

International Energy Agency Technology Collaboration Programme – Hybrid and Electric Vehicles

Final Report of Taskforce 41 “Electric Freight Vehicles”



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Introduction

Road freight transport is one of the fastest growing modes of transport and has an increasing share in the total GHG emissions of transport. Furthermore, higher gradients are observed for freight emissions compared to passenger travel emissions for most of the IEA countries [1]. Hence in order to meet the Paris Climate Agreement targets, the global road freight sector will need to cut its CO₂ emissions by 60% until 2050 [2]. Various technical and non-technical options exist for reducing the emissions of road freight transport, such as improving the efficiency of freight logistics, reducing the fuel consumption performance of conventional vehicles and introducing (near) zero tailpipe emission vehicles such as battery-electric vehicles (BEV) into the market that could result in the large-scale emission reduction. However, current emphasis is on incremental technology developments to reduce fuel consumption of conventional vehicles. Although electrifying the fleet is the ideal option for the future and has been the subject of significant discussion, there is still a high degree of uncertainty regarding technology developments of electric powertrain options. Specifically, the challenge has been to introduce electrification whilst continuing to meet the user requirements. This has given rise to numerous activities in the different vehicle segments of the freight sector with some uncertainty as to which solutions will be adopted in the longer term.

Task objective and working method

The Taskforce 41 “Electric Freight Vehicles” (EFV) of the IEA Technology Collaboration Program “Hybrid and Electric Vehicles” aimed to monitor progress and review relevant aspects for a successful introduction of electric freight vehicles (EFV) into the market. Four focus areas were included for this purpose.



EFV market structure

The first area “EFV market structure” looked at the current market developments of EFVs. This includes key characteristics of the truck market in Europe as well as the current EFV portfolio.



Technology development

The next area „technology development of EFV” addressed the technical viability of EFV. Based on available EFVs on the market, their performance were described to monitor the technical progress of EFVs.



Best practice & suitability

The third area of interest dealt with “best practices and suitability aspects of EFV” to identify potential application areas of EFV. Successful examples of EFV applications based on best practice pilot project were described and their opportunities and barriers for a broad market introduction were discussed.



Evaluation & policy framework

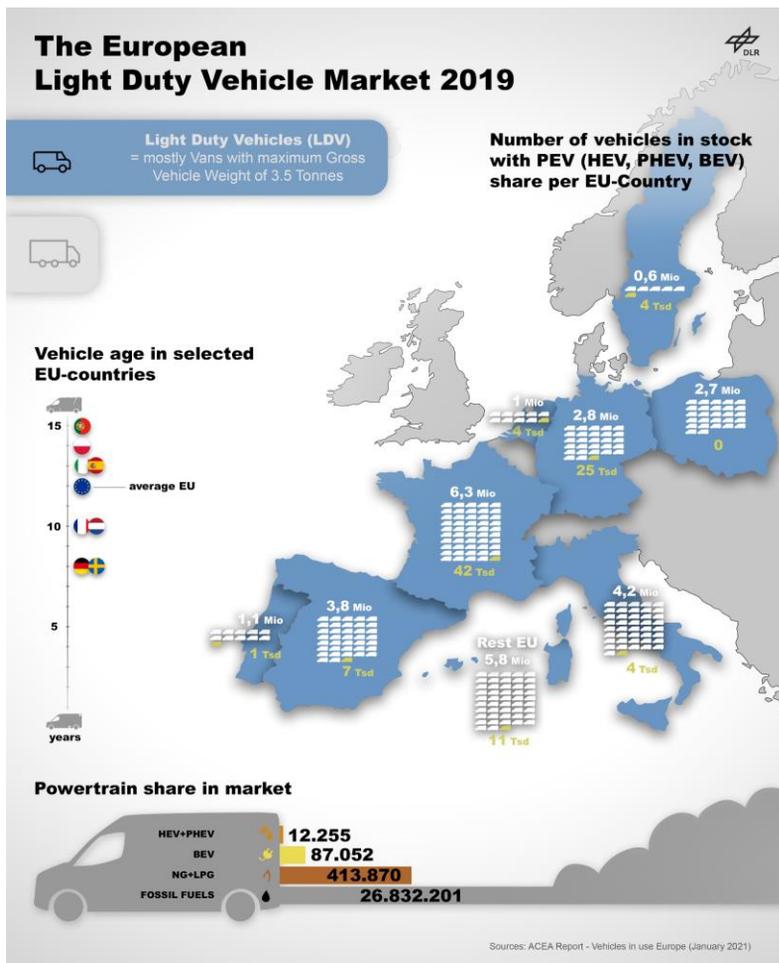
The last area looks at demand-side issues and was linked both to end costumers and to policies. Given the different suitability of EFV technologies for replacing conventional diesel engines, economic and ecological aspects of EFV were evaluated.

Topics of each focus area were linked in a series of stakeholder workshops and presented in form of fact sheets (see following pages) which provided the base to review the aspects for a successful introduction of EFV into the market (last page). The scope of Task 41 included vehicles of the size classes N1, N2 and N3 and all types of electrified or electric powertrains like hybrid, plugin-hybrid, battery-electric, fuel cell electric and electric road powertrain.



The European Light and Heavy Duty Vehicle Market

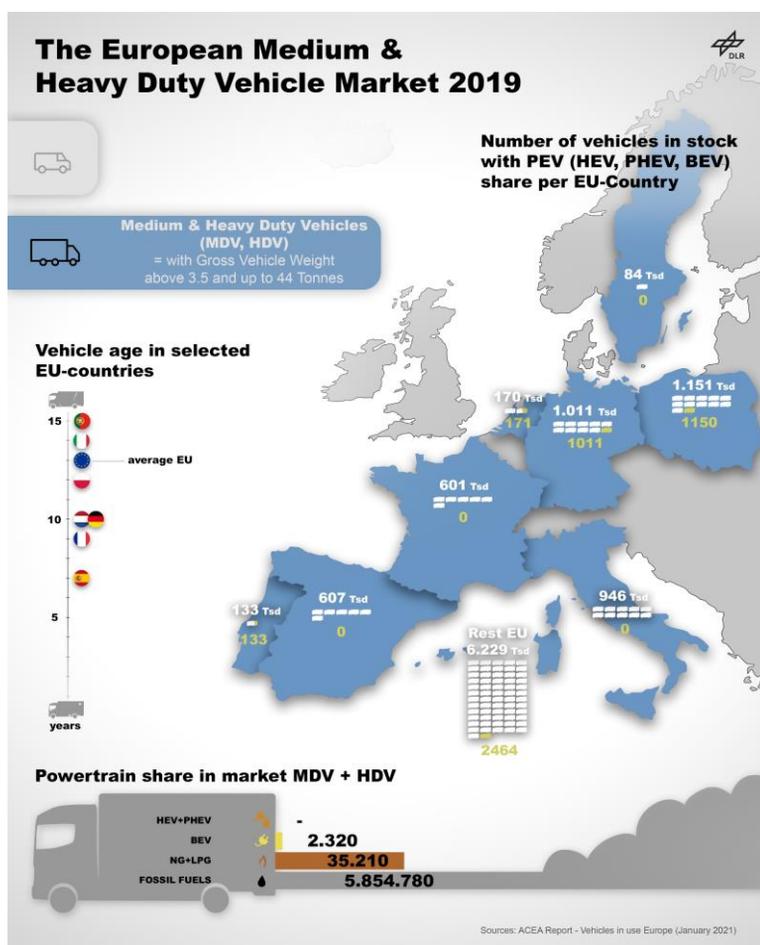
In 2019, 2.48 million Light and Heavy-Duty Vehicles were newly registered in Europe, 85% of which were Light-Duty Vehicles (LDV) under 3.5 tons gross vehicle weight (GVW). The following figures illustrate the European light and heavy-duty vehicle market in 2019. Eight selected countries are shown, representing about 75% of each of the European light and heavy-duty vehicle stock.



Most of the vehicles are powered by a diesel engine (92.8% LDV, 97.9% HDV). Alternative fuels, like CNG, LPG, biofuels and ethanol, had a share of approximately 1.4% in the overall commercial vehicle registration in 2019. The market niche is made up of Hybrid Electric Vehicles (HEV) with 0.2% of new registrations. However, the market share in the LDV has risen to almost 160% compared to the previous year (4,577 hybrid-electric vans in 2019). Another high increase was recorded by plug-in electric commercial vehicles (BEV, FCEV, REEV, PHEV) with 26,107 plug-in electric LDV and 747 plug-in electric HDV newly registered in 2019.

The year-on-year increase was stronger in the HDV segment (+109%) than in the LDV segment. The main markets for these vehicles are primarily Germany, followed by the Netherlands and France. [3, 4]

The diesel engine is by far the main drive train in the commercial vehicle segment. It is an efficient internal combustion engine and since the introduction of the Euro standards (1988), Euro 6 and exhaust after-treatment pollutant emissions from heavy-duty vehicles dropped significantly [5]. Nevertheless, to achieve the CO2 fleet targets, not only technological progress of the diesel engine itself is necessary, but also low- and zero-emission vehicles need to be promoted more in the market.

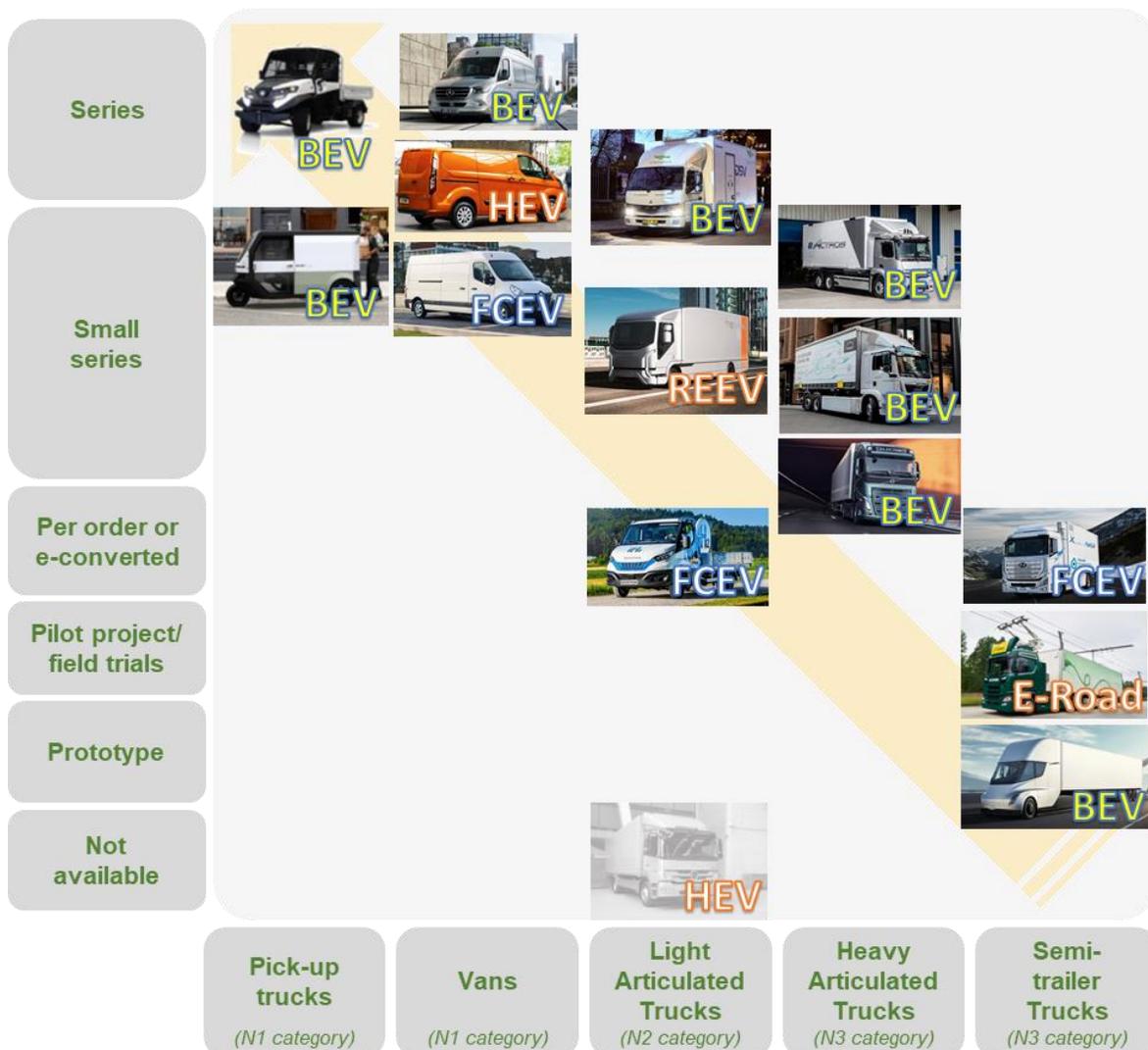


EFV market structure

Current market status for electric freight vehicles

The IAA Commercial Vehicle Fairs in 2018 and 2020 characterized an increasing electrification strategy for commercial vehicles. Different manufactures showcased their first battery-electric vehicle models. Especially in the LDV segment, vans from Volkswagen, Daimler, MAN, IVECO, Nissan and Renault are already in series production. Prototypical BEVs in the medium and heavy-duty segments are currently being tested in the last phase of various pilot projects with customers. The start of production (SOP) of these medium and heavy duty vehicles are set for 2022 or early 2023. Electric heavy articulated tractors and semitrailer trucks are currently also manufactured and sold by small suppliers such as the Swiss E-Force One AG and the German Framo GmbH [6, 7]. These are so-called electric vehicle converters, which replace the combustion engine of trucks from MAN, Daimler and Co. with their electric powertrain. The following figure shows the market readiness level of electric freight vehicle examples in different vehicle segment.

Electric Freight Vehicle Market Overview 2022



Most manufacturers already have battery-electric series vehicles for the light vehicle segment in their portfolio. With increasing gross vehicle weight, the transport applications of the vehicles are shifting toward long-distance operation and thus also higher range requirements. Pure battery solutions for the heavy vehicle segment (up to 26 tons) in distribution transport have been tested in recent years and have been in small series production since 2022. In heavy-duty long-distance transport, FCEVs, BEVs and electric vehicles with dynamic charging options are still being tested with customer participation.

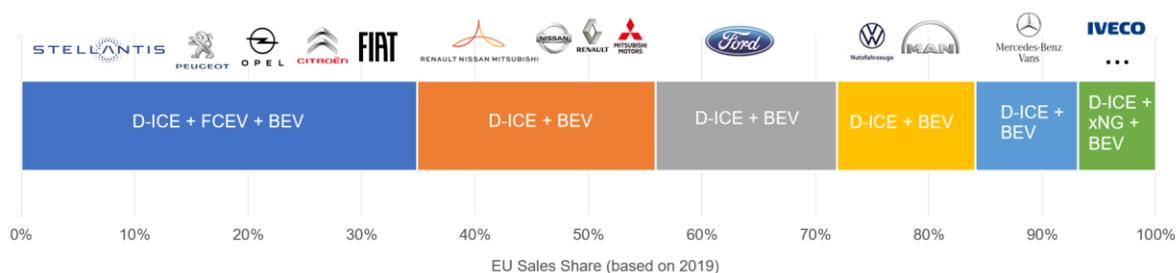


Prospects for electric freight vehicles from the manufacturers' point of view

In the media, the first long-term strategies of the manufacturers have appeared with information on the planned investments. For example, Daimler, the world's largest commercial vehicle manufacturer, plans to phase out all diesel engines in its trucks and buses (in addition to passenger cars) in their biggest market regions in the world (primarily Europe, Japan and North America) by 2039. In the future, trucks will be powered either by a traction battery system (BEV) or fuel cell systems (FCEV). The VW Group subsidiary TRATON, which is the largest producer of commercial vehicles in Europe and to which the commercial vehicle brands MAN and Scania belong, wants to invest one billion Euros in the development of electric mobility (primarily as BEVs) by 2025 and expects that by 2030 a third of its commercial vehicles could be driven with electric motors. [8]

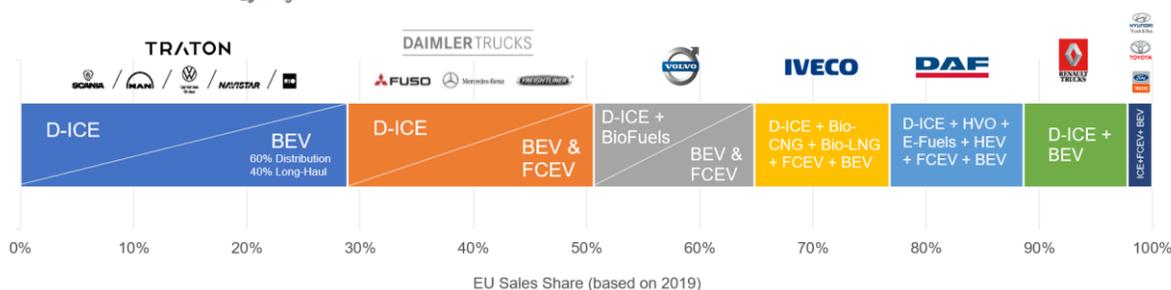
The market developments show that electrification efforts are beginning to take hold in the entire commercial vehicle segment. However, compared to the passenger car market, the manufacturers' strategies differ in some respects. The following figures show the largest manufacturers in Europe in terms of sales in 2019 respectively for the light and heavy goods vehicle segments. Based on the public announcements of the manufacturers, the long-term powertrain strategies are noted in the figures. In the van market, a strong preference for the BEV option is seen.

