

STUDY

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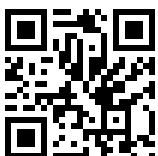


Alternative fuel infrastructures for heavy-duty vehicles

Overview briefing



Transport and Tourism



Policy Department for Structural and Cohesion Policies
Directorate-General for Internal Policies
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RESEARCH FOR TRAN COMMITTEE

Alternative fuel infrastructures for heavy-duty vehicles

Overview briefing

Abstract

This briefing presents the opportunities and challenges for the use and deployment of alternative fuels infrastructure in the EU for heavy-duty vehicles, in particular trucks. The current state of play and future needs are presented in the context of the ambitions of the Green Deal and current legislative developments, in particular the upcoming reviews of the Alternative Fuels Directive and the TEN-T Regulation.

This briefing will be followed by a full-length study that will provide a more in-depth analysis, an update of the policy context based on the 'Fit for 55' package and outcomes of stakeholder interviews and case study analysis.

This document was requested by the European Parliament's Committee on Transport and Tourism.

AUTHORS

CE Delft: Anouk VAN GRINSVEN, Matthijs OTTEN, Emiel VAN DEN TOORN, Reinier VAN DER VEEN, Julius KIRÁLY, Roy VAN DEN BERG

Research administrator: Ariane DEBYSER, Davide PERNICE

Project, publication and communication assistance: Mariana VÁCLAVOVÁ, Kinga OSTAŃSKA
Policy Department for Structural and Cohesion Policies, European Parliament

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ABOUT THE PUBLISHER

To contact the Policy Department or to subscribe to updates on our work for the TRAN Committee please write to: Poldep-cohesion@ep.europa.eu

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LIST OF ABBREVIATIONS

AC	alternating current
ACEA	The European Automobile Manufacturers' Association
AFI	alternative fuels infrastructure
AFID	Alternative Fuels Infrastructure Directive
BET	battery electric truck
CNG	compressed natural gas
DAC	direct air capture
DC	direct current
DME	Dimethylether
EC	European Commission
EP	European Parliament
EU	European Union
ERS	Electric Road System
EV	electric vehicle
FCEV	fuel cell electric vehicle
FCET	fuel cell electric truck
FQD	Fuel Quality Directive
GHG	greenhouse gas
GVW	gross vehicle weight
HDV	heavy-duty vehicle
HRS	hydrogen refuelling station
ICE	internal combustion engine

ICEV	internal combustion engine vehicle
LDV	light-duty vehicle
LNG	liquefied natural gas
LPG	liquefied petroleum gas
OEM	original equipment manufacturer
OME	oxymethyleneether
PEMFC	proton-exchange membrane fuel cell
RED	Renewable Energy Directive
SOFC	solid oxide fuel cell
TCO	total cost of ownership or total cost of operation
TEN-E	Trans-European Network for Energy
TEN-T	Trans-European Transport Network
tkm	tonne-kilometres
TRAN	(European Parliament's Committee on) Transport and Tourism
TTW	tank-to-wheel
vkm	vehicle-kilometres
WLPGA	World Liquid Petroleum Gas Association
WTW	well-to-wheel

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EXECUTIVE SUMMARY

KEY FINDINGS

- Because of their GHG emission reduction potential, alternatively fuelled low and zero-emission trucks will play a major role in realising the **EU Green Deal and the 55% GHG reduction target for 2030**. It is therefore essential that there is **sufficient and widespread recharging and refuelling infrastructure** available.
- For trucks the Alternative Fuels Infrastructure Directive (AFID) is geared mainly to alternative fuels like CNG and LNG. Given the Green Deal decarbonisation target, **the AFID should shift its focus to creating refuelling infrastructure for battery electric trucks (BET) and hydrogen fuelling infrastructure**. Electric road systems (ERS) could be further piloted on specific corridors.
- At present there is **only minimal publicly accessible refuelling and recharging infrastructure** for BETs and hydrogen-fuelled trucks. Chargers up to 350 kW have been piloted, while chargers up to 1 MW are being developed to limit charging times. A limited number of hydrogen refuelling stations for passengers' cars and buses are already in operation. **Accessibility** for trucks seems very limited and needs attention with respect **to size, spatial integration, compatibility of tank pressure and location choice**.
- Estimated future infrastructure requirements point to **a need for overnight depot charging points as the main recharging concept for BETs. To a lesser extent public overnight chargers and ultra-fast opportunity charging are required**. For medium- and long-haul transport, however, **publicly accessible fast-charging infrastructure** is essential and needs to be addressed via TEN-T and the AFID.
- Given the high power demand of truck charging at depots and roadside public charging stations, **the power grid and its capacity need to be suitably prepared** and made future-proof. These developments should be taken into account in the TEN-E revision.
- Although action is required in the short term, **lack of investment security, a stable long-term policy framework and a targeted, uniform approach** are hampering accelerated roll-out and increasing realisation times. Policymakers need to take suitable policy initiatives.

The need to decarbonise road freight transport

Given the Green Deal objective of reducing transport GHG emissions by 90% in 2050 and the current share of emissions from road transport and HDVs, trucks in particular, more effective action needs to be undertaken to decarbonise this vehicle segment. While alternative fuels and zero-emission powertrains offer major reduction potential, without sufficient and appropriate recharging and refuelling infrastructure they will fail to deliver. To date, however, policymakers and other stakeholders have focused mainly on creating fuelling infrastructure for passenger cars rather than trucks. The anticipated revisions of the Alternative Fuels Infrastructure Directive (AFID) and TEN-T regulation may improve this situation, along with strategies at the national level.

Current technologies

While biofuels and liquefied natural gas (LNG) are more mature and already more widely available, battery electric trucks (BET), fuel cell electric trucks (FCET) and electric road systems (ERS) still need major development and investment to ensure sufficient coverage in the long term, preferably along the TEN-T corridors.

The economic and operational feasibility of recharging and refuelling concepts for alternative fuels are hampered by relatively long recharging and refuelling times and low capacities. Further technological development is needed to match the higher energy demand of trucks and to enable the shift to long distances. Most pilots and first-mover initiatives on these technologies are taking place in Western European countries, parallel to initial uptake of the associated vehicles.

Low-carbon fuels can result in major GHG emission reductions in internal combustion engines. Infrastructure for biofuels and e-fuels can be relatively easily extended, using the current infrastructure for diesel if necessary.

Existing infrastructure and estimate of future needs

Apart from infrastructure for trucks running on gaseous fuels, other types of alternative infrastructure are still virtually absent. There is a paucity of data on its accessibility for trucks. The number of 1042 (hybrid) BETs currently on the road will be served by private (depot) charging infrastructure where vehicles can be recharged for short- and medium-haul trips. Depot charging is also expected to be the main form of BET recharging infrastructure in the future. Publicly accessible fast charging stations are in any case essential for long-haul as well as medium-haul transport.

Nonetheless, estimates of demand in 2025 and 2030 point to a need for rapid roll-out of such infrastructure in the coming few years. Geographically, there also needs to be a shift from a limited number of Member States to full EU-wide coverage. Given the major uncertainties involved, studies on future infrastructure requirements are in fair agreement with their projections of the number of charging and refuelling points needed, though they differ on expectations regarding full electrification (or more hybrid forms of transport).

Barriers and enablers

Developments on recharging and refuelling infrastructure are currently hampered by limited investment security and the lack of a stable long-term policy framework, including binding targets. Investors are also looking for large potential user groups to ensure guaranteed utilisation rates. This is beneficial for larger companies seeking cooperation and disadvantageous for small and medium-sized enterprises.

Appropriate grid connections and adjustments by grid operators also require a coordinated approach, often resulting in long procedures and thus long lead times. These and other investments will need to be made by large energy suppliers, as well as by companies needing charging infrastructure at their depots. Shared public infrastructure provides opportunities for higher utilisation rates, but should come with additional measures to inform users on accessibility and procedures for guaranteed refuelling or recharging, as needed.

Overall, stakeholders often operate quite independently, while cooperation could be beneficial for knowledge exchange and could accelerate harmonisation and standardisation. The vehicle-infrastructure interface, in particular, requires standardisation initiatives. Infrastructure roll-out is also hampered by legislative barriers.

Policy recommendations aimed at removing barriers

Policy-makers can contribute to the development of infrastructure for trucks by removing barriers by means of:

- an increase in investment security for investors by creating a stable policy framework (such as binding targets) and via smart funding mechanisms;
- a reduction in lead times by removing any disproportionate permit requirements given the size and scale of recharging and refuelling infrastructure;
- a reduction of long procedures and lead times for appropriate grid connections and adjustments to ensure sufficient capacity;
- bringing stakeholders together in a coordinated approach in which small and medium-sized enterprises can also benefit from scale advantages and particular attention is paid to the role of grid operators and other stakeholders in the energy sector;
- seeking synergies and smart solutions to maximise utilisation rates;
- development of information and reservation systems to improve accessibility and to reduce uncertainties related to availability, mainly for shared public infrastructure;
- striving for standardisation and harmonisation from the outset, especially for the vehicle-infrastructure interface;
- ensuring all Member States are on board, not only frontrunners.
- finally, the decarbonisation potential of renewable fuels (biofuels and e-fuels) in diesel engines should not be overlooked. Additional actions focussing on feedstock mobilisation and realisation of supply chains should be taken.

1. INTRODUCTION

1.1. Background to the study

This briefing contains the preliminary results of a study on alternative fuels infrastructure for heavy-duty vehicles.

The European Union's new target of reducing GHG emissions by 55% by 2030 means major action is required across all sectors of the European economy. It also means the majority of energy and climate legislation will have to be amended. The Commission plans to present its proposals on 14 July, 2021 as part of the 'Fit for 55' package, including a proposal for revising the Alternative Fuels Infrastructure Directive (AFID). A legislative proposal for revising the TEN-T Regulation is also planned for the third quarter of 2021. In advance of the 'Fit for 55' package, this briefing aims to inform the Members of the European Parliament on the current status of the topic. The scope of this study focuses on heavy-duty vehicles (HDV), in particular trucks¹, and includes a wide range of alternative fuels as part of the policy debate.

Later, this briefing will be followed by a full-length study that will provide a more in-depth analysis, an update of the policy context based on the 'Fit for 55' package and outcomes of stakeholder interviews and case study analysis. This will allow drafting of more specific policy recommendations.

1.2. Overview of the study

This briefing starts, in Chapter 0, with a description of the current policy context. Chapter 0 provides an overview of the technologies currently available to power HDVs, trucks in particular, and current infrastructure for refuelling and recharging these vehicles. Chapter 4 describes the barriers and enablers associated with roll-out of truck refuelling and recharging infrastructure. Chapter 5 then describes future needs for alternative fuels infrastructure, given the various policy objectives and projected vehicle fleet developments, and discusses the main factors and uncertainties involved. The briefing draws, in Chapter 6, some preliminary conclusions and identification of the main research gaps.

¹ The N2 and N3 categories of heavy duty vehicles are considered.

2. POLICY CONTEXT

KEY FINDINGS

- The **EU Green Deal, Climate Target Plan** and **European Climate Law** will together form the main driver of truck decarbonisation and thus determine demand for alternative fuels and alternative powertrains with their associated infrastructure.
- The higher level of ambition that is coming into play is likely to result in changes of **scope and major revisions** of the **Alternative Fuels Infrastructure Directive** and **TEN-T and TEN-E regulations**, as well as the **Renewable Energy Directive** and **CO₂ standards for trucks**.
- To date, policy initiatives on refuelling and recharging infrastructure for road vehicles have focused mainly on **passenger cars and vans**, with limited attention to **trucks**.
- At the **national level**, several Member States have recently developed **hydrogen strategies**, including use of this fuel by trucks, while electric trucks are only recently being included in **national charging infrastructure strategies**.
- **Zero-emission zones** are expected to play an important role at the local level.

2.1. EU strategies

There are several EU-wide strategies of relevance for alternative fuels infrastructure for HDV. We discuss the following in turn: we will start with the Green Deal, together with the 2030 Climate Target Plan and European Climate Law. Secondly, the Sustainable and Smart Mobility Strategy is discussed, followed by the Recharge and Refuel project and finally, the Hydrogen strategy.

The [EU Green Deal](#) launched in December 2019 has set the target of reducing transport-related emissions by 90% in 2050. As part of the Green Deal, the [2030 Climate Target Plan](#) has raised the greenhouse gas emission reduction target for 2030 to at least 55% reduction by 2030 compared with 1990 levels. The European Commission is currently preparing detailed legislative proposals on how this more ambitious reduction target is to be achieved. The aim is to review and, where necessary, propose revisions to all relevant policy instruments by July 2021. It is consequently anticipated that decarbonisation of the fuel mix and vehicle fleet renewal will be accelerated, with several transport-related Directives and Regulations therefore also being revised, or scheduled to be so. On June 28th 2021 the European Council has adopted the new [European Climate Law](#) making the Green Deal ambition legally binding ([European Council, 2021b](#)).

Modal shift from road freight to inland waterway and rail as well as road pricing are also mentioned in the Green Deal. These will provide opportunities for multimodal refuelling and recharging options, but could also result in competition between infrastructure investments. Road pricing could be designed with lower tariffs applying to trucks running on low- or zero-carbon fuels. In parallel, the Commission is to support deployment of public recharging and refuelling stations where persistent gaps exist, notably for long-distance travel, which will be beneficial for trucks.

Within the framework of the Green Deal a review of the Alternative Fuels Infrastructure Directive (AFID) and the Transport-European Transport Network (TEN-T) Regulation are expected (see 2.2).

