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Analysis of the challenges for the electrification of heavy-duty vehicles from a manufacturer and user perspective

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Executive Summary

Battery electric trucks are emerging as a promising technology for the decarbonisation of road freight transport. Analysing the perspectives of vehicle manufacturers and users of electric trucks on the transformation provides important information on the remaining challenges and need for action for the necessary, rapid change. The analyses are based on findings from qualitative and quantitative survey methods.

The analyses show that there is a clear trend towards battery-electric trucks as the new standard technology. However, expectations still differ greatly depending on the stakeholder group and level of experience with electric trucks. The expansion of the charging infrastructure and reliable long-term framework conditions to ensure economic operation, are seen as essential for market success.

Keywords: Heavy duty electric Vehicles & busses; Public Policy & Promotion; Consumer behaviour; Trends & Forecasting of e-mobility

1 Background and objectives

Road freight transport is the second most important source of CO_2 emissions in the transport sector worldwide after passenger car traffic [21]. Diesel-powered internal combustion engines dominate truck transport. Most emissions in road freight transport are caused by heavy duty vehicles in long-haul transport that are characterized by particularly high mileages. Against this backdrop, decarbonization of the transport sector can only succeed if road freight transport is included. This is reflected, among other things, in ambitious targets and stricter regulatory requirements at national, European and international level, which have recently been established and are beginning to take effect.

The introduction of electric heavy duty vehicles started with electrically powered buses for local and urban transport: in 2021, buses still accounted for around two thirds of new registrations of zero-emission heavy duty vehicles in the EU, while in China and North America the share was around three quarters in each case [[2], [3]]. In 2024, diesel trucks still dominate by far, accounting for over 95% of new registrations in Europe. The share of e-trucks was 2.3% [1].

To support the achievement of national and multinational climate targets through the market ramp-up of zero-emission trucks, countries have introduced incentives and regulations for battery-electric trucks (BET) at national level. 70 % of global zero-emission heavy duty vehicle (HDV) sales take place under the effect of

EV policies [4]. The type, target group and scope of the incentives and regulations offered vary between countries [4]. Target groups are either manufacturers of battery-electric trucks (OEMs) on the supply side or truck operators on the demand side (freight forwarders, transport companies).

The mandatory CO_2 emission standards in the European Union (EU), which were revised and tightened in 2024, are putting pressure on manufacturers to bring zero-emission vehicles onto the market. New HDVs registered in the EU must achieve a reduction of 43% by 2030 and 90% by 2040 (compared to 2019/2020) [5]. For the EU member states, the development of a public truck charging network every 60 to 100 km by 2030 is mandatory for all roads on the TEN-T network as part of the Alternative Fuels Infrastructure Regulation (AFIR) [5].

Truck manufacturers see Germany as a decisive market for the ramp-up of BET as it is one of the strongest markets for HDVs in Europe and has ambitious sustainable transport policies [6]. Indeed, the German government has set (non-binding) objectives that are more ambitious than the European regulations. According to the Climate Protection Programme 2030, one third of road freight transport mileage is to be covered by vehicles with electric powertrains or electricity-based fuels by 2030 [7]. To achieve these goals, a CO_2-based toll for HDVs, a CO_2 price on fuels and an exemption from vehicle tax for emission-free HDV were introduced by the German authorities (Hacker et al. 2024). The procurement of electric HDVs and the development of the necessary charging infrastructure at depots has been supported by a comprehensive federal funding program in recent years. However, this was ended earlier in 2024 due to state budget restrictions [8]. The federal government addresses the development of charging infrastructure in the Charging Infrastructure Master Plan II [9]. In 2024, a tender was issued for the installation of charging stations at around 130 unserviced motorway areas, in addition to the planned charging infrastructure at around 220 managed rest areas. The Federal Ministry for Digital and Transport estimates that this would cover two thirds of the demand for publicly accessible charging points on German highways [10]. The one third left is expected to be covered by private investments.

After diesel trucks have dominated the market for over a hundred years, the planned change in drive technology represents an unprecedented transformation in road freight transport. To achieve the tighter CO_2 emission standards, a significant increase in electric truck registrations is needed in the coming years [11] The key players in the transformation are the vehicle manufacturers on the supply side and the transport companies as vehicle users on the demand side. At the same time, there is a high dependency on framework conditions that are not set by these two players. In view of the long dominance of diesel technology and the early market phase of electric trucks, little reliable information is available to date on the strategies and challenges of these two key market players.

