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

Evaluation of the 2022 Cleanroom Talks with truck manufacturers

Contents

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Summary

A decisive factor for ensuring the rapid market ramp-up of heavy-duty vehicles (>12 t) with climate-friendly alternative drivetrains is the deployment of refuelling and charging infrastructures in line with the demand and synchronized with the ramp-up of the vehicles. Information on the vehicle ramp-up in the coming years can be obtained from the projected sales figures from truck manufacturers. These sales figures and the strategic orientation behind them can be acquired in confidential talks in compliance with applicable antitrust law. The Federal Ministry for Digital and Transport (BMDV – Bundesministerium für Digitales und Verkehr) and NOW GmbH conducted so-called cleanroom talks with several truck manufacturers in the summer of 2022. This evaluation summarises the results.

Of the three emission-free drivetrain options considered in the BMDV's "Overall Approach to Climate-Friendly Commercial Vehicles" (battery, hydrogen fuel cell, overhead line), electric drivetrains with battery and fuel cell are the focus of the manufacturers' alternative drivetrain strategies. One group of manufacturers focuses its planning on the establishment of an emission-free drivetrain only ("one-pillar strategy"). The focus of this strategy is on the battery-electric truck. Another strategy is being pursued by a group of truck manufacturers who are pushing battery and fuel cell drivetrain simultaneously ("two-pillar strategy"). The representatives of the one-pillar strategy argue that the low operating costs of battery trucks lead to a better total cost of ownership (TCO) than those of hydrogen and fuel cells. In addition, the use of battery trucks would achieve cost parity with conventional diesel trucks in a relatively short period of time. Representatives of the two-pillar strategy point to the multitude of applications and usage scenarios in road freight transport. Particularly for long-haul transport and international, cross-border traffic, hydrogen and fuel cells would be needed as a suitable drivetrain option.

Despite these different alternative drivetrain strategies, with a view to the EU heavy-duty vehicles' CO_2 standards for the year 2025, the focus is initially on battery-powered trucks for both groups due to their technological availability. Battery-powered trucks are already considered to be sufficiently ready for regional and distribution transport. The representatives of the strategy focusing on battery-powered trucks also believe that the technological development path for long-haul transport is sufficiently defined by the coming MCS standard[1] and that development leaps in the battery's durability and service life are in sight.

For most manufacturers pursuing this drivetrain technology, the technology and series-production readiness of the fuel cell truck is not expected until the second half of the decade. The field of application of the fuel cell truck is mainly long-haul and heavy-duty transport. There is a need for development especially in the robustness and system efficiency of the fuel cell. In addition, there is a need for development and standardisation in hydrogen storage technology, where several technological paths are being pursued (350 bar, 700 bar, liquid hydrogen (LH_2)). The availability of green hydrogen at competitive prices is cited by the manufacturers as a key challenge.

The responses on overhead line technology give a mixed picture. No manufacturer places its strategic priority on overhead line technology. Some manufacturers are fundamentally opposed to any further technology. Others see few problems in integrating an additional charging interface into a battery truck if overhead line technology is successfully established – especially if the overhead line infrastructure is adequate.

Yet regardless of the alternative drivetrain strategy chosen, truck manufacturers agree that infrastructure deployment is the most important building block for the establishment of climate-friendly commercial vehicles – this development must take place in an extremely timely manner. In view of the European CO_2 standards for 2025 and the ambitious climate protection goals for 2030, a rapid market ramp-up is necessary in a very short period of time. The manufacturers also see reliable and long-term transparent financial incentives for the switch to climate-friendly heavy-duty vehicles as particularly important for the emerging market development. With regard to the planned CO_2 toll, a clear differentiation of the toll rates between conventional and emission-free trucks is being demanded.

The European heavy-duty vehicles' CO_2 standards are cited as a decisive driver for the commitment of truck manufacturers in the area of climate-friendly commercial vehicles. The truck manufacturers have aligned their previous drivetrain strategies and product policies with the current European targets. A moderate increase in the EU heavy-duty vehicles' CO_2 standards for 2030 is already being factored into the truck manufacturers' considerations today. An excessive tightening of the targets for 2030 is classified as a threat to the existence of the industry. However, the analysis of the sales figures mentioned in the cleanroom talks as well as the company-specific and publicly communicated climate protection targets of individual companies prove that the manufacturers are already expecting very high shares of alternative drivetrains by 2030. These figures go beyond the existing EU targets, in some cases significantly. According to given information of the manufacturers, around 75% of new registrations of heavy-duty vehicles in Germany and around 60% in Europe will be emission-free by 2030.

[1] MCS = Megawatt Charging System

Introduction

For the rapid market ramp-up of heavy-duty vehicles with climate-friendly alternative drivetrains, the demand-oriented deployment of the refuelling and charging infrastructure, synchronized with the ramp-up of the vehicles, is a decisive factor for success. The coordination of infrastructure deployment and the market ramp-up of vehicles is one of the core tasks that the Federal Ministry for Digital and Transport (BMDV – Bundesministerium für Digitales und Verkehr) has set itself in the context of the "Overall Approach to Climate-Friendly Commercial Vehicles" ("Gesamtkonzept klimafreundliche Nutzfahrzeuge") published in November 2020. The Overall Approach is the BMDV's central roadmap for achieving the ambitious climate protection target in road freight transport: One third of the mileage in heavy-duty road freight transport is to be provided electrically by 2030.

To warrant a coordinated and harmonised deployment of the infrastructure and to ensure the necessary demand planning, information on the projected sales figures of the truck manufacturers in the coming years is needed, alongside various other parameters. This information could be obtained within the scope of cleanroom talks organised in compliance with antitrust law.

From June to August 2022, representatives of the Federal Ministry for Digital and Transport (BMDV), NOW GmbH as well as a law firm commissioned to ensure compliance with antitrust regulations held such cleanroom talks with several truck manufacturers for the first time. The manufacturers involved represent 95% of the market for heavy-duty vehicles of the EC vehicle class N3 (> 12 t) in Germany.

Within this context, the manufacturers provided data on their planned sales figures for trucks (> 12 t) in the next few years as well as on the future technical characteristics of the vehicles (e.g. range). Additionally, individual discussions were held with the manufacturers. As part of a structured interview, the strategic evaluation of the technology options, an assessment of the regulatory framework conditions and the infrastructure requirements were queried. The quantitative data was then anonymised and aggregated by the law firm. The qualitative statements obtained in the interviews, which were similarly anonymised, were also evaluated by the BMDV and NOW GmbH.

In this report, the results of these cleanroom talks are summarised. The evaluation of the quantitative data is mainly presented in graphs. The evaluation of the qualitative statements from the interviews is summarised in the text.

Especially in the current early market phase, the retrofitting of diesel vehicles can make an important contribution to the ramp-up of climate-friendly heavy-duty vehicles. Nevertheless, the retrofitting of trucks was not a subject of the cleanroom talks and is therefore not considered in this report.

