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MARKET DEVELOPMENT OF CLIMATE-FRIENDLY TECHNOLOGIES IN HEAVY-DUTY ROAD FREIGHT TRANSPORT IN GERMANY AND EUROPE

Evaluation of the
2024 Cleanroom Talks with
truck manufacturers

Contents

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Produced by
NOW GmbH
National Organisation Hydrogen and Fuel Cell Technology

Fasanenstraße 5 | 10623 Berlin | Germany
T. +49 (0)30 3116116-100
E. kontakt@now-gmbh.de

In cooperation with

BBG und Partner
bbgundpartner.de

National Centre for Charging Infrastructure
nationale-leitstelle.de

Commissioned by
Federal Ministry for Digital and Transport (BMDV)
Invalidenstraße 44
10115 Berlin | Germany

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Summary

In the context of the ‘Overall Approach to Climate-Friendly Commercial Vehicles’, published in November 2020, the Federal Ministry for Digital and Transport (BMDV – Bundesministerium für Digitales und Verkehr) has made the deployment of the refuelling and charging infrastructure for climate-friendly commercial vehicles one of its central tasks. Its expansion should be demand-driven and aligned with the market ramp-up of the vehicles.

With the aim of better assessing the market ramp-up of climate-friendly commercial vehicles and the resulting demand for charging infrastructure, representatives of the BMDV, NOW GmbH and a law firm commissioned to ensure compliance with antitrust laws held confidential talks (so-called cleanroom talks) with the most important European truck manufacturers in April and May 2024. The information on the manufacturers’ planned sales figures for the coming years and the underlying strategic orientation were used to update the findings of the cleanroom talks in 2022. The manufacturers involved in the recent cleanroom talks represent over 95 percent of the market for heavy-duty vehicles in the EC vehicle class N3 (>12t) in Germany. This evaluation summarises the results.

The transformation of road freight transport towards climate-friendly drivetrains may be more dynamic than many have assumed until now. This key finding of the last cleanroom talks in 2022 is confirmed by the current sales figures projected by the manufacturers. Around three quarters of new registrations of heavy-duty vehicles (N3/>12t) in Germany in 2030 will be zero-emission or low-emission. And the momentum will increase even further by 2033.

The battery-electric truck remains the dominant technology for zero-emission heavy-duty vehicles. With a predicted market share of 48 percent in Germany and 37 percent in Europe for new registrations in 2030, battery-electric trucks will be the main source of support for manufacturers to meet the ambitious European heavy-duty vehicles’ CO_2 standards in 2030. The manufacturers agree that the technology and series maturity of the drivetrain option is today already sufficiently developed for use in heavy-duty vehicles in regional transport and now also in long-haul transport. In addition to the technical maturity and robustness of the battery technology, this is also made possible by the near-completion of the standardisation of the Megawatt Charging System (MCS).

Compared to the 2022 cleanroom talks, the alternative drivetrain strategies of truck manufacturers have become more diverse. Although batteries and fuel cells remain at the centre of these strategies, they are being expanded to include hydrogen combustion engines and, in some cases, plug-in hybrid drivetrain. Some manufacturers are also adding alternative, low-emission fuels (bio-CNG/-LNG) to their drivetrain portfolio.

One of the main reasons for the expansion of drivetrain strategies is the decision taken by the European Union in spring 2024 to tighten the European heavy-duty vehicles’ CO_2 standards. In the discussions, all truck manufacturers have come to the conclusion that achieving the ambitious reduction targets for 2030 will be a considerable challenge. As a result, a range of options will be needed to meet the EU‘s CO_2 targets. The existing uncertainty regarding the speed of infrastructure deployment is another reason why manufacturers are keeping several options open.

The use of hydrogen in the conventional combustion engine – which will be optimised for the new fuel – is the most striking addition to the alternative drivetrain portfolio of several manufacturers compared to 2022. Overall, the share of hydrogen-powered vehicles with fuel cells and combustion engines in 2030 will be just under 20 percent, and thus slightly higher. The slight decline in fuel cell trucks in the current forecasts compared to 2022 is more than offset by the growth in hydrogen combustion engines, which did not yet play a significant role in 2022. This is explained by two developments: Firstly, the hydrogen combustion engine has been recognised as an emission-free drivetrain under certain conditions in the current amendment of the European heavy-duty vehicles' CO_2 standards. Secondly, the technology and market readiness of fuel cells for use in trucks will be delayed until the end of this decade. As the forecasts show, hydrogen-powered trucks will only come onto the market in larger numbers at the end of this decade. Trucks with hydrogen combustion engine will come onto the market somewhat earlier than the fuel cell-powered truck.

Almost all manufacturers have expanded their drivetrain portfolio to include hydrogen combustion engines as compared to 2022. The difference between the manufacturers at this year's talks is reflected in the strategic importance attached to the topic of hydrogen as a whole. One group of manufacturers sees the use of hydrogen as a necessary option for decarbonising all types of application and usage scenarios in road freight transport. They believe that hydrogen drives are the more suitable solution for heavy-load and long-haul transport. The other group of manufacturers, however, sees hydrogen as a niche application only. They consider hydrogen powered trucks to be a complementary solution to battery-electric trucks, suitable for very specific operating cases or application contexts in which cost-effective hydrogen is available. In addition to the disadvantages of hydrogen drives in terms of operating costs, these manufacturers consider the insufficient availability of affordable green hydrogen for road freight transport in a foreseeable and essential period to be particularly critical.

Consensus exists among the manufacturers that a change of drivetrain system in road freight transport requires clear, reliable and plannable framework conditions for all parties involved (including vehicle manufacturers, energy and fuel suppliers, infrastructure operators and vehicle users). This applies not only to the regulatory framework, but also to clarity regarding when the refuelling and charging infrastructure to be deployed will be available in terms of time and location. Long-term planning certainty is also particularly important for users. They must be able to make investment decisions in favour of purchasing climate-friendly commercial vehicles.

With a view to achieving the specified climate protection targets in road freight transport, the rapid expansion of public infrastructure, in particular the truck charging infrastructure, continues to be the top priority for manufacturers. It is the most important framework condition for the success of the market ramp-up. In the next few years, the bottleneck would not be the availability of vehicles, but of infrastructure. In view of the short time frame until 2030, government should now invest heavily in refuelling and charging infrastructure and in doing so create the conditions for the transformation of road freight transport.

Introduction

The previous cleanroom talks took place in 2022.[1] Since that time, the market ramp-up of climate-friendly commercial vehicles respectively the associated forecasts have become much more specific. This is due to the expanding range of vehicles, the incipient infrastructure deployment and the first experiences of users with climate-friendly commercial vehicles. The new regulatory framework is also providing important impetus for the start of the market ramp-up. Particular mention should be made here of the introduction of a CO_2 component in truck tolls, the requirements of the European Alternative Fuels Infrastructure Regulation (AFIR) and the tightening of European heavy-duty vehicles' CO_2 standards.

In light of these developments, representatives of the BMDV, NOW GmbH and a law firm specialising in antitrust law conducted cleanroom talks with the most important European truck manufacturers from April to May 2024. At the time of the talks, the manufacturers involved were once again representing over 95 percent of the market for heavy-duty vehicles in the EC vehicle class N3 (>12 t) in Germany and as much as 99 percent in Europe.

The objective of the cleanroom talks remains the same: to obtain information on the manufacturers' planned sales figures for the coming years and the underlying strategic orientation. The results are used primarily to steer the deployment of the refuelling and charging infrastructure in line with demand and in sync with the ramp-up of the vehicles. After all, the coordinated and concerted deployment of infrastructure is one of the key tasks that the Federal Ministry for Digital and Transport (BMDV) has set itself in the context of the 'Overall Approach to Climate-Friendly Commercial Vehicles' published in November 2020. According to the German government's ambitious climate protection targets for road freight transport, one third of the mileage in heavy-duty road freight transport is to be electric by 2030.

At this year's cleanroom talks, manufacturers also provided data on the sales figures they are planning for heavy trucks (> 12 t) in the next few years, as well as on the future technical properties of the vehicles (e.g. electric ranges).

In addition to the provision of data, individual discussions were held with each of the manufacturers. As part of a structured interview, the strategic evaluation of technology options, an assessment of the regulatory framework and technical developments, and infrastructure needs were queried. The quantitative data, anonymised and aggregated by the law firm, as well as the qualitative statements obtained in the discussions, which were also anonymised, were evaluated by the BMDV and NOW GmbH.

In this report, we summarise the results of the cleanroom talks held in 2024. The results of the analysis of the quantitative data are largely displayed in graphical form. The analysis of the qualitative statements from the talks is summarised in the text.

In addition to the findings for the deployment of the infrastructure, they also provide information that can serve as a basis for the decisions of other key players and stakeholders for the market ramp-up. These are, among others, infrastructure providers and operators, players in the energy industry and users such as transport, freight and logistics companies.