1.1 Manufacturer perspective

Prior to the adoption of the CO_2 standards for heavy-duty commercial vehicles at EU level, no clear technology strategy for reducing CO_2 emissions in road freight transport could be identified among manufacturers. A wide range of drive and fuel options were cited by manufacturers as possible technology alternatives [12]. Since the CO_2 standards came into force, a concentration of technical development on a few options can be observed. This is reflected in the increasing range of battery-electric vehicle models [13] on offer and the commitment and demand for the expansion of the charging infrastructure by vehicle manufacturers [14].

Overall, cross-manufacturer analyses of product strategies are still rare [12]. The results of confidential manufacturer interviews, which have already taken place twice in Germany, provide the first well-founded information on the product strategy of European manufacturers [[6], [15]].

1.2 Vehicle user perspective

Due to the low market penetration, most transport companies have little previous experience with electric trucks. While early adopters report good usability and scalability of electric trucks, research for the broader market indicates strong user expectations and requirements [[16], [17],[18]].

Already in 2020, research identified battery electric trucks to be the technologically advanced option [19]. Today, battery electric trucks are readily available, and manufacturers expect their future dominance [13]. Contrary to these signals, a few years ago users were still open on their future technology preference, leaning towards hydrogen [16]. Recent surveys, however, now point towards a shift of batterie electric trucks receiving the highest consumer acceptance rates [18].

Although battery electric trucks are increasingly seen as the future of road-bound logistics, many obstacles remain. In 2021, purchasing decisions were primarily influenced by the reliability and proven performance of vehicle models followed by total cost of ownership [16]. Recent research identified additional factors like competitors, corporate image and corporate social responsibility and market environment [[17], [18]]. Furthermore, purchasing costs and the availability of charging infrastructure are essential factors [18].

Addressing these and more user requirements will be crucial to ensure electric trucks reach users across the entire transport industry.

The aim of our analyses is to highlight and compare the challenges of truck electrification from the perspective of the above-mentioned stakeholders, to discuss needs for action for a successful market ramp-up, and to identify recommendations for further developing the framework conditions.

Our approach makes it possible to identify similarities and differences in the manufacturers' strategies at this early market phase. At the same time, comparing the perspectives of transport companies with and without previous experience of e-trucks offers the opportunity to identify the practical challenges in the current market phase on the one hand, and the necessary measures for attracting more transport companies to the electrification of their fleets on the other. The systematic comparison of the perspectives of the two central actors for the transformation of road freight transport, the vehicle manufacturers and the users, enables a differentiated view of the challenges of the transformation and forms the basis for deriving overarching and target group-specific recommendations for action.

2 Methodology

As part of the ELV-LIVE research project [20], both qualitative and standardized, quantitative data was collected on the strategies, challenges and need for action for the electrification of heavy duty vehicles with a focus on the German heavy duty vehicle market.

2.1 Perspective of vehicle manufacturers

On the manufacturer side, in addition to the results of a literature-based market analysis, guided question-based individual interviews with truck manufacturers as well as a joint synthesis workshop are available as a data basis [].

The results presented are based on the statements of a total of five heavy duty vehicle manufacturers active in Europe, which together cover around 90% of the European heavy duty vehicle market. The manufacturers' representatives were interviewed in the course of 60- to 90-minute guided interviews. The anonymized results of the interviews and the resulting recommendations for action were discussed in more detail at a joint workshop in June 2024. The interviews took place between the end of 2023 and mid-2024. During the process, discussions were held with manufacturer representatives from DAF, Daimler Truck, Tesla, Traton (Scania, MAN) and Volvo Group Trucks (Volvo Trucks, Renault Trucks). In addition, representatives of the charging infrastructure company Milence and the German National Organization for Hydrogen and Fuel Cell Technology (NOW) were interviewed with a focus on the required development of the charging infrastructure.

The individual interviews focused on the expected market development of alternative drive systems for trucks in Germany and in important international markets, the necessary public and private energy supply infrastructure, and the technical design and development prospects of possible drive and fuel alternatives for heavy-duty vehicles.

In the subsequent joint workshop of the interview partners, the synthesis of the individual interviews was validated and the challenges and needs for action identified for the market ramp-up of e-trucks were substantiated from the perspective of the manufacturers.