The evaluations provide important insights for the planning of the deployment of refuelling and charging infrastructure for zero-emission heavy-duty vehicles. In addition, they also provide information that can serve as a basis for the decisions of other central players and stakeholders for the market ramp-up. In addition to infrastructure providers and the energy industry, these also include users such as companies in the transport, freight forwarding and logistics sectors.

As part of the implementation of the Overall Approach to Climate-Friendly Commercial Vehicles, it is likely that the BMDV will hold annual cleanroom talks with truck manufacturers.

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

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

Manufacturers pursue various strategies – but battery-powered trucks are the main focus of them all

To achieve the climate protection targets for road freight transport, it is essential that truck manufacturers push ahead with the market ramp-up of alternative drive technologies for heavy-duty vehicles. Technological advances in recent years and changes in the framework conditions have already generated a high level of interest and commitment on the part of manufacturers.

Particularly with regard to infrastructure deployment, the important question arises as to how the three emission-free drivetrain alternatives (battery, hydrogen fuel cell, overhead line) are fundamentally assessed strategically by the manufacturers and what consequences the assessment has on model policy and sales figures.

Of the three possible emission-free drivetrain options, electric drives using batteries and fuel cells take the central role in the strategies of the manufacturers. Overall, the manufacturers' strategic approaches can essentially be divided into two categories:

- One group of manufacturers concentrates its efforts on the establishment of an emission-free drivetrain only ("one-pillar strategy"). The main focus of this strategy is on battery-electric trucks.
- Another strategy is being pursued by truck manufacturers who are pursuing battery and fuel cell drivetrains in parallel ("two-pillar strategy").

BATTERIES AND/OR FUEL CELLS ARE AT THE CENTRE OF THE COMPANIES' ALTERNATIVE DRIVETRAIN STRATEGIES. THE TRUCK MANUFACTURERS ARE PURSUING EITHER A ONE-PILLAR OR A TWO-PILLAR STRATEGY.

Although the two strategic approaches have similar perceptions and assessments of future customer requirements for alternative drivetrains, they are based on different expectations in terms of the costs and performance of the technologies. For example, proponents of the one-pillar strategy argue that the low operating costs of battery trucks lead to a better total cost of ownership (TCO) than those of hydrogen and fuel cells. In addition, the use of battery trucks would reach cost parity with conventional diesel trucks in a relatively short period of time. On account of the dominance of operating costs in an economic consideration, this argument is given a high priority by the representatives of this strategy. It is now deemed that the performance of the technology (in the sense that it can be used like a diesel truck) is given, assuming that there is a sufficient charging infrastructure in place. Representatives of the two-pillar strategy point to the multitude of applications and usage scenarios in road freight transport. Especially for long-haul traffic and international, cross-border transport, a second drivetrain option is needed in the form of hydrogen and fuel cells. Customers require a choice of how and for which purposes and mileage they use what technology.

In addition to these considerations, the key factor for the strategic evaluation of the alternative drivetrain options is whether the regulatory requirements in the core markets that are relevant for the manufacturer can be met with a particular drivetrain option.

Even if manufacturers have made a strategic commitment to one or two alternative drivetrains, this does not mean that other alternative drivetrain and fuel options are completely disregarded. As part of their corporate technology monitoring, manufacturers are also observing other options, trialling them on test benches or investigating them in research projects.

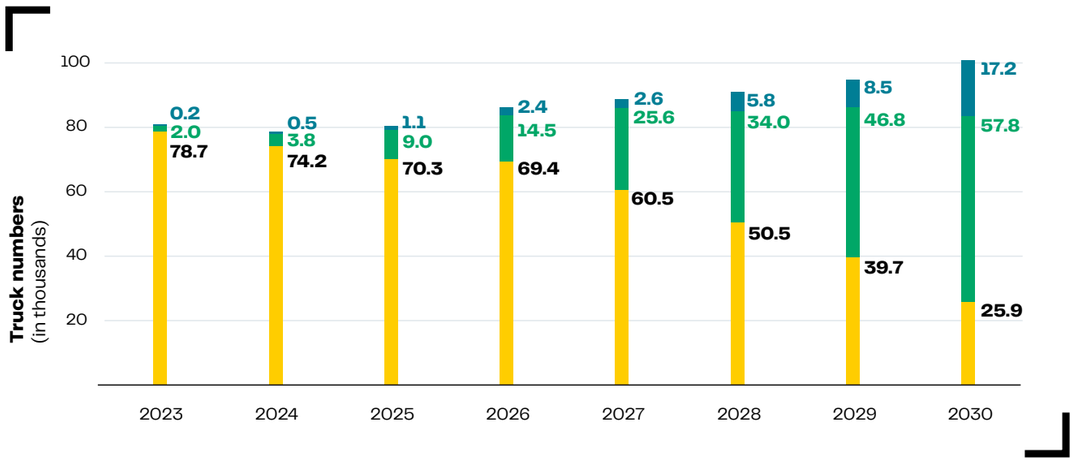
During the discussions, individual manufacturers mention that natural gas (CNG/LNG) or biogas are part of achieving their company's climate protection targets they have set for themselves.[2]

In view of the 2025 targets of the EU CO_2 standards for heavy-duty vehicles, the truck manufacturers are focusing on battery-electric trucks, despite different alterative drivetrain strategies, because of the technological maturity and availability on the market. Accordingly, the companies have made investment decisions for the production of battery trucks.

TO MEET THE CURRENT EU CO_2 STANDARDS FOR 2025, ALL MANUFACTURERS ARE FOCUSING ON THE BATTERY TRUCK.

Figure 1

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



Notes on uncertainty due to incomplete market coverage:
– Data is not available for all drivetrain types, manufacturers and years.
– For the second half of the decade, the response rate in terms of current market shares is 95%.
– For fossil fuel-based drivetrains, the response rate was between 70% and 90% by 2025.

For better readability, the low sales figures for PHEVs, H2 combustion engines and natural gas (CNG/LNG) are not listed.

[2] Manufacturers have also reported sales figures for heavy-duty vehicles powered by natural gas (CNG/LNG). The projected sales figures between 2026 and 2030 for Germany are in the mid three-digit range per year. In Europe, the figures are in the three-digit range from 2023 and 2025, growing to a mid-four-digit number of vehicles per year in the years between 2026 and 2030.

SUPPORT FOR THE OVERHEAD LINE IS LACKING FROM THE TRUCK INDUSTRY.

The technological and series maturity for fuel cell trucks is not anticipated by most manufacturers investing in this drivetrain technology until the second half of the decade. Manufacturers who are pursuing a second drivetrain option with the hydrogen fuel cell see the battery-electric truck as the technical basis for the fuel cell truck, because important technical components of the battery truck would also be used in the fuel cell truck in the future.

Responses from the cleanroom talks paint a mixed picture in terms of support from truck manufacturers for the overhead line option. No manufacturer is placing its strategic priority on overhead line technology. There are manufacturers who clearly express a negative attitude towards further technologies. Others see little problem in integrating an additional charging interface into a battery truck if overhead line technology is successfully established. However, even in ambitious hypothetical expansion scenarios (2,000 km by 2030 and 3,000 to 4,000 km of overhead line by 2035), the sales figures do not show any fundamentally different strategic assessments of the overhead line option.