The [EU Hydrogen strategy](#) was launched in July 2020 and identified mobility as one of the two lead markets for green hydrogen (the other being industrial applications). By first building local hydrogen networks where hydrogen is consumed near production sites, the second step would require transport of hydrogen over longer distances. This process requires a revision of the [Trans-European Networks for Energy \(TEN-E\)](#) (see 2.2). This should go hand-in-hand with the roll-out of refuelling stations, linked to the review of the AFID and revision of TEN-T. The strategy counts on the CO₂ emission standards regulation being an important driver for creating a market for hydrogen solutions (EC, 2020a).([EC, 2020a](#)).

Recharge and Refuel is one of seven flagship projects under the [NextGenerationEU Recovery and Resilience Facility](#) for the [2021 annual sustainable growth strategy](#). The concrete aim is to build, by 2025, half the 1,000 hydrogen stations and one million out of three million public recharging points needed in 2030. With a total of 672.5 billion euro allocated, the Recovery and Resilience Facility is the key instrument to help the EU emerge stronger and more resilient from the current crisis due to the global pandemic.

The [Sustainable and Smart Mobility Strategy](#) (December 2020) states that “greening mobility must be the new licence for the transport sector to grow”. This implies that an efficient and interconnected multimodal transport system should be enhanced by, among other things, “abundant recharging and refuelling infrastructure for zero-emission vehicles and supply of renewable and low-carbon fuels”. The communication also stressed that compared to the previous decade, additional investments of 130 billion euro per year will be needed for 2021-2030 (vehicles, vessels, aircraft, infrastructure). For the ‘green and digital transformation investment gap’ for infrastructure an additional 100 billion euro per year would be needed. Completing the TEN-T core network requires 300 billion over the next ten years ([EC, 2020d](#)).

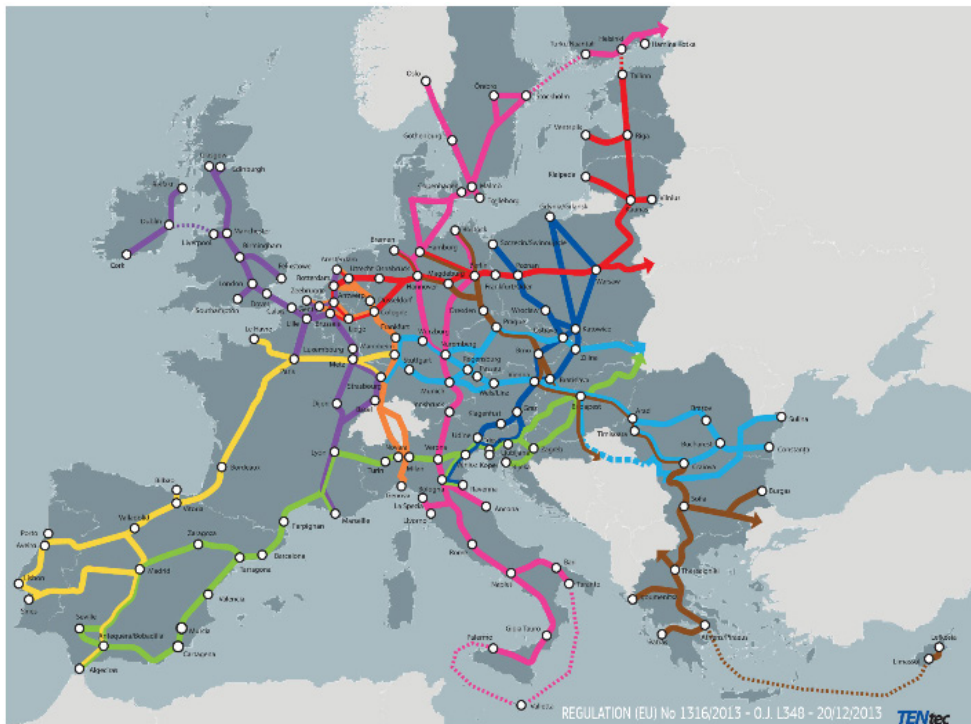
2.2. Relevant Directives and Regulations

The overarching strategies and communications often refer to changes to specific Directives and Regulations. This section describes the most relevant of these.

2.2.1. Infrastructure-related Directives and Regulations

The [Alternative Fuels Infrastructure Directive \(AFID\)](#) is the main policy instrument for advancing an EU-wide strategy to implement alternative fuels infrastructure. The existing AFID came into force in November 2014. The AFID is a common framework of measures for deploying alternative fuels infrastructure with a view to minimising dependence on oil and mitigating the environmental impact of transport. It sets minimum requirements for establishing alternative fuels infrastructure, including recharging stations for electric vehicles and refuelling points for natural gas (LNG and CNG) and hydrogen, to be implemented by means of Member States' non-binding national policy frameworks. The AFID has also guided standardisation of charging points and contains provisions regarding user information, which are also relevant for biofuels. It is important to note that the AFID is aimed at public infrastructure, while private charging points are also an important issue, particularly for HDVs.

The [Trans-European Transport Network \(TEN-T\) Regulation](#) aims to develop a Europe-wide transport network by closing gaps, removing barriers and applying innovative technologies. There is a core network of ten corridors which is to be completed by 2030.

Figure 1: TEN-T core network corridors

Source: [\(EC, 2021b\)](#).

The [Trans-European Networks for Energy \(TEN-E\) Regulation](#) aims to link the energy infrastructures of EU nations, with nine priority corridors for gas, oil and electricity and three priority thematic areas: smart-grid deployment, electricity highways and a cross-border carbon dioxide network. In December 2020 the Commission came forward with [a proposal](#) to revise the EU rules on the TEN-E regulation to make the TEN-E fit to support achievement of climate neutrality in 2050. The revised TEN-E framework is thus to include hydrogen infrastructure, power-to-gas and smart grids to support electric charging and hydrogen refuelling infrastructures and integration of offshore wind ([EC, 2020b](#)).

2.2.2. Vehicle-related Directives and Regulations

Vehicle emission standards are one of the key drivers of alternative fuel uptake in the EU. Stricter standards also make zero-emission vehicles more attractive for manufacturers. Emission standards for heavy-duty vehicles (HDV) are in force for emissions of both GHG ([Regulation 2019/1242](#)) and air pollutants ([Regulation 595/2009](#)).

[Regulation 2019/1242](#) was the first EU-wide CO₂ regulation for HDV, setting a 15% CO₂ emission reduction requirement for new HDVs for 2025-2029 and 30% reduction for the year 2030 and beyond. The reduction target applies to manufacturers and is based on reference emissions reported in the period 1 July 2019 to 30 June 2020.

The Regulation also contains an incentive mechanism for zero- and low-emission vehicles by means of a system of credits for manufacturers. In 2025 it is to be replaced by a benchmark system. The 2030 benchmark level will be set during the 2022 review, which also includes an assessment of the CO₂ standards. During that review hydrogen will also be included and there may also be introduction of assessment of lifecycle CO₂ emissions and CO₂ credits for manufacturers ([EC, 2019a](#)).

[Regulation 595/2009](#) established the Euro VI (air pollutant) emissions standards for HDV. As part of the Green Deal, the Commission has proposed [an initiative for Euro 7 standards](#)², planned for adoption at the end of 2021. The Euro standards also apply to Internal Combustion Engine vehicles (ICEVs) fuelled with alternative fuels.

The Green Deal also suggested that a change to the [Eurovignette Directive](#) might be an option for maintaining its original high level of ambition. Eurovignette is a road toll system for trucks with a gross vehicle weight of 12 tonnes or more that has higher tariffs for lower Euro emission classes.

2.2.3. Fuel-related Directives and Regulations

The [Renewable Energy Directive II \(RED II\)](#) was adopted in 2018 and is the successor of the RED. The RED II sets EU targets for consumption of renewable energy sources in 2030 based on the overall EU objective (of 32% renewable energy in final energy consumption), and outlines requirements for national contributions to these targets. For transport, the RED II obliges fuel suppliers to ensure that the share of renewable energy in the final energy consumption of the transport sector is at least 14% by 2030, with a sub-target of 3.5% for advanced biofuels. This minimum of 14% can in part be administratively achieved, using so-called multiplication factors. Biofuels, bioliquids and biomass fuels can only count towards the targets if certain sustainability criteria are met. The Commission is still currently working on the calculation methodologies for renewable electricity and renewable fuels of non-biological origin, such as (renewable) hydrogen; these will be adopted through delegated acts. As result of the higher ambition of the Green Deal, the RED II is already being revised even before many Member States have transposed the 2018 Directive into national legislation.

While the RED II sets a target for the minimum share of renewable energy in transport, the [Fuel Quality Directive \(FQD\)](#) has a reduction target for the average GHG intensity of fuels. Use of renewable energy in transport thus contributes to both the FQD target and the RED II target. No decision has yet been made on extending the FQD target towards 2030. Besides the reduction target, the FQD also lays down fuel specifications determining how much biofuel can be blended with regular road transport fuels. Biofuel blends not meeting the fuel specifications for regular road transport fuels, such as so-called 'high blends', must be marketed as a different product. Fuel specifications (and consequently vehicle compatibility) are issues both part of the FQD and the user information provisions of the AFID.

2.3. National strategies of EU Member States

National strategies may also be relevant for assessing the state-of-play across the EU. To identify issues requiring harmonisation and interoperability at the European level, we identified the main differences in national policies for the selected transitions.

2.3.1. AFID implementation

In March 2021 the Commission published [a report on implementation of the AFID in Member States](#). Based on national implementation reports, the document showed the importance of the AFID for roll-out of alternative fuels infrastructure. In certain Member States successful roll-out was hampered to varying degrees by a range of issues, including lack of national coordination and low initial investments. In 2020 most countries had not met the required targets, although there were large differences between Member States ([EC, 2021a](#); [IEA, 2021](#)).

² The Euro standards cover the exhaust emissions of all petrol and diesel cars, vans, trucks and buses. Euro 7 is planned to be announced in 2021 and come into force by 2025. It will probably be the last emission standard implemented before phase-out of Internal Combustion Engine Vehicles.

In relation to HDV, Member States' strategies regarding alternative fuels infrastructure differ in their level of ambition and policy focus. By and large, it is western European Member States that have begun developing specific strategies for hydrogen or electric HDV (such as Netherlands, Portugal, Germany, France, Spain, Italy).

2.3.2. Hydrogen strategies

As mentioned, several Member States (Netherlands, Portugal, Germany, France, Spain, Italy) have announced a hydrogen strategy, all containing specific targets for (mainly heavy-duty) transport, including hydrogen refuelling stations (HRS).. [Germany aims to have 400 HRS by 2025 and 1,000 by 2030, France 100 by 2023 and 400-1,000 by 2028, Spain 100-150 in 2030 and the Netherlands 50 by 2025, while Italy plans to have 2% of their roughly 1 million trucks³ fuel cell electric trucks \(FCET\) by 2030 \(Lambert & Schulte, 2021; FuelCellsWorks, 2020a\)](#). Advocacy to facilitate cross-border EU transport is also part of the strategies. In 2021 several Eastern European Member States also announced hydrogen strategies or road maps involving transport [Euractiv, 2021b](#)).

2.3.3. Strategies related to battery-electric trucks (BET)

In contrast to electric buses, it is only recently that battery-electric trucks have gained momentum as a serious option. National strategies for electric trucks are hence only in an early stage of development, as yet not comparable to hydrogen strategies, or lacking entirely. [The total number of new BETs registered in Europe was no more than 360 in 2019 and 450 in 2020 \(IEA, 2021\)](#). The Netherlands has a 'National Charging Agenda' in which implementation of urban zero-emission zones is identified as the main factor driving demand for truck charging points. The Agenda also emphasises the importance of connecting urban centres with logistical and distribution hubs in terms of charging locations. Additional research is considered necessary, though [\(RVO, 2020\)](#). In Germany, advancing charging infrastructure is a key measure of the federal government, with fast charging receiving two-thirds of the budget (300 million euro) [\(German Government, 2019\)](#).

2.3.4. Low- and zero-emission zones

Increasingly, low- and zero-emission zones and other access restrictions are being introduced in urban areas in certain EU countries, with access of the worst polluting categories of vehicles restricted permanently or in certain periods. These zones can be instrumental in shifting city logistics to zero-emission. Most such zones are in Italy, Germany, Belgium and the Netherlands, but urban access restrictions have also been introduced in Poland, Spain and France [\(Urban access regulations, 2021\)](#).

2.4. Policies and strategies of third countries

2.4.1. United States

Natural gas infrastructure has been promoted since 2015 by the [Fixing America's Surface Transportation Act](#), which requires the United States Department of Transportation to set aspirational targets for the deployment of alternative fuels infrastructure along key corridors. Taxation disadvantages for alternative fuels were also addressed [\(OECD, 2017\)](#).

In 2019 the US Senate passed the America's Transportation Infrastructure Act, earmarking \$1 billion to support development of fuelling infrastructure for electric, natural gas and hydrogen-powered vehicles [\(FuelCellsWorks, 2019\)](#).

³ Number of truck in Italy, see section 3.1

In the [2020 Hydrogen Program Plan](#), long-haul HDV is mentioned as an important growth market for hydrogen ([US DOE, 2020](#)); as of 2021, [there are 45 hydrogen refuelling stations in the US \(not specified per vehicle type, but only in California\)](#).

The North American Council for Freight Efficiency identified charging infrastructure as one of the main sources of concern for adoption of electric fleets. The Council believes that, for trucks, the principal charging infrastructure should be private, at depot or 'return-to-base' ([NACFE, 2019](#)).

In 2021 the Biden Administration announced an action plan to advance electric vehicle charging infrastructure and to realize a national network of [500,000 charging stations](#). Charging for freight infrastructure is an integral part of the plan. The plan has been developed in conjunction with the 'alternative fuel corridor program' for electric, hydrogen, propane and natural gas. This program aims to create a network for alternative fuel infrastructure built around interstate corridors ([The White House, 2021](#)).