The results of the talks will serve as a basis for the federal government to make transport policy decisions in order to ensure the forward-looking and needs-based deployment of charging and refuelling infrastructure, in particular to fulfil obligations to ensure a minimum supply. In that regard, the BMDV launched the first step in the tendering process in July 2024 for the planning, construction and operation of fast-charging infrastructure for battery-electric trucks and buses at around 130 unmanaged motorway rest areas. The necessary grid connections, which are provided by the federal government, create planning certainty for industry and the transport sector. The cleanroom talks also provide helpful information that enables the BMDV to efficiently use funding for infrastructure deployment. However, the federal government's activities are not part of this report.

All information and statements contained in this evaluation are based on the information from the cleanroom talks. For antitrust reasons, the information has been anonymised and aggregated. The report does not contain any evaluations or assessments by the Federal Ministry for Digital and Transport. The BMDV does not endorse the statements of the manufacturers.

The statements of the manufacturers reflect the state of knowledge at the time of the talks in April and May 2024 and therefore do not take into account any transport policy developments that have occurred since then.

[1] See the 2022 cleanroom talks report: https://www.klimafreundliche-nutzfahrzeuge.de/wp-content/uploads/2023/05/BroschuereNOWCleanroom_ENG_web.pdf

1 Corporate strategies for the market ramp-up of climate-friendly trucks

Manufacturer strategies have become more differentiated. Battery-electric trucks remain the dominant technology path.

In spring 2024, the European Parliament and the European Council adopted the amendment to the European heavy-duty vehicles' CO_2 standards. The existing standards provided for a 15 percent reduction in average specific CO_2 emissions per kilometre by 2025 and a 30 percent reduction by 2030 compared to the 2019 reporting period. As part of the amendment, the reduction target for 2025 was retained and the targets for 2030 were significantly increased to 43 percent. In addition, new targets have been set for the following years, with a 64 percent reduction by 2035 and a 90 percent reduction by 2040. With the new targets, the EU is also expanding the scope of the CO_2 standards to include, among other things, additional truck types as well as trailers and semi-trailers.

Truck manufacturers agree that achieving these targets will be a major challenge for the industry. This applies in particular to reduction targets up to 2030. The tight time frame and uncertainty about the speed of infrastructure deployment will increase the pressure even further. In addition, manufacturers are concerned about whether there will be enough customers for vehicles with climate-friendly drivetrains in the low-margin logistics industry. This is because failure to meet the targets will result in hefty fines.

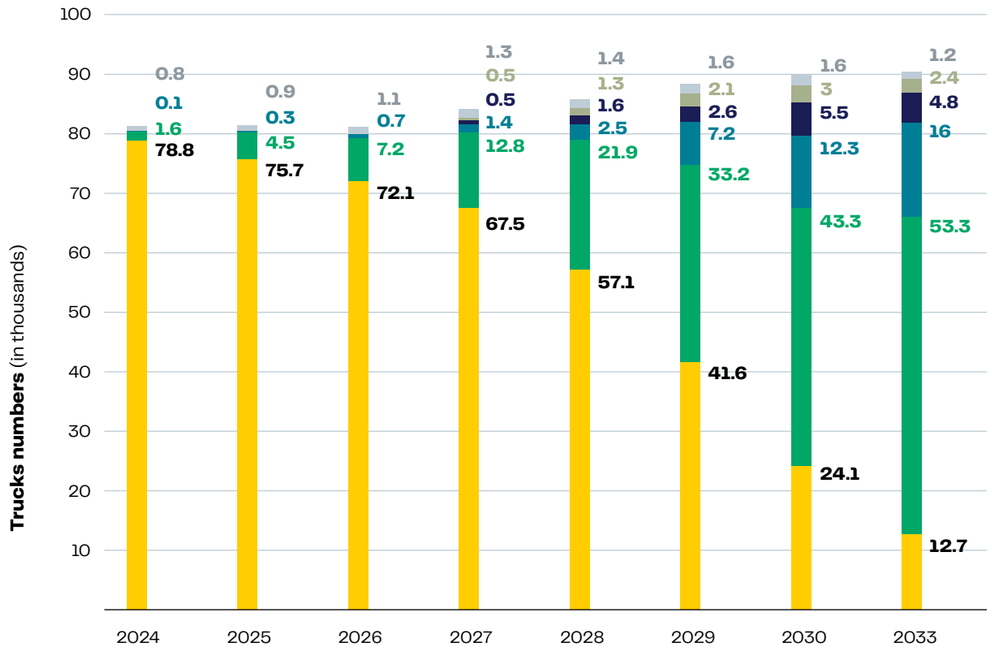
During the last cleanroom talks in 2022, the truck manufacturers' alternative drivetrain strategies still showed a clear focus on batteries and fuel cells. Other alternative drivetrains played only a marginal role. The clear focus on battery-electric trucks ('single-pillar strategy') by one group of manufacturers and on battery-electric and fuel-cell trucks ('two-pillar strategy') by a second group of manufacturers has since become more differentiated. This is shown by a look at the manufacturers' currently projected sales figures (see Figure 1). The reason for the differentiation of drivetrain strategies is the significant tightening of the European heavy-duty vehicles' CO_2 standards. Battery and fuel cell trucks are still the focus of the strategies, but are being expanded to include hydrogen combustion and, to a lesser extent, plug-in hybrid trucks. For some manufacturers, the drivetrain portfolio is also being supplemented by bio-LNG as a further pillar. In view of the existing uncertainties, most manufacturers are seeking to keep their options open by expanding their alternative drivetrain portfolio, thereby ensuring that they have several options for meeting the CO_2 targets. Some manufacturers have indicated that they need several drivetrain options to meet the reduction targets.

AGAINST THE BACKDROP OF THE MORE STRINGENT EUROPEAN CO_2 STANDARDS, THE STRATEGIES OF THE MANUFACTURERS HAVE BECOME MORE DIFFERENTIATED.

In contrast to 2022, the manufacturers' projected sales figures paint a much more accurate picture this time, especially with regard to market growth. In view of the existing stock figures and the relative saturation of the German and European markets, the projected and aggregated sales figures this time reflect market development more realistically than the figures from 2022, which the manufacturers claim to have been overly optimistic.

Figure 1

Forecast sales figures for heavy-duty vehicles (N3/> 12 t)
In Germany, according to manufacturer data



Note:
The response rate in relation to the current market shares was 96 percent.
The values have been rounded for better readability.

Source: Information from the truck manufacturers involved. Own representation.

THE EXISTING TECHNOLOGY AND SERIES-PRODUCTION READINESS MAKE THE BATTERY TRUCK THE DOMINANT TECHNOLOGY PATH FOR THE DECARBONISATION OF ROAD FREIGHT TRANSPORT.

The current cleanroom talks confirm the results from 2022: The EU's CO_2 targets for 2030 make the battery-electric drivetrain indispensable. The battery-electric truck will be the dominant option in the transformation of road freight transport beyond 2030. With a share of 48 percent (Germany) and almost 37 percent (Europe) of newly sold heavy-duty trucks in 2030, battery-electric trucks will bear the main responsibility for achieving the ambitious European CO_2 standards in the same year. According to the manufacturers, the main reason for this strategic focus is the existing technology and series maturity of battery-electric trucks. This applies not only to the use of trucks in regional and distribution transport, but explicitly also to long-haul transport. In addition to the technical maturity and robustness of the battery technology, this is also made possible by the almost completed standardisation of the Megawatt Charging System (MCS). MCS-capable trucks will become increasingly available from 2025 onwards. According to the manufacturers, the point at which battery-electric trucks can actually be used in long-haul transport depends on the speed at which the public charging infrastructure is built. The end of the KsNI funding programme and uncertainties about the speed of the charging infrastructure expansion will lead to market shares for battery-electric trucks by 2030 that are slightly lower than those predicted in the cleanroom talks in 2022. However, the dynamics for the market ramp-up remain very high.

Delays are also being experienced with regard to fuel cell trucks. Unlike battery-electric trucks, however, these are due to lags in the development of the fuel cells themselves. Despite technical advances, the majority of manufacturers believe that fuel cells still lack the robustness, efficiency and stability required for demanding long-haul transport applications. There is also a need for optimisation in terms of the costs, packaging and cooling of the fuel cell. The fuel cell truck is not expected to be ready for series production until the end of this decade or later. Hydrogen combustion engine trucks will be ready for series production somewhat earlier than fuel cell trucks, since the combustion engine is a mature technology that is well understood.

Besides the existing technology and series maturity, the low operating costs speak in favour of battery-electric trucks, from the point of view of the manufacturers surveyed. This means that, in terms of total cost of ownership (TCO), the battery-electric truck can achieve cost parity with the conventional diesel truck in a relatively short period of time. The high strategic importance of battery-electric trucks is also reflected in the development of production capacities and the long-term investment decisions that have already been made for this purpose. According to the manufacturers, production capacities are planned with a lead time of five to seven years. The importance is also substantiated by the advisory and support services that have been proposed to help customers convert their fleets (see Chapter 3).

The significance of hydrogen is assessed differently by individual manufacturers.