2.2 Perspective of vehicle users

On the vehicle user side, the information is based not only on a literature-based analysis of the transport market but also, and primarily, on the analysis of six selected case studies[1] in the project context with detailed interviews, on-site visits and joint workshops, as well as a standardized survey of a larger number of German transport companies.

The standardized survey is aimed at all transport companies that already use e-trucks and is intended to provide a comprehensive picture of the current use of e-trucks and the associated challenges. The target group is the fleet manager within the company. In smaller companies, these are often also members of the management who are directly responsible for the fleet. The main topics of the survey are the motivation for the procurement, a description of the previous e-truck deployment, experiences in use, preparations made and further expansion plans, as well as assessments of hurdles for further expansion and the potential of other alternative drive options.

The online survey was conducted between January 2024 and January 2025. For the online survey, owners of e-trucks were contacted in various ways over the course of a year. Companies that purchased e-trucks through the associated project partner Daimler Truck were referred to the survey by the company. In addition, the survey was advertised in a special newsletter sent to several thousand companies with e-trucks in Germany in connection with the German government's funding program for climate-friendly commercial vehicles. In

[1] The spectrum of companies involved ranges from small companies with just a few vehicles to medium-sized companies and the largest European logistics and transport companies.

addition, 159 companies with e-trucks were identified on the basis of an online evaluation of press releases, and these companies were contacted directly and made aware of the survey. Ultimately, 94 feedback responses were received. Of these, 55 questionnaires were fully completed, and 52 responses could ultimately be used for the analyses.

The case studies include six companies that are already using electric trucks in their daily operations. The spectrum includes companies with a small number of vehicles, large companies with a triple-digit number of vehicles and logistics companies that are among the largest in Europe. The companies in the case studies thus represent the spectrum of companies and fleets in the transport industry. During the on-site visits, guided interviews were conducted with the management, the dispatch department, as well as with drivers and driver trainers.

Furthermore, a separate survey of over 200 transport companies from 2021 is available as a basis for comparison [16]. This mainly includes transport companies without practical experience with alternative drives.

3 Results and discussion

3.1 Perspective of vehicle manufacturers

3.1.1 Views on market development

Advances in battery technology are already making it technically possible to use BET beyond regional transport. According to the manufacturers surveyed, the main application of battery-powered trucks will likely soon shift from regional to long-distance transportation due to operating cost advantages in particular. The availability of charging infrastructure as a key influencing factor and bottleneck at the same time will determine the speed of the market ramp-up.

The European CO_2 fleet targets are named as the main driver and key point of orientation for product strategy [19]. The forecasts for e-trucks from the Clean Room discussions of the German Federal Ministry of Transport [[6],[15]], which were held with commercial vehicle manufacturers in Germany in 2022 and 2024, are confirmed and in some cases an even more dynamic market development is expected. By 2030, they expect battery-electric trucks to account for over 50% of new registrations and battery-electric powertrains are seen as the dominant technology for trucks in the long term. Compared to CO_2 pricing (including the CO_2-differentiated truck toll in Germany), which is relevant to operating costs, manufacturers consider the promotion of vehicle purchase to be a less significant incentive. It is also considered not unlikely by the established manufacturers that new suppliers of electric trucks could try to gain market share at the expense of the established manufacturers in Europe, especially before the CO_2 targets for 2030 are reached.

All manufacturers expect battery-electric trucks to dominate road freight transport in the future. At the same time, all manufacturers are also involved in the development of hydrogen-powered drives (in combination with fuel cells and combustion engines). The majority of manufacturers do not believe that hydrogen-powered trucks will be economically competitive in the longer term and only see applications in niche markets, as they do not believe that the hydrogen price level required for the mass market is likely to be achievable without continued subsidies. A single manufacturer mentions a relevant potential for hydrogen-powered trucks in the order of 10–20% market share. Plug-in hybrid drives and alternative biogenic and electricity-based fuels were not mentioned in any of the discussions as an option for the decarbonization of heavy-duty trucks.