The federal structure of the U.S. means that different states have different policies, with California the most ambitious state. California has adopted the 'Advanced Clean Truck' regulation, initiating phased introduction of zero-emission trucks (no tailpipe emissions). The regulation puts a ZEV sale requirement on manufacturers. By 2035, zero-emission truck/chassis sales would need to be between 40 and 75%, depending on type and class. The rule also contains a one-time reporting obligation for large entities and fleets in order to identify challenges and design strategies for the future ([California Air Resources Board, 2020](#)).

2.4.2. Norway

Among Western countries, Norway has the majority of newly registered cars now electric, while the government has set the objective of 50% of all newly registered trucks being zero-emission in 2030. In addition, goods distribution in the biggest urban centres must be virtually zero-emission by 2030. By the end of 2019, 1 hydrogen truck and 21 electric trucks were registered in Norway, with at least 70 more hydrogen trucks and 75 electric trucks on order ([Scania, 2020](#)).

Norway sees hydrogen for heavy vehicles as a potentially good interim solution, but it expects battery-electric trucks to increasingly catch up with the benefits of hydrogen as more and more high-speed charging points become available along major corridors ([Norwegian Government, 2020](#)). Access to charging infrastructure is identified as one of the main bottlenecks for a successful transition to battery-electric trucks, including depot-charging and fast-charging facilities on main roads ([Hovi, Pinchasik, Figenbaum, & Thorne, 2020](#)). Norway has put forward as a key condition that development of alternative fuels infrastructure be market-driven, with government funding available for the initial stage only ([Norwegian Government, 2020](#)). Bio- and e-fuels are not deemed suitable for large-scale application for trucks (being aimed at other transport modes).

Norway has several direct and indirect policies to stimulate uptake of zero-emission transport, including tax benefits and reduced tariffs for infrastructure. Local authorities can decide whether to exempt electric vehicles from road tolls or parking fees. A national rule stipulates that zero-emission vehicles pay no more than half of toll station and ferry tariffs.

2.4.3. China

In China there has been a rise in use of natural gas trucks, driven by favourable prices and government policies, motivated by both air-quality and energy-security considerations. In 2016 there were 7,950 refuelling stations. However, the majority of natural gas vehicles were light-duty vehicles. Natural gas trucks were common in inland provinces where gas was produced domestically ([OECD, 2017](#)).

China has high ambitions for hydrogen in transport and its 13th five-year plan (2016-2020) included the target of large-scale deployment of hydrogen refuelling stations (HRS) in China. China already accounts for 94% of global fuel-cell buses and 99% of fuel-cell trucks (FCET), but its future strategy seems to focus mainly on passenger transport. For 2025 the target is 300 HRS with 50,000 FCEVs in service (80% passenger cars). In 2030 there should be over 1,000 HRS and over a million vehicles. Local and regional authorities may also have their own HRS targets ([Verheul, 2019](#)). Nonetheless, hydrogen trucks received more interest in 2020, backed by domestic manufacturers and government support ([Asia Times, 2021](#)).

Overall, policy initiatives have been limited to ambitions in strategies without strict binding targets. The next chapter will present the wide range of technological options for refuelling and recharging infrastructure that could be targeted by policy instruments in the short term.

3. EXISTING TECHNOLOGIES TO POWER HDV

KEY FINDINGS

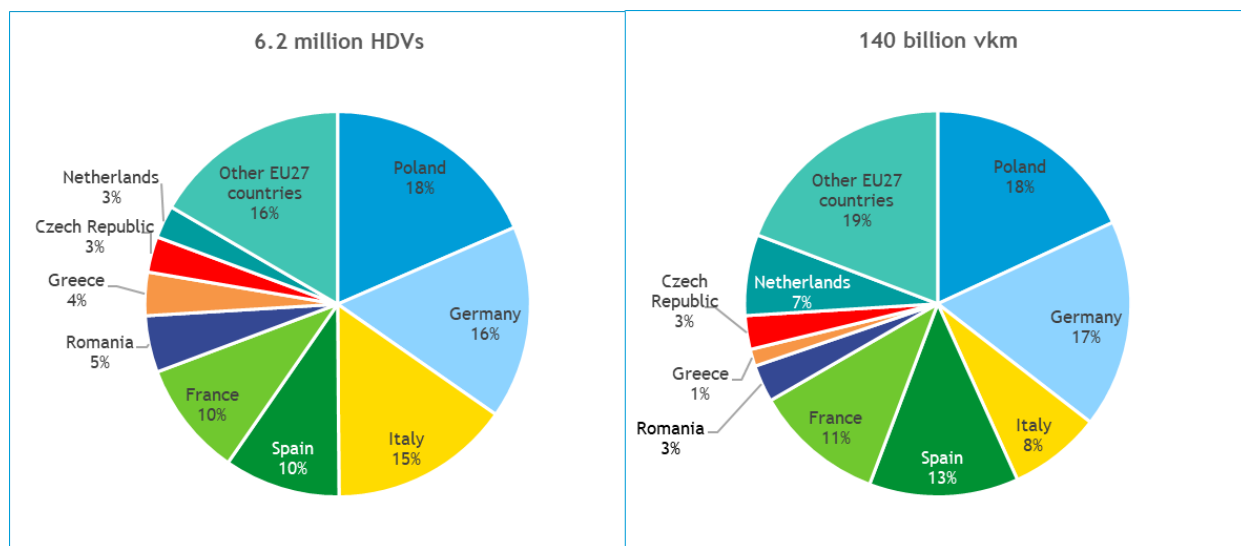
- Although technologies to recharge and refuel alternatively fuelled HDVs exist, **further technological development** and **an increase in production capacity** are required to enable large-scale application of alternatively fuelled drivelines and further cost reduction.
- From an environmental perspective, **zero-emission powertrains** will deliver the greatest GHG emission reduction when powered **with renewably sourced hydrogen or electricity**. **Low-carbon fuels** can also contribute significantly, while better performing fossil fuels contribute less on a well-to-wheel (WTW) basis.
- Refuelling and recharging infrastructure needs differ for **short-, medium- and long-haul transport**, in particular for battery electric trucks (BET). On short-haul distribution trips, BET will rely mainly on charging infrastructure **at the depot**, whereas on longer trips, **public charging** stations will be essential.
- **Pilots and first-mover initiatives** on BET and fuel cell electric trucks (FCET) and electric road systems (ERS) are taking place mainly in **Western European countries**.
- **Drop-in fuels** (liquid biofuels, gaseous biofuels and e-fuels) can be used in existing vehicles and infrastructure.

The ambition of the EU Green Deal is bound to affect fuel mix and vehicle fleet composition. In the long term, especially, the aim is essentially zero-emission mobility, implying the need for a major shift from internal combustion engines (ICE) to alternative power trains. How fast and to what extent policy objectives can be met in time depends partly on the current status and availability of recharging and refuelling concepts. In this chapter we present an overview of these concepts. This chapter starts, in Section 3.1, with a description of the current truck fleet and average truck performance. Section 3.2 describes the environmental performance of alternative fuels compared with fossil fuels, indicating the potential role of each in transport decarbonisation. There follow reviews of the technologies for electrical HDVs by means of charging points (3.3) and catenary concepts (3.44). For refuelling concepts we present the options for hydrogen (3.5), gaseous fuels (3.6), liquid biofuels (3.7) and e-fuels (3.88).

3.1. Current truck fleet and performance

The EU27 HDV fleet currently comprises [6.2 million trucks](#) of different types (categories N2 and N3) that in 2019 drove 140 billion vehicle-kilometres (vkm). Figure 2 shows the relative shares of registered trucks per country. As can be seen, Poland and a handful of large West-European countries operate the bulk of trucks in the EU, while the fleets of Spain and the Netherlands, in particular, have a larger share in vehicle-kilometres compared with their comparative fleet size, indicating a relatively high share of their trucks in long-distance transport.

Figure 2: Overview of EU truck fleet (2019) and vehicle-kilometres (2019) by country

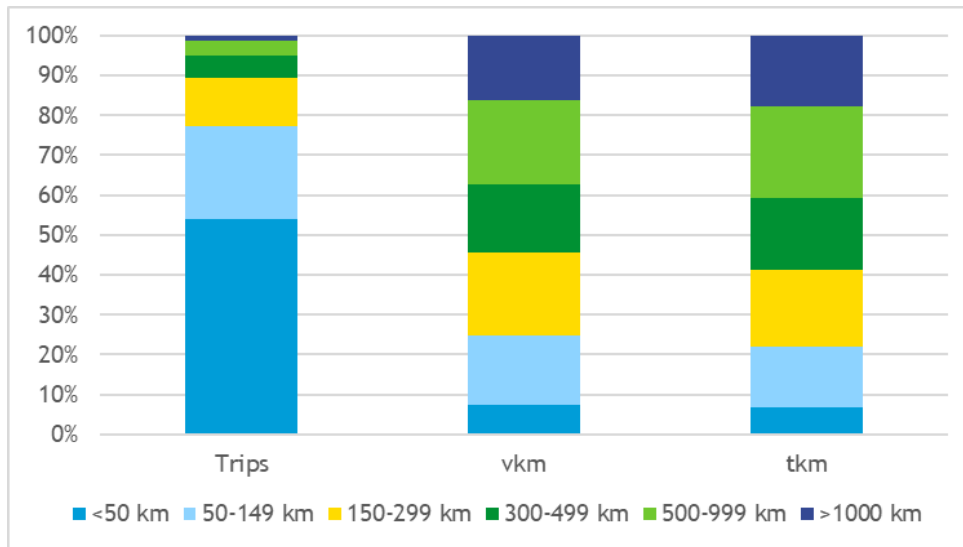


Source: registered vehicles per country: [\(ACEA, 2021b\)](#) vehicle kilometres in 2019: [\(Eurostat, 2020\)](#)

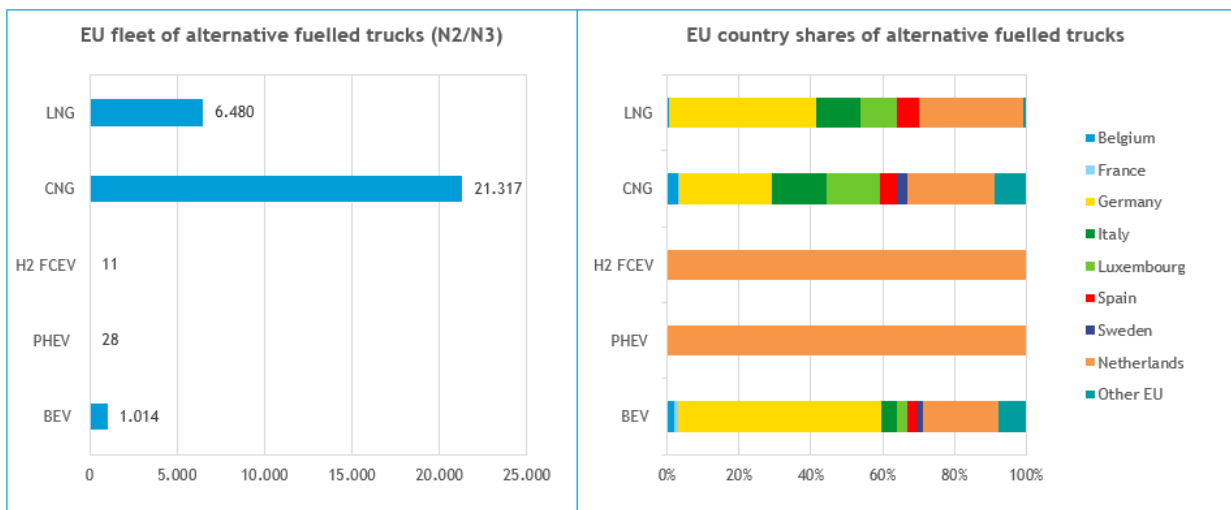
Given the differences in ranges of the different alternative fuel technologies, trip distance is an important criterion for assessing infrastructure needs. Truck trips can be divided into three rough categories: short-haul (intra-region; approx. 0-50 km), medium-haul (inter-regional; approx. 50-400 km) and long-haul (international, > 400 km [\(T&E, 2020a; T&E, 2020b\)](#)). Trucks involved in short-haul transport – typically city-logistics and port-to-warehouse trips – will return to base one or more times a day. Trucks in the medium-haul segment represent one-day round trips or one-way trips to destination. Trucks in the long-haul segment make multi-day trips, with overnight stops at trucking resting locations. Figure 3 shows, for the EU 27, the distribution of trips, vehicle-kilometres (vkm) and tonne-kilometres (tkm)⁴ over six distance classes. As can be seen, approximately 50% of truck trips are in the short-haul segment, corresponding to less than 10% of both vkm and tkm. The long-haul segment represents only about 5% of trips, covering over 40% of tkm [\(Eurostat, 2020\)](#). According to T&E, about 1.3 million (20%) of the trucks are active in long-haul transport [\(T&E, 2021\)](#).

The vast majority of trucks in the EU27 – about 98% – still runs on diesel [\(ACEA, 2021b\)](#). However, the number of alternatively fuelled trucks is increasing. Figure 4 shows the number of such vehicles by type of driveline and country [\(EAFO, 2021a\)](#).

⁴ Vehicle-kilometres express the distance travelled by vehicles, while tonne-kilometres express the transport work they provide, every tonne of freight moved over one kilometre contributing 1 tonne-kilometre.

Figure 3: Distribution of EU27 truck trips, vkm and tkm over distances classes based on year 2019

Compiled by authors based on Eurostat data ([Eurostat, 2020](#))

Figure 4: EU alternatively fuelled truck fleet: totals and shares per country in 2020

Compiled by authors based on data for 2021 from [European Alternative Fuels Observatory \(EAFO, 2021a\)](#) (extracted on 15 June 2021).