Looking at the differentiation of the alternative drivetrain strategies of the truck manufacturers, the greater importance of the use of hydrogen in combustion engines is particularly striking. During the cleanroom talks in 2022, the hydrogen combustion engine had not yet played a significant role. If we add trucks with hydrogen combustion engines and fuel cells, the share of hydrogen drives at this year's cleanroom talks is just under 20 percent of new registrations in Germany in 2030, which is slightly higher than in 2022. For 2033, the manufacturers expect this share to increase further, particularly for fuel cell trucks.

Three reasons are attributed to the greater role of hydrogen combustion engines. Firstly, the hydrogen combustion engine has been recognised as an emission-free drivetrain under certain conditions in the current amendment of the European heavy-duty vehicles' CO_2 standards.[2] This means that it also benefits from exemption from the truck toll in Germany. Secondly, the technology and market maturity of the fuel cell for use in trucks is not expected until the end of the decade. Thirdly, this option allows the use of a well-known and proven drivetrain technology. In terms of its procurement costs, the hydrogen combustion engine is seen as a comparatively cost-effective drivetrain option that has the potential to be ready for series production in the near future. The role that hydrogen combustion engines will play in the long term is the subject of debate among manufacturers. Several manufacturers see the use of hydrogen in combustion engines as a bridging technology on the way to a more efficient use of hydrogen in fuel cells. A smaller number of manufacturers also see specific long-term applications for both fuel cell trucks and trucks with hydrogen combustion engines. According to this view, fuel cell trucks will tend to be used in long-haul transport, while trucks with hydrogen combustion engines will be used particularly in heavy-load transport (e.g. as construction vehicles) (see Figure 3).

THE IMPORTANCE OF HYDROGEN HAS INCREASED. HOWEVER, VEHICLE MODELS WILL NOT COME ON THE MARKET UNTIL THE END OF THE DECADE.

A glance at the sales figures forecast by the manufacturers shows that both hydrogen options will only gain in relevance at the end of this decade and will then come onto the market in larger numbers (see Figure 1).

NECESSARY DRIVE OPTIONS OR NICHE? MANUFACTURERS HAVE VASTLY DIFFERING OPINIONS ABOUT THE ROLE OF HYDROGEN TECHNOLOGIES IN TRUCKS.

The clear distinction between manufacturers who only rely on battery-electric trucks and those who, in addition to battery-electric trucks, also consider fuel-cell trucks to be strategically necessary, is no longer possible with the current differentiation of alternative drivetrain strategies. This is because almost all manufacturers have added hydrogen combustion engines to their range of drivetrains. This time, however, one aspect in which some manufacturers are distinguishing themselves from the others is the strategic importance attached to the topic of hydrogen as a whole.

One group of manufacturers sees the use of hydrogen as a necessary option for decarbonising all applications and use cases in road freight transport. They claim that the use of hydrogen in fuel cells and combustion engines is a more suitable drivetrain solution for heavy-load and long-haul transport than battery-electric trucks. They point out the comparatively longer range of hydrogen vehicles, the shorter refuelling times and the lack of payload restrictions that exist for battery-electric trucks due to their heavy batteries. Furthermore, battery-electric trucks would be too dependent on Chinese battery manufacturers. This dependency would not exist with fuel cells and hydrogen combustion engines. Work is currently underway on a more efficient and cost-effective new generation of fuel cells that will lead to a convergence in vehicle prices between battery and fuel cell trucks in the future. With regard to the availability of green hydrogen, it is assumed that prices will fall significantly. The increasing demand for hydrogen in other sectors, such as the steel and chemical industries, will lead to an increase in the supply of green hydrogen. Investment in large-scale hydrogen production plants and international trade in the energy carrier will also benefit road freight transport.

The other group of manufacturers sees hydrogen as a niche application only. This applies to the use of hydrogen in combustion engines as well as – and to an even greater extent – to hydrogen fuel cells. This group of manufacturers sees hydrogen as a complementary solution to battery-electric trucks, to cover very specific operating cases or in application contexts where cost-efficient hydrogen is available (e.g. chemical industry). In addition to the disadvantages of hydrogen trucks in terms of operating costs, the sufficient availability of affordable green hydrogen for road freight transport in the foreseeable and necessary future is seen as particularly critical. Furthermore, other sectors would compete with the mobility sector for the scarce green hydrogen, where there would be a greater willingness to pay due to a lack of alternatives.

During the last cleanroom talks, no manufacturer had given overhead line a high strategic priority. During this year's talks, individual manufacturers who had been somewhat open to the topic announced that they would be discontinuing their development activities in relation to the overhead line. As a result, overhead line trucks no longer appear in the forecast sales figures this time. The manufacturers point to the lack of political support for this technology as the main reason for this decision. Without advance action and considerable government support, the necessary investments in the development of the overhead line infrastructure will not materialise.

TRUCK INDUSTRY IS WITHDRAWING ENTIRELY FROM THE TOPIC OF OVERHEAD LINES.

[2] Heavy-duty vehicles with hydrogen combustion engines are recognised as emission-free if their emissions do not exceed 3 g CO_2/tkm or 1 g CO_2/Pkm in accordance with EU Certification Regulation 2017/2400 (determined using the Vehicle Energy Consumption Calculation Tool – VECTO).

The decisive factor for cost parity between diesel trucks and climate-friendly trucks: Energy costs

Manufacturers emphasise that transport, haulage and logistics companies generally base their decisions on the purchase of a truck on more rational criteria than those applied to the purchase of a passenger car. In terms of the economic efficiency of vehicle use, the total costs over the service life or holding period of the vehicle must be considered. Because of the high mileage and high energy consumption, the operating costs, in particular the energy costs, are the decisive factor for the economic efficiency of the vehicles.

The gradual fall in vehicle prices over the next few years will contribute to an increasing cost parity between battery-electric trucks and diesel trucks. According to the manufacturers, a battery-electric truck costs two to three times as much as a diesel truck today. In 2030, the manufacturers agree in their estimates, the vehicle price should have fallen to between one and two and a half times the price of a diesel truck and in subsequent years, thanks to economies of scale in production and falling battery prices, it should continue to decrease.

Furthermore, the low operating costs and high efficiency of battery-electric trucks mean that, according to the manufacturers, the point of cost parity with diesel trucks could be reached quickly. The price of electricity is a crucial factor in operating costs. The lower the price of electricity and the higher the annual mileage, the faster the higher acquisition costs can be offset by lower operating costs. Road toll exemption and the savings on CO_2 pricing on diesel contribute to the rapid achievement of cost parity. According to the manufacturers, battery-electric trucks are already achieving cost parity with diesel trucks in specific application contexts (low-cost electricity, high mileage, use of toll roads, etc.). Most expect battery-electric trucks to achieve cost parity in the near future. Given the significantly higher purchase price at present, battery-electric trucks can only really exploit their low operating cost advantage when used for long-haul transport. That is why the deployment of a public charging infrastructure is crucial to achieving cost parity for battery-electric trucks in the near future.

COST PARITY HINGES ESSENTIALLY ON ENERGY COSTS.

For fuel cell trucks, the key to cost parity with diesel trucks is also linked to energy costs. According to the manufacturers, the availability of green and cost-effective hydrogen is crucial. There are different estimates among manufacturers for cost parity with diesel trucks. For some manufacturers, a hydrogen price of €8/kg is needed initially, which would then need to fall to €5–6/kg for cost parity between a fuel cell truck and a diesel truck. Other manufacturers do not expect cost parity until the hydrogen price falls well below €5/kg. Some talk about cost parity only at €3/kg.

Compared to diesel trucks, the additional investment costs for a fuel cell truck are incurred by the fuel cell itself, the peripheral components of the fuel cell, the hydrogen tanks and the additionally installed battery. Manufacturers also expect fuel cell truck prices to gradually decrease. In 2027, fuel cell trucks are forecast to cost three times as much as conventional diesel trucks, in 2030 two and a half to three times as much, and in 2035 to be approaching twice the price of a diesel truck.

For trucks with hydrogen combustion engines, some manufacturers assume that these will only be slightly more expensive than diesel trucks when mass-produced. However, the use of hydrogen in combustion engines is significantly less efficient than in fuel cells. Nevertheless, because of the assumed lower purchase price, hydrogen combustion engines could be more economical than fuel cell or battery trucks for certain applications.

ZERO-EMISSION TECHNOLOGIES OFFER NEW PLAYERS AN OPPORTUNITY TO ENTER THE EUROPEAN MARKET.

Truck manufacturers in Europe are expected to provide their customers with a service network that covers the whole of Europe. In the past, this significant hurdle has made it difficult for new competitors to enter the market. However, the manufacturers surveyed are aware that alternative drivetrains offer opportunities for new competitors to enter the market in Europe. They assume that non-European manufacturers specialising in battery trucks will be increasingly likely to bring their vehicles to Europe in the next few years. The industry is paying particular attention to the progress made by Chinese truck manufacturers. Reference is made to the electric buses in which Chinese manufacturers have succeeded in gaining a foothold in the European market with competitive models.