OEM Targets for Light Commercial Vehicle Sales in Europe until 2030



In the heavy truck segment, manufacturers are pursuing different strategies. The TRATON Group is currently following almost a single BEV strategy like in the VW Passenger Cars Group. Daimler Trucks and Volvo Group are focusing more on a dual strategy with BEV and FCEV. In common, these three largest truck manufacturer groups aim to provide at least every second vehicle with an electric drive by 2030. Other manufacturers in the heavy-duty segment also see potential in CNG and LNG as well as renewable fuels such as biofuels and synthetic fuels. [9]

OEM Targets for Heavy Commercial Vehicle Sales in Europe until 2030



From a vehicle design perspective, fuel cell makes particular sense in heavy-duty traffic, where longer distances are covered and more demanding payload profiles are required compared to light-duty traffic. The higher gravimetric energy density of the fuel cell compared to the battery offers systemic advantages for the vehicle design.



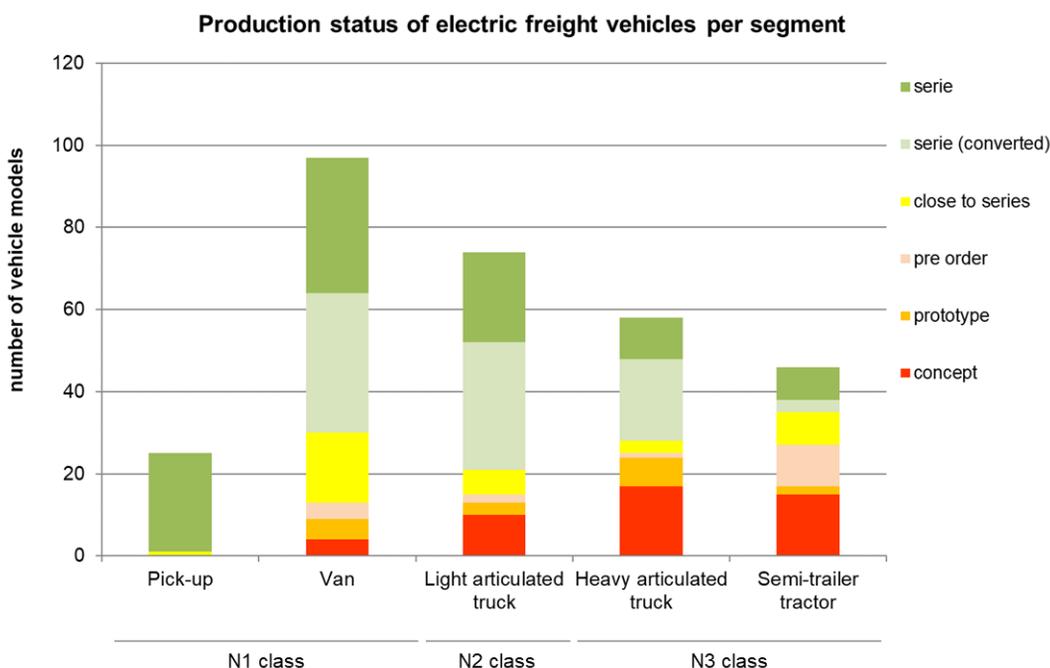
The State of the Art of Electric Freight Vehicles

Technical Performance – Range and Payload

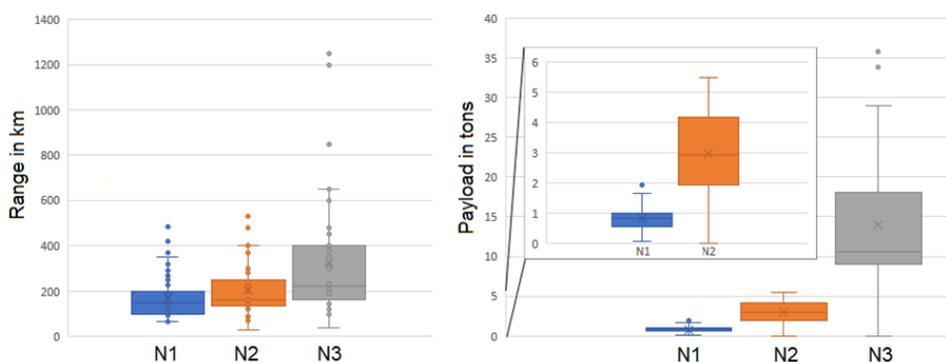
The main challenges in the technical performance of Electric Freight Vehicles (EFV) are the available range, payload and charging time today. The traction battery has a major influence on the indicators. In addition, the limited availability of EFV models and the rapid technological development plays a major role in the attractiveness of EFV in the market [10]. However, the market is developing rapidly. The question therefore arises whether the current state of performance of EFV is competitive with a conventional freight vehicle today.

A benchmark analysis of EFV was carried out using technical information on all available vehicle models and concepts that are publicly known. This includes Hybrid Electric Vehicles (HEV), Range Extended Electric Vehicles (REEV), Fuel Cell Electric Vehicles (FCEV) and Battery Electric Vehicles (BEV). The collected information was compiled over a time period from April 2018 to April 2022 and has been consolidated in a vehicle database. The data contains the standard specifications of the vehicles with technical data such as power, battery capacity, range etc. From the research, 265 vehicles were collected.

The following figure shows the collected numbers of electric vehicle models regarding their market readiness level and the segment. In principle, a lower market readiness level can be identified with increasing gross vehicle weight. This is mainly due to the technical requirements for heavy-duty vehicles in long haul transport that cover longer distances and have more demanding payload profiles.



On average, the range of the battery-electric vans available on the market is 150 km. The ranges go from 64 km to 500 km – see figure below. In the upper section, REEV is more likely to be found than BEV. The increase of the electric range and thus the battery capacity goes hand in hand with an increase in the mass of the traction battery, which is in conflict with the available vehicle payload in the corresponding vehicle segment. This optimization problem is one of the challenges for the design of EFVs but has improved in recent years with developments in battery efficiency. The vehicle payload of electric vans ranges from 200 kg to 1,950 kg with 835 kg on average. Regarding the driving range of N2 category vehicles, the current performance varies from 30 km to 530 km with an average of 160 km. Vehicle payload ranges from 1,000 kg to 5,500 kg with 3,100 kg on average. For the N3 category vehicles, the driving range varies between 40 km to 1250 km with 220 km on average. Vehicle payload ranges from 4,400 kg to 36,000 kg with 11,100 kg on average.



The State of the Art of Electric Freight Vehicles

Technical Performance – Battery and Infrastructure

Whether the range is a limiting factor for vehicle operation also depends on the availability of the charging points and the charging speed [11]. Charging time varies largely depending on the type of electric vehicle supply equipment and type of battery in the vehicle. Alternating Current (AC) and Direct Current (DC) charging systems are available. With the AC system, regular charging is possible via the household power grid (e.g. via wall-box). DC charging has the problem that the batteries in the vehicle can quickly become overheated. An example of series battery-electric freight vehicles with information about the battery capacity and the charging time according to AC and DC is shown in Table below.

Battery capacity and charging time of series battery-electric freight vehicles

Vehicle Class	Vehicle model	Battery capacity [kWh]	Charging time AC 0-100% [h]	Charging time DC 0-80% [min]	Max. range [km] (without payload)
N1	Nissan E-NV200 (3,5 t.)	40	5,5 (11 kW)	40 (50kW)	275 (NEFZ)
	Mercedes eVito (3,5 t.)	41,4	10 (11 kW)	80 (50kW)	150 (WLTP)
N2	IVECO Daily Electric 50C (7,5 t.)	80	4,2 (22 kW)	40 (50 kW)	280 (NEFZ)
	FUSO eCanter (7,5 t.)	82,8	12 (22 kW)	105 (50 kW)	100 (WLTP)
N3	Volvo FL Electric (16 t.)	300	13 (22 kW)	60-120 (150 kW)	300 (NEFZ)
	Volvo FE Electric (27 t.)	300	10 (22 kW)	90 (150 kW)	200 (NEFZ)

Depot charging is most attractive for freight transport because it offers a high degree of flexibility in operation. For depot charging, fleet operators usually need their own charging points at the depot. The vehicles are then preferably charged overnight or during the day (opportunity charging), as in some transport tasks vehicles have to return to the depot during the day. For the heavy duty vehicle segment 150-kW DC-charger is appropriate but a minimal standard. For most sub-contractors or similar logisticians who do not have a private parking space for their vehicles it is more difficult to find suitable charging business cases. Their vehicles are usually parked overnight on public roads. For electric vans there is the possibility to charge them via the current public charging infrastructure. For this purpose common 50-kW DC-Chargers (standard CCS) are suitable.

Logisticians often complain about the long charging time of EFV. However, 90 percent of today's vans are parked overnight at a fixed depot [12]. Considering the average charging time via an 11kW/22kW AC-charger, electric vans could be conveniently recharged overnight. Public 50kW/150kW DC-Charger could be additionally used to recharge the vans between the daily tours. As mentioned, public charging is seen more as a supporting factor in the charging strategy of EFVs, and will not be able to replace the own charging station with fixed parking space in the depot [12]. However, the relatively long charging time compared to conventional diesel refueling can be regarded as no problem in some applications already today.

The way and frequency of charging and discharging determine the battery life. The charging time of the battery depends on the limited electrical intensity to avoid irreversible damage to the battery [11]. A health indicator of batteries is the capacity. Lithium-Ion (Li-Ion) batteries lose on average more than 20% of their capacity over lifetime [11]. For Li-Ion batteries in electric vehicles the lowest capacity loss is reached by charging the Li-Ion battery (at 20°C) between 25-75 percent state of charge (SOC). This would delivery around 3,000 cycles (to 90% capacity) [13]. In real operation these operational parameters (charging strategy (speed), depth of discharge, operating temperatures, tour profile etc.) vary strongly and make it therefore harder to estimate the average lifetime of the battery.

EFVs available on the market today demonstrate important technological progress in comparison to vehicles from 10 years ago. The technical indicators show that some EFV are potentially as efficient as conventional vehicles. With the rapid development in battery technology, further technological improvements can still be expected.

Best practice & suitability

Vehicle technologies and applications of battery-electric freight vehicles in city logistics



The first Task 41 workshop “battery-electric freight vehicles in urban logistics” were held in Stuttgart (Germany) on October 15th 2020. Dedicated topics of the workshop were: current technical characteristics of battery-electric freight vehicles, development of the charging infrastructure and practical experience and knowledge from pilot projects. The workshop was a joint activity by the ERA-NET project "Promoting Electric Mobility in Urban Europe" (proEME) and the task force 41.



Twenty-four local and international guests from logistics as well logistics associations, vehicle industry, charging infrastructure, city administration and research took part in the discussion on opportunities and hurdles for the successful implementation of battery-electric freight vehicles in urban logistics. The workshop was introduced with impulse presentations by companies from the vehicle, infrastructure and logistics sectors. The first session “current technical characteristics of battery-electric freight vehicle” was held by the vehicle manufacture Daimler with insights on their current electrification strategy. In the second session “development of the charging infrastructure: costs and availability” three key charging infrastructure suppliers in Germany: ABB, ChargeHere by EnBW and EBG compleo, have introduced dedicated AC and DC charging stations for commercial vehicle application with information on suitable power ranges and current available charging points in Germany. The third session “practical experience and knowledge from pilot projects and initial applications” was structured by impulse presentations from the logistic loading company Dachser in Stuttgart, Germany and Fier Automotive from Helmond, the Netherlands. Dachser share their experiences with the Fuso eCanter and Mercedes-Benz eActros in Stuttgart and Fier Automotive presented the results from the EU-Project ElectricGreenLastMile.

On the basis of the technical and experience reports, the guests of the workshop discussed the problems and solutions for the implementation of vehicles and suitable charging infrastructure in urban logistics in two interactive groups. The main topics of the group discussion were the still ongoing uncertainty in battery electric as well as fuel cell technologies, the lack of space for electric charging stations and loading stations in urban areas and the uncertainty about necessary charging capacities for different transport applications. Furthermore, the discussion with the participants showed that there is no urgent need for fast charging solutions in urban logistics. It could be useful for the logistic and fleet operators to learn more about current applications with battery-electric freight vehicles including information on their total cost of ownership. The discussions were noted on two flipcharts and illustrated in the following tables.

Group 1: Operating of Electric freight Vehicles

Challenges	Potentials
<ul style="list-style-type: none"> Operationalisation: range vs. payload; secured payload for greater planning reliability; planning effort for loading stops; flexibility (loading time) Space for loading: sufficient loading capacity; sufficient loading points at the delivery zones; intermodal hubs?; delivery zone-building-ramps Purchase decision: high investment costs, vehicle classes (Vectro); investment vs operating costs; too high investment costs result in return of investment above total cost of ownership Operator = Energy supplier 	<ul style="list-style-type: none"> Post-delivery: effectiveness through 24/7 delivery, planning security (e.g. driving ban), fleet management Politics: Generate cost parity; extend tolls; extend discount for e-drives; clear regulations with time horizon Attractiveness of the profession of professional driver Company Image Use of renewable energy and reduction of emissions new financing concepts – leasing and rental in combination with BEV Privileges/limitations/directions can reduce the relevant of investments /price; „Stars with low hanging fruits“- niche applications with better business cases”

Group 2: Charging Infrastructure for electric freight vehicles

Problems	Solutions	Prospects
<ul style="list-style-type: none"> Uncertainties about the BEV vs. Fuel Cell technologies Areas for charging stations in the city Distribution traffic is standing anyway at night → no need for fast charging station Feed-in power of grid for electricity currently not available Unclear which capacity is required where Life cycle costs for vehicle- battery- infrastructure bi-directional function → standards as well as technical and economical 	<ul style="list-style-type: none"> Perspective more loading zones necessary haulage with BEV means more space is needed Electricity „no-regret” Energy management Charging station for commercial vehicles Divide area for charging areas Battery regulation for 2nd and 3rd life 	<ul style="list-style-type: none"> Invest risk Orientation of charging points to customer behaviour Charging point close to energy production (wind, solar and substations) Fuel Cell for Heavy duty vehicles No business case for fast charging solution in commercial vehicle

Best practice &
suitability

Electrification of Heavy-Duty Vehicles in Long Haul Transport



On September 29th 2020, the Task41 team hosted the 2nd online workshop on “Electrification of Heavy-Duty Vehicles in Long Haul Transport”. In three sessions experts shared and discussed the present state of technologies, experiences and best practices – covering alternatives including fuel cell electric, battery-electric and catenary electric freight vehicles. In total, thirty-four attendants from industry, research, logistics and governmental organization joined the webinar.