There are vastly more gas-fuelled trucks than electric and hydrogen-fuelled trucks. This can be attributed to them being longer on the market already. Most of the other alternatively fuelled trucks are registered in Germany (BET) or the Netherlands (BET and H2-FCET). Uptake of hydrogen trucks in the EU 27 is still minimal, with only 11 trucks registered in the Netherlands ([EAFO, 2021a](#)).

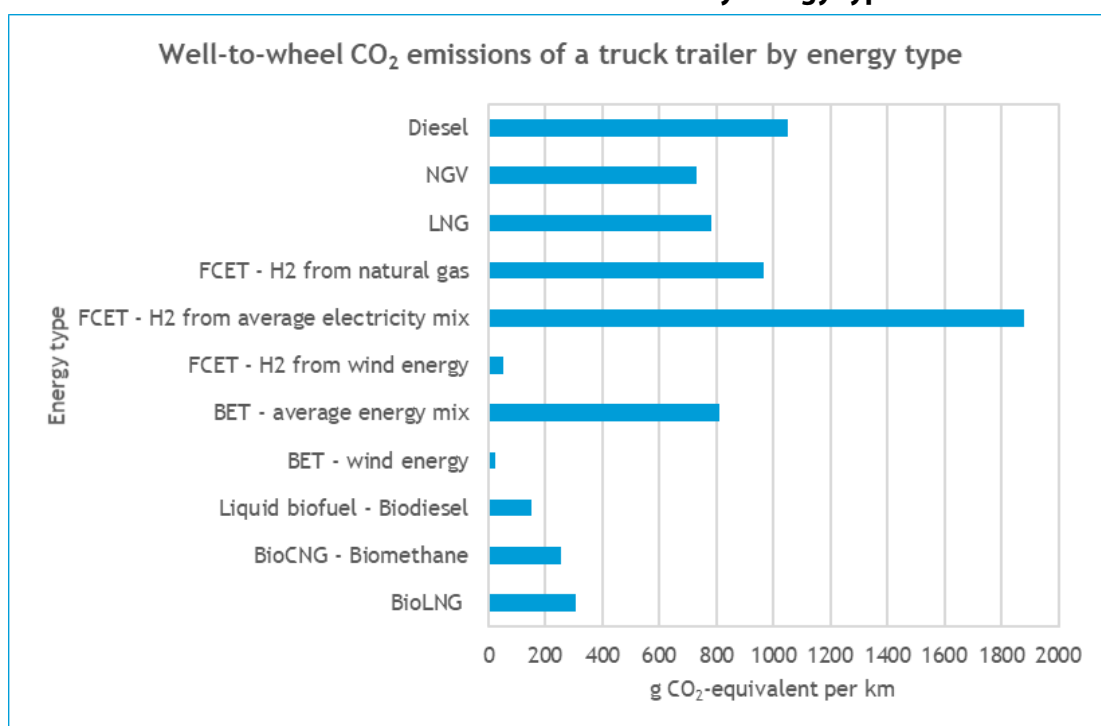
3.2. Environmental performance

Improving the environmental performance of truck transport is the main factor driving deployment of alternatively fuelled trucks. Given the importance of greenhouse gas emission reduction goals in the EU Green Deal, this section focuses on the GHG emission performance of the various truck technologies. It should be noted, though, that moving from fossil to alternative fuels also generally reduces air-pollutant emissions, depending on the fuel/energy type involved.

Figure 5 presents the well-to-wheel (WTW) CO₂-equivalent emissions per kilometre of a reference truck-trailer of 40 tonnes gross vehicle weight (GVW) with different fuels and drivelines as reported in the 2020 'Outlook Hinterland and continental freight' (CE Delft & TNO, 2020). WTT emissions are based on the Dutch energy mix and average feedstocks used.

A truck trailer running on gaseous fuel has 25-30% lower emissions per km compared with one burning conventional diesel fuel, mainly because of the fuel's lower carbon content. FCET and BET also are more energy-efficient than internal combustion engines, owing to their electric powertrains. These two technologies also result in zero Tank-to-Wheel (TTW) emissions. As can be concluded from Figure 5, WTW emissions strongly depend on the primary energy sources used for electricity and hydrogen production (Steenberghen & López, 2008); (ICCT, 2017)).

Figure 5: Well-to-wheel emissions of 40t GVW truck-trailer by energy type



Source: (CE Delft & TNO, 2020)

A BET powered by renewable sourced electricity has 98% lower emissions than the diesel reference. If electricity from the (Dutch) grid⁵ is used, however, WTW emissions are only 23% lower than the diesel reference. A similar pattern is seen with FCET using hydrogen produced from either renewable (wind) energy (-95% WTW) or natural gas (-5% WTW) or electricity from the grid (+78% WTW).

While the GHG emissions occurring during production of the vehicles and (recharging/refuelling) infrastructure should in principle also be considered, in practice they have only a limited impact on the comparison between the various options (Ricardo Energy & Environment, 2020; CE Delft, 2021).

The (gaseous) fuels of biological origin have the potential to reduce emissions by 70-85%. These cuts depend very much on the feedstock used for biofuel production, though. At the EU level, the Renewable Energy Directive II aims to phase out biofuels made from food and feed crops because of the negative impact of the indirect emissions associated with land use change, while aiming for growth of so-called advanced biofuels from waste and residues.

⁵ Based on 133 g CO₂-eq./ MJ, the Dutch grid average in 2018.

For all energy sources, the availability of renewable sources, such as renewable hydrogen or feedstocks for advanced biofuels, might form a barrier ([Trencher & Edianto, 2021](#)). However, having a strong and stable demand from the transport sector will also boost investments in production capacity.

With respect to LNG, fugitive emissions of methane along the LNG supply chain need to be addressed, as they have a much higher global warming potential than CO₂. Gas leakage from LNG tanks during venting need to be effectively recovered through boil-off recovery systems in order to prevent additional emissions ([Serra, et al., 2019](#)).

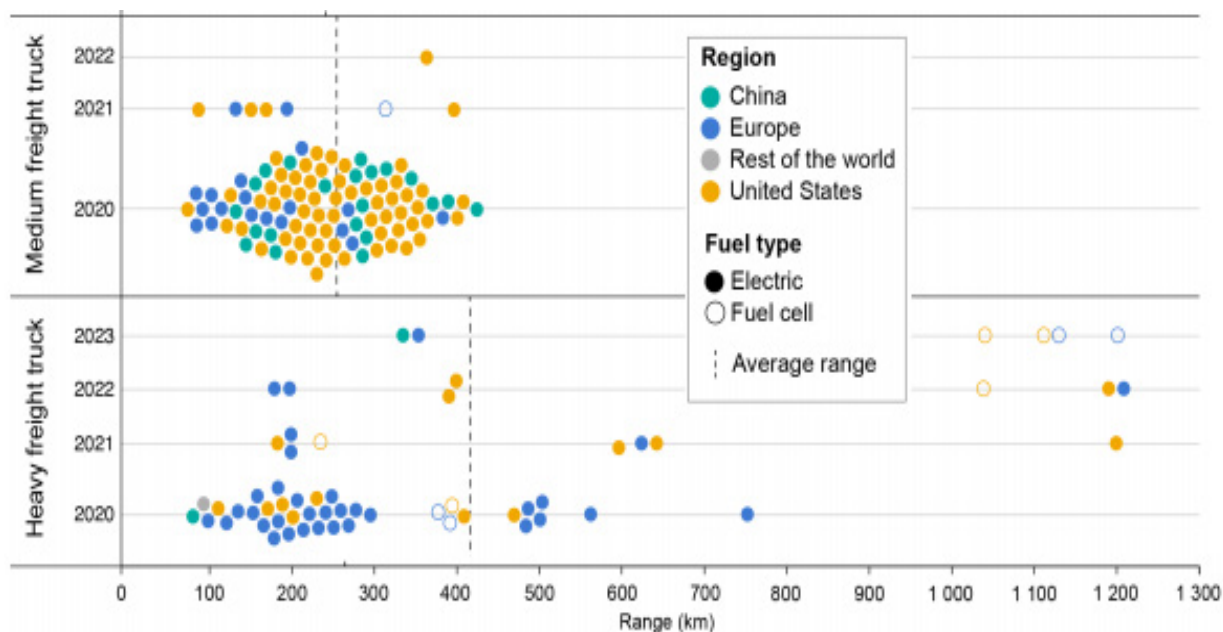
Finally, achieving GHG reduction targets in transport will not come solely from switching to lower-emission fuels and alternative technologies. Additional reductions may be achievable through more aerodynamic truck designs and by leveraging complementary technologies, like (Cooperative) Intelligent Transport Systems ((C)-ITS) and automation ([Serra, et al., 2019](#)).

3.3. Technologies to power HDVs running on electricity

3.3.1. Vehicle developments

Battery-electric trucks (BETs) with ranges up to 400 km are already being commercially produced (e.g. Volvo, DAF, Mercedes, Renault, VW (MAN & Scania), while R&D to increase ranges continues. Figure 6 from the IEA ([IEA, 2021](#)) shows the number of HDV models announced per continent, with the expected release year on the y-axis and the distance range (with a full battery/tank) in kilometres on the x-axis. Many medium-freight truck models (< 12 tonne) are being produced or have been announced in the US. In the heavy-freight truck market the number of models produced and announced in Europe is relatively high compared with other parts of the world. Currently, BETs are used mainly for city logistics by frontrunners and to gain experience. Besides Germany, a relatively high number of current BETs are operating in the Netherlands, where zero-emission zones for freight transport are set to be introduced by 2025 in 30-40 cities ([Dutch Government, 2019](#)).

For trucks on the road for less than 12 hours per 24 hours and driving less than 750 km – which account for the bulk of logistical activity in Europe ([T&E, 2020a](#)) – BETs may soon become a cost-effective zero-emission solution, before other zero-emission options ([Clean Energy Wire, 2020](#)).

Figure 6: Current and announced zero-emission HDV models by segment, release year and powertrain in major markets, 2020-2023

Source: Global EV Outlook 2021 ([IEA, 2021](#)); IEA, All rights reserved. As modified by authors.

3.3.2. Infrastructure developments

The infrastructure requirements of BETs depend on the recharging method employed. There are three options: plug-in cable charging, inductive charging (wireless) and battery swapping. Plug-in charging and inductive charging take place at charging stations/points and takes time (during which the vehicle remains idle). Battery swapping means batteries can be charged before swapping, saving time and limiting idle time substantially. As yet, however, batteries are still in the development phase, there is no universal system and battery swapping stations come at high cost, because of the high number of extra batteries needed ([McKinsey, 2020](#)). Except for few passenger cars in China from manufacturers NIO and BAIC ([Danilovic & Liu, 2021](#); [Bloomberg, 2021](#)) battery swapping is currently scarcely applied.

Inductive (wireless) charging is an alternative to plug-in cable charging that is more user-friendly and durable and of higher aesthetic quality. It is currently used for buses in cities like London, Madrid and Turin ([IPI Technology, 2021](#)).

At the moment, though, it is only plug-in cable chargers that are commonly used for trucks. An important consideration is that these systems have a higher energy efficiency and lower costs ([Brenna, Foadelli, Leone, & Longo, 2020](#)). Plug-in cable chargers for BETs are similar to those for passenger cars (Combined Charging System, type 2), as standardised by the AFID for public charging points. In principle, then, charging points for HDV do not differ from those for LDVs. Since HDVs are several times larger than LDVs, however, not all recharging points will be accessible for them. Because of the larger battery packs, moreover, in practice only fast-charging is an option for charging HDVs within a reasonable time. Current fast-chargers are in the power range of 50 kW-350 kW. Even higher-power chargers (up to 1 MW) are foreseen for the largest trucks ([Buck Consultants; CE Delft; et al., 2019](#); [T&E, 2020a](#)), which would allow them to charge for an extra 100-150 km in 10 minutes. This implies several megawatts of power being needed to supply a motorway charging station during peak hours.

Several studies have shown that trucks involved in short- and medium-haul transport will charge mainly at depots and distribution centres overnight ([McKinsey, 2020](#); [Buck Consultants; CE Delft; et al.,](#)

[2019; Rodríguez, Hildermeier, & Jahn, 2020](#)). A larger battery to complete the trip without needing to recharge during the day is favoured in terms of costs and reliability. For long-haul trips, besides chargers at depots, charging stations at overnight and resting places along the road (TEN-T corridors) are needed ([ACEA, 2019; T&E, 2020a](#)). BET recharging infrastructure is dependent on the physical presence and capacity of the local energy grid. Considerable grid investments are expected to be needed at depots with many truck recharging stations and overnight locations for trucks.

3.3.3. Existing infrastructure

The number of public electric recharging points in the EU is growing rapidly (from 120,000 in 2018 to around 225,000 in 2020), with around 10% fast-charging points (22 kW+) ([EFAO 2021](#)). However, existing public recharging infrastructure is dedicated to serving passenger vehicles and light commercial vehicles, given the physical space and power level available. According to the ACEA, as of May 2021 there were fewer than ten publicly accessible charging points for electric trucks available and operational in the EU ([ACEA, 2021a](#)). In all likelihood the 1042 (hybrid) battery-electric trucks currently operational will have their private (depot) charging infrastructure in place for charging these short- and medium-haul vehicles.

Charging stations are offered by several suppliers, including OEMs, such as DAF, part of PACCAR truck manufacturers. DAF provides charging solutions for commercial vehicles, with (mobile) chargers up to 50 kW for overnight (depot) charging, and ultra-fast chargers with a capacity up to 350 kW recharging an average truck battery in approximately two hours ([DAF, 2021](#)).