Two manufacturers are currently actively working on the technology and plan to build small series of overhead line trucks in the event of a comprehensive trial of dynamic charging with the aid of overhead lines. Even in the hypothetical ambitious expansion scenario given in the discussions, the manufacturers indicate sales figures for overhead line trucks in the lower four-digit range. All manufacturers agree that if this option is pursued, a combination of batteries and overhead lines would be the most effective.

During the talks, advantages of overhead line technology were mentioned: a higher level of energy efficiency, less space requirements, time savings due to the elimination of charging and refuelling processes. For the majority of manufacturers, however, the counter arguments outweigh the advantages. The main opposing argument is that the construction of the overhead line infrastructure on a larger scale would probably take more time than the construction of the infrastructure for other technologies. Reference is made to the necessity of having to make greater up-front financial contributions for overhead line infrastructure. While a business case for the charging and H_2 refuelling infrastructure is given from a relatively small number of vehicles, considerable investments must be made in advance for the overhead line infrastructure due to the high fixed-step cost. Moreover, this would need to be undertaken on a Europe-wide basis.

Although this applies to refuelling and charging infrastructure as well, the need for Europe-wide deployment was particularly emphasised in the talks. This is not only necessary for cross-border transport, but also for high sales figures and the economic viability of this technological option, as well as for the secondary use of the vehicles.

Decisive factor for strategic evaluation: Technological maturity

The assessment of technological maturity compared to conventional diesel drivetrains plays a central role in the strategic evaluation of alternative drivetrains as well as the market ramp-up and the timing of infrastructure deployment.

In the cleanroom talks, all the manufacturers who rely on battery-electric drivetrain as part of their one-pillar or two-pillar strategy attest the readiness for series production of battery-electric trucks with regard to local and regional transport. When looking at long-haul transport (over 500 km), there are different assessments. Some manufacturers believe that all fundamental technological questions have been resolved for battery-powered trucks. The MCS charging standard, which is crucial for use in long-haul transport, is well on its way. For other manufacturers, there is still a considerable need for development of the battery truck regarding long-haul transport. The characteristics of a tractor unit with a diesel engine are seen as a benchmark. There is a particular need for development in the stability and service life of the battery and the stability of the entire electric drivetrain (see Chapter 3).

THE TECHNOLOGICAL AND SERIES PRODUCTION READINESS OF THE BATTERY-POWERED TRUCK IS SEEN AS GIVEN FOR REGIONAL AND DISTRIBUTION TRANSPORT. THE TECHNOLOGICAL DEVELOPMENT PATH IS ALREADY DEFINED FOR LONG-HAUL TRANSPORT. HOWEVER, TO ACHIEVE THE ROBUSTNESS AND CHARACTERISTICS OF A DIESEL TRUCK, FURTHER DEVELOPMENT STEPS ARE NEEDED.

THE TECHNOLOGICAL MATURITY OF FUEL CELL TRUCKS FOR LONG-HAUL TRANSPORT IS SEEN AS BEING ACHIEVABLE IN THE SECOND HALF OF THE DECADE. IN ADDITION TO THE NEED FOR TECHNICAL DEVELOPMENT, THERE ARE STANDARDISATION ISSUES RELATING TO STORAGE AND TANK TECHNOLOGY.

The representatives of a two-pillar strategy do not anticipate the technological and series production maturity of the fuel cell truck until the second half of the decade. In addition to the technological development steps that still have to be taken, this reflects the fact that for most manufacturers the field of application of the fuel cell truck is essentially long-haul and heavy-duty transport. For long-hauls in particular, there is still a lack of stability and robustness in the technology, especially in the fuel cell itself. In addition, there is a need for development in hydrogen storage technology, where several technological paths are currently being followed (350 bar, 700 bar, LH_2). Standardisation issues are still unresolved here. This applies to the refuelling infrastructure as well, where new refuelling protocols are needed.

Despite the focus on long-haul transport, there are already a few series-produced fuel cell vehicles for regional transport that mainly rely on the 350-bar fuel cell technology.

Cost parity is decisive in cost-sensitive road freight transport

From the manufacturer's perspective, apart from further technical development and future economies of scale, three factors are decisive for cost parity with conventional diesel trucks in terms of total costs.

Firstly, financial incentives through funding programmes or a CO_2-differentiated toll are mentioned; secondly, regulatory framework conditions such as the EU heavy-duty vehicles' CO_2 standards; and thirdly, energy costs and their development. The latter would play a central role for heavy-duty vehicles, as the operating costs are particularly decisive for the economic efficiency of vehicle use. In this context, reference is made to the particularly high electricity prices in Germany compared to other European countries.

When it comes to achieving cost parity of the alternative drivetrain options in detail, the manufacturers' estimates differ significantly. While some manufacturers see cost parity for battery-powered trucks compared to diesel trucks as early as the middle of this decade, other manufacturers believe that subsidies and significant financial incentives (e.g. a widely spread CO_2 toll) will be necessary until the end of the decade. The assessments of fuel cell trucks also differ considerably. While for some, cost parity with conventional trucks is not feasible in the case of hydrogen due to the energy efficiency disadvantages and the resulting costs, others see cost parity as realistic due to economies of scale in vehicle production and especially in the case of an economic ramp-up of hydrogen production.

REGULATORY FRAMEWORK CONDITIONS AND ENERGY COSTS ARE DECISIVE FOR THE COST PARITY OF EMISSION-FREE DRIVETRAINS COMPARED TO CONVENTIONAL DIESEL TRUCKS.

2 Manufacturers' demands on the future framework conditions

The ramp-up can only succeed under ambitious political framework conditions that ought to stimulate and support the manufacturers simultaneously.

New technologies such as climate-friendly drivetrains need political and regulatory framework conditions that provide incentives for the technological transition. This also applies to the switch from emission-intensive, conventional diesel trucks to climate-friendly commercial vehicles with alternative drivetrains. With the Overall Approach to Climate-Friendly Commercial Vehicles, the BMDV has confirmed its intention to create a targeted regulatory environment that ensures the competitiveness of products and investment security. Against this background, the question arises as to what extent truck manufacturers consider existing and planned political and regulatory framework conditions to be beneficial to the market ramp-up.

THE RAPID AND RELIABLE DEPLOYMENT OF THE REFUELLING AND CHARGING INFRASTRUCTURE IS SEEN AS THE KEY TO SUCCESS FOR THE MARKET RAMP-UP OF HEAVY-DUTY VEHICLES WITH ALTERNATIVE DRIVETRAINS.