Essential for the implementation of electric freight vehicles in long-haul transport are the new developments in battery and fuel cell technology. Akasol AG predicted that in between 2021 and 2025 the energy density of their high energy batteries for commercial vehicle applications would likely increase from 140 Wh/Kg today to 240 Wh/kg – a near 100% increase. For their high power batteries, which are especially suitable for fast charge and hybrid power applications, Akasol expect the charge capacity to increase from 500 W/kg today to 800 W/kg in 2024 – an increase of over 50%. The Speaker from the International Council on Clean Transportation (ICCT) noted that the battery prices for truck applications are dropping with two to three years delay to car applications – hence the reduction in price observed in the passenger car market can be expected to be seen in the freight sector. As an alternative, or as an adjunct to the battery for energy storage there is also the option of a fuel cell. This is viewed as attractive for the long haul freight sector. However, there is a cost issue to overcome. The Akasol speaker stated that 1 kWh of fuel cells today costs five to six times more than one kWh of battery. In addition to cost the issue around fuel cell and battery is wider than how to specified the vehicle. To be successful with deployment of any alternative it is essential for the vehicle operation that the infrastructure is aligned to the specific tour (profile use case) in order words the energy should be available where the vehicle is being used.

The MAN Truck and Bus SE, together with logisticians from the Council for Sustainable Logistics, has been testing nine electric MAN-CNL trucks on Austrian roads since 2018. The speaker from MAN highlighted that the charging process and communication needs to become as soon as possible standardized and mandatory across the different charging station operators around Europe (which would make cross-boarder freight movement easier). For long-haul transport, MAN expects that with the next battery generation the capacity will allow long-haul related ranges in tractor trucks.

Another best practice example for long-haul applications is the eHighways from the Siemens AG. The presenter from Siemens described that in general heavy-duty vehicles drive long distances and are often away from their base. Their transport tasks are highly concentrated on the highway network. Therefore, The presenter recommends using a dynamic charging approach, in this case catenary, on highways when this is possible and move to battery on the distributor routes (from the highway to the depot or delivery point). Other dynamic charging approaches, for example infrastructure embedded in the highway, may also be possible and are under consideration.

One of the topics in the panel discussion was on the total cost of ownership (TCO) parity of Electric Freight Vehicle and the speaker from Quantron AG answered that he does not expect that the purchase price of fuel cell electric vehicle (FCEV) will get below diesel trucks in the next ten years. However, there should be business cases for customers during this time depending on their specific transport task. The speaker from ICCT stated that access to capital is one of the key barriers they have seen in the past for fleets to invest in efficient technologies. Thus, it will require innovative financing solutions to ensure that the barrier of upfront cost and the access to capital can be overcome and depreciate over the vehicle operation time. The speaker from Transport Decarbonisation Alliance (TDA) shared that customers are also willing to pay for transportation and not only for the TCO. This requires new business models such as transport as services or leasing options. Nevertheless, there must be some frontrunners who are willing to pay a little extra for the TCO of electric freight vehicles. Besides, the workshop speakers are seeing cities as powerful ecosystems for this transition since they can push multiple local actors collaborations.

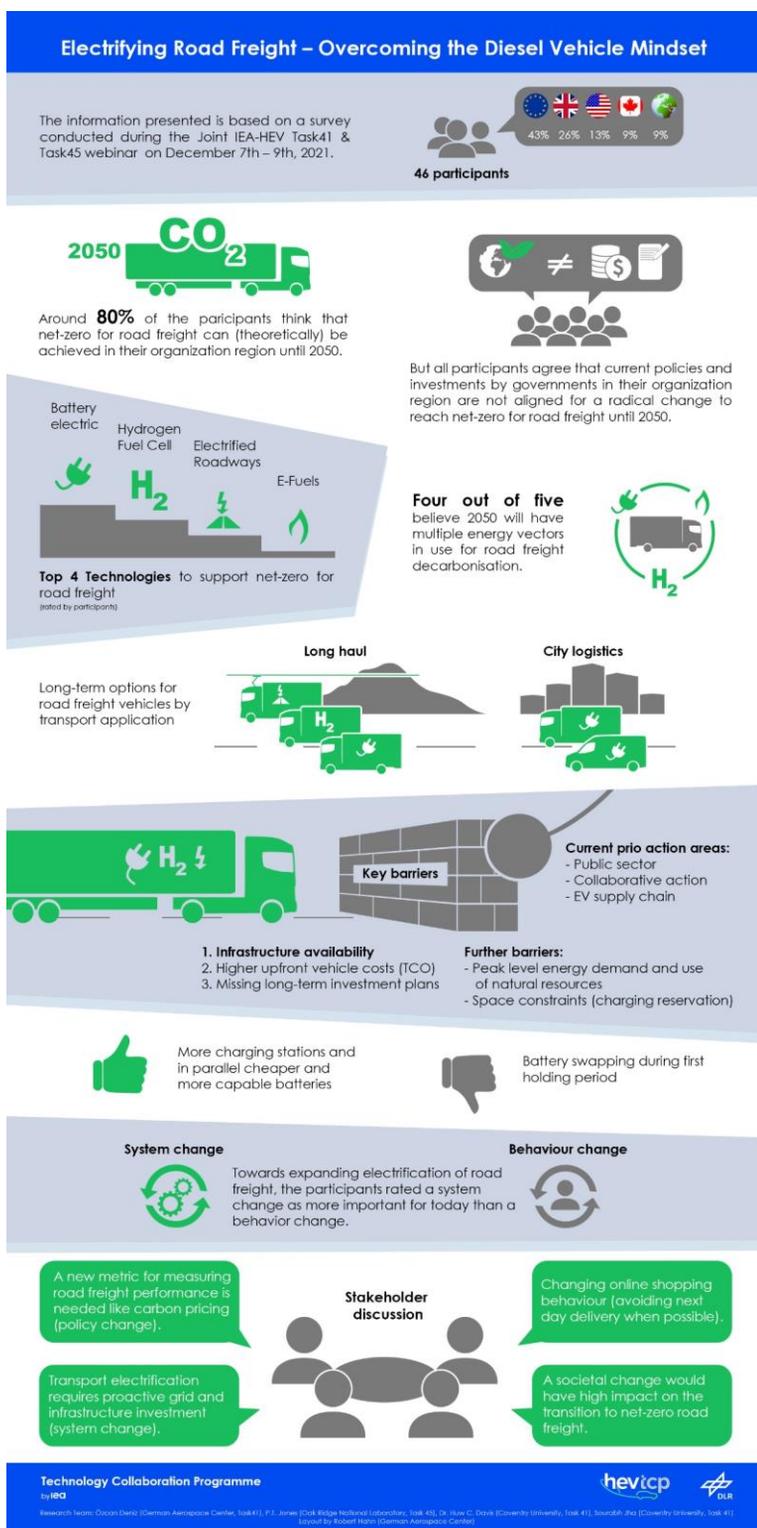
Best practice & suitability

Electrifying Road Freight Overcoming the Diesel Vehicle Mindset



The third Task 41 workshop “Electrifying Road Freight – Overcoming the Diesel Vehicle Mindset on new performance evaluations for electrified road freight was a jointly hosted online event together with the Taskforce 45 of the HEV TCP. The workshop took place from December 7 to 9, 2021 with 46 participants in total from North America, Europe and Asia, in addition to stakeholders from the road freight sector, including energy providers, government actors, researchers and NGOs. The event was structured in the form of a webinar with expert-led presentations and panel discussions.

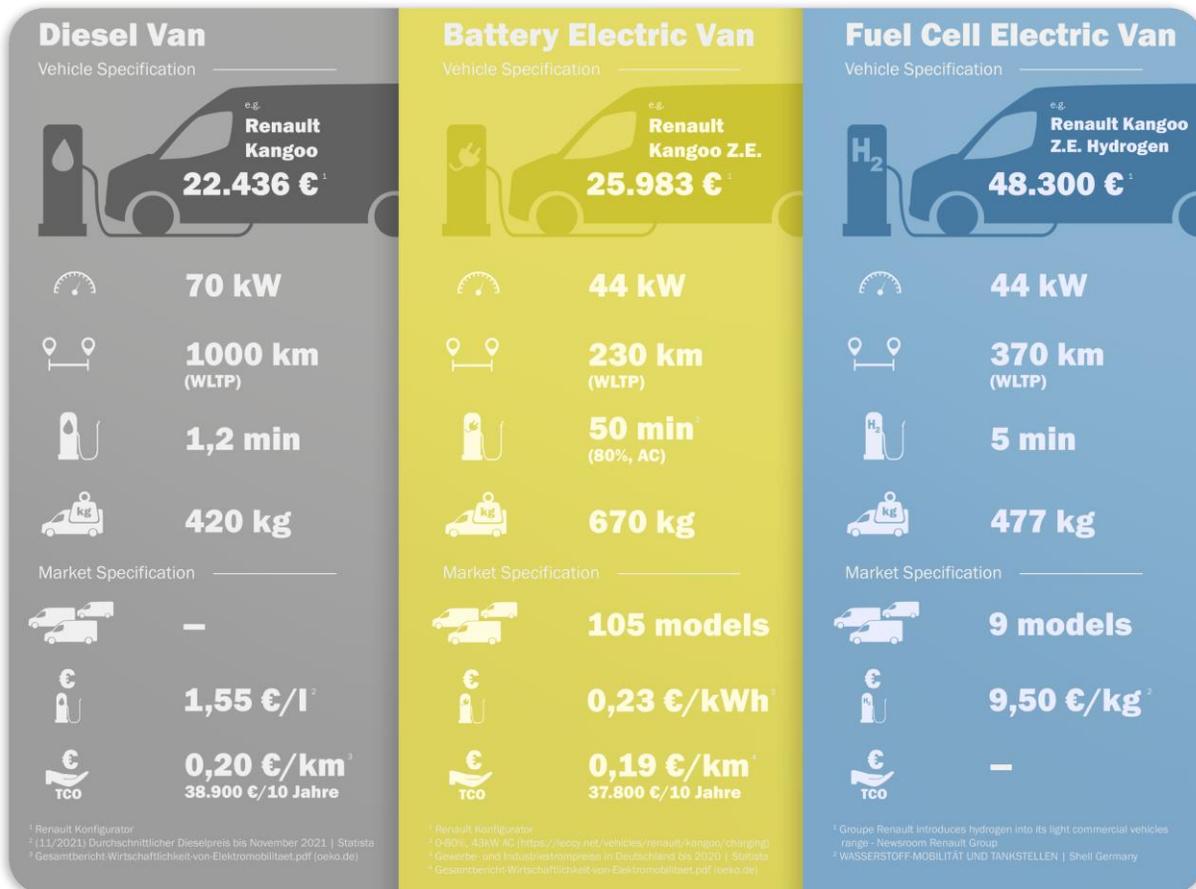
The introductory statement of the three-day workshop was that for the electrification of road freight systems the current existing diesel vehicle mindset needs to be overcome. This was in recognition that the system in which new technology is to be deployed needs to be adapted accordingly if that new technology is to be successful. Therefore, Day 1 of the webinar focused on identifying the system challenges. For this purpose, different stakeholders from political, environmental, societal, technical, economic and legal areas shared their views and discussed the question on system challenges. The next day was characterized by presentations on solutions for electric road freight innovation systems. The selection of presentations was based on covering the gamut of solutions - from technology to user-based. On day 3, participants were asked to evaluate the suitability of solutions (discussed on day 2) in the context of the challenges identified (discussed on day 1) and concluded with an open session on identifying how governments, logistics and industry can be mutually supportive in moving on from the present diesel mindset in freight. In parallel to the 3-day event, a survey was carried out. The figure here illustrates the main outcome of the surveys.



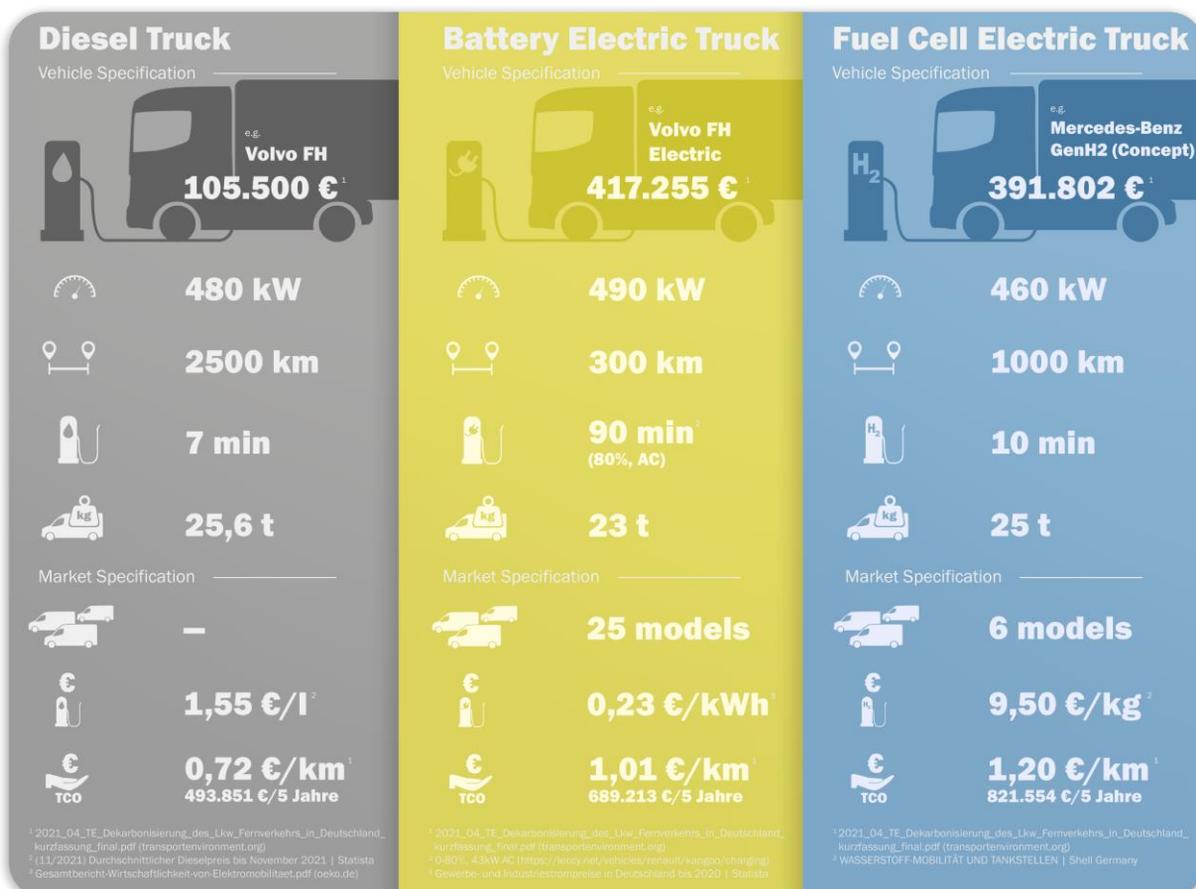
Evaluation & policy framework

Technical-economic comparison of electric alternatives for light and heavy freight vehicles

The following figures compare the vehicle and market specifications of diesel, battery-electric and fuel cell-electric vans and heavy-trucks in 2020. The information was obtained from the Task41 vehicle database and external studies.



The comparison shows among others that battery-electric vans for the considered use case (urban delivery) can have a lower TCO than diesel vans. In comparison, battery-electric and fuel cell-electric alternatives for heavy-duty trucks do not yet achieve economic advantages in the considered long-haul applications. Furthermore, the comparison shows that there are still significant differences in the vehicle ranges.