3.3.4. Developments in third countries

United States

In 2019 Penske Truck Leasing launched four charging stations in California, designed and deployed specifically for HDVs. A total of fourteen fast chargers of 50-150 kW direct current (DC) capacity are installed, making these the first charging points in the USA for battery-electric HDVs ([Electrek, 2019](#)). Since April 2021 a charging station with several 150-200 kW public chargers dedicated to HDVs have been operation in Portland, Oregon, by Daimler in cooperation with the local grid manager PGE. This public station is serving as a pilot for Daimler Trucks for further deployment of HDV charging infrastructure ([OPB, 2020; Electrek, 2021](#)). Daimler's main strategy in the EU and North-America is development of HDV charging infrastructure at truck customers' depots, providing mainly overnight charging solutions for BETs (Daimler Truck AG, 2021a). In order to make charging infrastructure compatible for HDV, the charging industry is working to standardise high-power charging for commercial vehicles, with power levels of over 1 MW becoming available in the future ([RMI, 2020](#)).

Norway

In Norway, there were 34 BETs on the road as of early 2021 ([EAFO, 2021a](#)). They are used for city distribution by retailers and supermarkets and have depot overnight charging infrastructure with a maximum charging power of 150 kW ([Scania, 2020; InsideEVs, 2020](#)).

China

Globally, China has the highest number of electric trucks on the roads, with the country accounting for around 90% of new electric trucks registrations worldwide in 2019 and 2020 ([IEA, 2021](#)). Refuse collection trucks, in particular, are being electrified ([World Economic Forum, 2020b](#)).

According to the World Economic Forum, China has a fleet of over 60,000 electric trucks and vans ([World Economic Forum, 2020a](#)), most of them active in city logistics and municipal services. The number of electric charging points geared to and suitable for BETs is unknown, however.

3.4. Technologies to power HDVs running on overhead catenaries

3.4.1. Vehicle developments

Electric road systems (ERS) employing overhead wires (catenaries) are an innovation that could provide a zero-emission solution for motorway freight transport, enabling charging while driving as well as highly efficient traffic flows. They also create opportunities for autonomous vehicles.

Siemens has developed a prototype pantograph to draw electricity from a catenary system. The system has been applied at several test locations with hybrid Scania trucks ([Siemens, 2021](#)). The overhead lines provide electricity to hybrid trucks, which use BET, ICEV or conventional ICEV hybrid systems to cover the distances between the ERS sections of the route. According to Siemens, 89% of non-motorway truck movements are less than 50 km and if long stretches of motorway are electrified as ERS, battery capacity as well as charging infrastructure requirements can be kept significantly lower.

3.4.2. Existing infrastructure

Electric road systems are not yet available for commercial use, only as pilot projects. In Sweden a 2 km stretch of catenary infrastructure is deployed on the E16 highway north of Stockholm for testing two diesel-hybrid trucks ([Siemens, 2021](#)). In Germany a 5 km stretch at the A5 motorway has been fitted with overhead lines in both directions for diesel-hybrid trucks. A 10 km section of the A1 in Schleswig-Holstein and 4 km of the B462 in Baden-Württemberg are scheduled for testing in 2021.

3.4.3. Developments in third countries

United States

ERS infrastructure in the US presently comprises a two-mile-long overhead catenary system for hybrid electric trucks installed between the ports of Los Angeles and Long Beach. It is only accessible for dedicated trucks participating in the pilot project.

Norway

We are not aware of any initiatives in Norway on overhead catenary systems or other ERS.

China

According to Danilovic et al., China is not working on the development of ERS (Danilovic, 2019).

3.4.4. Infrastructure developments

Catenary infrastructure requires precise coordination of routes and comprehensive investments and installation measures before the benefits can be reaped. Considering these restraints, it is highly unlikely that catenary systems will be applied on all freight transport routes. The first iterations of ERS will probably cover fixed shuttle services and motorway stretches with the highest intensities of truck traffic.

Germany and Sweden have several pilot projects testing operation of overhead catenaries under everyday road conditions ([Siemens, 2021](#)). In Germany some of these are cooperative projects involving local government and commercial parties ([Electric Roads, 2021](#)). In Sweden there is also a new pilot project underway with a wireless (induction-based) ERS.

3.5. Technologies to power HDVs running on hydrogen

3.5.1. Vehicle developments

The current generation of fuel cell electric trucks (FCET) is powered mainly by proton-exchange membrane fuel cells (PEM) using hydrogen as a fuel. In the longer term, solid oxide fuel cell (SOFC) technology that can convert other, denser fuels (like methanol) may also be an option; this is currently being researched. Different modes of on-board storage are feasible (liquid, 350 and 700 bar), with different implications for refuelling architecture (CNHi, 2020). As passenger cars have little room for on-board tanks, the hydrogen is usually compressed to 700 bar. For buses with roof space available, 350 bar is often applied. For long-haul trucks, compression to 700 bar is most likely.

Because of hydrogen's high mass energy density, FCETs are considered promising for long-haul transport. Its relatively low volume energy density, however, requires a greater internal tank volume (approx. 7 times for H₂ at 700 bar) for the same range as diesel (CNHi, 2020; JEC, 2020a). FCETs are currently being produced on a pilot scale, but several test concepts have been developed with ranges over 400 km, which is more than current BETs (CE Delft & TNO, 2020). In April 2021 Daimler and Volvo announced creation of a fuel-cell joint venture aiming to start series production of hydrogen-fuelled FCETs in 2025 (Daimler Truck AG, 2021b). According to the two companies, hydrogen-fuelled FCETs will be the preferred option for heavier loads and longer distances. Other OEMs, such as Renault (Renault group, 2021) and MAN (Volkswagen, 2020) are also investing in hydrogen technology, while Scania is focussing more on BET (Scania, 2021).

Hydrogen can also be used to fuel ICEs, which requires minor adaptation of the ignition and ventilation system to cope with the high flammability of hydrogen. This is currently being researched (FEV, 2021; Volkswagen, 2020).

3.5.2. Infrastructure developments

The infrastructure for FCETs requires additional safety measures compared with conventional refuelling infrastructure, but refuelling time is equally short (under 10 minutes). Refuelling stations can be supplied by trucks, pipelines (possibly retrofitted gas pipelines) or by on-site hydrogen production. As yet, however, there is no standardisation of pressure level or storage technology. Mobile refuelling stations have also been developed, introducing a high degree of location flexibility (FuelCellsWorks, 2020b). The volume energy density of hydrogen is low compared with diesel. Supplying hydrogen to a refuelling station by truck therefore requires far more truck movements compared with supplying the same diesel energy content (TNO, 2019), according to the figures provided in (CNHi, 2020; JEC, 2020a), at least seven times more.

3.5.3. Existing infrastructure

As of 2021, there are 144 hydrogen refuelling stations (HRS) in operation in the EU, the majority in Germany, France, Denmark, the Netherlands and Belgium. They offer hydrogen compressed to either 700 or 350 bar; as yet there are no liquid refuelling stations in the EU. The bulk of these 145 HRS service passenger cars, with only 16 delivering 350 bar H₂ to HDVs, mainly city buses (HRS map EU, 2021). Depending on compressor type and on-board storage pressure, these HRS might be suitable for refuelling hydrogen trucks, but this is not made clear in the literature or in the information provided by HRS operators. The amount of H₂ stored at the HRS is crucial for such application, because of the greater fuel demand for long-haul transport compared with city buses and passenger cars.

3.5.4. Developments in third countries

United states

According to the US Alternative Fuels Data Center (AFDC) 49 hydrogen refuelling stations (status July 8th, 2021 have been realised ([US DOE, 2021](#)). Most of these are stated to be for local users of hydrogen-fuelled electric vehicles, as the number of hydrogen trucks in the US is negligible.

China

FCEVs in China are almost exclusively buses and trucks, unlike most other countries where cars predominate. China accounts for 94% of global fuel-cell buses and 99% of fuel-cell trucks. In absolute numbers these are approximately 5,500 buses and 3,500 trucks⁶, while the country has 16% (around 90) of the world's hydrogen refuelling stations ([IEA, 2021](#)), but another source already mentions 101 operational HRS ([Yicaiglobal, 2021](#)). Most HRS are 350 bar installations used mainly for refuelling buses and commercial vehicles, a large proportion of which are deployed as pilot vehicles (Netherlands Innovation Network China, 2019).

3.6. Technologies to power HDVs running on gaseous fuels (LNG, CNG, LPG)

3.6.1. Vehicle developments

Trucks running on gaseous fuels have already been on the market for some time. CNG and LNG are both derived from natural gas, with the natural gas being compressed at high pressure in CNG and liquified at very low temperatures in LNG. CNG has a lower energy density and is therefore not optimal for long-haul heavy transport, whereas LNG trucks have ranges over 1,000 km and are suitable for such transport. LNG trucks have an around 30% higher purchasing price than diesel trucks, but this can be recuperated because of the lower fuel costs ([CE Delft & TNO, 2020](#)). An LNG truck takes around 7 minutes to refuel. Some OEMs, including Volvo, are investing in LNG technology as one option to reduce the climate impact of truck transport, while for others, like Mercedes, LNG trucks are not part of their decarbonisation strategy ([Schuckert, 2020](#)).

LPG is a mix of propane and butane and has a relatively low energy density. It is used mainly in passenger cars, buses and forklift trucks and is not in widespread use for (road transport) trucks (approx. 9,000 trucks in the EU27, of which 8,000 in Poland ([Eurostat, 2021](#))). According to the World Liquid Petroleum Gas Association (WLPGA) in 2017, there has been little development of new LPG engines for HDVs in recent years ([WLPGA, 2017](#)). LPG will consequently not be discussed in detail in this briefing.

3.6.2. Infrastructure developments

Supply to refuelling stations is to be by truck or on-site liquefaction at the location of a refuelling station in case of LNG or compression in case of CNG. LNG/CNG refuelling stations require dedicated storage and fuelling infrastructure. When gaseous biofuels are applied, biogas is often upgraded to biomethane meeting natural gas quality standards enabling the replacement of fossil LNG and CNG by bioLNG and bioCNG. In the future, renewable fuels from non-biological origin (gaseous e-fuels) could be used as well.

⁶ Estimated from graph presented in source (Figure page 36)

3.6.3. Existing infrastructure

There are currently over 400 LNG filling stations in the EU, mainly in Spain, Italy, France, Germany, the Netherlands and Sweden. They are rare in Eastern EU member states. There are around 4000 CNG filling stations in the EU, dispersed over more countries and mainly used by passenger cars ([NGVA Europe, 2021b](#)). Italy accounts for over a third of them, reflecting its disproportionate share (55%) of registered CNG passenger cars in the EU ([NGVA Europe, 2020](#)).

The number of LNG refuelling stations in the EU grew by 60% in 2020, mirroring the trend in new LNG vehicle registrations. In that year the number of CNG stations in the EU was 8% higher than in 2019, indicating that this technology is also maturing ([NGVA Europe, 2021a](#)).

3.7. Technologies to power HDVs running on liquid biofuels

3.7.1. Vehicle developments

Some internal combustion engines can be directly fuelled with bio-alternatives for diesel. Biodiesel can be blended with regular diesel, or either used as neat (100%) fuel in engines suitable (in many cases adapted) to run on neat biodiesel. For biodiesel the two most familiar and widely applied options are: Fatty Methyl Ester (FAME) and Hydrotreated Vegetable Oil (HVO)⁷. According to the current fuel specifications, regular diesel may contain up to 7% (volume %) of FAME (B7). Most conventional diesel engines can run on blends up to 10 or 20%. Not all vehicle manufacturers provide warranty if blends higher than 7% are used, because FAME can potentially cause fuel quality and microbial growth issues. On the contrary, HVO is a drop-in fuel: a fuel without the need for any significant modification in engines and infrastructures. Many truck manufacturers have their Euro VI engines cleared to run on 100% HVO, important for maintaining engine warranties. The advantage of drop-in fuels is that they can be applied in the current fleet, providing a rapid decarbonisation option in the short term.

3.7.2. Infrastructure developments

To an extent, the midstream and downstream infrastructure for biofuels can use existing infrastructure for conventional, fossil fuels, since storage and refuelling conditions are similar. From an infrastructural angle, liquid biofuels are consequently the best positioned of all alternative fuels, especially the drop-in biofuels.

3.7.3. Existing infrastructure

Liquid biofuels can be applied as a drop-in for conventional mineral oils or in low blends in regular diesel and petrol (adhering to the fuel specifications laid down in the Fuel Quality Directive (FQD)). Most diesel already contains a small amount of biodiesel, thanks to the Renewable Energy Directive and the GHG intensity target of the FQD. Since fossil fuels make up the vast bulk of transport fuels, the required infrastructure is widely available throughout the EU in the form of conventional filling stations ([EAFO, 2021b](#)), where specific medium and high blends can be added to the range of products on offer.

⁷ FAME stands for “fatty acid methyl esters”, a biofuel with similar physical properties to conventional diesel fuel. HVO stands for “hydrotreated vegetable oil” and is produced by the hydroprocessing of (waste) oils and fats (ETIP, 2021).

3.8. Technologies to power HDVs running on e-fuels

3.8.1. Vehicle developments

E-fuels are synthetic fuels made from hydrogen synthesised using renewably powered electrolysis and carbon dioxide (CO₂) captured from a concentrated source (industrial flue gases) or the air (direct air capture) ([Concawe, 2020](#)). They include e-diesel, e-methane, e-methanol, e-hydrogen and e-ammonia. E-fuels can be used with relatively minor adaptations in internal combustion engines, still in use in over 98% of EU27 trucks. E-fuels are still only in the pilot phase, but should be commercially available post-2030.