+2 Manufacturers' requirements for political and regulatory framework conditions

The political environment and the regulatory framework for the switch to climate-friendly commercial vehicles have changed significantly since the cleanroom talks in 2022. With the introduction of a CO_2 component in the road toll for trucks and the support for the amendment of the EU heavy-duty vehicles' CO_2 standards, the BMDV has created a targeted regulatory environment for the market ramp-up of climate-friendly commercial vehicles, as announced in the 'Overall Approach to Climate-Friendly Commercial Vehicles'. With the funding decisions made in the period 2021 to 2023, the BMDV guideline for the funding of commercial vehicles with alternative, climate-friendly drivetrains and the associated refuelling and charging infrastructure (KsNI guideline) has provided an important impetus for the ongoing market ramp-up of climate-friendly commercial vehicles and the associated infrastructure. Against this background, the question arises as to how truck manufacturers assess the current framework conditions with regard to the planned market ramp-up of the vehicles.

Planning certainty is vital for both manufacturers and their customers.

MANUFACTURERS GENERALLY WELCOME THE REGULATORY FRAMEWORK THAT HAS BEEN CREATED.

The regulatory framework created in recent years (CO_2 standards, CO_2 toll and CO_2 pricing) for the decarbonisation of road freight transport is generally welcomed by most truck manufacturers. The CO_2 component in the truck toll, for example, is seen as an important instrument for the switch to climate-friendly commercial vehicles. From the manufacturers' point of view, clear guidelines and incentives are needed to achieve the climate protection targets.

The manufacturers agree that a change of drivetrain system in road freight transport requires clear, reliable and plannable framework conditions for their companies and their customers. They need predictability not only when it comes to the long-term design of regulatory frameworks, such as toll exemptions or reductions for zero-emission trucks beyond 2027 and CO_2 pricing on diesel fuel, but also with regard to the when and where of the refuelling and charging infrastructure to be built, as well as the design of funding programmes.

From the customers' perspective, the purchase of climate-friendly trucks, which are significantly more expensive, and the investments in infrastructure deployment required for their operation, will only pay off after several years. With a truck holding period of five years as a rule, transparent and long-term calculable framework conditions are needed so that customers can make the necessary investment decisions for the switch.

Clear communication from political decision-makers would also help to ensure planning certainty. The manufacturers would like a clear signal from policymakers that the transformation of road freight transport is desired, especially the deployment of refuelling and charging infrastructure. Some of the manufacturers would like to see communication that emphasises the priority deployment of charging infrastructure for trucks. In view of the existing technology and series maturity of battery-electric trucks, this would create clarity for customers. However, given the current halt to hydrogen funding programmes, another group of manufacturers would like to see the government take a stand on hydrogen and the deployment of the hydrogen refuelling infrastructure.

KSNI HAS ENABLED THE TRANSITION TO COMMENCE. MANY MANUFACTURERS SEE GOOD REASONS FOR A RE-ISSUE OF THE VEHICLE INCENTIVE PROGRAMME.

Considering the current start of the series ramp-up and the existing reluctance to invest after the end of the KsNI funding programme, the majority of truck manufacturers consider a relaunch of the funding programme to be necessary. This is because the switch to climate-friendly commercial vehicles will not happen overnight. Their customers will initially test a new technology with a smaller number of vehicles. A decision on a larger-scale fleet conversion would only be taken at a later date. Since this testing and decision-making process could take several years, the manufacturers believe that an investment stimulus is needed now in the form of a funding programme. This is because the funding would enable customers – in particular smaller transport companies – to adopt new technology despite the additional costs. Without funding, it would be very challenging to persuade customers to take this first step. This timely first step in the fleet conversion is important for manufacturers to achieve the European CO_2 standards. Doing so would buy time for customers to implement a major fleet conversion before 2030. From the manufacturers' point of view, a new funding programme for the purchase of commercial vehicles could have a significantly lower funding intensity than the 80 percent in the KsNI guideline with regard to the additional investment costs of climate-friendly commercial vehicles, which could also be successively reduced over the term of the funding guideline. A minority of manufacturers were of the opinion that there was no longer a need for funding for investments in climate-friendly commercial vehicles and that funding only led to dependencies.

Establishing the infrastructure quickly is a decisive condition for the ramp-up.

For truck manufacturers, the pace of infrastructure deployment, especially the deployment of public charging infrastructure, is the biggest factor in the success of the market ramp-up and the achievement of climate protection targets in road freight transport. The bottleneck in the next few years will not be the availability of vehicles, but of infrastructure. The deployment of refuelling and charging infrastructure is the key to the success of the market ramp-up. The truck manufacturers see it as the obligation of the government to create the appropriate framework conditions for the transformation of road freight transport by rapidly developing the infrastructure. This applies in particular to the deployment of the charging infrastructure, since battery-electric trucks will account for the majority of new registrations of climate-friendly commercial vehicles in the short to medium term. In view of the short period of time remaining before 2030, government should invest heavily in the refuelling and charging infrastructure now.

ACCORDING TO THE MANUFACTURERS, THE RAPID EXPANSION OF THE PUBLIC REFUELING AND CHARGING INFRASTRUCTURE IS THE TOP PRIORITY AND THE MOST IMPORTANT FRAMEWORK CONDITION FOR THE MARKET TO TAKE OFF.

They also suggest conducting an annual assessment that not only monitors the achievement of targets under the European Alternative Fuel Infrastructure Regulation (AFIR), but also allows the infrastructure build-up to be aligned with the vehicle ramp-up. To finance the expansion of the infrastructure, some manufacturers suggest using a portion of the additional revenue from the CO_2 components in the truck toll.

MANUFACTURERS CONCERNED THAT DELAYS IN DEPLOYMENT OF DEPOT CHARGING INFRASTRUCTURE COULD IMPEDE MARKET RAMP-UP.

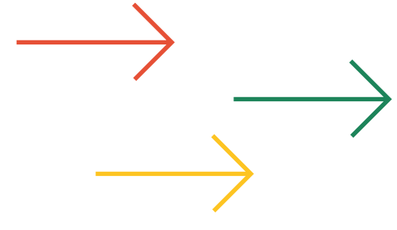
The truck manufacturers agree that the majority of charging processes in the future will take place in the depot, at charging infrastructure that is not publicly accessible (see Chapter 3). Depot charging is also of central importance for the economic efficiency of an battery truck. This is because depot charging of trucks is more cost-efficient and more predictable than public charging. Since there are concerns that the deployment of the public charging infrastructure could take longer, the manufacturers believe that it is all the more important for the market ramp-up, that users be supported in the deployment of the depot charging infrastructure.

Furthermore, it is necessary to deal with the existing framework conditions, since it is not possible to change the location in case of necessity, as is the case with the deployment of public charging infrastructure. This often means high investment costs. In addition to a funding programme for depot charging infrastructure, support is needed for the rapid processing of the grid connection request as well as for the implementation of the grid connection and its expansion.

New technologies require new technical standards or modifications to the existing legal framework. During the cleanroom talks, the need for adjustments was discussed by the manufacturers, particularly with regard to hydrogen technologies.

For example, manufacturers see a particular need for adjustment in the European regulations on maximum weights and dimensions of heavy-duty vehicles. On the one hand, this concerns vehicle length: The placement of hydrogen tanks behind the cab means that for some manufacturers, the longer tractor unit causes the entire semitrailer-truck to exceed the existing vehicle length specifications. On the other hand, it affects the permissible weight of the vehicles and the permissible axle loads. Both battery and fuel cell trucks are affected here, which lose payload due to the additional weight of the heavy batteries and a different drivetrain design compared to diesel trucks. This need for adaptation is to be addressed with the amendment of EU Directive 96/53/EC, which is currently in progress.

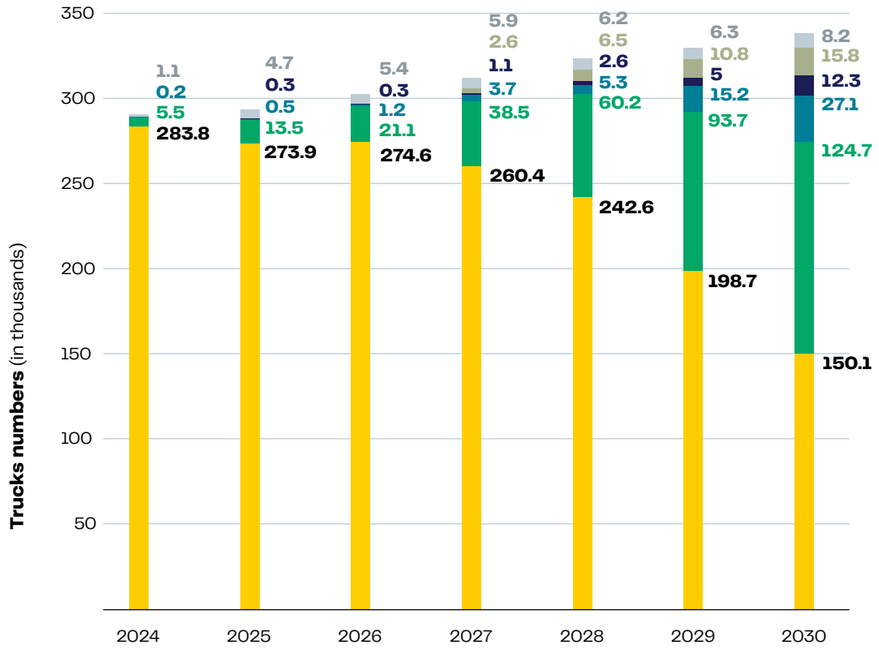
HYDROGEN USE IN ROAD FREIGHT TRANSPORT REQUIRES SOME AMENDMENTS TO THE REGULATORY FRAMEWORK.