Evaluation & policy framework

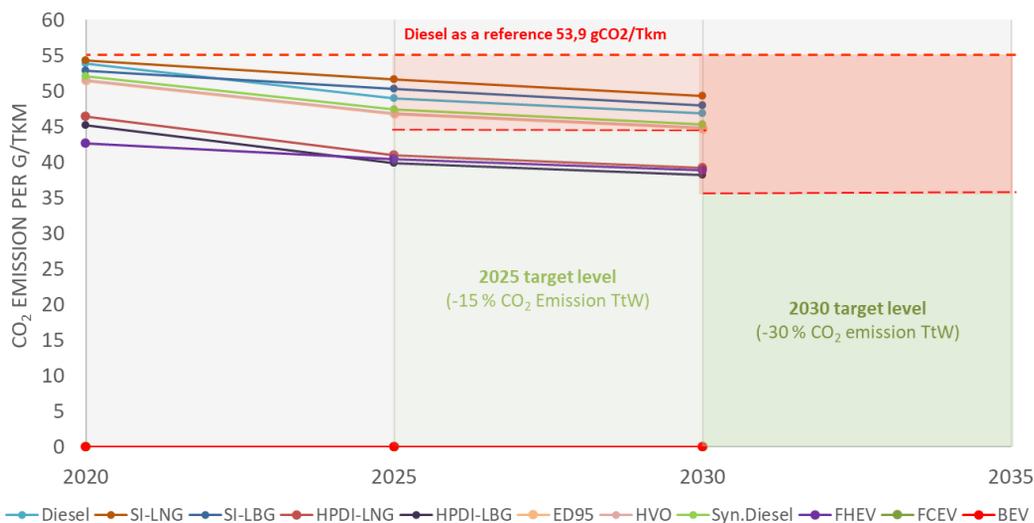
Evaluation of powertrain and fuel options for HDV to meet the EU CO2 fleet targets



CO2 emissions from heavy-duty vehicle transport in Europe have increased by 25% since 1990 and are responsible for 27% of CO2 emissions in road transport today. Large lorries such as semi-trailer tractors on long-haul transport account for the largest share (65 to 70%) of the CO2 Emissions from HDV transport in Europe. [13] Hence, the first European CO2 standards are set and aim to reduce the Tank-to-Wheel (TtW) CO2 emissions of newly registered HDV by 15% in 2025 and 30% in 2030 compared to 2020. In this chapter, current and future energy and emission consumption of conventional and alternative powertrain systems in heavy-duty vehicle on long-haul transport are compared and weighed regarding the EU CO2 emission fleet targets. The analysis was developed in the framework of cooperation between the two IEA TCP [14] AMF Annex 57 and HEV Task41.

The basis for the investigation is the simulated energy consumption of different powertrain and fuel options in heavy-duty vehicles. The data on internal combustion engine (ICE) powered trucks were generated by AMF within the chassis dynamometer tests of a semi-trailer tractor with a 13 liter engine in Finland. The used simulation data on hybrid and electric trucks was generated within the Task 41. For the calculation of the Tank-to-Wheel (TtW) and Well-to-Wheel (WtW) CO2 emissions, fuel-specific CO2 emission factors in g CO2/MJ from the JEC Well-to-Tank report v5 [15] are used. The simulated CO2 emission of the different powertrain and fuel options are compared to the EU CO2 emission reduction targets, with -15% in 2025 and -30% in 2030 relative to 2020 [16]. The reference values for the comparison are the simulated WtT and TtW CO2 emissions of the diesel HDV in 2020. The simulated values are given for 2020, 2025 and 2030, describing anticipated progress.

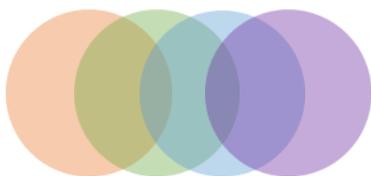
Tailpipe CO₂ emissions in g/Tkm for different powertrain and fuel options



* 40 tons GVWR as reference for FHEV, FCEV and BEV
42 tons GVWR as reference for all ICEs (rest)

The Figure shows the development of the calculated TtW CO2 emission per ton-kilometer for different powertrain and fuel options until 2030. TtW (tailpipe) CO2 emissions are used as the basis for all vehicle CO2 regulations today [17]. The main message derived from the figure is that ICE vehicles based on diesel, methane spark-ignition or ED95 engines, whether operated on fossil or renewable fuels, will not meet the 2025 TtW CO2 reduction targets with improvements to the engine only, even if relative efficiency improvements of 10% for diesel and 5% for SI engine are assumed. BEV, FCEV and only a few advanced ICE based powertrains (including FHEV) can meet this target. This would lead to a decreased supply of ICE vehicles and more hybrid and electric vehicles in the future. The results highlight the challenge in meeting the 2030 tailpipe CO2 emission reduction target with the conventional powertrains today.

When the CO₂ assessment is carried out on a WtW basis, both upstream (WtT) and end-use (TtW) emissions are considered, the picture is different. The analysis again assumes that reduction targets are -15% and -30%, relative to 2020 fossil diesel, but on a WtW basis. In the case of ICE powertrains, all renewable fuel options meeting the 2030 target with a wide margin. As a summary, it can be stated that going from a pure tailpipe CO2 based regulation system to a wider WtW type approach probably would increase flexibility for OEMs as well as truck operators. In the way CO2 regulations are set up currently, they are in principle mandates for certain technologies. The ideal situation would be that regulations define the targets in a technology neutral way, by letting the markets respond to the targets in the most functional and cost-effective ways.



Relevant aspects for a successful market-acceleration of electric freight vehicles

Given the numerous activities in the different vehicle segments and applications, practitioners are now urgently looking for information on how to navigate through the present, uncertain situation with the risk of stranded investments when envisaging extended operations. In response to the challenge as outlined the following key aspects are important from the taskforce point of view:



1 Increased focus on vehicle reliability

When comparing EFVs with today's applications, not only the total cost of ownership but also aspects relating to the reliability or practicability of EFVs are central purchase criteria for fleet operators. EFV must also be able to respond to a close-to-production oriented transport demand (such as just-in-time delivery). Thus higher vehicle ranges (above the daily range) are demanded and payload limitations are not accepted (in order to ensure high flexibility). However, the diesel mindset needs to be overcome to enable potential adoption of EFVs.



2 Longer delivery times constrain vehicle availability

Economic advantages for EFV are seen for selected operations today due current policy frameworks. Hence, the vehicle models and charging infrastructure need to be made available now. Currently, smaller manufacturers (such as e-converter vehicle manufacturers) are meeting the demand for EFVs. Following the announced pledges of the manufacturers, the number of EFV models will steadily increase in the next years. However, long delivery times (of one year) regardless of the current situation (supply chains and war) have to be taken into account.



3 Align the pace of infrastructure developments with EFV market transition

Current infrastructure developments are focusing on urban areas and the performances are only applicable to electric light freight vehicles. For long-distance transport, Megawatt Charging Systems (MCS) near (European) highways need to be developed rapidly. This requires the implementation of standards for MCS charging, the adaptation of international laws and the extension of fiscal incentives to include infrastructure. Incentives policies should not exclude infrastructure on private properties, as many logistics depots are already located close to highways. Charging on one's own depot avoids the risk/complexity associated with reservation of public charger. Currently, 800kW charger is considered as minimum for long distance transport (together with a 700kWh battery capacity in one-shift operation).



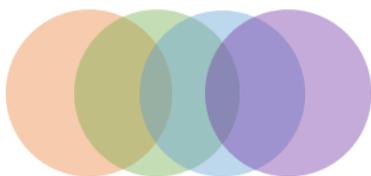
4 Battery Technology trends

The current technical trend (at least for the next 5 years) shows for most EFV applications that Lithium Ion batteries with NMC (Nickel Manganese Cobalt oxides) cathode will be the state of the art. In this context, the truck market benefits from cost degression potentials achieved in the passenger car volume market (since Li-NMC is predominantly used here as well). - Li-NMC batteries are particularly advantageous because of their high energy density and long service life. - For some "extreme" transport applications (e.g. in very hot or cold regions) also Li-LFP (Lithium iron phosphate battery) can have applications for EFVs.



5 Electric Road Systems out at scale

Electric Road Systems (ERS) include inductive and conductive as well as in road (or roadside) rail and overhead line power transfer technologies. ERS can minimise localised loading on grid - from higher power static charging - and spread energy demand - charge on the move over longer time period - and reduce size of onboard energy storage. Challenges are the multiplicity of options leading to dilution in investment - potential for different systems in different markets and not achieving critical mass in any one. ERS needs a role out at scale. As other solutions develop - lower cost and high capacity batteries - the role of ERS is marginalized leading to higher costs.



Relevant aspects for a successful market-acceleration of electric freight vehicles

6 Funding for pilots in city logistics



Cities are powerful ecosystems for the adoption of EFV, especially in last mile. More field trials are needed to identify further best cases – especially for more demanding driving profiles or niche applications – which can boost the acceptance for EFV among new operators. Through joint commitments and target action by all stakeholders the transition process can be accelerated. However, the limited space in urban area (e.g. for charging stations) is particularly problematic. New logistics concepts (like route consolidation) need to be incorporated for this purpose.

7 Technology-open guidance for long-haul transport



For Long haul transport, there is a dichotomy regarding suitable technologies. The challenge is to innovate business models and products concurrently – Either business models are changed for existing technologies or technologies are adapted for existing business models. – Thus, we see that technology providers and users in the BEV sector are looking for higher ranges and faster charging solutions, which could shift the problem to other system actors. For example, energy providers, which will need to respond on the distribution side (grid). However, the ability of these system actors to respond is different across markets (due to regulatory, economic etc. aspects).

8 Setting up a target regulatory framework that ensures competitiveness of EFV



Fiscal incentives today such as (80%) reduction of additional investment costs for EFV and charging infrastructure as well as toll and vehicle tax exemptions like in Germany, Austria and Switzerland are showing economic advantages for customers. These incentives are essential to reach TCO-parity. But they might come with authorities hurdles, which could slow down the conversion process. Furthermore, plannability is crucial for making investment decisions. Thus, long-term fixed incentives like road toll reductions are necessary to ensure investment security for the stakeholders. Especially road toll reductions are a very strong incentive to introduce EFV on long haul operations.

9 Updating CO2 emission standards



CO2 emission standards for light and heavy duty vehicles (such in EU regulation) are strong policies to push EFV into the market. An addition with energy efficiency standards could have a strong leverage for EFV. However, the use of CO2 emission levels is a strong government lever, business-oriented support for the transformation of transport should also be implemented.

10 Integrating new technologies into an overall system



Electrification of trucks require a holistic system approach. The overall ecosystem in which new technology is to be deployed needs to be adapted accordingly if that new technology is to be successful. For this, all stakeholders interacting with the commercial vehicle sector need to be identified and their awareness raised in order to promote collaborative activities. For example, the transformation of the energy market must take place beforehand and faster. But investors are hesitating of stranded investments. Collaborative approaches can break the barriers.

11 Vehicle Automation with EFV



Advancing driver automation will become increasingly prevalent for trucks. Particularly on long-distance (hub-to-hub) transport. Vehicle energy consumption could be reduced by efficient route management, but could also be increased by the additional equipment. With fossil diesel, this would have a bad impact on the environment.

From the essential user perspective, the alternatives in the cost-sensitive truck market must first achieve competitiveness. To achieve this, the total operating costs of the trucks must be reduced and a nationwide electricity charging network must be made available on European motorways. To this end, a targeted subsidy program for vehicles and infrastructure must be established and expanded.

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Appendix

- Fact sheet: Evaluation of powertrain and fuel options for heavy-duty vehicles to meet the EU CO2 emission fleet targets
- Fact sheet: The State of the Art of Electric Freight Vehicles
- Fact sheet: The European Truck Market and Potential Powertrain Technologies
- Workshop summary: Vehicle technologies and applications of battery-electric freight vehicles in city logistics
- Workshop summary: Electrification of Heavy-Duty Vehicles in Long Haul Transport
- Workshop infographic: Electrifying Road Freight Overcoming the Diesel Vehicle Mindset

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Evaluation of powertrain and fuel options for heavy-duty vehicles to meet the EU CO₂ emission fleet targets

Introduction

CO₂ emissions from heavy-duty vehicle (HDV) transport in Europe have increased by 25% since 1990 and are responsible for 27% of CO₂ emissions in road transport today. Large lorries such as semi-trailer tractors on long-haul transport account for the largest share (65 to 70%) of the CO₂ Emissions from HDV transport in Europe.¹ Hence, the first European CO₂ standards are set and aim to reduce the Tank-to-Wheel (TtW) CO₂ emissions of newly registered HDV by 15% in 2025 and 30% in 2030 compared to 2020. The average fleet consumption of the newly registered trucks can be reduced by further improvements of the existing ICE technologies and promoting new alternatives such as electric vehicles into the market. However, there is still a high degree of uncertainty regarding the technological development of potential powertrain and fuel options in the HDV-market. In this working paper, current and future energy and emission consumption of conventional and alternative powertrain systems in heavy-duty vehicle on long-haul transport are compared and weighed regarding the EU CO₂ emission fleet targets. There are difference potentials for the powertrain and fuel options seen between Tank-to-Wheel (TtW) and Well-to-Wheel (WtW) CO₂ emissions assessment approach. A technology-neutral assessment of the available options also requires a wider CO₂-based regulatory system.

The analysis was developed in the framework of cooperation between the two IEA TCP² AMF Annex 57 and HEV task41. AMF Annex 57 “Heavy Duty Vehicle Evaluation”³ aims to demonstrate and predict the progress in energy efficiency of heavy-duty vehicles with internal combustion engine and alternative fuels technologies. The main objectives of the HEV Task 41 “Electric Freight Vehicles”⁴ are to monitor progress and review relevant aspects for a successful introduction of electric freight vehicles into the market.

Methodology

The basis for the investigation is the simulated energy consumption of different powertrain and fuel options in heavy-duty vehicles. The data on internal combustion engine (ICE) powered trucks (diesel, Spark-ignited - liquefied natural gas (SI-LNG), High pressure direct injection - liquified natural gas (HPDI-LNG) and Bioethanol ED95) were generated by AMF within the chassis dynamometer tests of a semi-trailer tractor with a 13 liter engine in Finland. The used simulation data on hybrid and electric trucks (Full Hybrid Electric Vehicles (FHEV), Fuel Cell Electric Vehicle (FCEV) and Battery Electric Vehicles (BEV)) was generated within the Task 41 Electric Freight Vehicles. The relevant parameters for the energy consumption data by HEV are based on a techno-economic evaluation approach for the assessment of future commercial vehicle concepts called “Transport Application based Cost

¹ https://ec.europa.eu/clima/policies/transport/vehicles/heavy_en

² <https://www.iea.org/programmes/technology-collaboration-programme>

³ https://www.iea-amf.org/content/projects/map_projects/57

⁴ <http://www.ieahev.org/tasks/task-41-electric-freight-vehicles/>

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Model” (TACMO)⁵. TACMO is calculating the energy consumption for transport task-specific vehicle configurations. The vehicle configuration is based on current characteristics of key electric powertrain components, such as battery and fuel cell. Table 1 summarizes the covered powertrain and fuel options. In the case of ICE powertrains, further fossil and renewable fuels (HVO, synthetic diesel, Spark-ignited - liquefied biogas (SI-LNG), High pressure direct injection - liquefied biogas (HPDI-LNG) were evaluated in parallel. In the case of EVs, electricity based on EU mix 2016 and predicted EU mix 2030 were used. The hydrogen pathway was based on natural gas (EU mix 2016).