3.8.2. Infrastructure developments

The diversity of e-fuels means a range of different storage and distribution conditions and systems. E-methane is compatible with existing powertrains and can use existing infrastructure for gaseous fuels like CNG and LNG. E-hydrogen requires the same (new) infrastructure as other types of hydrogen. E-ammonia is readily stored in liquid form, but distribution infrastructure is still lacking ([Concawe, 2020](#)). It is currently more mentioned as a decarbonisation option for maritime shipping. In contrast to gaseous e-fuels, most liquid e-fuels are relatively easy to store and transport and can be used in existing ICE vehicle fleets.

3.8.3. Existing infrastructure

Existing transportation infrastructure and storage facilities as well as filling stations can be used for e-fuel supply and distribution. Depending on the type and form of the e-fuel, the dedicated infrastructure for oil-like fuels and gaseous fuels can be used.

From a technological perspective a wide range of options exist to facilitate the recharging and refuelling of trucks, but it can be questioned how fast these infrastructures can be realized. In the next chapter, the main barriers are discussed which hinder a fast roll-out and which could be (partly) reduced by policy intervention.

4. BARRIERS AND ENABLERS

KEY FINDINGS

- Development of truck recharging and refuelling infrastructure is currently hampered by **limited investment security** and **lack of a stable long-term policy framework**, including **binding targets**, making investment in alternative infrastructure for trucks (and other HDV) more attractive to investors.
- Investors are also looking for **large potential user groups** to ensure sufficiently **high utilisation rates**, benefiting **larger companies** seeking cooperation and putting small and medium-sized enterprises at a disadvantage.
- **Shared public infrastructure** provides opportunities for higher utilisation rates, but it should come with additional efforts to **inform users on accessibility and procedures for guaranteed refuelling or recharging**, as needed.
- Overall, stakeholders generally operate fairly independently, while **cooperation** could benefit knowledge exchange and accelerate **harmonisation and standardisation**, especially for the **vehicle-infrastructure interface**.
- Legal barriers are created through **disproportionate requirements** for refuelling infrastructure similar to those for large-scale production facilities.
- **Appropriate grid connections and adjustments** by grid operators also demand a coordinated approach. The current approach often results in long procedures and thus **long lead times**.

As we saw in the previous chapter, alternative fuels infrastructure for trucks is still very limited, especially for zero-emission technologies, where it is still mostly in the pilot phase. The feasibility of the various refuelling and recharging concepts over the coming decade will be determined by the extent to which barriers and enablers hinder or accelerate deployment. This chapter aims to identify relevant barriers and enablers based on a desktop study. Where possible, an example is provided for one of the alternative fuels. The final study will contain a more in-depth analysis covering all refuelling and recharging concepts, with more evidence from both the literature and interviews.

4.1. Technical barriers/enablers

There are several barriers related to the technical aspects of electric truck charging. In the first place, the power levels of today's charging stations are too low for sufficient BET charging during stops (driver resting times). Current fast-chargers are in the power range of 50 kW-350 kW, with 1 MW charging points still being developed. Another technical aspect is that the power grid at truck charging locations will often need strengthening to deliver the required power ([Hendriksen, Sloots, & Jong, 2021](#)).

With respect to hydrogen refuelling infrastructure, the current lack of standardisation of on-board H₂ storage systems for trucks affects the entire value chain, including refuelling equipment. The various options (350, 500 and 700 bar, liquid, cryo-compressed) all have their pros and cons. A coordinated approach is lacking, however, with individual OEMs focussing on different types of solution. With greater certainty on which on-board storage technology or technologies are to be used, installation of hydrogen refuelling stations could be accelerated in the short term. The more options on offer, the

more complex refuelling operations will become, with a range of refuelling protocols and equipment being needed. Closely linked to the need for a single standard on on-board storage is the need for standardised refuelling protocols. A further barrier is the lack of a good communications interface between trucks and refuelling stations ([Ruf, Baum, Zorn, Menzel, & Rehberger, 2020](#)).

4.2. Operational barriers/enablers

The main operational barrier for BETs and FCETs is the lack of a connected (inter)national network of refuelling stations, and for ERS trucks a completed ERS network. Other operational barriers relate to shared use of charging stations and the simultaneous recharging needs of companies with similar trip characteristics. The availability of charging points at certain times of day is crucial for companies' operational planning, and sharing public (or private) infrastructure might lead to unacceptable uncertainties. To avoid excessive time losses requires sufficient (fast-)charging points and a well-functioning reservation system, which will need to be developed, as will overall information on public and private charging points (in terms of characteristics and accessibility), which is still lacking.

The accessibility of public, unattended areas (without staff) where charging infrastructure is available is often high, while attended areas (with staff) are often less accessible. One disadvantage of public, unattended charging points is that charging sometimes requires drivers to leave their vehicles unattended, however, which might violate insurance conditions ([Hendriksen, Sloots, & Jong, 2021](#)). ([Ruf, Baum, Zorn, Menzel, & Rehberger, 2020](#)).

On the other hand, existing infrastructure can provide opportunities. For example, existing hydrogen refuelling stations for cars and buses could be upgraded to make them fit for truck refuelling – a key opportunity. After upgrading, capacity utilisation could rise close to 100%, reducing operational expenditure (OPEX) by up to 25% ([Ruf, Baum, Zorn, Menzel, & Rehberger, 2020](#)).

4.3. Economic barriers/enablers

The main economic barriers for alternative fuels in general and the related infrastructure is the competition with a well-established transport system that has been operated and optimised for over a century and offers stakeholders a predictable income. The infrastructure for alternative fuels is still to be built, at both higher cost and higher risk, creating less predictable business cases for investors ([IEA Bioenergy, 2020](#)). Fleet operators, too, will have difficulty making a positive business case for alternative fuels. Besides higher vehicle purchasing costs and the risk of reduced residual value, operating costs may also be higher owing to limited refuelling infrastructure, although fuel prices may be lower for some fuels ([Serra, et al., 2019](#)).

Larger companies are better-placed than small and medium-sized enterprises (SME) when it comes to investing in charging infrastructure for BETs, which will create an unfair playing field. Larger companies can also benefit more from economies of scale and lower scale-related tax tariffs. For example, in the Netherlands energy taxes per kWh are lower for larger grid connections. These companies can take larger risks, moreover, implying less need to insure against loss of turnover ([Hendriksen, Sloots, & Jong, 2021](#)).

In terms of fiscal incentives, the cited report also mentions barriers related to differences in energy taxation between large and SME companies. There are also examples of energy taxes being paid twice in the context of storage and certain forms of smart charging (vehicle-to-grid). In addition, subsidy schemes sometimes favour grid feed-in of electricity generated on-site rather than direct consumption for charging the own fleet. The schemes and condition will differ per Member State.

In terms of investment security, the market for shared truck charging infrastructure is not yet sufficiently mature and therefore less attractive for investors compared with investment in similar infrastructure for passenger vehicles. Investors would also like to have some guarantee in terms of users, which again favours larger-scale user groups and so larger companies ([Hendriksen, Sloots, & Jong, 2021](#)).

For HRS the lack of targeted funding and incentive schemes have been identified as the main economic barrier ([Ruf, Baum, Zorn, Menzel, & Rehberger, 2020](#)).

4.4. Institutional and regulatory barriers/enablers

There are several institutional and regulatory barriers for BETs. First, there are uncertainties regarding the size of grid connections in relation to grid capacity, which need to be properly handled by grid operators and authorities. Second, logistical parties aiming to share infrastructure are failing to come to appropriate agreements and it is generally unclear how liability and damage will need to be handled from a legal perspective. Third, to optimise the use of grid capacity and charging infrastructure, subsidy schemes could be designed to include requirements for sharing infrastructure, although for some stakeholders this might act as a barrier for shifting to EV. Finally, companies often experience problems with investment security in the absence of stable support mechanisms over the longer term ([Hendriksen, Sloots, & Jong, 2021](#)).

For hydrogen refuelling stations (HRSs), the HyLaw project has described multiple legal and administrative barriers. The permit process for HRSs is currently long and costly, while the outcome is uncertain. The stakeholders involved have insufficient knowledge to streamline efforts and guarantee a smooth process, resulting in cost increases and delays. Current permit requirements for HRSs are based mainly on obligations established at EU level, including:

- risk assessment ([SEVESO Directive](#));
- health and safety requirements together with conformity assessment procedures ([ATEX Directive](#));
- integrated environmental obligations (IED);
- Environmental Impact Assessment procedures ([SEA](#) and [EIA Directives](#)).

These directives are designed mainly for regulating large scale, heavily polluting industrial processes, but they also apply to small-scale, non-emitting hydrogen initiatives. Their requirements are consequently severely inhibiting deployment of HRSs with on-site electrolysis and pushing up the overall costs and time required for development. Transposition of these EU directives into national law has resulted in differences in procedures between Member States, moreover. Hydrogen refuelling should be possible alongside other fuels, permitting use and adaptation of existing infrastructure. Although multifuel HRSs exist, safety distances and other rules limit the options for co-locating hydrogen in existing refuelling stations. Currently, on-site production of hydrogen requires HRS siting in industrial zones, as hydrogen production is deemed an industrial activity. The rules on storing low to medium quantities of hydrogen also create barriers for siting in areas where HRSs would be close to consumers. For the use in vehicles HyLaw concludes that regulatory and administrative barriers are limited, though the lack of consistent supporting policies limits large-scale development ([Hydrogen Europe, 2019](#)).

4.5. Social and attitudes, user acceptance

For biofuels, certain barriers to user acceptance have been identified, which will also hold for other alternative fuels. Negative public perception and fundamental scepticism will need to be overcome to achieve user acceptance. This perception may be linked to associated sustainability risks, and discussions and speculations on engine compatibility concerns. When there is uncertainty about operational performance, companies might be hesitant to switch to BET, FCET or low-carbon fuels. Low user acceptance also often relates to a lack of incentives for potential user groups ([IEA Bioenergy, 2020](#)). Similar social barriers to hydrogen acceptance are due to limited experience and safety concerns about hydrogen technology. This holds for both industry and the public ([Ruf, Baum, Zorn, Menzel, & Rehberger, 2020](#)).

4.6. Organisational barriers/enablers

Deployment of BET charging infrastructure is currently being slowed down by the involvement of numerous stakeholders in the supply chain. It is also being hampered by a dearth of initiators and a lack of clarity on business models and division of labour. Mutual cooperation agreements between end users and owners are needed to remove charging-related uncertainties as soon as possible, but at present stakeholders are not readily finding one another. Public authorities can help to accelerate this process ([Hendriksen, Sloots, & Jong, 2021](#)).

Besides barriers, opportunities for increased HRS utilisation can also be identified. Thus, establishing a network of multi-purpose HRSs for different transport modes will lead to improved asset utilisation and consequently lower costs for stakeholders. Synergies can also be achieved by alignment of TEN-T and TEN-E corridors, thus linking HRS with energy infrastructure (Ruf, Baum, Zorn, Menzel, & Rehberger, 2020).

Barriers might prevent an optimal level of infrastructure in 2030, where there is sufficient infrastructure to recharge and refuel to meet the demands from vehicles. In the next chapter, a first summary of infrastructure needs based on vehicle projections is presented.

5. FUTURE INFRASTRUCTURE REQUIREMENTS

KEY FINDINGS

- **Fleet projections** point to trucks employing a **wider variety of powertrains in 2030**, with the main focus on **battery electric trucks**, followed by **hydrogen-powered fuel-cell trucks**. In the meantime, gas-fuelled and diesel trucks with suitable ICEs can contribute to low-carbon transport, as refuelling infrastructure for these fuels already exists throughout Europe and **biofuels and e-fuels** can be used to replace liquid and gaseous fossil fuels.
- A tremendous increase in investment and subsequent **large-scale roll-out** of recharging and refuelling infrastructure is needed. The majority of electric recharging points are expected **at (semi-)private depots and distribution hubs, providing overnight charging** at 50-100 kW. **Public charging on major freight corridors (TEN-T)** should be at higher power capacity (> 350 kW) for adequate recharging during vehicle idle time. **Hydrogen refuelling stations** need to be located strategically along major freight routes, while technological standardisation for trucks and refuelling infrastructure is necessary for international coverage.
- Trucks do not necessarily have to be full electric yet. The respective shares of mild hybrid, plug-in hybrid trucks (PHET) and battery-electric trucks (BET) **differ widely** in the available scenarios, which therefore come to very **different conclusions** as to where infrastructure will be needed (depot charging versus fast-charging on motorways) and the power capacity required.
- Kilometre projections of overhead catenary infrastructure in the EU depend very much on the extent to which ERS is to become the major technology.

The previous chapter set out the main factors hampering or enabling deployment of alternative fuels infrastructure. Based also on the level of infrastructure required to meet policy objectives, policy recommendations can be formulated for the actions to be taken in the coming years. This chapter therefore discusses scenario projections of the need for dedicated alternative refuelling and recharging infrastructure for HDVs.

To understand the data on future infrastructure requirements, in Section 0 we first present projections of HDV fleet composition in 2030. Next, in Section 5.2, we review the projections of dedicated HDV refuelling and recharging infrastructure requirements in 2030 found in impact assessments and other literature. The HDV fleet and infrastructure projections are based on a number of institutions' predictions for the future technologies used in the HDV segment. In most instances we present the baseline figures – indicating the state of play under current and intended policies, and a regulatory path – providing estimates under an ambitious policy scenario, in which the more ambitious overall EU goal of 55% GHG emission reduction in 2030 is secured.

