3.1	2.7	2.7	1.7	2.0	1.0	1.9	2.3	2.0	1.6
24. Maintenance cost	2.1	1.7	2.2	2.5	2.2	2.7	2.0	1.5	1.7	2.0	2.1	2.0	2.5
25. Reliability	2.1	1.7	1.9	2.7	2.5	2.7	1.5	1.8	1.3	1.9	2.1	2.3	1.9
26. Data exchange protocols and standards between vehicles, CPOs and grid operators	2.1	1.9	2.3	2.8	2.8	2.0	1.8	1.8	1.0	1.9	2.2	1.7	1.6
27. Lack of mandatory standards for recharging	2.0	1.9	2.2	2.6	2.7	2.0	1.8	1.5	1.0	2.0	2.5	1.7	1.6
28. Lack of mandatory standards for payments	2.0	2.0	2.3	2.5	2.8	2.0	1.5	1.5	1.3	1.8	2.6	1.3	1.8

We conclude that the primary barrier to deploying a widespread recharging network for HDVs is grid capacity, not the cost or technology of chargers. To accelerate the deployment of zero-emission HDVs, it will be crucial to prepare electricity grids for increased electricity demand at recharging hubs as well as depots, by strengthening the grid and addressing permitting processes to reduce lead times for grid connections.

6. CONCLUSIONS

6.1. MARKET ANALYSIS

The vehicle market analysis highlights that the transition to zero-emission heavy-duty vehicles is progressing rapidly, though challenges remain. To reach the 45% reduction targets of the CO2 performance standards, manufacturers, accounting for energy improvements, need to put on the market 1 in 3 zero-emission vehicles by 2030. This represents a sharp increase considering that, today, the share of zero-emission vehicles in new sales is about 2%. It is expected that battery electric vehicles will play a crucial role in meeting the new CO_2 standards emissions reduction targets. This was confirmed in the second workshop: 80% of about 80 respondents either agreed or strongly agreed with the statement "**Until 2030, the zero-emission HDV in the new fleet will be predominantly represented by BEVs. Those BEV's will rely on stationary recharging (as opposed to Electric Road Systems)**".

Battery electric vehicles in fact dominate the zero-emission vehicle market in Europe, with all major original equipment manufacturers offering a wide portfolio of models in all market segments and planning to introduce new models by 2030. A few H2 vehicles are also part of the offer for the long-haul and regional delivery use cases. A couple of H2ICE models have also been announced to enter the market before the end of the decade for long-haul and other specific demanding operations.

According to both manufactures and operators (shippers, forwarders etc.), currently, battery electric vehicles are most suited for regional and urban delivery, as well as urban buses, but it is expected that, with new models available, performance will further improve for all use cases. Performance improvements are expected for both H2 vehicles and BEV in all segments and especially in the long haul.

Reaching the 45% emission reduction target requires the deployment of zero-emission vehicles in all market segments. It is not sufficient to decarbonise urban and regional transport: vehicles in the long-haul segment need to be contribute significantly to the emissions reductions as well. In particular, group 5-LH is responsible for large part of emissions and registrations (about 66% of all trucks in the regulation for the 2021/2022 reporting period). In this segment, hydrogen vehicles are seen as a complementary solution to battery electric vehicles for demanding long-haul operations due to their longer range and potentially faster refuelling times, which can make their operation similar to that of conventional diesel vehicles, depending on the quality and capacity of the H_2 infrastructure to sever multiple vehicles in quick succession. However, they are affected by higher costs, lower efficiencies (especially source to wheel) and a high uncertainty on prices and availability, in particular, of green H_2. Hydrogen fuel cell vehicles today make up a very small fraction of the market with only a few models available. These elements result in greater uncertainties related to the deployment of H_2 fuelled vehicles with respect to BEVs.

Under the assumptions of the 'study scenario' by 2030, BEV will play the predominant role in reaching the targets of the revised CO_2 standards. However, the expectation for H_2 in the long-haul result in a share of H_2 vehicles in the zero-emission fleet of 16% with corresponding energy need of 28.5% of the total zero-emission fleet. These results are based on desk research and the expected market shares as reported by the stakeholders. However, given the few models currently available, the low penetration of H_2 currently observed in the market, the contribution of FCEVs vehicles and H2ICE in 2030 should still be considered one of the main sources of uncertainty in the results presented in this study.