Table 1: Summary of investigated engine and fuel options

Powertrain:	Energy sources:
Diesel	fossil diesel, HVO (waste cooking oil), synthetic diesel (wood waste based)
Spark-ignited LNG	SI-LNG, SI-LBG (manure based)
High Pressure Direction Injection LNG	HPDI-LNG, HPDI-LBG (manure based)
Compression-ignition ethanol	ED95 (Wheat straw-based ethanol)
Full Hybrid Electric Vehicle	fossil diesel and Electricity (EU mix 2016 and EU mix 2030)
Fuel Cell Electric Vehicle	Hydrogen (NG based, electricity EU mix 2016)
Battery Electric Vehicle	Electricity (EU mix 2016 and EU mix 2030)

The energy consumption data generated in AMF was used as a starting point. The data indicates that current best-in-class HDV diesel engines deliver an efficiency of close to 46% at the crankshaft (brake thermal efficiency (BTE)) in typical long-haul driving (average value for the WHVC motorway phase). For heavy-duty SI methane engines, the corresponding value is some 37%.⁶ The estimates of the potential for efficiency improvements are based on targets of the US Super Truck II program (55% BTE)⁷ and the European H2020 project LONGRUN (50% BTE)⁸. In the simulations, it was estimated that 50% BTE will be achieved by 2025 and that 53% BTE could be reached by 2030. The corresponding efficiency improvements in relative terms are some 10% and 15%, respectively. For the SI-LNG engine, smaller relative improvements were assumed around 5% in 2025 and 10% in 2030.

The electric powertrain already has a high TtW energy efficiency depending on the driving cycle. For the highway application profile, an efficiency rate of up to 80% is possible (with recaptured energy from regenerative braking)⁹. With the dynamic market development of electric mobility, energy efficiency improvements of the key powertrain components are to be expected. By adding up the efficiency potentials of electric motor, power electronics and in particular traction battery and fuel cell system, the corresponding energy efficiency improvements for electric powertrains (FHEV, FCEV, BEV) in relative terms are 5% in 2025 and 10% in 2030¹⁰. Table 2 summarizes the assumptions for efficiency improvements.

⁵ https://elib.dlr.de/111576/1/2017_EEVC_Kleiner%20and%20Friedrich.pdf

⁶ [IEA AMF Annex 57 final report](#)

⁷ <https://dieselnet.com/news/2020/07supertruck.php>

⁸ <https://h2020-longrun.eu/>

⁹ <https://fueleconomy.gov/feg/atv-ev.shtml>

¹⁰ Florian Kleiner, 2020, Dissertation, Nutzfahrzeugkonzepte der Zukunft: Systemische Technologiebewertung konkurrierender Antriebskonzepte, DLR, Stuttgart

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Table 2: Assumed relative efficiency improvements by 2025 and 2030

Engine type/ powertrain	Efficiency improvement by 2025	Efficiency improvement by 2030
Compression-ignition	10 %	15 %
Spark-ignition	5 %	10 %
BEV, FCEV, PHEV	5 %	10 %

The analysis was carried out for semi-trailer combinations. In the case of ICE vehicles, the starting point was hot start world harmonized vehicle cycle (WHVC) data for a 30 tons truck. The assumption for the vehicle combination was a 4x2 tractor and a three-axle semitrailer. The configuration is quite common in Europe. Two slightly different curb weights for the tractor were used, depending on the fuel. Diesel and ED95 as well as synthetic diesel and HVO on the one side and LNG (SI and HPDI) and LBG (SI and HPDI) on the other. For the configuration of the electric vehicle concepts, the approach from TACMO was used. The assumption was also a 4x2 tractor combined with a semi-trailer in the application profile long-distance haulage. The total gross vehicle weight of the combination is the sum from the vehicle curb weight (tractor + trailer) and the payload. The curb weight of the tractor is calculated from the mass of the key powertrain related components and the mass of the glider (rest of the vehicle). Table 3 summarizes the characteristic data for the investigated vehicle configurations. The simulated vehicle weight of BEVs is calculated to be significantly higher compared to conventional vehicles.

Table 3: Summary of investigated vehicle configurations

	Diesel and ED95	SI-LNG and HPDI-LNG	FHEV	FCEV	BEV
Gross vehicle mass rating (GVMR) (kg)	42,000	42,000	40,000	40,000	40,000
Tractor curb weight (kg)	8,300	8,750	9,894	10,083	17,180
Trailer curb weight (kg)	6,800	6,800	4,962	4,962	4,962
Simulated vehicle weight (kg)	15,100	15,550	14,856	15,045	22,142
Simulated payload (kg)	15,100 (57 %)	14,700 (55 %)	17,319 (67 %)	17,319 (67 %)	17,319 (67 %)
Simulated combined vehicle mass (kg)	30,000	30,000	32,171	32,360	39,460

The energy consumption was calculated according to the WHVC, which is made up of the three driving cycles urban, rural and motorway cycle. To represent a typical long-haul driving task, the specific energy consumption was defined with the following split: 80% motor way, 20% rural and 0% urban cycle. The results regarding energy consumption were then multiplied

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to correspond to the typical daily German long-haul daily service of 698 km¹¹. For the calculation of the Tank-to-Wheel (TtW) and Well-to-Wheel (WtW) CO₂ emissions, fuel-specific CO₂ emission factors in g CO₂/MJ from the JEC Well-to-Tank report v5¹² are used. When estimating CO₂ reductions, the value for an assumed average 2020 diesel truck operating on fossil fuel was set as the 2020 reference.

Results

The simulated CO₂ emission of the different powertrain and fuel options are compared to the EU CO₂ emission reduction targets, with -15% in 2025 and -30% in 2030 relative to 2020¹³. The reference values for the comparison are the simulated WtT and TtW CO₂ emissions of the diesel HDV in 2020. The simulated values are given for 2020, 2025 and 2030, describing anticipated progress.

Figure 1 shows the development of the calculated TtW CO₂ emission per ton-kilometer for different powertrain and fuel options until 2030. TtW (tailpipe) CO₂ emissions are used as the basis for all vehicle CO₂ regulations today¹⁴. FCEV and BEV do not emit tailpipe emissions. Thus, this option meets the 2025 and 2030 targets for TtW CO₂ emission reductions.

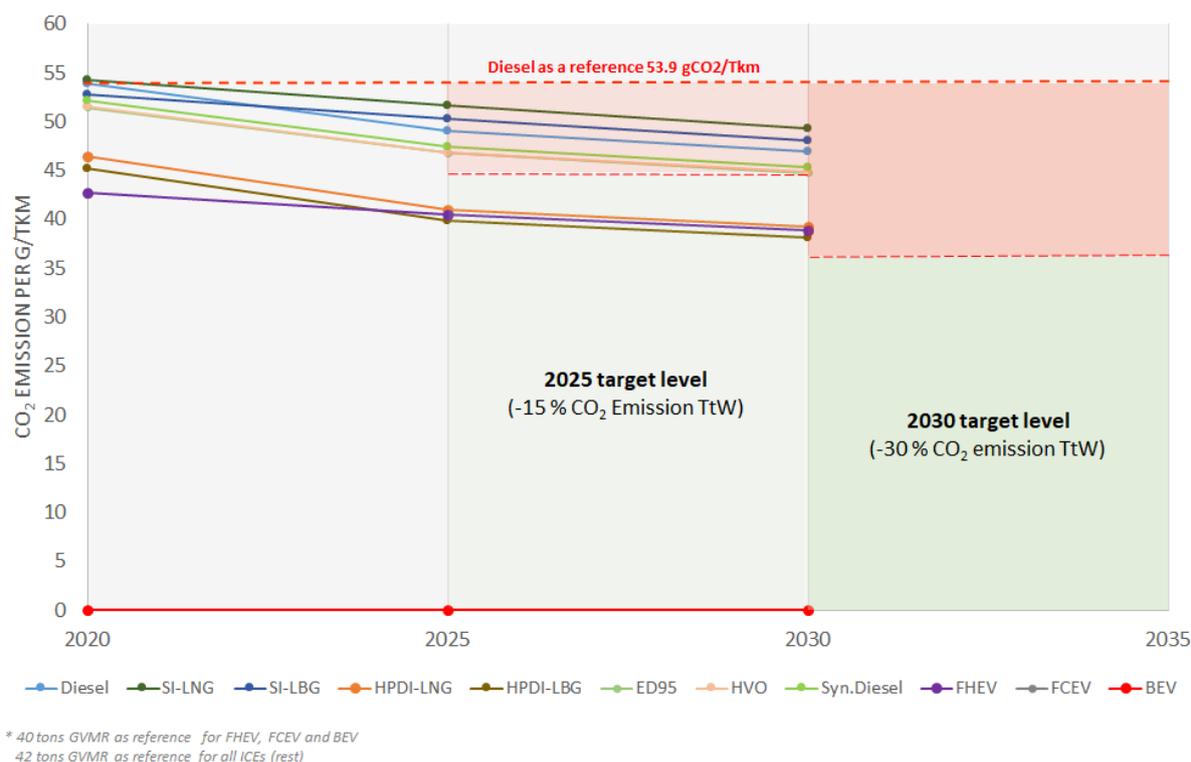


Figure 1: TtW CO₂ emissions in g per ton-kilometer for different powertrain and fuel options

¹¹ https://elib.dlr.de/111576/1/2017_EEVC_Kleiner%20and%20Friedrich.pdf

¹² <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/jec-well-wheels-report-v5>

¹³ https://ec.europa.eu/clima/policies/transport/vehicles/heavy_en

¹⁴ https://ec.europa.eu/clima/policies/transport/vehicles_en

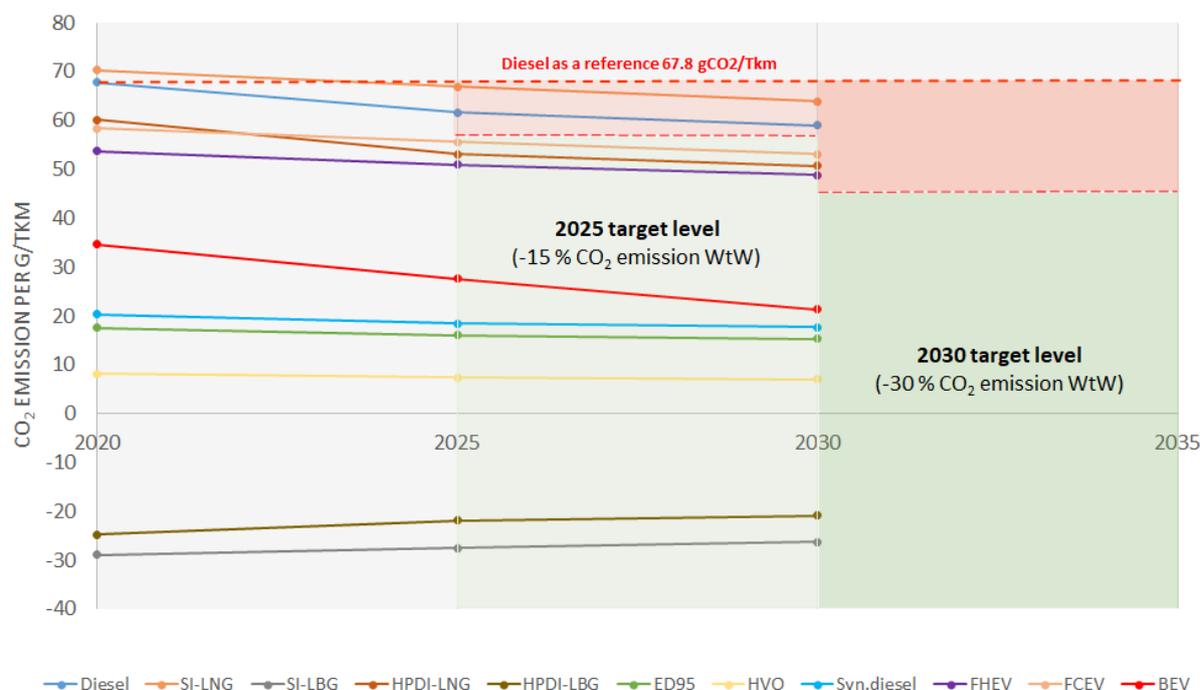
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Figure 1 shows minor differences in terms of the ICE fuels: fossil diesel, synthetic diesel, HVO (biodiesel), ED95, but also spark-ignited LBG and LNG. The calculated TtW CO₂ emissions per Tkm of these vehicle configurations in 2025 are above the EU CO₂ emission limit. **The slight differences are due to the CO₂ intensity of the fuel.** The only pure ICE powertrain alternative that achieves the 2025 target with a margin is HPDI LNG/LBG. Also, FHEV-Diesel meets the 2025 target with a margin, but not the 2030 target level.



* 40 tons GVMR as reference for FHEV, FCEV and BEV
42 tons GVMR as reference for all ICEs (rest)

Figure 2: WtW CO₂ emissions in g per ton-kilometer for different powertrain and fuel options

Figure 2 shows the development of the calculated WtW CO₂ emission per ton-kilometer for different vehicle configuration until 2030. In this figure, both upstream (WtT) and end-use (TtW) emissions are considered. The analysis again assumes that reduction targets are -15% and -30%, relative to 2020 fossil diesel, but on WtW basis. As stated above, the WtT values stem from the JEC Well-to-Tank report v5 which considers reference values for each corresponding fuel. The only alternatives that cannot meet the 2025 target of -15% are diesel (fossil) and SI-LNG (fossil). HPDI-LNG, FHEV and FCEV on hydrogen from fossil natural gas meet the target, but with a small margin. All renewable alternatives (ICE) and BEV on predicted EU 2030 electricity mix meet the 2025 target with a wide margin, as they also meet the 2030 target of -30%. Consequently, the fossil alternatives HPDI-LNG, FHEV (on diesel) and FCEV (on hydrogen from natural gas) do not meet the 2030 target.

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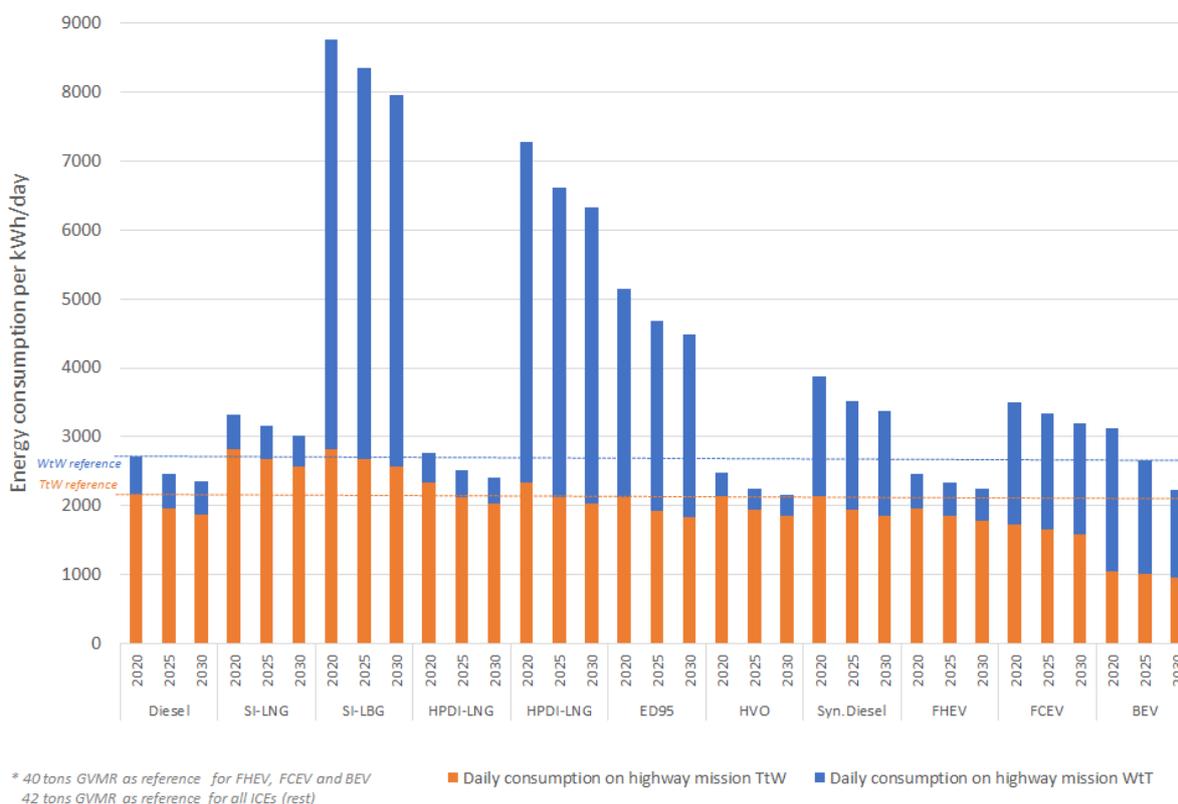


Figure 3: Daily WtW (WtT+TtW) Energy consumption for different powertrain and fuel options

Figure 3 shows the development of the calculated WtW daily energy consumption for different vehicle configuration until 2030 with split up in WtT and TtW parts. The average WtT CO₂ emission intensity of energy carriers are used from the JEC Well-to-Tank report v5¹⁵. The ratio of TtW energy consumption between the least and most efficient option is about 3:1. Variation in upstream or WtT energy consumption is even higher, up to 20:1. LBG (SI and HPDI) have the highest and HVO the lowest daily WtW energy consumption across all simulation years. However, LBG (SI and HPDI) have a high WtT energy consumption, almost twice as high as the TtW energy consumption. In 2020, the daily WtT energy consumption of LBG (SI and HPDI) is more than 8-10 times higher than the daily WtT energy consumption of Diesel. BEVs have the lowest TtW energy consumption. Approx. half of the daily TtW energy consumption of diesel. However, the daily WtT energy consumption of BEVs and FCEVs is particularly high. Considering the future share of renewable energies in the EU electricity mix by 2030, the daily WtT energy consumption of BEV and FCEV decreases more significantly than other considered vehicle configurations by 2030. For the assumed trend development of the EU electricity mix until 2030 from the JEC WTT Report v5, the WtT energy consumption of BEV decreases by 38%.