The internal hydrogen combustion engine (H2 ICE) has gained in importance for many manufacturers. Against this background, manufacturers see a need for adjustment in the area of energy taxation for hydrogen. While the use of hydrogen in fuel cells is not subject to energy tax, the use of hydrogen in combustion engines is taxed. This disparity in tax treatment leads to billing problems, especially at hydrogen filling stations. The manufacturers would like to see hydrogen taxed uniformly, regardless of whether it is used in fuel cells or in combustion engines.

Figure 2

Forecast sales figures for heavy-duty vehicles (N3/> 12 t)
In Europe, according to manufacturer data



Note:
The response rate in relation to the current market shares was 90 percent.
The values have been rounded for better readability.

Due to incomplete information from the manufacturers, no figures are shown for Europe for 2033.

H_2 fuel cell
Battery
Diesel
Bio gas
Plug-in hybrid
H_2 combustion

Source: Information from the truck manufacturers involved. Own representation.

Manufacturers who see hydrogen drives for trucks as playing an important role in their product portfolio also see a need for adjustment in the Europe-wide agreement on the transport of dangerous goods (ADR)[3]. According to the ADR, climate-neutral transportation of hydrogen to hydrogen refuelling stations is not currently permitted with a fuel cell or hydrogen combustion truck. A draft for the next regular update of the ADR stipulates that fuel cell trucks and trucks with hydrogen combustion engines may also transport hydrogen.

Another request from the manufacturers is for greater support for the use of hydrogen as part of the implementation of the European Renewable Energy Directive by giving multiple crediting of green hydrogen in the greenhouse gas reduction quota. They emphasised that it is particularly important that the certification of green hydrogen be designed in a transparent and trustworthy manner.

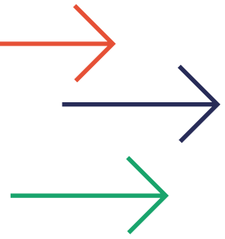
GERMANY IS A CRUCIAL SALES MARKET FOR TRUCK MANUFACTURERS IN ACHIEVING THE EU CO_2 STANDARDS.

A comparison of the sales figures for Germany (see Figure 1) and for Europe (EU-27, N, CH) (see Figure 2) provided by the manufacturers clearly shows Germany's pioneering role in the market ramp-up of climate-friendly commercial vehicles. Given that the German market is one of the strongest markets for heavy-duty vehicles in Europe in terms of sales, it plays a central role for truck manufacturers in achieving the European CO_2 standards.

[3] ADR is the acronym for 'Accord européen relatif au transport international des marchandises dangereuses par route', the European agreement concerning the international carriage of dangerous goods by road.

In 2030, the share of zero-emission or low-emission drives (BEV, PHEV, H2 ICE, FCEV, bio gas) in the total number of new vehicles sold in Germany is 73 percent according to the cumulative forecasts of the manufacturers. In Europe, the share at the same time is only 56 percent. According to the manufacturers' forecasts, a similarly high market share as in Germany will be achieved by zero-emission or low-emission drives in Europe somewhat later, namely around 2033.

+3 Challenges of the various technological paths



VEHICLE MANUFACTURERS CONSIDER BATTERY TECHNOLOGY TO HAVE REACHED THE NECESSARY ROBUSTNESS AND MATURITY FOR USE IN TRUCKS, EVEN IN LONG-HAUL TRANSPORT.

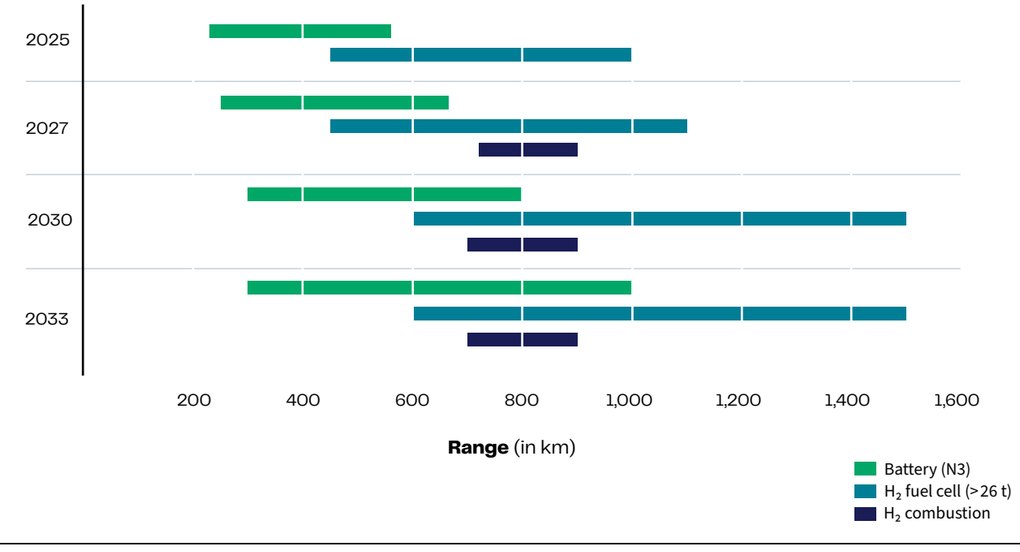
Questions relating to the status of the technology, further development steps, technical specifications and specific infrastructure requirements were once again discussed during the cleanroom talks. This information is particularly relevant for the planning and development of the infrastructure and the framework conditions.

Battery and charging infrastructure

Battery technology has seen continuous advancements over the past two years, reaching a level of maturity and robustness that makes it suitable not only for regional and distribution transport but also for long-haul applications. This assessment of battery-electric trucks is shared by all the truck manufacturers surveyed. And this despite the fact that the installation of the battery in a truck is significantly different from that in a car. While car batteries are typically placed in the underbody and shielded from damage by a robust crash frame, truck batteries are mounted within and on the main frame, leaving them more exposed to mechanical stress, water splashes, and significant temperature fluctuations.

Figure 3

Predicted range of heavy-duty vehicles (> 12 t) with alternative drivetrains



Source: Information provided by the truck manufacturers involved. Own representation.

NO QUANTUM LEAPS ARE ANTICIPATED IN BATTERY DEVELOPMENT IN THE COMING YEARS. INSTEAD, INCREMENTAL IMPROVEMENTS IN ENERGY DENSITY, COSTS, LIFESPAN AND EFFICIENCY WILL PREDOMINATE.

Battery-electric truck models suitable for long-haul transport are expected to be available starting at the end of 2024. According to the manufacturers, these trucks will feature sufficient battery capacity and range for use in long-haul transport. In addition, appropriate charging inlets for megawatt charging should be installed or retrofittable. The ranges of battery-electric trucks will also continue to increase over the next few years (see Figure 3), which is largely due to the higher battery capacities being installed in long-haul trucks (see Figure 5). The manufacturers no longer perceive any fundamental challenges to the adoption of battery-electric trucks in the daily logistics practice of both regional and long-haul transport.

The truck manufacturers surveyed do not expect any major leaps in the development of battery technology this decade. Instead, they expect a continuous process of improvement, similar to the progress seen in recent years. The optimisation efforts are focused on energy density, costs, battery lifespan and efficiency.

Both volumetric and gravimetric energy density have already increased rapidly in recent years. According to manufacturers, battery energy density is continuously improving by five percent per year. Looking ahead, a major area of potential for further energy density improvements is seen in battery architecture. While batteries today still use a modular basic structure, so-called ‘cell-to-pack’ systems will eliminate the need for battery modules in the future. Instead, battery cells will be inserted directly into the battery pack. This new packaging concept not only boosts energy density but also reduces costs. Additionally, the space required for the battery will remain unchanged, despite the increased capacity.