5.1. Vehicle fleet projections

In Table 1 vehicle fleet projection figures of different sources ([The impact assessment of European Climate Target plan](#), [IEA](#) and [ACEA](#)) are listed. As can be seen, the fleet projections include different electrification options. In a mild hybrid an electric motor assists the internal combustion engine, and generally allows recovery of braking energy, feeding it into (small) batteries. A mild hybrid's motor cannot power the vehicle on its own and mainly decreases the efficiency losses of the combustion engine. Plug-in and traditional hybrids, on the other hand, do have an electric motor that can power the vehicle on its own. While conventional hybrids are charged during driving, plug-in hybrid electric trucks (PHET) can also be charged by connecting the battery to the grid. Battery-electric trucks have no combustion engine, only a battery.

The impact assessment of the European Climate Target plan presents shares of the heavy-duty vehicle stock⁸ in 2030 by type of powertrain (no absolute figures are given). The shares are given for several scenarios. For this briefing we consider the baseline scenario (covering current and planned pre- 2030 policies to achieve the energy and climate 2030 targets) and the regulatory scenario (REG), in which a higher ambition is assumed, aiming for 55% reduction of EU GHG emissions in 2030 ([EC, 2020c](#)). For these two scenarios, the shares of HDVs by type of powertrain are presented in Table 1. In the baseline scenario for 2030, the vast majority of vehicles is still diesel-powered with 77.5% conventional diesel and 16% mild hybrid diesel trucks. Only 0.5% of the fleet is expected to be BETs. In the baseline, the share of hydrogen-powered trucks is negligible. In the 'high ambition scenario' the share of hydrogen fuel cell trucks in 2030 rises to 0.5%, while the share of BETs is still only 0.5%. The share of diesel trucks has decreased to 74%, mainly at the cost of a greater number of gas-powered HDVs (9% compared to 6% in the baseline). The 'high ambition scenario' envisions larger shifts to BET and hydrogen trucks after 2030 (not shown).

The [International Energy Agency](#) (IEA) assumes a 2030 European fleet of approx. 7.5 million trucks. The IEA baseline⁹ projection projects a 1.7% share of electric trucks in 2030, comprising PHETs (0.8%), BETs (0.9%) and FCETs (0.02%). In the IEA's sustainable development scenario, the share of electric trucks is 10%, comprising PHETs, (4.1%) BETs (4.9%) and hydrogen FCETs (1.0%).

In its position paper on charging and refuelling infrastructure requirements, ACEA presents its expectations on the alternatively fuelled HDV fleet in 2025 and 2030. ACEA distinguishes no scenarios. Its predictions are based on current and intended climate commitments, and the strategies and efforts of governments and the truck manufacturing industry regarding carbon-neutral powered vehicles, especially in relation to the CO₂-standards for trucks as laid down in 2019/1242 ([ACEA, 2021a](#)). ACEA projects 270,000 BETs and 60,000 hydrogen FCETs by 2030 and considers these numbers minimum estimates, as the technology strategies of the various manufacturers differ and the impact of further changes to the regulatory framework (e.g. the European Green Deal) was not considered.

⁸ No definition of 'heavy-duty vehicles' is given, so we assume these EU Climate Target figures include buses, trucks and trailers, among other types of heavy commercial vehicles.

⁹ Similar assumptions on the effect of existing and planned policies apply for the IEA baseline as for the baseline in the impact assessment of the European Climate Target.

Table 1: EU fleet projections by powertrain type, 2030

Source	Diesel (ICE) trucks	Diesel mild-hybrid trucks	ICE gas trucks (LNG/CNG)	PHET	BET	Hydrogen (FCET)	Total
Impact assessment EU Climate Target plan part 2 (2020)^a							
Baseline scenario	5,813,000 (77.5%)	1,200,000 (16%)	450,000 (6.0%)	-	37,000 (0.5%)	1,000 (0.01%)	7,500,000 (100%)
High ambition scenario (-55%)	5,550,000 (74%)	1,200,000 (16%)	675,000 (9%)	-	38,000 (0.5%)	38,000 (0.5%)	7,500,000 (100%)
IEA EV database (2021)^b							
Baseline scenario	7,371,000 (98.3%)			61,000 (0.8%)	66,000 (0.9%)	1,600 (0.02%)	7,500,000 (100%)
Sustainable Development Scenario (-55%)	6,752,000 (90%)			309,000 (4.1%)	364,000 (4.9%)	75,000 (1.0%)	7,500,000 (100%)
ACEA position paper on HDV charging infrastructure (2021)^c							
ACEA scenario	NS	NS	NS	NS	270,000	60,000	NS
T&E: Unlocking electric trucking in the EU: recharging along highways (2021)^d							
Baseline scenario	NS	NS	NS	NS	236,000	NS	NS
Road 2	NS	NS	NS	NS	617,000	NS	NS
Zero scenario							
T&E: recommendation	MS	NS	NS	NS	520,000	NS	NS

Note: numbers are rounded to 1,000; the sum of the figures per category might not add up to the total because of rounding; NS: not specified in the source; - : no trucks of this type in scenario

- a The absolute figures are approximated, using the fleet stock data (1,500,00 vehicles) projected by the IEA (see below under b), as absolute numbers are not given in the Climate Target plan impact assessment. The relative figures are estimated from Figure 61 part 2. .
- b IEA figures for Europe include the EU27, Norway, Iceland, Switzerland and the United Kingdom. The total number of 1,500,000 trucks has been calculated by dividing the number of EVs by the share of EVs in the total.
- c ACEA figures for Europe include EU27 and the UK.; Excluding UK: 230,000 ([ACEA & T&E, 2021](#))
- d T&E figures are for the EU27. The baseline and "Road 2 zero" figures include non-regulated trucks (approx.15%). The recommendation excludes non-regulated trucks and corresponds to 85% of the 'Road 2 zero' scenario without the 15% non-regulated trucks.

T&E presented 3 different scenarios on the number of BETs. The figures of their baseline (low) and "Road 2 Zero" scenario (high) are presented in Table 1. The baseline scenario is based on average sale shares of battery-electric trucks of 2.8% in 2025 and 20% in 2030, based on announcements of OEMs (taking 0% for OEMs without announcement). The "Road 2 Zero" scenario is based on T&E's 2050 transport decarbonisation strategy ([T&E, 2021](#)). The number of trucks used in the T&E recommendation is based on the "Road 2 Zero" scenario, excluding 15% non-regulated trucks above 16 tonnes, of which charging requirements are deemed uncertain.

We can conclude that the predictions for the alternatively powered HDV fleet composition in 2030 are not skewed towards one specific technology and the shares of these alternatively powered trucks span a vast range. This is in line with the current degree of uncertainty on (the speed of) developments in HDV powertrain technology.

Considering the fleet stock figures from different sources, we conclude that diesel ICE trucks will still constitute the overwhelming majority of vehicles in 2030, comprising approx. 7 million of the estimated fleet of 7.5 million trucks. To achieve lower emissions, the EU Climate Target plan impact assessment assumes a significant share of liquid and gaseous biofuels will power transport¹⁰ (EC, 2020c). The estimates on the number of alternatively fuelled trucks vary among the sources, owing to uncertainty about development of the supporting infrastructure, vehicle and operational cost structure and the vehicle range of these types of truck. The Climate Target impact assessment is on the low end with 37,000 BETs in the baseline, while the IEA predicts about 360,000 BETs in the high ambition scenario in 2030 and T&E even 617,000 BETs in the “Road 2 Zero” scenario. The number of hydrogen-powered trucks is lower than that of BETs in all projections. The estimates of hydrogen-powered FCETs range from a couple of thousand to 75,000 in the IEA's high ambition scenario. There are no specific estimates on the number of catenary-powered trucks.

5.2. Demand for infrastructure based on vehicle developments

As the fleet projections present alternatively powered trucks as part of the operational fleet in 2030 and beyond, the question remains how these trucks are to be recharged and refuelled. For a number of energy carriers, alternative infrastructure will be needed to supply trucks with the required power.

In the following sections we present projections of refuelling and recharging infrastructure requirements, broken down by type of energy carrier, in the same sequence as in Chapter 0. [The impact assessment of European Climate Target plan](#), and the [IEA](#) give no precise estimates of demand for dedicated recharging and refuelling infrastructure for trucks. We therefore gathered data from a variety of institutional sources. A compilation of the findings in the following sections, in relation to the existing infrastructure from Chapter 3 is given in Table 2.

Table 2: Estimated current and future needs (2025 and 2030) for alternative fuel recharging and refuelling infrastructure in the EU

Type of refuelling and recharging infrastructure for trucks	Number of refuelling and recharging points		
	Current	2025	2030
Overnight depot charging points	n.a.	40,000-130,000	around 300,000
Public overnight chargers	<10	4,000 to 14,000	11,000 to 40,000
Ultra-fast ‘opportunity charging’	n.a.	n.a.	7,000 to 45,000
Electric road systems (ERS)	<10 km	500 km	1,700 km
Hydrogen refuelling stations (350 bar)	<16	0-300	250-1,000
LNG refuelling stations	400	700	1,500
CNG refuelling stations	4,000 (but mainly for passenger cars)	400	500

Source: compiled by authors from sources in following sections. Current numbers are taken from Chapter 3

¹⁰ This figure includes aviation and maritime transport, however.

5.2.1. Battery recharging infrastructure

Although the projected number of BETs in the future is debatable, BETs are expected to have a substantial share in future fleet and will need recharging infrastructure. Given the different cost structure of BET operation, different charging strategies could arise in different trucking segments (McKinsey, 2020). Depending on the daily energy use and distance covered by a truck, fleet owners may opt for overnight-charging only, or a combination of overnight, mid-route and destination charging. Needs for charging infrastructure therefore strongly interdepend on the trip profiles and options and choices with regard to the range of the trucks.

Allego, a European supplier of battery-charging infrastructure, also divides the trucking market into distance segments, leading to a diversified recharging infrastructure landscape. For long-haul transport, Allego proposes opportunity charging¹¹ stations every 75-100 km, each station having at least 20 chargers (with 450 kW DC power outlets) along the main logistics corridors (e.g. TEN-T). Furthermore, port sites should also be equipped with charging infrastructure for use during freight transshipment. For the majority of last-mile transport, overnight depot and destination charging would suffice (50-150 kW) (Allego, 2020). Absolute numbers for the EU are not given.

E-Laad, a Dutch knowledge and innovation centre in charging infrastructure, has also made a projection of charging infrastructure needs. Once again, the location of charging stations and consequent share of daily energy demand per location is a function of average daily trip length. As 80% of European truck trips are under 150 km, the vast majority of the BET fleet can operate using overnight depot charging only (E-Laad, 2020). The estimated number of charging points per 1000 operational BETs is shown in Table 3. Additionally, we have made a rough estimate of the required number of recharging points in the EU, both private (depot) and public, based on the IEA fleet projections in the scenario of 55% emission reduction (Sustainable Development Scenario), considering this scenario as an average of the presented fleet scenarios that are targeting the 55% emission reduction.

Table 3: Energy demand per location and number of charging points per BET in 2030

Charging type	Share of daily energy demand	Required charging points per 1000 BET ^a	Required EU charging points ^b
Overnight depot (50 kW)	80%	800	288,000
Shared charging hubs (50 kW)	10%	150	54,000
Public overnight (70-100 kW)	3%	30	10,800
Motorway service area (500 kW+)	7%	20	7,200

Source: E-Laad, Outlook E-trucks internationale logistiek (2020)

- These numbers should be seen as minimum numbers of charging points deployed. the sum total of these figures gives the total number of public and privately deployed recharging points required per 1,000 BET in 2030.
- Own calculations based on IEA fleet projections for BETs in the 55% emission reduction scenario. These figures are totals for the EU27, Norway, Iceland, Switzerland and the United Kingdom.

¹¹ Opportunity charging is charging during the time trucks are idle during loading/unloading or during obligatory driver resting times.

The ACEA bases its estimate of charging infrastructure needs for battery-electric HDVs on its estimates HDV fleet segmentation, as described in Section 0. The ACEA numbers include infrastructure requirements in the EU27 and the UK and are presented in Table 4. To recharge the projected (hybrid) electric truck fleet will require tremendous growth of public and private charging points throughout the EU. The ACEA distinguishes between public chargers and destination chargers. Most of the charging in this segment is expected to be from overnight charging and charging while loading and unloading at logistics hubs. The destination chargers should be located at logistics hubs or at private transport companies where trucks are loaded and unloaded. For long-distance transport, the ACEA advises that the revised AFID should require at least one high-power charging station (500 kW+) with at least four charging points on the TEN-T network every 100 km in 2025 and every 50 km in 2030. Also, at least one charging point per station should be accessible for coaches ([ACEA, 2021a](#)).

Table 4: ACEA estimate of number of HDV charging points by location and power type (EU27+ UK) (trucks and buses)

Charging type	No. of charging points in 2025	No. of charging points in 2030
Overnight depot chargers (50-100 kW)	40,000	270,000
Public and destination chargers (< 350 kW) ^a	1,000 (4,000 ^b)	5,000 (40,000 ^b)
Public and destination fast chargers (350 kW) ^c	12,000	15,000
Public ultra-fast chargers (500 kW+)	2,000	30,000

Source ([ACEA, 2021a](#)):

- a) These charging points should be located at public stops and logistics hubs/distribution centres of private companies where trucks load and unload.
- b) Required public overnight chargers if fast and ultra-fast charging points are not equipped to deliver lower-power night charging.
- c) These fast chargers should allow upgrades to ultra-fast charging (also called megawatt charging (MCS, 500 kW+) when technology is available.

According to the ACEA, for the powering of long-haul BETs approximately 40,000 100 kW public overnight chargers will need to be deployed at truck parking areas along motorways. The ACEA also estimates that every BET will need a depot charging point, implying some 270,000 depot charging points in 2030 across the EU27 and the UK.