¹⁵ <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/jec-well-wheels-report-v5>

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Discussion

The main message derived from Figure 1 is that ICE vehicles based on diesel, methane spark-ignition or ED95 engines, whether operated on fossil or renewable fuels, will not meet the 2025 TtW CO₂ reduction targets with improvements to the engine only, even if relative efficiency improvements of 10% for diesel and 5% for SI engine are assumed. However, in combination with other measures, e.g. mild-hybridization (Mild Hybrid Electric Vehicle), reduction of auxiliary losses and measures to the vehicle itself, such as reduced vehicle weight and aerodynamic drag, the target could be reachable.

The only pure ICE powertrain alternative that has the potential to achieve the 2025 target with a margin and no modifications to the vehicle itself is HPDI LNG/LBG. This is a consequence of diesel-like efficiency and the favourable specific CO₂ emission of methane. Furthermore, Figure 1 indicates that HPDI LNG/LBG and FHEV will not be able to deliver a reduction of about 25% in 2030. But in combination with some additional measures on the vehicle itself both would most probably reach the 2030 target (an HPDI LNG/LBG hybrid powertrain most certainly).

The results above highlight the challenge in meeting the 2030 tailpipe CO₂ emission reduction target with the conventional powertrains today. BEV, FCEV and only a few advanced ICE based powertrains (including FHEV) can meet this target. This would lead to a decreased supply of ICE vehicles and more hybrid and electric vehicles in the future.

When the CO₂ assessment is carried out on a WtW basis, the picture is different. In the case of ICE powertrains, all renewable fuel options meeting the 2030 target with a wide margin. In Figure 2, LBG from wet manure is interesting, as the JEC WTW report gives negative WtT values for this option. The explanation is that LBG (or compressed biogas (CBG)) captures and utilizes methane that otherwise would escape into the atmosphere.

Not shown in Figure 2 are renewable electricity (e.g., hydro, wind and photovoltaic) and renewable hydrogen from renewable electricity. For example, the usage of electricity from wind energy (0 gCO₂eq/MJ) for BEVs or for hydrogen via electrolysis (9,5 gCO₂eq/MJ) in FCEVs would emit zero or close to zero WtT CO₂ emissions. In this case, FCEV would also reach the 2030 target level with a wide margin and BEVs would also count as zero-emission according to WtW basis.

There are discussions going on regarding the possibility to include renewable fuels in vehicle CO₂ legislation. The regulation (EU) 2019/1242 on CO₂ emissions from heavy-duty vehicles is currently under revision. Regarding renewable fuels, the following issues are discussed¹⁶:

- Assessment of contributions to decarbonization
- CO₂ credits for manufacturers
- Life-cycle assessment of CO₂ emissions

One challenge relates to the question of how it can be guaranteed that, e.g. diesel trucks actually run on renewable diesel. To solve this issue, the German consulting company Frontier handed a report to the German Federal Ministry for Economic Affairs and Energy (BMWi) in spring 2020. In its report, Frontier proposed a crediting system for renewable fuels

¹⁶ https://ec.europa.eu/jrc/sites/jrcsh/files/dg_clima_ze-hdv-jrc-webinar-2810020_public.pdf

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within the EU regulations on transport CO₂ emissions¹⁷. The basic idea of the CO₂ crediting system is that renewable fuels are produced and brought to the market. OEMs buy renewable fuel credits from the fuel suppliers. The credits are reported to a database system, and the OEMs have the possibility to use the credits to lower their fleet average CO₂ values. Whether and how OEMs could use this option will also depend among other aspects like the future price of the credits.

Also, the vehicle energy consumption should be assessed on a WtW basis. Regarding TtW energy use it is obvious that BEV is to most efficient alternative, while SI LNG/LBG is the least efficient option. As stated in the methodology chapter, all engines based on diesel-type combustion (compression ignition) deliver roughly the same energy efficiency. The upstream or WtT parts of diesel and LNG are quite efficient. The same applies to waste cooking oil based HVO. Production of synthetic diesel from wood residues, production of hydrogen from natural gas as well as average European power generation are quite high in energy intensity. Highest WtT energy consumption is for biogas/LBG from wet manure.

The outcome of all this is that LBG has by far the highest overall WtW energy consumption, whether used in a SI or an HPDI engine. With the fuel and energy pathways selected, HVO has the lowest overall energy consumption throughout 2020 to 2030. Conventional diesel and HPDI LNG are less energy intensive than BEV on EU electricity mix in 2020 and 2025. However, the ongoing decarbonization of the power sector puts BEV slightly below diesel and HPDI LNG in 2030. As mentioned above, the overall energy consumption for BEV would be significantly reduced if the reference would be renewable electricity,

Figure 3 shows also that the BEV truck would need about 1000 kWh of electricity to cover the daily driving of approximated 700 km. A battery of this size would weigh around 10 tons, meaning that fast charging along the route could be necessary. The amount of diesel fuel needed to cover the same distance is only some 200 liters.

Although both low CO₂ emissions and energy consumption should be valued, it should be noted that these two parameters are not interlinked.

As a summary, it can be stated that going from a pure tailpipe CO₂ based regulation system to a wider WtW type approach probably would increase flexibility for OEMs as well as truck operators. In the way CO₂ regulations are set up currently, they are in principle mandates for certain technologies. The ideal situation would be that regulations define the targets in a technology neutral way, by letting the markets respond to the targets in the most functional and cost-effective ways.

¹⁷ https://www.bmwi.de/Redaktion/DE/Downloads/C-D/crediting-system-for-renewable-fuels.pdf?__blob=publicationFile&v=4

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Task force 41
Electric Freight Vehicles

The State of the Art of Electric Freight Vehicles
Technical Performance

The main challenges in the technical performance of Electric Freight Vehicles (EFV) are the available range, payload and charging time today. The traction battery has a major influence on the indicators. In addition, the limited availability of EFV models and the rapid technological development plays a major role in the attractiveness of EFV in the market [1]. However, the market is developing rapidly. The question therefore arises whether the current state of performance of EFV is competitive with a conventional freight vehicle today.

Benchmarking Electric Freight Vehicles

A benchmark analysis of EFV was carried out using technical information on all available vehicle models and concepts that are publicly known. This includes Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), Range Extended Electric Vehicles (REEV), Fuel Cell Electric Vehicles (FCEV) and Battery Electric Vehicles (BEV). The collected information was compiled over a time period from April 2018 to April 2020 and has been consolidated in a vehicle database. The data contains the standard specifications of the vehicles with technical data such as power, battery capacity, range etc.

From the research, 265 vehicles were collected. These are divided into 108 light-duty vehicles (N1 category, under 3.5t GVW), 65 medium-duty vehicles (N2 category, 3.5 - 12t GVW) and 92 heavy-duty vehicles (N3 category, 12 - 40t GVW) – see Figure 1. In the light segment, almost every second vehicle registered is also available in series production, and if e-converted vehicles are included, this applies to almost 70% of the light-duty vehicles. Therefore a high degree of production readiness has already been achieved in the light-duty segment. In the N2 category are fewer series vehicles and more vehicle concepts available than in the N1 category. The start of series production of these vehicles is announced by the manufacturers for mid-2020 and 2021 [2–4]. More vehicle concepts are known in the N3 category than in the N2 category. These are mainly new market players with concepts and prototypes. In principle, a lower production readiness level can be identified with increasing gross vehicle weight. This is mainly due to the technical requirements for heavy-duty vehicles in long haul transport that cover longer distances and have more demanding payload profiles.

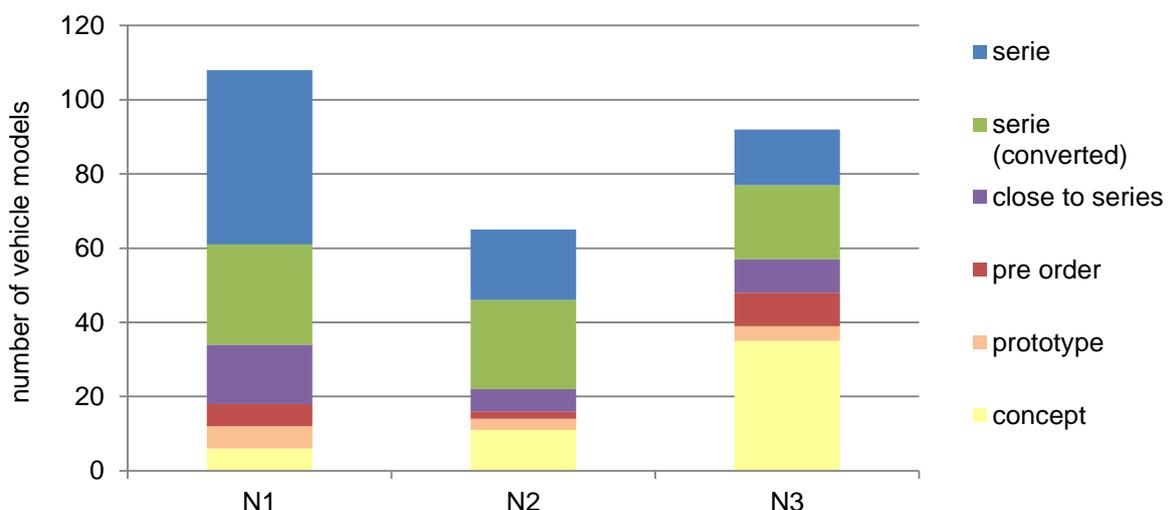


Figure 1: Production readiness of EFV by vehicle category

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Range and Payload of EFV

On average, the range of the battery-electric vans available on the market is 150 km. The ranges go from 64 km to 500 km – see Figure 2. In the upper section, REEV is more likely to be found than BEV. The manufacture VW promises a range of 173 km according to NEDC for the Model e-Crafter (BEV). After WLTP the value is even lower as first tests shows that for the VW e-Crafter 120 km seem to be more realistic [5]. The diesel version of the VW Crafter has a range of about 1000 km. Based on the typical daily tour profile of a delivery vehicle in urban area, a range of 100 to 150 km is probably sufficient [1]. However, the limiting factor depends strongly on logistic operations, such as payload, and external conditions such as temperatures, driving style and traffic [1, 6].

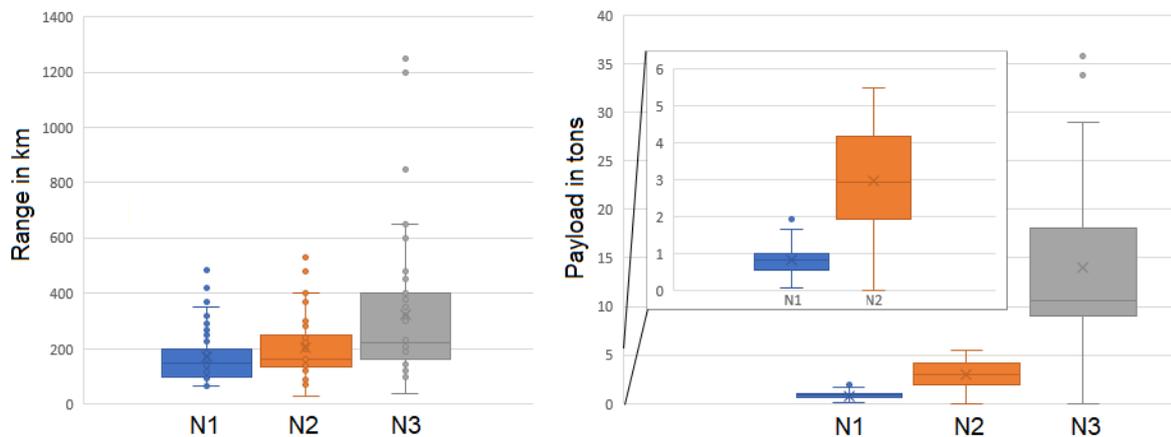


Figure 2: range and payload of EFV

The increase of the electric range and thus the battery capacity goes hand in hand with an increase in the mass of the traction battery, which is in conflict with the available vehicle payload in the corresponding vehicle segment. This optimization problem is one of the challenges for the design of EFVs but has improved in recent years with developments in battery efficiency. The vehicle payload of electric vans ranges from 200 kg to 1,950 kg with 835 kg on average (see Figure 2). Regarding the driving range of N2 category vehicles, the current performance varies from 30 km to 530 km with an average of 160 km. Vehicle payload ranges from 1,000 kg to 5,500 kg with 3,100 kg on average. For the N3 category vehicles, the driving range varies between 40 km to 1250 km with 220 km on average. Vehicle payload ranges from 4,400 kg to 36,000 kg with 11,100 kg on average.

Charging time of EFV

Whether the range is a limiting factor for vehicle operation also depends on the availability of the charging points and the charging speed [7]. Charging time varies largely depending on the type of electric vehicle supply equipment and type of battery in the vehicle. Alternating Current (AC) and Direct Current (DC) charging systems are available. With the AC system, regular charging is possible via the household power grid (e.g. via wall-box). DC charging has the problem that the batteries in the vehicle can quickly become overheated. Most EFV are driven by an AC motor. In the mentioned database, 72% of the listed EFV have synchronous motors, most of them as permanent magnet synchronous motors due to their high efficiency. The remaining 28% have an asynchronous motor. An example of series battery-electric freight vehicles with information about the battery capacity and the charging time according to AC and DC is shown in Table 1.

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Table 1: Battery capacity and charging time of series battery-electric freight vehicles

Vehicle Class	Vehicle model	Battery capacity [kWh]	Charging time AC 0-100% [h]	Charging time DC 0-80% [min]	Max. range [km] (without payload)
N1	Nissan E-NV200 (3,5 t.)	40	5,5 (11 kW)	40 (50kW)	275 (NEFZ)
	Mercedes eVito (3,5 t.)	41,4	10 (11 kW)	80 (50kW)	150 (WLTP)
N2	IVECO Daily Electric 50C (7,5 t.)	80	4,2 (22 kW)	40 (50 kW)	280 (NEFZ)
	FUSO eCanter (7,5 t.)	82,8	12 (22 kW)	105 (50 kW)	100 (WLTP)
N3	Volvo FL Electric (16 t.)	300	13 (22 kW)	60-120 (150 kW)	300 (NEFZ)
	Volvo FE Electric (27 t.)	300	10 (22 kW)	90 (150 kW)	200 (NEFZ)

Depot charging is most attractive for freight transport because it offers a high degree of flexibility in operation. For depot charging, fleet operators usually need their own charging points at the depot. The vehicles are then preferably charged overnight or during the day (opportunity charging), as in some transport task vehicles has to return to the depot during the day. For the heavy duty vehicle segment 150-kW DC-charger is appropriate but a minimal standard. For the most sub-contractors or similar logisticians who do not have a private parking space for their vehicles it is more difficult to find suitable charging business cases. Their vehicles are usually parked overnight on public roads. For electric vans there is the possibility to charge them via the current public charging infrastructure. For this purpose common 50-kW DC-Chargers (standard CCS) are suitable.