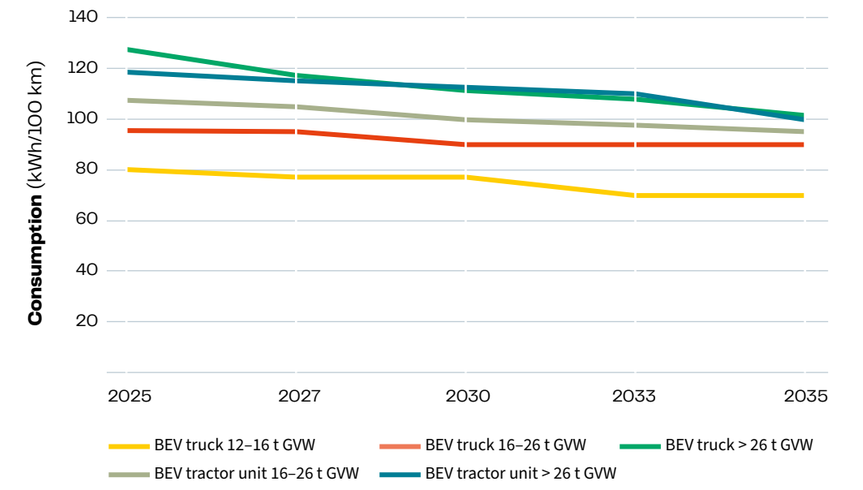
Similar to the outlook of battery development, manufacturers do not expect any surprising price jumps in battery costs over the next few years. In their view, the expected gradual development of battery prices will cause them to fall by 10 to 15 percent every three to four years. The manufacturers see opportunities for cost reduction in both the material composition of the batteries and in the production process. While the current world market price for lithium batteries is 200 dollars per kilowatt hour, the goal is for the battery price to fall below 100 dollars per kilowatt hour. However, temporary material shortages (e.g. of lithium) and newer, initially more expensive battery technologies would have the effect of increasing prices.

There has also been progress in terms of battery lifespan. The robustness of battery technology now enables manufacturers to guarantee their customers a battery lifespan of more than one million kilometres when used for long-haul transport. Other manufacturers guarantee a battery lifespan of up to eight years with a ‘state of health’ of 80 percent.

The targeted lifespan of the battery is based on the duration of the vehicle’s service life. The EURO 7 regulation adopted by the European Union in 2024, which stipulates a minimum durability for batteries, also goes in this direction. According to the regulation, traction batteries in battery trucks must last for at least 900,000 km. Batteries are currently used conservatively to maximize their lifespan. For instance, battery management systems and temperature control mechanisms are employed to minimize significant and continuous temperature fluctuations. To prevent premature ageing of the batteries, the manufacturers also limit the usable capacity range in the batteries of their vehicles. The development and adoption of new cell chemistries are expected to significantly extend the lifespan of the battery.

Figure 4

Average consumption of heavy battery-electric vehicles (BEV) (> 12 t)



Source: Information provided by the truck manufacturers involved. Own representation.

The continuous improvements to battery-electric trucks are also reflected in the energy consumption of the vehicles (see Figure 4). Here, the manufacturers anticipate achieving a double-digit percentage increase in efficiency over the next ten years. In particular, average improvements of 18 percent (tractor unit) and 24 percent (truck) in consumption are expected for heavy-duty trucks and combinations of tractor units and semi-trailers with a gross vehicle weight (GVW) of over 26 tonnes.

LITHIUM IRON PHOSPHATE (LFP) BATTERIES ARE BECOMING INCREASINGLY IMPORTANT FOR USE IN TRUCKS.

The selection of a suitable battery type for truck applications always involves certain trade-offs. All cell chemistries have specific strengths and weaknesses. While truck manufacturers have almost exclusively used nickel-manganese-cobalt (NMC) batteries, lithium iron phosphate (LFP) batteries have been gaining in importance since 2022. Both battery technologies offer distinct advantages: NMC batteries are lighter and have a higher energy density. LFP batteries, on the other hand, have a longer lifespan, which is contributed to by their superior cycle stability. A larger capacity range can be released (instead of 75 percent, approximately 90 percent of the nominal capacity) and they are more environmentally friendly as they do not require toxic heavy metals like cobalt and nickel. Finally, they are currently generally less expensive.

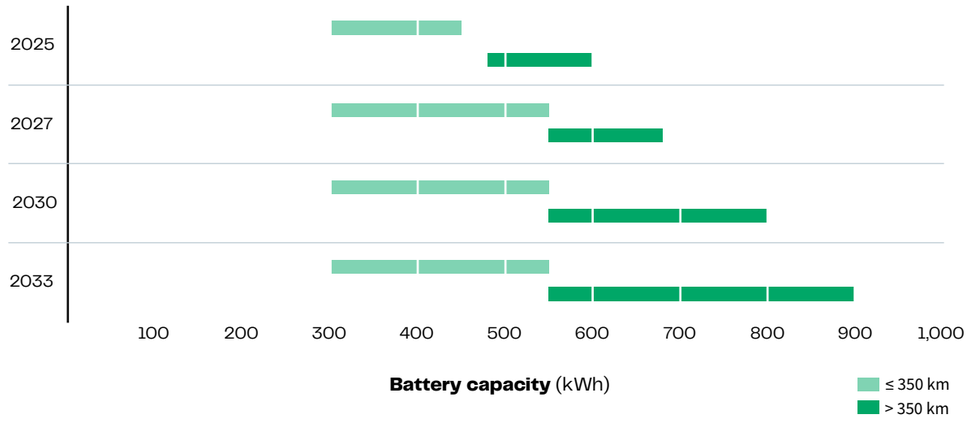
Opinions differ among the truck manufacturers surveyed regarding the LFP battery. While some already consider this battery chemistry to be better suited for use in trucks and see a competitive advantage in its use, others do not consider the LFP battery to be suitable for long-haul transport due to its lower energy density, but rather for regional transport. They initially want to continue using NMC batteries in long-haul trucks. Others assume that the properties of both battery technologies will converge in the coming years.

VEHICLE MANUFACTURERS DO NOT EXPECT SOLID-STATE BATTERIES TO BE READY FOR SERIAL PRODUCTION FOR SOME YEARS YET.

A significant technological leap in battery technology is anticipated with the development of solid-state batteries. Their higher energy density could enable longer ranges, lower costs, shorter charging times, and an extended lifespan. Additionally, by eliminating liquid electrolytes, these batteries would be far less affected by temperature, significantly reducing battery aging. However, it is anticipated that several years will pass before this new technology is ready for industrial-scale production.

Figure 5

Predicted battery capacity for heavy battery-electric vehicles (> 12 t)



Source: Information provided by the truck manufacturers involved. Own representation.

MANUFACTURERS ARE PURSUING VARIOUS STRATEGIES TO ENSURE THE SUPPLY OF THE NECESSARY BATTERIES. IN GENERAL, THERE IS A HIGH DEPENDENCY ON CHINESE SUPPLIERS.

A key factor for the adoption of battery-electric trucks is a reliable supply of batteries. All manufacturers agree that the dependency on Chinese battery suppliers is very high. As a result, truck manufacturers are responding to this dependency with different strategies. Some are working to establish their own production capacities or are entering into joint ventures to produce battery cells. Other manufacturers are securing agreements with multiple battery producers to reduce their dependency. Additionally, some manufacturers are pursuing a diversification strategy, involving long-term contracts, multiple suppliers, flexible supply agreements, and the use of different cell chemistries.

THE MARKET LAUNCH OF MCS-CAPABLE BATTERY-ELECTRIC TRUCKS WILL BEGIN IN 2025.

Manufacturers believe that the adoption of the Megawatt Charging System (MCS) will make battery-electric trucks viable for long-haul transport. The standardisation process for the new charging system, which will capable of supporting charging capacities of 1 MW and beyond, is reportedly nearing completion. Some manufacturers have already announced the start of large-scale production of MCS-capable battery trucks by 2025. Other manufacturers do not want to install MCS charging inlets until 2026 or 2027. Some manufacturers want to gradually increase the charging capacity of the vehicles, starting at up to 750 kW and then increasing to 1,000 kW and more in the following years. They also consider charging capacities of up to 1,500 kW to be conceivable. Other manufacturers consider charging capacities of over 1,000 kW to be technologically feasible, but the thickness and weight of the charging cable required for this are considered to be cumbersome and impractical. Since MCS charging can also be used for lower charging capacities, some manufacturers predict that from a certain point in time, only MCS charging will be used. However, a long transition period is assumed.

According to the majority of manufacturers, the MCS charging inlet is expected to be installed in trucks used by customers in long-haul transport in the next few years. However, it would also make sense to use MCS charging in regional transport for heavy battery-electric trucks used in three-shift operations. Otherwise, CCS (Combined Charging System) charging inlets would be installed as standard in vehicles used in regional and distribution transport. This is because the established CCS charging standard will continue to be the norm for charging at depots due to its lower cost and complexity. Manufacturers estimate the maximum vehicle-side charging power for CCS charging to be between 350 kW and 400 kW. For depot charging, especially overnight charging, two-digit charging powers would also be sufficient in many cases. Some truck manufacturers also see cases in which normal charging with an AC charging device is sufficient.

HEAVY BATTERY-ELECTRIC TRUCKS FOR REGIONAL AND DISTRIBUTIVE TRANSPORT WILL CONTINUE TO BE CHARGED ACCORDING TO THE CCS STANDARD.