Regardless of the chosen alternative drivetrain strategy, there is agreement among truck manufacturers that the deployment of infrastructure is the most important building block for the establishment of climate-friendly commercial vehicles. The focus is particularly on the public refuelling and charging infrastructure. This must be deployed swiftly, because in view of the 2025 targets of the EU heavy-duty vehicles' CO_2 standards and the ambitious climate protection goals for 2030, a rapid market ramp-up is necessary and to be expected in a short time. With a view to their customers and the planning certainty they need when switching to a new vehicle drivetrain, the manufacturers demand a high level of reliability with regard to the deployment of refuelling and charging infrastructure. Customers need to know how infrastructure will be built by the middle of the decade and beyond. This must also be communicated jointly by industry and policymakers. The establishment of a joint venture between several manufacturers for the deployment of charging infrastructure can also be understood as a signal to customers that the large truck manufacturers are pursuing a long-term interest.

With regard to the importance of infrastructure deployment, an ambitious design of the "Alternative Fuels Infrastructure Regulation" (AFIR) is demanded from the EU, because the AFIR is considered to be of central importance for the necessary Europe-wide deployment of refuelling and charging infrastructure.

ESPECIALLY IN THE EARLY YEARS, PREDICTABLE AND CLEAR FINANCIAL INCENTIVES ARE ESSENTIAL FOR A RAPID MARKET RAMP-UP.

With reference to the low profit margins in logistics, truck manufacturers consider purchase incentives and the introduction of a CO_2 toll to be particularly important for the switch to climate-friendly commercial vehicles. According to the manufacturers, attractive funding of the purchase and clear incentives with regard to operating costs are particularly important in the first few years of market development, which is just beginning. This could be the main motivation for the changeover. Long-term plannability (4 to 5 years) is also pivotal in terms of financial incentives.

All manufacturers are in favour of differentiating the HGV toll according to the CO_2 emissions of the vehicles. They demand a clear differentiation of the toll rates between conventional and emission-free heavy-duty vehicles and a start of the CO_2 toll in 2023.

With regard to the BMDV funding programme on commercial vehicles with alternative, climate-friendly drivetrains and the associated fuelling and charging infrastructure (KsNI), it is noted that transparency on financial support in the coming years would create certainty and predictability for the market. In addition, the representatives of the two-pillar strategy emphasise that there is still a need for purchasing subsidies after 2024 and that the KsNI funding guideline should be extended beyond its current term until the end of 2024.

Existing CO_2 standards for heavy-duty vehicles are of great importance for 2025, with a view to 2030 the amendment is crucial

The adopted European CO_2 standards for new heavy-duty vehicles are key drivers for truck manufacturers to bring climate-friendly commercial vehicles with alternative drivetrains onto the market. It is important, with which technologies the manufacturers will meet the existing targets for 2025 and 2030. The EU Commission has announced an amendment to the regulation, which was first adopted in mid-2019. To what extent do the truck manufacturers expect the EU heavy-duty vehicles' CO_2 standards to be tightened and what consequences would this have for them?

THE EXISTING EU HEAVY-DUTY VEHICLES CO_2 STANDARDS ARE STRONG DRIVERS FOR INVESTMENT IN CLIMATE-FRIENDLY DRIVETRAIN SYSTEMS AND ARE ACHIEVABLE FOR TRUCK MANUFACTURERS – BY 2025 WITH MORE EFFICIENT DIESEL ENGINES AND BATTERY-POWERED TRUCKS, BY 2030 WITH BATTERY-POWERED AND FUEL CELL TRUCKS.

The European CO_2 standards are a decisive driver for the truck manufacturers' commitment to climate-friendly commercial vehicles. The looming penalties for non-compliance with the standards could, according to their own observations, be an existential threat for the companies.

The truck manufacturers have aligned their alternative drivetrain strategies and product policies with the current European requirements. Achieving the existing CO_2 standards was not raised as a problem in the cleanroom talks. Individual manufacturers go beyond the existing EU targets, in some cases significantly, with their plans and with their self-defined company-specific and publicly communicated climate protection targets.

The CO_2 standards for heavy-duty vehicles from 2025 onwards, which require manufacturers to reduce average specific CO_2 emissions per kilometre by at least 15% compared to 2019/20, are achievable both with efficiency measures for conventional diesel engines and with sales of battery electric trucks. Fuel cell trucks do not play a role for the manufacturers in achieving the 2025 targets. While the importance of efficiency measures for conventional diesel trucks (more efficient engines, improved rolling resistance and aerodynamics) is assessed differently by the manufacturers, all manufacturers that also offer diesel trucks are already planning high sales figures for battery-electric trucks for 2025. The majority of heavy-duty battery trucks will already be used in long-haul transport operations.

Climate-friendly heavy-duty vehicles are of paramount importance for achieving the EU heavy-duty vehicles CO_2 standards from 2030 onwards, for which a reduction of at least 30% compared to 2019/20 is specified as a requirement. While most of the representatives of the one-pillar strategy are fully committed to the battery truck and are planning corresponding sales figures, among the manufacturers who prefer a two-pillar strategy, the fuel cell truck will play an increasingly important role by 2030. It is still unclear what the distribution will look like in 2030 between battery and fuel cell trucks among these manufacturers. This would depend on the infrastructure available, energy prices and technical developments.

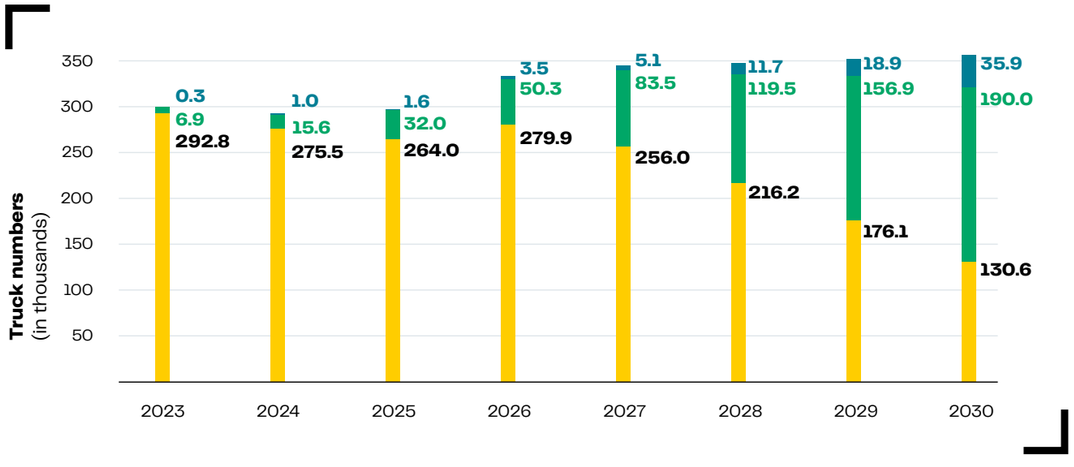
GERMANY IS A CRUCIAL SALES MARKET FOR TRUCK MANUFACTURERS IN ACHIEVING THE EU HEAVY-DUTY VEHICLES' CO_2 STANDARDS.