Logisticians often complain about the long charging time of EFV. However, 90 percent of today's vans are parked overnight at a fixed depot [1]. Considering the average charging time via a 11kW/22kW AC-charger (see Table 1), electric vans could be conveniently recharged overnight. Public 50kW/150kW DC-Charger could be additionally used to recharge the vans between the daily tours. As mentioned, public charging is seen more as a supporting factor in the charging strategy of EFVs, and will not be able to replace the own charging station with fixed parking space in the depot [1]. However, the relatively long charging time compared to conventional diesel refuelling can be regarded as no problem in some applications already today.

Battery technology of EFV

The way and frequency of charging and discharging determine the battery life. The charging time of the battery depends on the limited electrical intensity to avoid irreversible damage to the battery [7]. A health indicator of batteries is the capacity. Lithium-Ion (Li-Ion) batteries loses on average more than 20% of their capacity over lifetime [7]. For Li-Ion batteries in electric vehicle the lowest capacity loss is reached by charging the Li-Ion battery (at 20°C) between 25-75 percent state of charge (SOC). This would delivery around 3,000 cycles (to 90% capacity) [8]. In real operation these operational parameters (charging strategy (speed), depth of discharge, operating temperatures, tour profile etc.) vary strongly and make it therefore harder to estimate the average lifetime of the battery.

Most electric freight vehicle are using Li-Ion batteries. Furthermore, LiFePO₄ is the most common cathode material in the Li-Batteries. Compared to the passenger car market, few vehicles with Li-NMC batteries are known in the commercial vehicle market. In addition, there are many vans (mostly older models) that are operated with a lead-acid battery. However, lead-acid batteries have a lower energy density and shorter lifetime than Li-Ion batteries. Figure 3 shows the known battery technologies of the battery-electric freight vehicle according to the vehicle categories.

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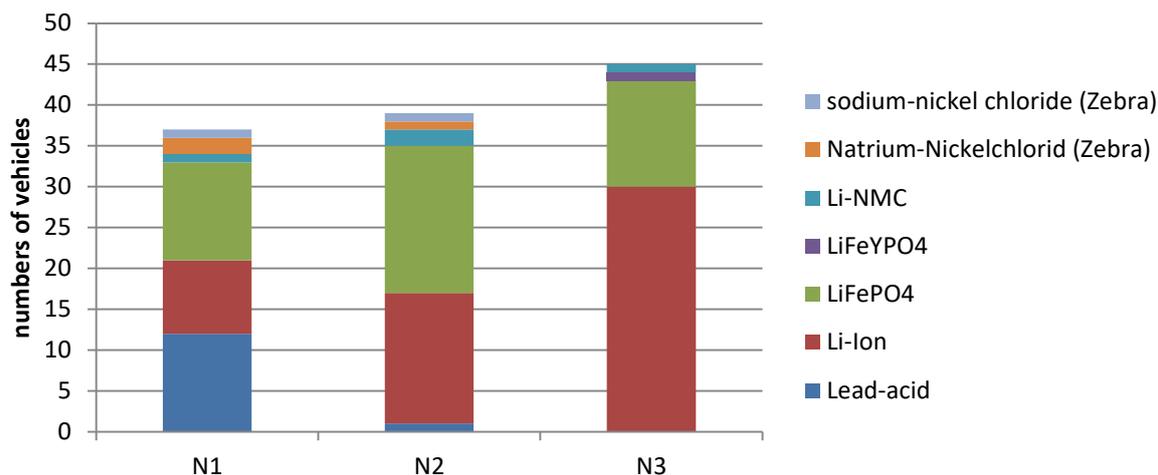


Figure 3: Battery technologies of EFV

EFVs available on the market today demonstrate important technological progress in comparison to vehicles from 10 to 20 years ago. The technical indicators show that some EFV are potentially as efficient as conventional vehicles. With the rapid development in battery technology, further technological improvements in terms of range and payload of freight vehicles can still be expected.

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The European Truck Market and Potential Powertrain Technologies

Market share of alternative freight vehicle powertrains

In 2019, 2.48 million Light and Heavy-Duty Vehicles were newly registered in Europe, 85% of which were Light-Duty Vehicles (LDV) under 3.5 tons gross vehicle weight (GVW). Most of the vehicles are powered by a diesel engine (92.8% LDV, 97.9% HDV). In the LDV-segment, gasoline is the next preferred fuel with 4.4% of newly registered vehicles. The main markets are especially Spain, Italy, France and the UK. In the HDV-segment, the share of gasoline is very low (0.2%). The alternative fuels, like CNG, LPG, biofuels and ethanol, had a share of approximately 1.4% in the overall commercial vehicle registration in 2019. The niche in market is made up of Hybrid Electric Vehicles (HEV) with 0.2% of new registrations. However, the market share in the LDV has risen to almost 160% compared to the previous year (4,577 hybrid-electric vans in 2019). Another high increase was recorded by plug-in electric commercial vehicles (BEV, FCEV, REEV, PHEV) with 26,107 plug-in electric LDV and 747 plug-in electric HDV newly registered in 2019. The year-on-year increase was stronger in the HDV segment (+109%) than in the LDV segment. The main markets for these vehicles are primarily Germany, followed by the Netherlands and France. [1, 2]

The diesel engine is by far the main drive train in the commercial vehicle segment. It is an efficient internal combustion engine and since the introduction of the Euro standards (1988), Euro 6 and exhaust after-treatment pollutant emissions from heavy-duty vehicles dropped significantly [3]. Nevertheless, in order to achieve the European CO₂ fleet targets, not only technological progress of the diesel engine itself is necessary, but also low- and zero-emission vehicles need to be promoted on the market. In some countries incentives and subsidies are offered to encourage EV sales for the heavy-duty segment.

The IAA Commercial Vehicle Fair in 2018 characterized an increasing electrification strategy for commercial vehicles. Different manufactures showcased their first battery-electric vehicle concepts. Especially in the LDV segment, vans from Volkswagen, Daimler, MAN, IVECO, Nissan and Renault are already in series production. Prototypical BEVs have also been developed for the medium and heavy-duty segments and are currently being tested in various pilot projects with customers. For example, Daimler is testing its electrified Actros model with different logistic companies like DACHSER and Hermes [4]. Since 2018, MAN Truck & Bus has also been testing the eTGM model in cooperation with its Austrian partner, the Council for sustainable logistics (CNL) [5]. The start of production (SOP) of these medium and heavy duty vehicles is set for mid-2020 and 2021. However, electric heavy articulated tractors and semitrailer trucks are currently manufactured and sold primarily by small suppliers such as the Swiss E-Force One AG and the German Framo GmbH [6, 7]. These are so-called electric vehicle converters, which replace the combustion engine of trucks from MAN, Daimler and Co. with their electric powertrain. In the future the heavy freight vehicle market may also be shaped by American start-ups such as Tesla, Thor and Nikola Motors. They promise higher ranges for their vehicle concepts than the current market average in the respective vehicle segment. Figure 1 shows the availability of different battery-electric commercial vehicles by brand and segment. The availability is characterized by the current status of production readiness and the announced year of market entry by the manufactures.

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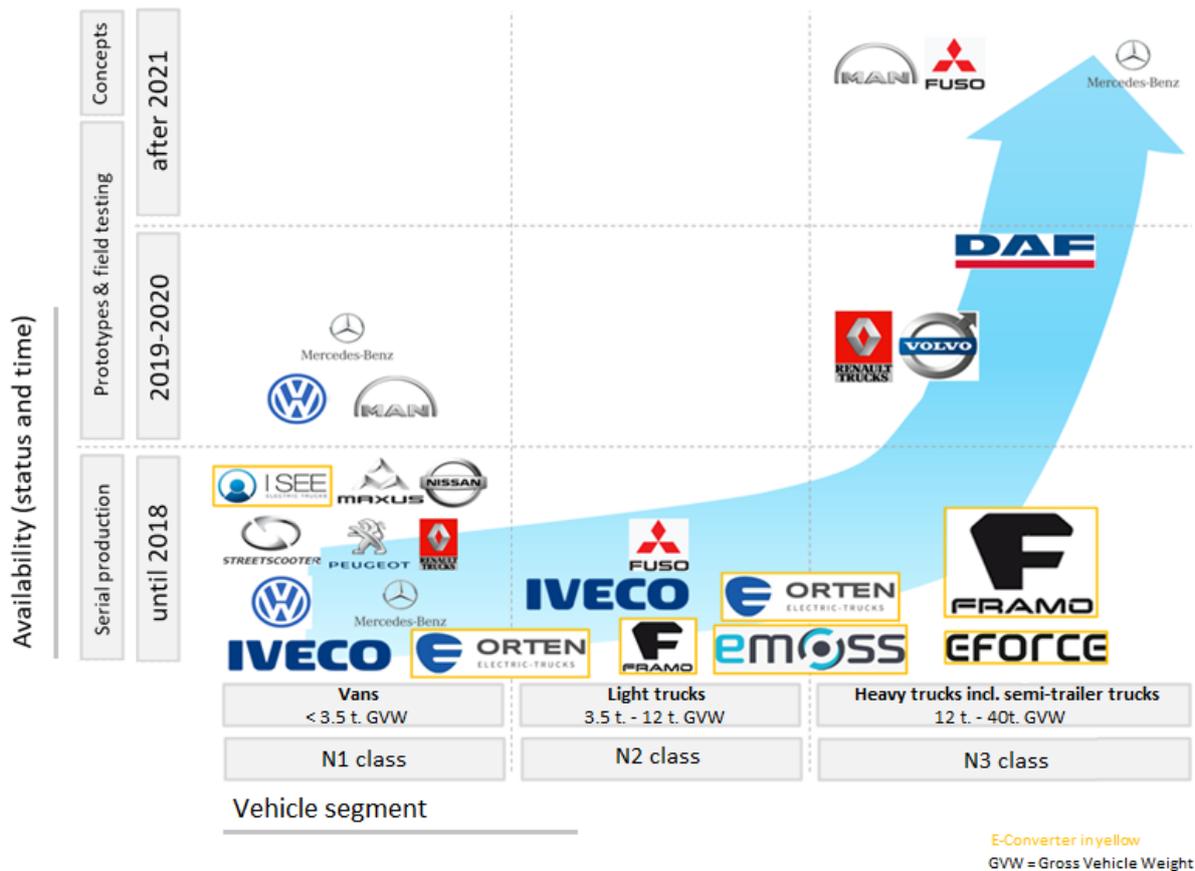


Figure 1: Roadmap battery-electric freight vehicles - Availability of battery-electric freight vehicles by brand and segment

In the media, the first long-term strategies of the manufacturers have appeared with information on the planned investments. For example, Daimler, the world's largest commercial vehicle manufacturer, plans to phase out all diesel engines in its trucks and buses (in addition to passenger cars) in almost all regions of the world (primarily Europe, Japan and North America) by 2039. In the future, trucks will be powered either by a traction battery system (BEV) or fuel cell systems (FCEV). The first battery-electric vans are already in production and can be ordered. From 2022, the first trucks with electric powertrains are also to be offered in series production in Europe. By 2030, mass-produced fuel cell trucks are to be added. [8] The VW Group subsidiary TRATON, which is the largest producer of commercial vehicles in Europe and to which the commercial vehicle brands MAN and Scania belong, wants to invest one billion Euros in the development of electric mobility (primarily as BEVs) by 2025 and expects that by 2030 to 2035 a third of its commercial vehicles could be driven with electric motors. [9] The pioneers in the European market with battery electric vehicles are Nissan with the model e-NV200 and Renault with the models Master Z.E. and the trucks D Z. & Wide Z.E. The model e-NV200 has been on the market since 2014 and has already been sold 17,500 times (until end of 2019). Therefore, the production line of the corresponding diesel version (NV200) was closed at the end of 2019. [10]

The US group Paccar is represented in Europe with the DAF brand in the heavy segment and is focusing on fully electric powertrain in their long term strategy. Volvo Trucks and IVECO sees LNG as the diesel alternative for today's trucks in addition to the electric motor.

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In 2019, IVECO presented for the first time an battery-electric semitrailer tractor (Model Tre) developed in cooperation with the start-up company Nikola Motors from the USA. Nikola Motors is actually focusing on fuel cells in its company strategy and has already been able to attract many investors, such as the German tier-1-supplier Bosch. IVECO sees the development activities of the BEV as a basis for the start of FCEV and aims to bring fuel cell powertrain into series production by 2023. [11] The South Korean manufacturer Hyundai is currently not highly represented in the European commercial vehicle market. In Switzerland, however, 50 heavy fuel cell trucks are currently being tested by Hyundai. By the year 2025, 1600 heavy-duty trucks with a gross vehicle weight of 34 tons are planned to be operated in Switzerland. [12] Long-established companies such as Hyundai and start-ups companies such as Nikola Motors are examples that illustrate that the shift to alternative powertrains in the European commercial vehicle market will also involve new players.

The market developments show that electrification efforts are beginning to take hold in the entire commercial vehicle segment. However, compared to the passenger car market, the manufacturers' strategies differ in some respects. Mainly BEV, FCEV or both are mentioned as the future powertrains. Based on the collected OEM announcement and strategies on the potential of alternative powertrains, their effect on the future EU sales market was extrapolated. For this purpose, the manufacturer-specific powertrain strategies and announcements were weighted with regard to the current market shares of the manufacturers. Most manufacturers mentioned 2030 or later as the time when the alternative powertrain will enter the market. Figure 2 shows the projection of the current powertrain strategies of the commercial vehicle manufacturers weighted with regard to the EU-market shares of the manufacturers.

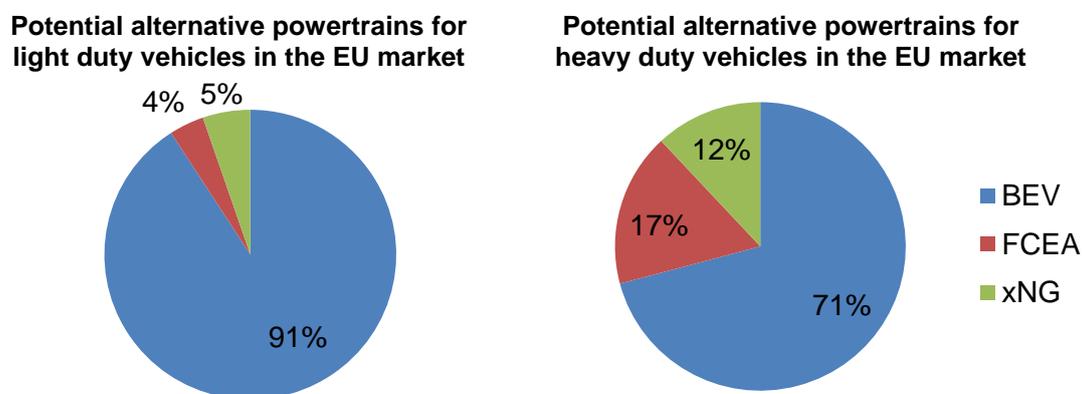


Figure 2: Potential alternative powertrain technology for freight vehicles in the EU market, based on manufacture strategies and announcement

The aim of the illustration in Figure 2 is to show which alternative to diesel could potentially enter the EU-market in 2030 or later, assuming that diesel is not selected then. In the light and heavy commercial vehicle segment, BEVs are seen as the powertrains of the future. In the heavy-duty segment, in addition fuel cell electric truck is also considered to have significant potential as a future powertrain. From a vehicle design perspective, fuel cell makes particular sense in heavy-duty traffic, where longer distances are covered and more demanding payload profiles are required compared to light-duty traffic. The higher gravimetric energy density of the fuel cell compared to the battery offers systemic advantages for the vehicle design.