Most manufacturers intend to continue installing a CCS charging inlet in every truck they sell, even if the vehicles are used for long-haul transport. This is because CCS is expected to remain important in the long term due to its compatibility and long-haul trucks will also rely on CCS charging standard, particularly in the depot, but also at public charging points. A small number of manufacturers want to install MCS charging inlets as standard in their vehicles in the future and only install a CCS charging inlet if the customer specifically requests it.

Regarding the position of MCS charging inlets on vehicles, there is a recommendation that they be installed on the left side of the vehicle.[4] In contrast, there is no such agreement among manufacturers on a specific vehicle side for the CCS charging inlet. For most heavy battery-electric trucks, the CCS charging inlet is located on the right or left side of the driver's cab. Almost all manufacturers now offer the option of installing the charging inlet at the rear of the vehicle at the customer's request.

CUSTOMERS PREFER A FLEXIBLE USE OF THEIR VEHICLES AND TYPICALLY PREFER LARGE BATTERY CAPACITIES AND THE INSTALLATION OF BOTH TYPES OF CHARGING INLET.

The battery accounts for the most expensive and heaviest part of the battery-electric truck. In view of this, the majority of truck manufacturers surveyed want to continue to offer a modular and scalable number of battery packs in their vehicles in the future. This would enable customers to choose the optimal or sufficient battery capacity for their application, thereby saving costs and increasing the available payload. Despite the additional costs incurred, manufacturers see a tendency for their customers to choose a larger number of battery packs. According to the manufacturers' interpretation, transport, freight and logistics companies seek to maintain flexibility in the use of their vehicles due to uncertainty about future order volumes and shifting customer demands and the lack of a public charging infrastructure. The manufacturers assume that there is a similar tendency with regard to the two charging standards and the installation of the charging inlets. If customers are given the choice, they would 'play it safe' and have both a CCS and an MCS charging inlet installed in their vehicles.

[4] See www.charin.global/media/pages/technology/knowledge-base/c708ba3361-1670238823/whitepaper_megawatt_charging_system_1.0.pdf

THE AFIR PROVISIONS REPRESENT THE ABSOLUTE MINIMUM IN TERMS OF SPEED AND SCOPE OF EXPANSION FOR TRUCK CHARGING INFRASTRUCTURE.

The Alternative Fuels Infrastructure Regulation (AFIR) requires EU member states, among other things, to set minimum targets for the establishment of charging infrastructure for heavy-duty vehicles. The targets can be met through public or private investment. Truck manufacturers are sceptical as to whether the EU's minimum requirements for the necessary market ramp-up of climate-friendly commercial vehicles will be sufficient. While the 60 km distance between charging parks on the trans-European transport networks, as called for by AFIR, is considered appropriate, there are concerns that the required number of charging points at the locations will not be sufficient from as early as 2030 and will slow down the market ramp-up. Furthermore, criticism is levelled at the fact that AFIR is currently not making any specifications for MCS charging infrastructure.

The manufacturers surveyed base their demands for a charging network on the current calculations of the European vehicle manufacturer association ACEA.[5] Following the amendment of the European CO_2 standards, the association is currently calling for the EU-wide deployment of at least 50,000 public charging points for heavy-duty vehicles by 2030. This should include around 35,000 public MSC charging points. For Germany, which is expected to play a pioneering role in the deployment of charging infrastructure, it would mean the construction of 10,000 public MCS charging points by 2030.

A MAJORITY OF CHARGING PROCESSES WILL REMAIN AT NON-PUBLIC CHARGING INFRASTRUCTURE IN THE DEPOT.

Truck manufacturer do not yet have a clear understanding of how the ratio of depot charging to public charging will evolve in practice in the future. For the next few years, a ratio of 80 percent depot charging to 20 percent public charging is initially assumed across all applications. Looking ahead, the manufacturers expect that in 2030, almost 100 percent of vehicles in distribution and regional transport will still be charged at depots. As the availability of publicly accessible charging infrastructure increases, the share of public charging will increase. However, manufacturers estimate that depot charging will continue to account for up to 70 percent of the energy consumed in regional transport. They also assume that depot charging will account for 50 percent or more of long-haul transport in the future.

Manufacturers state that the reason for the central importance of depot charging is that it is both cheaper and easier to plan than public charging. The electricity price can be negotiated independently with the local energy supplier and is known. In addition, self-generated electricity from renewable sources can be used. With public charging, however, one is dependent on the price specifications of the charge point operators.

[5] See www.futuredriven.eu/wp-content/uploads/2024/04/ACEA_Trucks-and-Buses-Manifesto.pdf

TRUCK MANUFACTURERS ARE SUPPORTING THEIR CUSTOMERS IN THE CHANGEOVER WITH A COMPREHENSIVE PACKAGE OF BATTERY-ELECTRIC TRUCKS AND CHARGING INFRASTRUCTURE SOLUTIONS.

The transition from the familiar diesel truck to the innovative battery-electric truck presents a major challenge for the logistics industry. For most logistics companies, charging infrastructure and the associated energy issues are not part of their core business. In view of the urgent requirements imposed by the European CO_2 standards (see Chapter 1) and the existing need for support among their customers, many truck manufacturers are currently expanding their range of consulting and support services. The sale of vehicles is complemented by a more or less comprehensive range of charging infrastructure solutions.

In addition to a wide range of consulting services (e.g. for site planning, applying for a grid connection, project management, hardware installation, financing, etc.), many truck manufacturers have added services from charger manufacturers and infrastructure providers to their portfolio in the area of depot charging infrastructure, with whom they have entered into cooperative agreements. Some truck manufacturers have set up new business units and now also offer their customers turnkey solutions in the field of charging infrastructure, some of which even include battery storage for using self-generated electricity from photovoltaic systems.

Manufacturers are also involved in the area of public charging infrastructure: in addition to the joint ventures of several manufacturers to develop public charging infrastructure in Europe, individual manufacturers are planning to set up public charging infrastructure at their branches and service centres and have it managed by cooperating charge point operators. In addition, individual manufacturers are setting up a roaming platform for partnerships with various charge point operators in Europe. This will enable customers to charge their battery trucks at fixed prices in the emerging network using a charging card.

Hydrogen drives and hydrogen refuelling infrastructure

With the differentiation of drivetrain strategies, the topic of hydrogen is becoming more important for manufacturers' sales planning due to the additional use of the fuel in combustion engines (see chapter 1). While individual small series of fuel cell trucks and hydrogen combustion engines are already available, the majority of manufacturers do not expect large-scale production of hydrogen trucks to be ready until the end of this decade. Compared to the results of the cleanroom talks in 2022, the forecasts have been pushed back. This is also reflected in the predicted sales figures (see Figures 1 and 2). A significant increase in the number of fuel cell trucks and trucks with hydrogen combustion engines sold does not begin until 2027/2028, when it then rises relatively steeply towards the end of the decade.

The variety of onboard hydrogen storage options pursued by manufacturers continues to be discussed as a challenge for infrastructure deployment. Depending on the manufacturer, hydrogen is to be stored on board the truck at either 350 bar, 700 bar or in liquid form (sLH_2). The arguments that the respective manufacturers cite in favour of the storage option they have opted for have essentially not changed in the last two years. The lower costs and lower energy requirements for hydrogen supply are said to speak in favour of 350 bar. A higher pressure level is associated with higher energy consumption and thus with a higher hydrogen price at the filling station. For sLH_2, the supply chain is not yet technologically mature and process steps such as liquefaction are still very expensive.

AMONG THE VARIETY OF HYDROGEN STORAGE TECHNOLOGIES, 700 BAR IS EMERGING AS A POSSIBLE COMMON DENOMINATOR AMONG MANUFACTURERS OF HYDROGEN TRUCKS FOR LONG-HAUL APPLICATIONS.

On the other hand, long-haul suitability and flexibility are key arguments for the manufacturers who are backing 700 bar and sLH_2. In their view, this is where the real strength of hydrogen trucks lies, especially in comparison to battery trucks. Cryogenic liquid hydrogen promises an even greater range for fuel cell trucks. Another argument is the delivery of hydrogen to the filling stations, since liquid hydrogen can be supplied in high volumetric density. The manufacturers are aware that evaporation losses will be unavoidable with liquid hydrogen when the vehicles are stationary for long periods.

This year's cleanroom talks give the overall impression that 700 bar could be accepted by manufacturers as a common onboard storage option. The 700-bar system is seen as the most sensible choice from a cost and benefit perspective, and a 700-bar tank would also make it possible to use the existing 350-bar truck hydrogen refuelling infrastructure. Furthermore, current discussions give the impression that there is greater openness among manufacturers to using hydrogen storage solutions other than the preferred option if necessary, should these become established as standard solutions in the deployment of hydrogen refuelling infrastructure.

Another storage option is cryocompressed (CcH_2), which is not yet in practical use. While some manufacturers see the greatest potential for use in long-haul trucks, this is not an option for others. This is explained not only by the high costs for storage and filling station infrastructure, but also by the fact that CcH_2 is not considered in the AFIR.