In the talks, the truck manufacturers clearly state that Germany is a decisive market for the ramp-up of climate-friendly commercial vehicles and the achievement of the CO_2 standards. This assessment is also reflected in the comparison of the stated sales figures for Germany (see Fig. 1) and for Europe (see Fig. 2). The shares of the two emission-free drivetrain options are higher in Germany than in Europe as a whole. Germany is one of the strongest markets for heavy-duty vehicles in Europe. In addition, there are expectations that Germany, as an automotive industry location and with its ambitious climate protection goals, will become a pioneer in the establishment of climate-friendly commercial vehicles through the early deployment of infrastructure and the creation of corresponding framework conditions.

Figure 2

Forecast sales figures for heavy-duty vehicles (> 12 t)

In Europe according to manufacturer data



Notes on uncertainty due to incomplete market coverage:
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– For fossil fuel-based drivetrains, the response rate was between 70% and 90% by 2025.

For better readability, the low sales figures for PHEVs, H2 combustion engines and natural gas (CNG/LNG) are not listed.

In view of the stricter CO_2 standards announced by the EU Commission as part of the “Fit for 55” programme, which have been in place since 2019, manufacturers almost universally expect a moderate increase in the direction of a 40% reduction for the year 2030. This increase in the target values is already being taken into account by manufacturers in their considerations. It was emphasised that a tightening of the standards must always be discussed in conjunction with the deployment of the refuelling and charging infrastructure required for the use of the vehicles.

A MODERATE INCREASE IN THE EU CO_2 STANDARDS FOR HEAVY-DUTY VEHICLES FOR 2030 IS ALREADY BEING TAKEN INTO ACCOUNT BY THE TRUCK MANUFACTURERS. A DRASTIC TIGHTENING OF THE TARGETS FOR 2030 IS VIEWED CRITICALLY, BECAUSE IT POTENTIALLY ENDANGERS THE INDUSTRY. HOWEVER, A LOOK AT THE PROJECTED SALES FIGURES WEAKENS THIS ARGUMENT.

A strong tightening of the EU heavy-duty vehicles’ CO_2 standards for 2030 in the direction of a doubling of the reduction targets is viewed critically by the manufacturers. Such a regulation could threaten the existence of the European truck industry if the ramp-ups were not feasible and high fines were imposed. There may possibly not be enough customers in the low-margin logistics sector to purchase the required number of emission-free heavy-duty vehicles by the end of the decade. The concerns expressed in the talks are put into perspective by the aggregated sales figures of the manufacturers for the year 2030 (see Fig. 2). According to the manufacturers’ plans, a large proportion of the heavy-duty vehicles coming onto the market in 2030 will already consist of battery or fuel cell trucks. It can be assumed that this share will vary from manufacturer to manufacturer and that higher standards will therefore have different effects on individual truck manufacturers.

3 Challenges of the various technological paths

THE BATTERY IS READY FOR SERIES PRODUCTION FOR USE IN TRUCKS FOR REGIONAL AND DISTRIBUTION TRANSPORT.

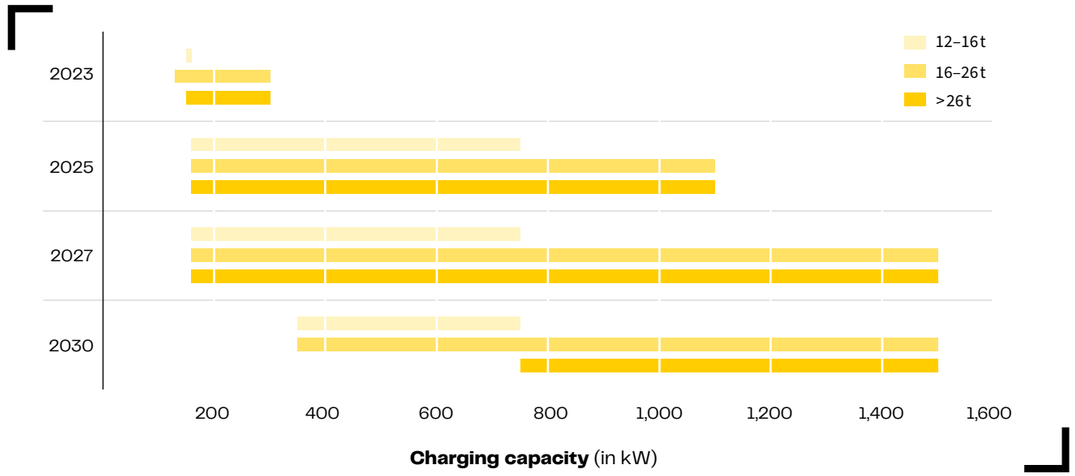
Another aim of the cleanroom talks was to generate up-to-date information on the status of the technology, the necessary development steps and the concrete infrastructure requirements. This information is highly relevant for shaping the deployment of the infrastructure and the framework conditions.

Battery / charging infrastructure

According to the truck manufacturers surveyed, battery technology has reached maturity for use in battery-powered trucks for short and medium distances. With the existing ranges of the vehicles, light and medium-duty load transport could be served. No fundamental challenges are seen for these applications. All manufacturers already have the first models of electric heavy-duty trucks on the market. Others have been announced. The rapid progress in the development of battery technology (energy density, charging speed) in recent years has made this development possible.

Figure 3

Anticipated development of the charging capacity of battery trucks (> 12 t) by permissible gross weight (2023–2030)



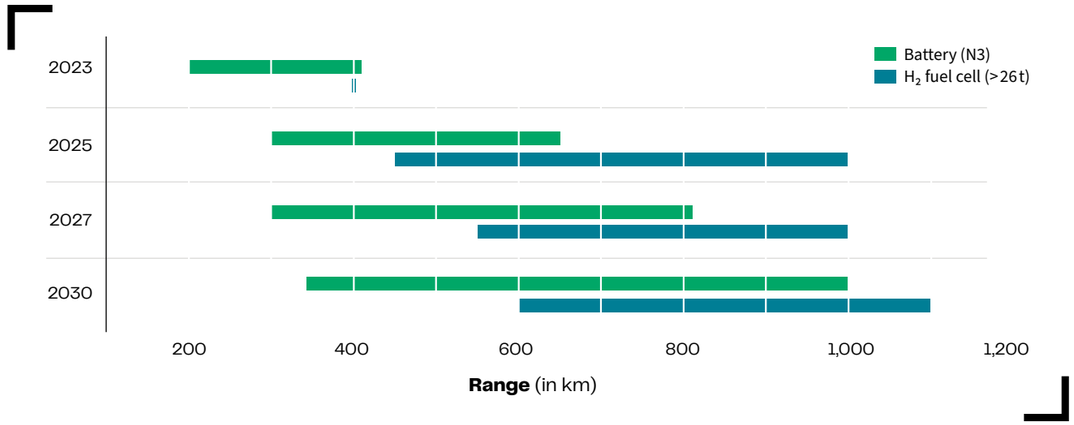
KEY TECHNOLOGICAL AREAS OF DEVELOPMENT FOR THE USE OF BATTERY TRUCKS IN LONG-HAUL TRANSPORT: ROBUSTNESS, SERVICE LIFE, ENERGY DENSITY AND CYCLE STABILITY.