In the Cambridge Econometrics report 'Trucking into a greener future', it is assumed that 65% of the trips by EU trucks are under 600 km. Assuming a 700 kW battery, the daily distance can be covered without en-route charging for this truck segment. This means public chargers will only need to be installed for a third of the BETs, assuming that sufficient depot and destination chargers are deployed for the aforementioned short- and medium-haul trucks. Cambridge Econometrics estimates that sixteen trucks can use a single charger per day, for a period of 45 minutes (during obligatory rest times). An estimated 11,000 fast-charging points (700 kW DC output) will be needed to support the EU BET fleet in 2030, and a total of 320,000 depot chargers of which 95,000 with low and 225,000 with high power ([Cambridge Econometrics, 2018](#)) ; see Table 5.

Table 5: Projected number of chargers by type in the EU27 + UK

Charging type	No. of charging points in 2025	No. of charging points in 2030
Overnight depot (low: 22 kW)	70,000	95,000
Overnight depot (high: 90 kW)	57,000	225,000
Public fast (700 kW)	4,000	11,000

Source: [Cambridge Econometrics, 2018](#); The figures are approximated by cumulating the annual figures as read from Figure 4.4 and 4.5 of the reference.

The predictions by T&E ([T&E, 2021](#)) are not presented separately in this briefing, but their estimates are within the same ranges as the other sources. We observe that the requirements, conditions and assumptions vary across the various sources consulted. Most sources have a wide geographical coverage of Europe, including countries adjacent to EU member states. The sources reporting HDV charging infrastructure needs are considering trucks/trailers only, except the ACEA, which also includes buses. However, it is still plausible to compare the figures from the different sources, including the ACEA, as buses are expected to rely solely on overnight (depot) charging and destination charging. Public charging is thus geared to the commercial freight transport sector.

There is limited spread in the estimates. The breakdown of truck trip length is the main factor determining the need for charging infrastructure and its local development and distribution. The overall expectation is that overnight charging infrastructure will be supplying the lion's share of truck battery energy. According to the sources discussed above, by 2025 already, approx. 40,000-130,000 overnight charging points, and 4,000 to 14,000 public fast-chargers are needed. These overnight charging points can be deployed both at depots and at public trucking stops, with estimates close to the number of total BETs, i.e. between 270,000 and 360,000 charging points in all in the EU and the UK in 2030 according to ACEA and IEA figures.¹² The projections expect and require the development of ultra-high power (500 kW+) charging technology, moreover. Estimates of the number of public overnight charging stations in 2030 (approx. 100 kW/h charging) have a wide range: from 11,000 to as many as 40,000. The projected number of (ultra-)fast high-power charging points (350 kW+) required is between 7,000 and as many as 45,000 in the most optimistic scenario of fast technology adoption and fleet composition in 2030. This technology is still in the development phase, however.

Given the current number of public charging points for trucks (<10 in the EU27 according to ACEA ([ACEA, 2021a](#))), the figures presented indicate a need for tremendous investment, growth and effort for the roll-out and installation of appropriate charging infrastructure for trucks. As overnight charging is expected to play a significant role in the BET energy supply, there will need to be active involvement and cooperation from and with the private transport companies where overnight charging takes place if there is to be adequate deployment and international coherence in the required infrastructure.

5.2.2. Infrastructure for overhead catenary

The impact assessment of the European Climate Target plan does not make any assumptions on the deployment of a European network of overhead catenary infrastructure on motorways. Individual

¹² According to the impact assessment of the EU Climate Target plan, the number would amount only 37,000, which is very low as compared to the other sources.

member states or local governments may possibly initiate this type of infrastructure for specific operations (e.g. between ports and overhaul and storage locations with a high intensity of road freight transport).

A report by the ICCT ([Moultak, Lutsey, & Hall, 2017](#)) states the total cost of ownership (TCO) of overhead catenary HDVs (including charges for the ERS infrastructure) would be approximately 25-30% lower than the total cost of ownership of diesel vehicles. The total costs for vehicle investment and operation are lower than for other technologies, irrespective of the chosen technology for the main vehicle drive system (diesel-hybrid, battery-electric trucks (BET) or fuel-cell electric trucks (FCET)). However, the feasibility of using overhead catenary infrastructure requires a major (coordinated) effort on infrastructural investment and development from Member States ([Moultak, Lutsey, & Hall, 2017](#)).

Cambridge Econometrics presents figures for the estimated cost of infrastructure development. The scenario in which electric road systems (ERS), i.e. overhead catenary lines, constitute the key technology for long-distance HDVs is their 'ERS scenario' and can be seen as maximum ERS deployment along the main transport routes, the assumption being that it will be deployed across the core TEN-T network. In two other scenarios where battery-electric and fuel-cell HDVs are the key technology (the BET and FCET scenario, respectively), ERS is still deployed across the main TEN-T routes as a supplementary technology, although on a smaller scale than in the ERS scenario. The figures for estimated infrastructure requirements are presented in Table 6.

Table 6: Projected kilometres of overhead catenary infrastructure in the EU+UK

Deployment (km) of ERS by scenario	2020	2025	2030	2040	2050
ERS scenario	50	600	1,700	9,000	15,500
BET and -FCET scenario	0	250	500	900	1,600

Source: [\(Cambridge Econometrics, 2018\)](#), figures are approximated from reading [Figure 4.2 in reference](#).

Even though member OEMs of the ACEA are currently performing pilots with overhead catenary trucks, the ACEA position paper on the infrastructure for alternatively fuelled HDVs includes no scenarios or assumptions for overhead catenary-powered trucks as part of the solution for a zero- and low-carbon future. The same holds for the other institutional sources, which make no allowance for large-scale roll-out of overhead catenary infrastructure.

5.2.3. Fuelling infrastructure for hydrogen

The future need for hydrogen refuelling stations (HRS) for HDVs is mentioned in several scenario reports. The Fraunhofer Institute for Systems and Innovation Research ISI has calculated that a national network of 140 HRS in Germany are sufficient to meet the hydrogen demand of fuel cell electric trucks (FCET) in 2050. This figure will be 70 in 2030, supplying around 50,000 trucks ([Fraunhofer ISI, 2020](#)). This comes down to deployment of approx. one HRS per 700 hydrogen fuel cell trucks.

According to the ACEA, use of hydrogen for long-distance transport will require dedicated (high storage and dispensing capacity) refuelling stations with a pressure level of at least 700 bar. Because there is no standardised refuelling concept and market-proven, truck-suitable HRS, there needs to be a coordinated effort on infrastructure development. The ACEA estimates of the number of HRS required in the EU27 and UK are given in Table 7. The estimates are based on the number of hydrogen-fuelled trucks in operation in 2030.

Cambridge Econometrics makes predictions on the required number of HRS in their FCET scenario, which can be seen as a 'high' scenario for hydrogen-powered trucks (Table 8). They distinguish HRS with daily dispensing capacities of 10,000 and 25,000 kg hydrogen, with 17 and 42 dispensers, respectively. A dispenser for hydrogen refuelling will be comparable to a dispenser for conventional fuels at today's filling stations.

Table 7: Required number of hydrogen refuelling stations (EU27 + UK)

HRS	2025	2030
Truck-suitable HRS (700 bar)	300	1,000

Source: (ACEA, 2021a)

Table 8: Projected number of hydrogen refuelling stations (EU27 + UK)

HRS type (capacity)	2025	2030
10,000 kg/day	0	250
25,000 kg/day	0	95

Source: (Cambridge Econometrics, 2018); The figures are approximated by cumulating the annual figures as read from Figure 4.6 of the reference.

5.2.4. Fuelling infrastructure for gaseous fuels

In the EU Climate Target impact assessment, biogas is estimated to comprise only about 0.2% of total transport fuel consumption in 2030 (EC, 2020c). Refuelling infrastructure for biomethane is similar to that for CNG (CNGFuels, 2021). The ACEA states that the infrastructure for gaseous truck refuelling requires a more comprehensive network than currently exists. Natural gas refuelling infrastructure can be used for renewable gas and biogas (biomethane) as well (Prussi, Julea, Lonza, & Thiel, 2021). Considering the increase in the use of gaseous fuels in the projected scenarios, the required refuelling infrastructure posited by ACEA states can be justified. The number of refuelling stations required to service the growing gas-fuelled truck fleet is presented in Table 9.

Table 9: Required number of LNG and CNG refuelling stations (minimum estimates)

Type of gas refilling station	2025	2030
CNG stations	400	500
LNG stations	750	1,500

Source: (ACEA, 2021a)

5.2.5. Fuelling infrastructure for liquid biofuels

According to the Climate Target plan impact assessment, liquid biofuels are expected to make up 5-7% of the energy mix in 2030 ([EC, 2020c](#)). Concawe states that existing fuelling infrastructure can remain in use for the transportation and storage of liquid biofuels ([Concawe, 2020](#)). According to the EAFO, the refilling infrastructure for E10, renewable ethanol, is already widely available since it is a drop-in fuel ([EAFO, 2021b](#)). No further requirements for the development of fuelling infrastructure are stated.

5.2.6. Fuelling infrastructure for e-fuels

As e-liquids become available on the market in the coming decades, dedicated infrastructure will be needed, depending on the type of e-fuel. For several e-fuels, their physical properties allow for use of similar refuelling infrastructure and the same storage facilities as currently in place ([Concawe, 2020](#); [Searle & Christensen, 2018](#)). The German Energy Agency, too, states that e-fuels with a high energy density can utilise the transport, storage, distribution and fuelling infrastructure that is already in place in Europe and internationally ([Siegemund, Trommler, Kolb, & Zinnecker, 2017](#)). For the e-fuels ammonia and dimethyl ether, there are additional infrastructural requirements for fuelling and storage, implying a possible need for investment by industrialists and suppliers if these e-fuels are to be used by trucks. Given the current immaturity of development, conclusions on future requirements vis-à-vis roll-out of e-fuel refuelling infrastructure necessitate many assumptions and is not further assessed in this briefing.

6. PERSPECTIVES AND RECOMMENDATIONS

6.1. Perspectives

Current policy developments have stressed **the need for faster decarbonisation of trucks** and other HDV, and consequently **faster development of recharging and refuelling infrastructure**. Recent policies have focussed on LDV or alternative fuel infrastructure in general. It is only recently that stakeholders are starting to adopt a more targeted approach towards infrastructure for trucks. Given the Green Deal ambition and the efforts and realisation time needed to implement sufficient coverage of infrastructure, **current developments are lagging behind** and there is a strong urgency to act today.

For **charging of battery-electric trucks** the main challenges are **the realization of higher-power chargers (up to 1 MW)**, the accommodation of **peaks in energy demand** (likely several mega-watts) when multiple trucks at a location aim to charge at once, and the associated **realization time** of grid adjustments. For **hydrogen**, the main challenges are **the standardisation of pressure level and storage technology and additional safety aspects**. More mature technologies, such as LNG, CNG and LPG, do face less challenges, although their environmental performance asks for **a shift towards the biofuel or e-fuel counterparts** of those fuels. Biofuels and e-fuels can mostly make use of existing infrastructure, especially in case of drop-in quality (with identical chemical characteristics compared to the fossil fuel). Nonetheless, **further scale-up activities**, related to, for example, biomass feedstock mobilisation, and building **supply chains** will be necessary, also given the fact that there is **hardly any experience with large scale distribution of e-fuels**.

Given the major uncertainties involved, independent studies on future infrastructure requirements are in fair agreement on their projections of the number of charging and refuelling points needed, **though they differ on expectations regarding full electrification (or more hybrid forms of transport)**. Studies from stakeholders with clear interests at stake often present **more extreme scenarios** in which either battery-electric trucks or hydrogen trucks dominate the demand for refuelling and recharging infrastructure.

6.2. Policy recommendations and research gaps

Following the attention for gaseous and liquid alternative fuels, such as LNG, the revision of the AFID should now give particular attention to development of a network of battery-charging and hydrogen-refuelling stations across the TEN-T corridors and other important corridors, creating a network that allows medium- and long-haul transport to start operating BETs and hydrogen-fuelled trucks. Given the time left to 2030, policy actions should increase **investment security** by means of a **stable policy framework** (including binding targets and smart funding mechanisms). **Efforts to improve utilisation rates** of charging points and filling stations, while **reducing uncertainties related to availability** are also required to convince investors and market actors. Where possible, policy makers should remove any barriers which result in **unnecessary long lead times**. Bringing stakeholders from different sectors together and initiatives aimed at **harmonisation and standardisation** result in a higher efficiency and thus could also help to speed up the realisation of infrastructure.

Further research initiatives should focus on **the implications of the various policy revisions and the interactions between the different objectives**. Now the revisions are taking place simultaneously, it would be good to assess the **overall policy framework** after the publication of the proposals of the

individual revisions. Additional research on the **integration of transport and energy infrastructures** would also help to improve insight in the link between charging locations and grid issues. Finally, the introduction of **standardised data collection** from operational infrastructure is a necessity to monitor the realisation of policy objectives.

6.3. Next steps

The full study as follow up to this briefing will further elaborate on the various challenges. Besides an extensive policy update based on the European Commission's **Fit for 55 Package**, the full study will include a more in-depth analysis of the future needs and main uncertainties and further identification of barriers and enablers, including the interview outcomes.

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This briefing presents the opportunities and challenges for the use and deployment of alternative fuels infrastructure in the EU for heavy-duty vehicles, in particular trucks. The current state of play and future needs are presented in the context of the ambitions of the Green Deal and current legislative developments, in particular the upcoming reviews of the Alternative Fuels Directive and the TEN-T Regulation.

This briefing will be followed by a full-length study that will provide a more in-depth analysis, an update of the policy context based on the 'Fit for 55' package and outcomes of stakeholder interviews and case study analysis.

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