To conclude, whereas there are clear targets for manufacturers, on the demand side, there are currently less clear policy drivers to spur the transition. Some incentives that are already in place are for example the Eurovignette directive, the Clean Vehicles Directive (CVD) and the Weights and Dimensions Directive. However, operators currently include zero-emission vehicles in their fleet mainly to reach their own voluntary targets or allow the clients who have also set targets for themselves to reach them. In this context, ETS2, road tolling, and the revision of the ETD are often cited as important pieces of the puzzle that, where and when in place, provide an incentive for the use of heavy-duty zero-emission vehicles.

6.2. INFRASTRUCTURE REQUIREMENTS

As the market for Battery Electric Vehicles (BEVs) expands, specifically in the heavy-duty vehicle (HDV) sector, diverse requirements for recharging infrastructure are anticipated. Vehicles with long-haul operations and coaches will heavily rely on publicly accessible recharging points, necessitating strategic placement and high-output (kW) recharging options supporting their extensive operational requirements. Urban delivery vehicles, buses, and vocational vehicles, however, are likely to depend primarily – or in the case of buses almost exclusively - on private recharging solutions at depots, with regional lorries' needs contingent upon specific use cases and routes.

Stakeholder expectations point to a utilization rate of 2-30% for publicly accessible recharging stations, indicating a potentially vast disparity in infrastructure use and emphasizing the challenge of accurately projecting future needs. Charge Point Operators (CPOs) are preparing for future demands by investing in Combined Charging System (CCS) and Megawatt Charging System (MCS) technologies, forecasting the introduction of thousands of high-power recharging stations by 2030. However, these developments are currently constrained by limited grid capacity and the often lengthy timelines required for grid upgrades.

For hydrogen (H2) vehicles, a considerable reliance on public refuelling infrastructure is forecasted, with only 5-15% of fleet operators expected to have private facilities. There is anticipation for a mixed range of output pressures, with a preference for 700 bar for longer distance applications. The adoption of Electric Road Systems (ERS) is not expected to make a substantial contribution to HDV electrification before 2030, owing to the nascent state of the technology and the extensive infrastructure and policy support required.

The analysis projects a requirement for **18,000 recharging points**, with a focus on chargers delivering over 150 kW, and **1,100 refuelling points**, predominantly at 700 bar, to meet the infrastructure needs for BEVs and H2 vehicles. These demands, however, significantly rely on a set of assumptions and input data, and hence, are subject to substantial uncertainty.

Lastly, AFIR sets mandates for a considerable infrastructure coverage along the TEN-T road network, in urban nodes and parking areas. However, the regulation only addresses the TEN-T network with a minimum energy output (kW/bar) to be provided at each recharging pool/refuelling location. Additional infrastructure will be required outside the TEN-T network, and higher output will be required at locations with higher traffic volumes. This additional infrastructure should be ideally provided through market forces. The demand for energy from publicly accessible infrastructure can be expected to be partially met by the fulfillment of the AFIR targets by a range of **50%-80%** (for BEVs) and **50%-65%**, respectively, depending on the scenario.

6.3. BARRIERS

The primary barriers to zero-emission HDV adoption are high TCO, limited electricity grid capacity and lengthy administrative procedures for grid connection, lack of public recharging infrastructure, and uncertainty in hydrogen pricing in particular for green hydrogen.

Among these, electricity grid capacity constraints present a significant obstacle to recharging infrastructure development, as they limit the potential size of recharging locations, directly affecting the deployment rate of recharging stations along key transport corridors. To address this, the grid must be strengthened to support increasing electricity demands at HDV recharging hubs, both at depots/warehouses/industrial locations and along motorway networks. Administrative processes related to grid connection permitting also contribute to longer lead times and increased costs, underscoring the need for more efficient approval mechanisms to be developed.

Stakeholders are confident that the scarcity of electric recharging and hydrogen refuelling infrastructure can be overcome through the mandatory deployment targets established under AFIR. However, realisation of the targets for electric recharging will also depend on sufficient grid infrastructure to support the deployment. Stakeholders are optimistic that technological advancements and market maturity will reduce cost-related barriers by 2030, particularly through economies of scale in vehicle production and more mature recharging markets. However, uncertainty remains around hydrogen price competitiveness due to its low energy efficiency and reliance on subsidies. Coordinated efforts to improve grid capacity, expedite administrative processes, and enhance public recharging options are critical to achieving widespread adoption of zero-emission HDVs.

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