Besides the MCS charging standard (see below), the battery truck still lacks robustness and service life for long-haul suitability (over 500 km). This is the opinion of several truck manufacturers. For them, the attributes of a tractor unit with a diesel engine serve as a benchmark. The conventional tractor units (4 × 2) typically used in long-haul transport are characterised by high mileage (1 million km and more over the life cycle), high annual mileage (200,000 km and more) and multi-shift operation. There is a particular need for development in the long-term stability of the battery, whose life cycle is currently shorter than the service life of the vehicle when used in long-haul transport. Changing the battery during the vehicle's service life would not only disrupt the business model but would have an impact on the vehicle's resale value. Therefore, some manufacturers are placing their expectations on new battery technologies that are better suited for the use in trucks. In addition to durability and service life, gravimetric energy density and cycle stability are other key optimisation paths for the battery. Others emphasise that the battery capacity has to increase in the future. A battery capacity of 600 kWh is currently planned to achieve a range of about 500 km. In the medium term, it is planned to reach battery capacities of 800 to 1,000 kWh. Other manufacturers are focusing on lower battery capacities also in the medium term in conjunction with more frequent megawatt charging.

In addition to the battery, there is still a considerable need for development in the stability of fully integrated electric axles and power electronics. In the field of power electronics, manufacturers are focusing on 800-volt technology. Another important development task is the electrification of the auxiliary units.

Figure 4

Anticipated development of the range of battery and fuel cell trucks (2023–2030)



LITHIUM-ION TECHNOLOGY WILL REMAIN THE BASIS OF BATTERY TECHNOLOGY IN THE MEDIUM TERM. THE POTENTIAL OF THE SOLID-STATE BATTERY IS CONSIDERED HIGH.

Currently, the truck manufacturers surveyed use lithium-ion batteries with different cell chemistries (including nickel-ferrum-cobalt, nickel-manganese-cobalt, lithium-nickel-cobalt-aluminium-oxide). In the next few years, so-called lithium iron phosphate (LFP) batteries will play a greater role. The reason given by the manufacturers for this is the better environmental compatibility of the LFP battery. They do not contain the toxic heavy metals cobalt and nickel. In addition, LFP batteries are a cheaper alternative with a longer service life. This longer service life is essential because of the high driving performance. On the other hand, however, they have lesser range and are heavier.

In principle, there will be further improvements in lithium-ion battery technology in the next few years. It is assumed that the performance of batteries will increase by about 30% by 2030. Development potential is also seen in the improvement of gravimetric energy density. Even if no “miracle battery” is to be expected, the solid-state battery could become a decisive technological leap. However, there is no unanimous opinion among truck manufacturers as to whether and when a marketable solid-state battery will be available. This could be as early as 2030, but could also take longer than 2035. The advantage of the solid-state battery lies in the absorption of larger amounts of energy, the associated significantly higher ranges, shorter charging times and a higher insensitivity to temperature at lower costs.

The megawatt charging system (MCS) is the key to long-haul capabilities of battery-powered trucks. With this, charging capacities of 1 MW and more are possible. Initially, charging power of between 800 kW and 1,200 kW is expected. Such high charging powers are sufficient to charge a battery truck during the statutory rest period. With an MCS charging infrastructure available throughout the country, the battery capacity in the vehicle could also be significantly smaller. According to individual manufacturers, this would result in a better business case than with larger battery capacities.

Several truck manufacturers are actively working on the CharIN (“Charging Interface Initiative e. V.”) standardisation initiative to establish the MCS connector as a global standard. Most truck manufacturers expect the MCS standard to be published in 2024. Some manufacturers are planning to launch MCS-capable battery trucks on the market as early as 2024. The majority of manufacturers will follow with larger volumes from 2025 onwards.

MEGAWATT CHARGING IS CRUCIAL FOR THE LONG-HAUL CAPABILITY OF BATTERY-POWERED TRUCKS. THE FIRST MCS-CAPABLE BATTERY-POWERED TRUCKS ARE EXPECTED TO COME ONTO THE MARKET AS EARLY AS 2024.

THE MANUFACTURERS SEE THE NEED FOR A FORWARD-LOOKING AND COMPREHENSIVE (EUROPE-WIDE) DEPLOYMENT OF PUBLIC CHARGING INFRASTRUCTURE, DESPITE THE FACT THAT A LARGE PROPORTION OF THE CHARGING PROCESSES ARE ANTICIPATED TO TAKE PLACE AT NON-PUBLIC CHARGING INFRASTRUCTURE IN THE DEPOT.

Whether or not MCS charging inlets should be installed in the battery trucks is disputed among the manufacturers. Some are planning to offer both charging options (CCS and MCS) in their vehicles. Others intend to decide on the installation depending on the context of use and customer requirements. For cost reasons, other manufacturers welcome the installation of only one charging inlet in the vehicle. Since the MCS plug can also be used for charging at low power levels, a CCS inlet is, in principle, not absolutely necessary.

In the view of the truck manufacturers surveyed, the rapid market ramp-up of battery-powered trucks, which is necessary to achieve the EU CO_2 standards, requires the timely establishment of an initial network of public truck charging infrastructure. This charging infrastructure is the crucial bottleneck. Especially for this initial phase, the manufacturers demand government support (see Chapter 2). During this phase, the utilisation rate will still be low and the deployment will be financially unattractive and risky for private investors. Responsibility for coordinating the deployment of the charging infrastructure should also lie with the government. This is an important signal for future users and a fundamental factor to build trust.

The business case for truck charging infrastructure is principally considered positive. Since the majority of trucks travel on repetitive routes, the demand is easier to calculate and localise than for passenger cars. This is also potentially associated with a higher utilisation of the charging infrastructure.

With regard to the size of the charging infrastructure network for battery-powered trucks, most manufacturers refer to calculations by the European vehicle manufacturers' association ACEA. In a statement on the amendment of the AFIR, the association calls for the EU-wide installation of 11,000 charging points for heavy-duty vehicles by 2025 and 42,000 charging points by 2030.[3] The manufacturers also point out that if the EU CO_2 standards were to be raised, the number of charging points required would increase accordingly.

In terms of the ratio of public charging to depot charging, a majority of truck manufacturers expect this ratio to be 80% to 20% across all use cases, namely around 80% of the energy will be charged in the depot. Especially in the early years, depot charging is said to play an important role. The reason for this is that charging at the depot is cheaper and more predictable than public charging. However, the picture differs depending on the logistics sector. In distribution transport, it is expected that up to 100% can be charged in depots. In long-haul transport, several manufacturers assume a ratio of about 50:50. For regional transport, the ratio cannot be specified at present due to heterogeneity and insufficient data.