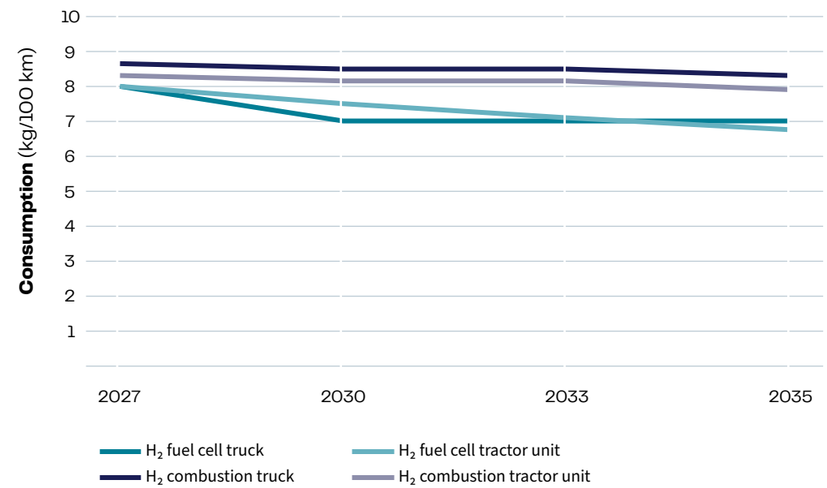
FUEL CELLS REQUIRE FURTHER DEVELOPMENT. HOPES REST ON A NEW GENERATION OF THE TECHNOLOGY.

Contrary to the expectations expressed by European manufacturers in the last cleanroom talks, the technology and market maturity of fuel cells for use in trucks by the end of the decade seems to be delayed. The fuel cell lacks the robustness and stability for demanding use in trucks, and in particular, the serial standard for use in long-haul transport has not yet been achieved. There is also a need for development in terms of costs, system efficiency, cooling and service life. Even for the series-produced fuel cell vehicles, already in use today in regional transport, the operating periods of battery-electric trucks cannot be guaranteed, which is currently compensated by some manufacturers by means of a scheduled change of the fuel cell after a certain mileage.

Manufacturers for whom fuel cell trucks play a central role in their drivetrain strategy are pinning their hopes on a more efficient and cost-effective new generation of fuel cells, which is currently being developed. Improvements in energy density, power, compactness and, in particular, costs are expected to bring battery and fuel cell truck prices closer together in the future.

Figure 6

Average consumption of heavy-duty hydrogen-powered vehicles (> 12 t)



Source: Information provided by the truck manufacturers involved. Own representation.

TRUCKS WITH INTERNAL HYDROGEN COMBUSTION ENGINES: MORE AFFORDABLE TO BUY BUT DOWN ON EFFICIENCY COMPARED TO FUEL CELL TRUCKS.

With the recognition as emission-free drivetrain as part of the amendment of the European CO_2 standards in spring 2024, almost all manufacturers have included the internal hydrogen combustion engines in their drivetrain strategy. By using hydrogen in a modified combustion engine, manufacturers see an opportunity to achieve climate protection requirements relatively inexpensively. The combustion engine is a proven and mature technology, and the advantages of the hydrogen combustion engine are that it is considered to be robust, that it can be maintained in existing workshops and that it is well accepted by customers. In addition, the hydrogen purity level does not have to meet the high requirements for use in fuel cells.

The main challenge in modifying a conventional diesel truck combustion engine for use with hydrogen lies primarily in adapting the injection system and developing the corresponding combustion process. Both intake manifold and low-pressure direct injection (LPDI) utilise the Otto engine principle with spark ignition. Both processes are at an advanced stage of development and have already been tested on the road. However, they have disadvantages in terms of efficiency, which is why high-pressure direct injection (HPDI) is also currently being developed along the lines of the diesel engine principle – self-ignition, or pilot injection. As with the conventional combustion engine, the development and production of the components necessary for the modification and optimised for hydrogen operation are undertaken with the help of supplier companies.

Even a hydrogen combustion engine that has been optimised in terms of efficiency is subject to thermodynamic limits, which is why it will continue to have efficiency disadvantages compared to the use of hydrogen in fuel cells (see Figure 6). According to the manufacturers, a truck with a hydrogen combustion engine consumes an average of 2 kg more hydrogen per 100 km than a fuel cell truck. This means that, due to its significantly lower purchase price, the hydrogen combustion engine would be the more economical hydrogen-powered drivetrain up to a certain mileage threshold. However, for the annual mileage typical of long-haul transport, it would be the fuel cell truck.

The manufacturers who see hydrogen as an important element of their drivetrain strategy consider it the responsibility of policymakers to establish hydrogen fuelling stations. The industry is investing billions in vehicle development, and the expectations are that government should invest accordingly in infrastructure deployment. Such investments would send a clear signal to industry and its customers that government considers the use of hydrogen in the transport sector to be relevant. Furthermore, it is strongly desired that the deployment of the hydrogen infrastructure should move ahead swiftly.

The European AFIR stipulates that by the end of 2030, a hydrogen refuelling station must be built every 200 km along the trans-European transport networks, with additional refuelling stations at urban and multimodal hubs. For many of the manufacturers surveyed, the AFIR requirements are initially sufficient.

MANUFACTURERS BELIEVE THAT THE GOVERNMENT SHOULD PROMOTE THE DEPLOYMENT OF HYDROGEN FILLING STATIONS MORE RAPIDLY.

TO DATE, MANUFACTURERS' OWN INVOLVEMENT IN THE FIELD OF HYDROGEN FUELING INFRASTRUCTURE IS STILL LIMITED.

According to one manufacturer, these values would be sufficient to supply 10,000 to 15,000 hydrogen-powered trucks, which would be a good starting point for the further market ramp-up after 2030. It is important that the capacities and system design (including compressors) of hydrogen refuelling stations meet existing demand and that enough hydrogen is stored. In addition, redundancies must be in place to ensure that vehicles are supplied. Another group of manufacturers considers the AFIR targets to be insufficient and would like to see more ambitious expansion targets.

In contrast to the activities that the manufacturers are developing to support their customers in the area of truck charging infrastructure, few activities in the area of hydrogen infrastructure were mentioned in the cleanroom talks. The most concrete commitment is among those manufacturers who are involved in the infrastructure operator H2 MOBILITY in Germany, or are part of the pan-European H2Accelerate initiative of vehicle manufacturers and infrastructure providers.

4 Outlook

Dynamic market development and ambitious climate protection targets

By 2030, around a third of the mileage in heavy-duty freight transport is to be electric. To achieve this goal, rapid transformation will be required across the vehicle, infrastructure, and logistics industries. This evaluation of this year's cleanroom talks reaffirms the central result of the last such talks in 2022: According to the sales figures forecast by truck manufacturers, the market launch of climate-friendly commercial vehicles will take place at a rapid pace by the end of this decade. In particular, the major advances in the maturity and robustness of battery technology are making this swift change possible. The range of heavy-duty vehicle models with climate-friendly drives will continue to grow quickly. In addition to the predicted increase in vehicle sales, achieving the ambitious climate protection targets will require a convincing range of advice and support services for users, a conducive regulatory framework and the speedy deployment of infrastructure.

Making use of the results

With the call for tenders for a fast-charging network for trucks along the federal motorways published in September 2024, the BMDV, in collaboration with the National Centre for Charging Infrastructure and Autobahn GmbH, is laying the groundwork for the use of battery-electric trucks on long-haul routes. The demand analysis for the roll-out planning and the call for tenders for the fast-charging network for trucks is based on the results of the cleanroom talks conducted in 2022. The current talks confirm the central role of battery-electric drives in the market ramp-up of climate-friendly commercial vehicles. The new results will be incorporated into future demand analysis for the fast-charging network for trucks. The findings also provide important indicators for the financing and funding measures envisaged by the BMDV for the truck charging infrastructure on company premises, transshipment hubs and in industrial parks, as set out in the Charging Infrastructure Masterplan II. The evaluation of the cleanroom talks will also be incorporated into a hydrogen demand plan for the N3 segment for 2030 and beyond, which is currently being developed. This is the basis for planning a comprehensive basic network of hydrogen refuelling stations for commercial vehicles in Germany.

The targeted regulatory framework already created by the BMDV in recent years can be expanded on the basis of the results of the cleanroom talks. In particular, the adaptation of existing regulations can further support the market ramp-up of alternative, climate-friendly drivetrains.

Ongoing dialogue with manufacturers

The transformation of road freight transport to climate-friendly drives requires the joint and coordinated action of all stakeholders. With this in mind, all the manufacturers involved in the talks welcome the dialogue. Alongside the dialogue itself, the results of the cleanroom talks enable the provision of basic information for other stakeholders in the transformation process. The results documented in this report are helpful not only for politicians, but also for the energy industry, infrastructure operators and users. In this sense, the participation of truck manufacturers in the cleanroom talks is welcomed and appreciated by the BMDV. In view of the dynamics of the market ramp-up, ongoing technological development and changing framework conditions, the BMDV intends to hold cleanroom talks with truck manufacturers again in two years.

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