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However, it should be noted that figure 2 does not show a sales or stock market. Rather, it should be considered for orientation and weighting of the manufacturer-specific powertrain strategies.

From the essential user perspective, the alternatives in the cost-sensitive truck market must first achieve competitiveness. To achieve this, the total operating costs of the trucks must be reduced and a nationwide electricity charging network must be made available on European motorways. To this end, a targeted subsidy program for vehicle and infrastructure must be established and expanded.

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Joint proEME and IEA-HEV Task Force 41 workshop

Battery-electric freight vehicles in city logistics



1st Workshop: Vehicle technologies and applications of battery-electric freight vehicles in city logistics

1 p.m. to 5 p.m., October 15th 2019

DLR Stuttgart, Pfaffenwaldring 38-40, 70569 Stuttgart

The first Task 41 workshop “battery-electric freight vehicles in urban logistic” was held in Stuttgart (Germany) on October 15th 2020. Dedicated topics at the workshop were:

- current technical characteristics of battery-electric freight vehicle
- development of the charging infrastructure: costs and availability
- practical experience and knowledge from pilot projects and initial applications

24 local and international guests from logistics as well logistics associations, vehicle industry, charging-infrastructure, city administration and research took part in the discussed on opportunities and hurdles for the successful implementation of battery-electric freight vehicles in urban logistics.



The workshop was introduced with impulse presentations by companies from the vehicle, infrastructure and logistics sectors. The first session “current technical characteristics of battery-electric freight vehicle” was held by the vehicle manufacture Daimler with insights on their current electrification strategy. In the second session “development of the charging infrastructure: costs and availability” three key charging infrastructure suppliers in Germany: ABB, ChargeHere by EnBW and EBG compleo, have introduced dedicated AC and DC charging stations for commercial vehicle application with information on suitable power ranges and current available charging points in Germany. The third session “practical experience and knowledge from pilot projects and initial applications” was structured by impulse presentations from the logistic company Dachser in Stuttgart, Germany and Fier Automotive from Helmond, the Netherlands. Dachser share their experiences with the Fuso eCanter and Mercedes-Benz eActros in Stuttgart and Fier Automotive presented the results from the EU-Project ElectricGreenLastMile

Agenda

13:00	Introduction	Stadt Stuttgart, DLR
<u>Pitches 1: Current technical characteristics of battery-electric freight vehicles</u>		
13:15 – 13:30	Daimler AG QUANTRON	Moritz Grüters Tbd
<u>Pitches 2: Development of the charging infrastructure: costs and availability</u>		
13:30 – 13:45	EBG compleo	Manfred Frenger
13:45 – 14:00	ABB EV Charging	Barbara Dörsam
14:00 – 14:15	EnBW ChargeHere	Konrad Benze
<u>Pitches 3: Practical experience and knowledge from pilot projects and initial applications</u>		
14:00 – 14:15	Dachser Emission-Free Delivery Stuttgart	Christian Polziehn
14:15 – 14:30	Project eGreenLastMile (Fier Automotive)	Harm Weken
14:45	Coffee Break	
<u>Workshop session</u>		
15:00	Introduction <i>Workshop concept: Two topics will be addressed in group work in line with the impulse lectures.</i> <i>a. Potentials and challenges of the use of battery electric commercial vehicles in urban traffic</i> <i>b. Problems and solutions of the charging infrastructure for the urban supply of battery-electric commercial vehicles</i>	
15:15 – 15:45	Group work 1 <i>Two groups each work on one of the topics on flipcharts</i>	
15:45 – 16:15	Group work 2 <i>Change of topics in the groups</i> <i>Repeat group work</i>	
16:15 – 16:45	Presentation and discussion of the results (15 min per topic) <i>Objective: To identify opportunities and hurdles for the successful operation of battery-electric commercial vehicles in urban traffic</i>	
16:45	Summary	
17:00	Closing of workshop	

On the basis of the technical and experience reports, the guests of the workshop discussed the problems and solutions for the implementation of vehicles and suitable charging infrastructure in urban logistics in two interactive groups.

The main topics of the group discussion were the still ongoing uncertainty in battery-electric as well as fuel cell technologies, the lack of space for electric charging stations and loading stations in urban areas and the uncertainty about necessary charging capacities for different transport applications. Furthermore, the discussion with the participants showed that there is no business case for fast charging solution in commercial vehicles. It could be useful for the logistic and fleet operators to learn more about current applications with battery-electric freight vehicles including information on their total cost of ownership.

The discussions were noted on two flipcharts and illustrated in the following tables:

Group 1: Operating of Electric freight Vehicles

Challenges	Potentials
<ul style="list-style-type: none">• Operationalisation: range vs. payload; secured payload for greater planning reliability; planning effort for loading stops; flexibility (loading time)• Space for loading: sufficient loading capacity; sufficient loading points at the delivery zones; intermodal hubs?; delivery zone-building-ramps• Purchase decision: high investment costs, vehicle classes (Vecto); investment vs operating costs; too high investment costs result in return of investment above total cost of ownership• Operator = Energy supplier	<ul style="list-style-type: none">• Post-delivery: effectiveness through 24/7 delivery, planning security (e.g. driving ban), fleet management• Politics: Generate cost parity; extend tolls; extend discount for e-drives; clear regulations with time horizon• Attractiveness of the profession of professional driver• Company Image• Use of renewable energy and reduction of emissions• new financing concepts – leasing and rental in combination with BEV• Privileges/limitations/directions can reduce the relevant of investments /price; „Stars with low hanging fruits“- niche applications with better business cases“

Group 2: Charging Infrastructure for electric freight vehicles

Problems	Solutions	Prospects
<ul style="list-style-type: none">• Uncertainties about the BEV vs. Fuel Cell technologies• Areas for charging stations in the city• Distribution traffic is standing anyway at night → no need for fast charging station• Feed-in power of grid for electricity currently not available• Unclear which capacity is required where• Life cycle costs for vehicle- battery- infrastructure• bi-directional function → standards as well as technical and economical	<ul style="list-style-type: none">• Perspective more loading zones necessary• haulage with BEV means more space is needed• Electricity „no-regret“• Energy management• Charging station for commercial vehicles• Divide area for charging areas• Battery regulation for 2nd and 3rd life	<ul style="list-style-type: none">• Invest risk• Orientation of charging points to customer behaviour• Charging point close to energy production (wind, solar and substations)• Fuel Cell for Heavy duty vehicles• No business case for fast charging solution in commercial vehicle

Task force 41 Electric Freight Vehicles

Webinar

Electrification of Heavy-Duty Vehicles in Long Haul Transport

International Energy Agency
Hybrid & Electric Vehicle - Technology Collaboration Programme

Task 41 "Electric Freight vehicles"

The IEA-HEV Task41 aims to monitor progress and review the relevant aspect for a successful introduction of Electric Freight Vehicles (EFV) into the market. The electrification of freight is a direct response to the requirement to reduce the GHG emissions from road transport. The challenge has been to introduce electrification whilst continuing to meet the user requirements. This has given rise to numerous activities in the different vehicle segments of the freight sector with some uncertainty as to which solutions will be adopted in the longer term. Users are now urgently looking for information how to navigate through the present, uncertain situation with a view to minimising risk of stranded investments when envisaging extended operations with electric drive and especially looking to long haul applications. In response to the challenge as outlined above, on September 29th 2020, the Task41 team hosted a webinar on "Electrification of Heavy-Duty Vehicles in Long Haul Transport". In three sessions experts shared and discussed the present state of technologies, experiences and best practices – covering alternatives including fuel cell electric, battery-electric and catenary electric freight vehicles. In total, thirty four attendants from industry, research, logistics and governmental organization joined the webinar.

Essential for the implementation of electric freight vehicles in long-haul transport are the new developments in battery and fuel cell technology. Mr Eberleh from the Akasol AG, took to the floor and as part of his presentation he predicted that in the next four years the energy density of their high energy batteries for commercial vehicle applications would likely increase from 140 Wh/Kg today to 240 Wh/kg – a near 100% increase. For their high power batteries, which are especially suitable for fast charge and hybrid power applications, Akasol expect the charge capacity to increase from 500 W/kg today to 800 W/kg in 2024 – an increase of over 50%. Besides, cost reduction, there is also an expectation of an increase in the cycle life for both types of Li-ion batteries at Akasol.

It is expected that the high energy batteries will become more attractive over time due to the low initial price. Mr Rodrigues from the International Council on Clean Transportation (ICCT) calculates a value of 176 EUR/kWh for the traction battery today and expects a further reduction in the next few years. Mr Rodrigues also noted that the battery prices for truck applications are dropping with two to three years delay to car applications – hence the reduction in price observed in the passenger car market can be expected to be seen in the freight sector. Nevertheless, many manufacturers and vehicle retrofitters such as the Quantron AG criticize the present limited availability of battery cells. Mr Flaschenträger from the Quantron AG proposed that the European market needs a commitment for battery supply of five to ten years before. As an alternative, or as an adjunct to the battery for energy storage there is also the option of a fuel cell. This is viewed as attractive for the long haul freight sector. However, there is a cost issue to overcome. Mr Flaschenträger stated that 1 kWh of fuel cells today costs five to six times more than one kWh of battery. Further, he described that in addition to cost the issue around fuel cell and battery was wider than how you specified the vehicle. To be successful with deployment of any alternative it is essential for the vehicle operation that infrastructure and to align that infrastructure to the specific tour (profile use case) is essential i.e. you need to have the energy available where the vehicle is being used.

The MAN Truck and Bus SE, together with logisticians from the Council for Sustainable Logistics, has been testing nine electric MAN-CNL trucks on Austrian roads since 2018. In the field test, all vehicles were tracked and the data from this activity was collected and analyzed. Mr Radix from MAN summarized that electric mobility with truck works and it is today more sufficient for the range in urban delivery. He expects that customers might be required to change their habits with the transition, but the extent of that change would be limited to certain cases. Mr Radix also highlighted that the charging process and communication will become standardised and made mandatory across the different charging station operators around Europe (making cross-boarder freight movement easier). For long-haul transport, he expects that with the next battery generation the capacity will allow long-haul related ranges in tractor trucks.

Task force 41 Electric Freight Vehicles

Another best practice example for long-haul applications is the eHighways from the Siemens AG. Mr Akerman from Siemens described that in general heavy-duty vehicles drive long distances and are often away from their base. Their transport tasks are highly concentrated to the highway network. Therefore, Mr Akerman recommends using a dynamic charging approach, in this case catenary, on highways when this is possible and move to battery on the distributor routes (from the highway to the depot or delivery point). Other dynamic charging approaches, for example infrastructure embedded in the highway, may also be possible and are under consideration. The development of the eHighways vehicle's technology is today in the 3rd generation, which stands for field trials (1st generation: Proof-of-concept, 2nd Swedish and US demonstration projects). There are three field trials in Germany with each around five km track length and five trucks in operation. The powertrain of the catenary truck is either battery-electric or hybrid-electric designed.

In addition to pilot projects on battery electric trucks in inner-city delivery and on ehighways, Mr Uhl of Clean Logistics GmbH from Germany presented their first Fuel Cell Electric Vehicle prototype on the webinar, which they call Hybat-Truck. Clean logistics is planning to set up their own hydrogen supply network in the upcoming years to be able to tank and operate their Hybat-Truck emission-free with hydrogen. The green hydrogen will be produced using the energy generated by wind turbines, which will be disconnected from the grid at suitable times.

Regarding the question about the total cost of ownership (TCO) parity of Electric Freight Vehicle from the audience, Mr Flaschenträger from Quantron AG answered that he does not expect that the purchase price of fuel cell electric vehicle (FCEV) will get below diesel trucks in the next ten years. However, there should be business cases for customers during this time depending on their specific transport task. Nevertheless, Mr Rodrigues from ICCT stated that access to capital is one of the key barriers they have seen in the past for fleets to invest in efficiency technologies. Thus, it will require innovative financing solutions to ensure that the barrier of upfront cost and the access to capital can be overcome and depreciate over the vehicle operation time. Mrs Holtslag from the Transport Decarbonisation Alliance (TDA) said that customers are also willing to pay for transportation and not only for the TCO. This requires new business models such as transport as services or leasing options. Nevertheless, there must be some frontrunner who are willing to pay a little extra for the TCO of electric freight vehicles. She criticized that the strong demand ordering of big amount of vehicles is still missing for the heavy-duty segment. Mrs Holtslag illustrated the transition process towards Zero-Emission Freight Vehicles in waves. The first waves will focus on urban and regional delivery, then medium freight, followed by heavy regional freight and corridor long haul. Besides, she is seeing cities as powerful ecosystems for this transition since they can push multiple local actors collaborations.

Results of this webinar will feed into the discussion at the HEV-TCP on pre-competitive research and policy measures.



Electrifying Road Freight – Overcoming the Diesel Vehicle Mindset

The information presented is based on a survey conducted during the Joint IEA-HEV Task41 & Task45 webinar on December 7th – 9th, 2021.



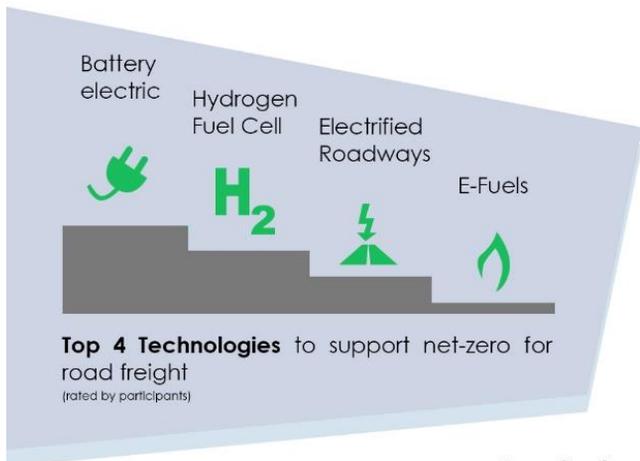
46 participants



Around **80%** of the participants think that net-zero for road freight can (theoretically) be achieved in their organization region until 2050.



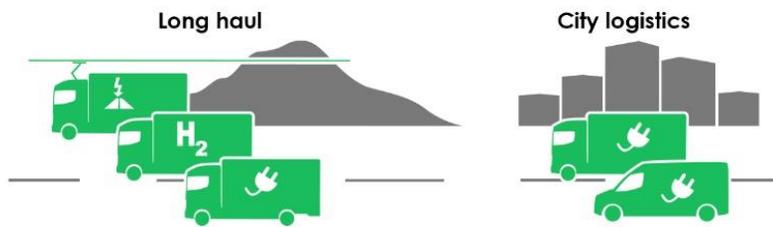
But all participants agree that current policies and investments by governments in their organization region are not aligned for a radical change to reach net-zero for road freight until 2050.



Four out of five believe 2050 will have multiple energy vectors in use for road freight decarbonisation.



Long-term options for road freight vehicles by transport application



Key barriers

Current prio action areas:

- Public sector
- Collaborative action
- EV supply chain

- 1. Infrastructure availability**
 2. Higher upfront vehicle costs (TCO)
 3. Missing long-term investment plans

- Further barriers:**
 - Peak level energy demand and use of natural resources
 - Space constraints (charging reservation)



More charging stations and in parallel cheaper and more capable batteries



Battery swapping during first holding period

System change



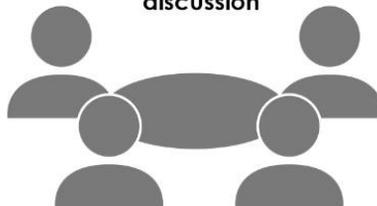
Towards expanding electrification of road freight, the participants rated a system change as more important for today than a behavior change.

Behaviour change



A new metric for measuring road freight performance is needed like carbon pricing (policy change).

Stakeholder discussion



Changing online shopping behaviour (avoiding next day delivery when possible).

Transport electrification requires proactive grid and infrastructure investment (system change).

A societal change would have high impact on the transition to net-zero road freight.