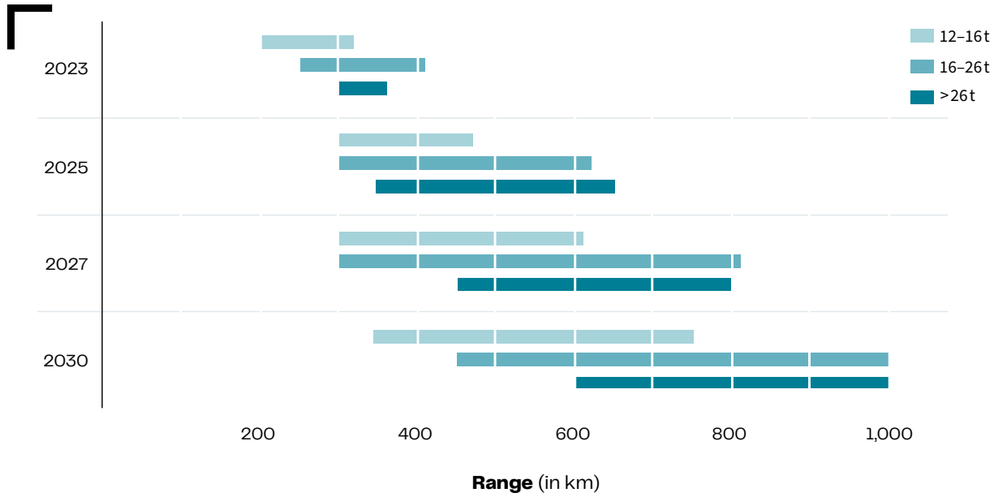
Fuel cell / hydrogen refuelling infrastructure

The cleanroom talks reveal that the development path for hydrogen fuel cell drivetrains is not as clearly defined as for battery electric systems. This becomes particularly clear in the case of hydrogen storage technology. Depending on the manufacturer, hydrogen is to be stored on board of the truck at 350 bar, 700 bar or in liquid form (LH_2). A majority of the manufacturers who will offer fuel cell trucks in their portfolio are planning to carry so much hydrogen on board the truck as to achieve the usual range of diesel tractor units of around 1,000 km. Other manufacturers do not wish to use the characteristics of a conventional diesel truck as the benchmark. After all, the fuel cell truck can also refuel during the statutory rest periods and thus be used in long-haul transport with less energy on board. High ranges would therefore not be necessary, which would also lower the technological hurdles. The manufacturers agree that the fuel cell should be used in heavy-duty vehicles or semi-trailer trucks with a gross vehicle weight (GVW) of 26 tonnes or more.

[3] These values include public charging infrastructure as well as semi-public charging infrastructure at target locations (logistics hubs, distribution centres, etc.). The specifications do not include charging infrastructure for public overnight charging. Broken down to Germany, 3,750 charging points would have to be built by 2025, and 14,350 by 2030.
(see **www.acea.auto/uploads/press_releases_files/ACEA_TE_letter-Making_AFID_fit_for_zero-emission_heavy-duty_vehicles.pdf**).

Figure 5

Anticipated development of the range of battery trucks (> 12 t) 2023–2030 by permissible gross vehicle weight



COMPARED TO BATTERY-POWERED TRUCKS, FUEL CELL TRUCKS STILL REQUIRE MORE DEVELOPMENT. READINESS FOR SERIES PRODUCTION IS NOT EXPECTED UNTIL THE SECOND HALF OF THIS DECADE.

While small series of fuel cell trucks with 350 bar storage technology are now available on the market, the majority of manufacturers do not expect large series production with high unit numbers to be ready until the second half of this decade. This is reflected in the forecast sales figures, which show a significant increase in the number of fuel cell trucks sold only towards the end of the decade (see Fig. 1).

With regard to the need for technological development, the same applies to fuel cell trucks as to battery trucks. In particular, there is a need for development in the robustness and service life of the drivetrain. While important components could be taken over from battery-powered trucks, the additional development needs for fuel cell trucks lie in the fuel cell and hydrogen storage technology. In the case of the fuel cell, there is a need for development not only in terms of robustness, but also in terms of optimising cooling and system efficiency. Of central importance, however, is the establishment of fuel cell production on a large scale.

Hydrogen can be used not only in a fuel cell, but also in an internal combustion engine modified for this purpose.[4] This means that a well-established technology can be used. The majority of manufacturers have dealt with the subject on test benches or in research activities, but see more disadvantages than advantages in the hydrogen combustion engine. They cite the poorer efficiency compared to the fuel cell, the remaining emission of pollutants (NOx, PM) and, to a lesser extent, CO_2 emissions, as well as the lack of recognition as a zero-emission technology in the regulatory context (e.g. USA, UK).

With regard to the development of a hydrogen refuelling infrastructure, the variety of storage technologies is a particular challenge. Manufacturers are pursuing pressurised storage (350 bar, 700 bar) and liquid hydrogen storage (LH_2). Cryocompressed storage (CcH_2) as a further option does not currently play a practical role. Advantages are mentioned by the respective manufacturers for all three storage options. The lower costs and lower energy requirements speak in favour of 350 bar. A higher pressure level or the liquefaction of the hydrogen is associated with a considerably higher energy requirement and thus with a higher hydrogen price at the filling station. Long-range suitability and flexibility, on the other hand, are the main arguments of the manufacturers who rely on 700 bar and LH_2. This is seen as the real strength of the fuel cell truck, especially in comparison to the battery-powered truck. Cryogenic liquid hydrogen promises an even longer range for fuel cell trucks. The argument here is also based on the delivery of hydrogen to the filling station, since hydrogen is supplied to the filling stations at a high volumetric density. With liquid hydrogen, evapouration losses cannot be avoided when the vehicles are stationary for longer periods of time.

THE DIVERSITY OF HYDROGEN STORAGE TECHNOLOGIES IS PROVING TO BE A CHALLENGE IN THE FUTURE DEPLOYMENT OF A FILLING STATION INFRASTRUCTURE.

Since three different technological paths are being pursued, a separate infrastructure with its own technological standards is needed for each of the three storage options. This includes refuelling protocols and standardisation of the refuelling infrastructure. However, the manufacturers are confident that the standardisation issues for the respective storage options can be solved by the middle of the decade.

Hydrogen filling stations are a fundamental prerequisite for the operation of fuel cell trucks. The manufacturers have different views on by when and how large a network of hydrogen filling stations should be established. They all agree that the network should be set up as soon as possible. It is important to provide an initial network to avoid the chicken-and-egg problem and to make a refuelling infrastructure available to customers of the truck manufacturers.

THE ESTABLISHMENT OF A STATE-FUNDED BASIC NETWORK OF HYDROGEN FILLING STATIONS SHOULD SOLVE THE CHICKEN-AND-EGG PROBLEM. THE OPERATION OF HYDROGEN REFUELLING STATIONS FOR FUEL CELL TRUCKS COULD BE ECONOMICALLY VIABLE.

[4] Manufacturers have also indicated heavy-duty vehicles with hydrogen combustion engines in their sales figures. The figures mentioned increase from a double-digit number of vehicles in 2027 and 2028 to 1,250 vehicles in 2030.

Depending on the storage technology as well as the timing of the series launch of the company's own fuel cell trucks and ideas about the size of a hydrogen filling station, there are different views on the deployment of the infrastructure in Germany. One view is that a basic network of about 50 filling stations should be established by the middle of the decade. This network should then grow to more than 100 hydrogen filling stations by the end of the decade. However, there is also the view that more than 150 filling stations should be in operation by 2025. All manufacturers point out that a Europe-wide development of the refuelling infrastructure is fundamentally necessary.

With reference to initial experience in the operation of refuelling stations, it is said that their operation is already profitable with a fixed number of fuel cell trucks in the low double-digit range that regularly refuel with hydrogen. The establishment of private joint ventures for the construction of hydrogen filling stations underscores this assessment.

The provision of green hydrogen at competitive prices is of decisive importance for the market ramp-up and competitiveness of fuel cell trucks. As there is not enough electricity from renewable energies for hydrogen production in Germany at the present time, Germany is dependent on imported green hydrogen.

Moreover, very large production facilities are needed for the cost-effective production of hydrogen. On the regulatory side, however, there is legal uncertainty due to pending legislation by the European Commission that defines the requirements for green hydrogen. As part of the revision of the EU's Renewable Energy Directive (RED II), the European Parliament (EP) proposed on 14 September 2022 that the requirements should not be defined by a delegated act, but should be incorporated directly into RED II. The EP proposal also contains lower requirements than those envisaged by the European Commission. The EP decision will most likely lead to further delays in terms of legal certainty for the production of green hydrogen. The current draft would slow down the development of European hydrogen production considerably.

RED II obliges fuel distributors to reduce greenhouse gas emissions. Green hydrogen is a compliance option. In the negotiations on the revision of RED II, a possible mandatory sub-quota for hydrogen and its derived products in 2030 is also being discussed. To meet this sub-quota, the distributors would have to make green hydrogen available at low cost at the filling stations to ensure that it is also consumed.

In order to achieve a competitive price for hydrogen, which, according to the manufacturers of fuel cell trucks, should be €4 to €5 per kg, government subsidies would still be needed in 2030.

THE AVAILABILITY OF GREEN HYDROGEN AT COMPETITIVE PRICES IS THE KEY CHALLENGE.

Overhead lines

The assessments and evaluations of the overhead line truck and its technological maturity or need for development vary considerably between the truck manufacturers, as only individual manufacturers are strategically pursuing overhead line technology.

Those manufacturers for whom the overhead line is an option name various advantages of the overhead line truck. They point out that the technology is already available and that the overhead line is particularly efficient. Another advantage is that less space is needed along the motorways for dynamic charging and that charging while driving reduces or even eliminates the need for interruptions for stationary charging. In addition, the battery capacity can be designed smaller.

In the talks, reference was made to the need for technological development, especially with regard to the pantograph. Development needs were mentioned for the stability of the pantograph, the price and the aerodynamics, especially when the wind and weather conditions affect the extended pantograph. The effect of constant recharging with high charging currents on the battery was highlighted as an open question.

DYNAMIC CHARGING WITH OVERHEAD LINES HAS ADVANTAGES, BUT THERE IS STILL NEED FOR DEVELOPMENT.

Some of the manufacturers consider the current technological challenges, such as parallel charging of larger fleets on the overhead line, lack of experience on long-haul routes and dealing with difficult weather conditions (e.g. ice on the overhead line), to be solvable technological obstacles. On the other hand, there are truck manufacturers who consider overhead line technology not yet ready for use.

The manufacturers surveyed all agreed on the question of which alternative drivetrain technology the overhead line should be combined with: the battery electric truck. In that case, the pantograph would then be understood as a further charging interface.

INFRASTRUCTURE DEVELOPMENT IS THE CRITICAL FACTOR FOR THE OVERHEAD LINE. GOVERNMENT NEEDS TO PROVIDE SUPPORT.

The lack of support from truck manufacturers for overhead lines is specifically linked to the development of infrastructure (see Chapter 2). For many manufacturers, a Europe-wide development of the overhead line infrastructure is a basic condition for a successful ramp-up of the overhead line truck. Only then would an economically worthwhile demand for overhead line trucks be triggered. In principle, this also applies to the other technologies. In contrast to charging infrastructure and hydrogen filling stations for trucks, however, there is a lack of private-sector incentives for the construction of overhead line infrastructure, especially because of the high fixed-step costs. The government would therefore need to make substantial upfront investments in this area. Due to the long lead times for planning and implementation of the infrastructure deployment, the creation of a sufficient overhead line infrastructure is predominantly assessed as improbable. The construction of the overhead line would take too long in view of the pressing climate protection goals. These can only be achieved with batteries and/or fuel cells within the specified period.

4 Outlook

Dynamic market development and ambitious climate protection targets

The evaluation shows that the transformation of road transport to climate-friendly drivetrains could possibly be much more dynamic than many have assumed to date. As the basis for all three zero-emission drivetrains, the strong technological progress in batteries enables a very rapid transformation. After light commercial vehicles, the range of heavy-duty vehicles with climate-friendly drivetrains has also been growing recently. This development will continue. This is clearly shown by the sales figures forecast in the cleanroom talks of 2022. The accelerating pace of the transformation of road freight transport is also urgently needed in view of the German government's ambitious climate protection targets for 2030. The switch to emission-free drivetrains in road freight transport can and must become an important lever for the climate protection targets in the transport sector.

Use of results

For the transformation to be successful, it is necessary to build up the refuelling and charging infrastructure in line with demand and in coordination with the ramp-up of the vehicles. Information on market developments is therefore indispensable. The results of the cleanroom talks are an important stimulus for the further implementation of the Overall Approach to Climate-Friendly Commercial Vehicles. This not only applies to shaping the regulatory framework, but also to the coordinated and joint action of all stakeholders involved.

The results are particularly important with regard to the planning and development of refuelling and charging infrastructure. The results of the talks will be used in particular for the demand analysis envisaged in the German Master Plan for Charging Infrastructure II, for the roll-out planning and for the invitation to tender for an initial public charging network for battery-powered trucks.[5] The results are also important for the timely need for the financing and funding measures for charging infrastructure on company premises, transhipment sites and in industrial estates set out in the Master Plan for Charging Infrastructure II. This is because non-public charging will play a key role in the operation of battery-powered trucks, especially in distribution transport. In the coordinated development of a basic network of hydrogen refuelling stations for trucks, the results of the cleanroom talks are of great value for all parties involved as well as for the BMDV, which can better plan the design of funding opportunities.

Regular talks with manufacturers

The potential for decarbonising road freight transport can only be realised through dialogue and joint action by all stakeholders. In this sense, the participation of truck manufacturers in the cleanroom talks is beneficial for policymakers, infrastructure providers and users.

Against the backdrop of gradually more concrete plans by the manufacturers and technological developments, the BMDV is intending to hold annual cleanroom talks with the truck manufacturers in future as part of the implementation of the Overall Approach to Climate-Friendly Commercial Vehicles.

[5] See **https://bmdv.bund.de/SharedDocs/DE/Anlage/G/masterplan-ladeinfrastruktur-2.pdf?__blob=publicationFile**

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