The availability of a fail-safe charging infrastructure is seen as the key prerequisite for market ramp-up of e-trucks. A lead time for the expansion compared to the planned increase in the number of e-trucks should always be ensured and a temporary oversizing is considered tolerable. The charging infrastructure in the depot is a central component of electrification. However, its importance can only be estimated based on simulations and a few practical examples. Public (fast) charging infrastructure is particularly relevant for long-distance transport and must be developed primarily along and near the highway network. Charging parks will probably include a combination of CCS and MCS charging options – with an increasing focus on MCS-capable charging points, especially for long-distance transport. The AFIR specifications represent good basic coverage for Europe, but a significantly higher level of expansion is already required for Germany today. A predominantly private-sector implementation of the public charging infrastructure in Germany is expected. In particular, the necessary rapid expansion over the next 10 years is seen as challenging, especially with regard to the requisite grid connections. The lack of suitable sites with sufficient grid connection capacity and the need for longer-term concessions to develop sites economically exacerbate the problem.

3.1.2 Views on challenges and needs for action

Grid connection of charging infrastructure

The expansion of charging infrastructure is consistently rated as the most important lever for the market ramp-up of e-trucks. In this context, the sometimes high costs and, above all, the long lead times for grid

expansion and connection are seen as particularly critical – both for private and public charging infrastructure. For Germany in particular, the large number of distribution network operators is seen as critical, as this makes it difficult to take a uniform approach and build up knowledge quickly, among other things. In view of the outstanding importance of grid expansion and connection, forward-looking planning by politicians and grid operators is considered essential. Even in the short term, greater transparency regarding available grid connection capacity is seen as helpful for site planning.

Development of private charging infrastructure

It is confirmed that charging at the depot is the most obvious option for the vast majority of applications. However, practical implementation often presents major challenges. Large fleets with a high degree of electrification and intensive truck use with short downtimes in particular require a high grid connection power. In view of the main challenge of connecting depots to the grid, it is considered important to raise companies' awareness of the sometimes long lead times and restrictions on grid connection capacity. Where grid connection costs are high, unbureaucratic state subsidies should be used wherever possible. In addition, more incentives should be established for charging at night, which places less strain on the grid. In view of the high implementation costs and the limited capacities of transport companies, consulting companies that provide expertise on the development of charging infrastructure to the companies concerned are considered to be of great importance for the development of depot charging.

Reliable framework conditions in the long term

Manufacturers' representatives believe that the long-term CO_2 fleet targets, the introduction of a CO_2 price for road transport via the ETS 2 and – in the case of Germany – the CO_2-based truck toll provide a reliable framework that robustly secures the economic viability of e-trucks and provides planning security for manufacturers and users. The possible less ambitious design and further development of existing regulations in the current European legislative period is seen as a risk for the investment decisions that have already been made. The continuation of a CO_2 price on fuels and the CO_2-based truck toll in Germany were named as particularly relevant in this context, as these robustly safeguard the overall cost advantage of e-trucks. Their continuation and Europe-wide expansion – in the case of the truck toll – were named as important levers. The continuation of state subsidies for vehicle procurement was considered less relevant and the prospect was held out that e-trucks could be economically viable and dominate the market from 2030 without any subsidies. Similar to the highly effective regulation of the supply side through the European CO_2 fleet targets, reference is made to the lack of regulatory impetus for the demand side. It is noted that comparable targets for the demand side (e.g. registration quotas for e-trucks for fleet operators) could already have a short-term effect and accelerate vehicle sales.

Development of public charging infrastructure

The European regulation on the deployment of alternative fuels infrastructure (AFIR) creates planning certainty for all stakeholders regarding the Europe-wide development of a public charging infrastructure for heavy duty vehicles with basic coverage. However, the commitment of the member states to the development varies, so that the area coverage will show greater differences in Europe in the coming years and thus enable the use of e-trucks in Europe to varying degrees. If it is not possible to implement depot charging to the extent forecast – in particular due to restrictions on grid connection – the AFIR targets are considered to be significantly too low. The updating of the European Alternative Fuels Infrastructure Regulation (AFIR) is seen as an important measure for the planning security of all stakeholders involved. The formulation of national expansion plans that go beyond the level of ambition of the AFIR is considered important and necessary, including for Germany. The possibility of sanctions for member states that fail to meet the AFIR targets is also being considered to further increase the binding nature of the expansion, although the likelihood of this being implemented is considered to be rather low. Government funding or support is considered particularly necessary for the development of (MCS) high-power charging infrastructure.

Sites for (public) charging infrastructure

A high demand for large and efficient charging parks is to be expected along long-distance transport corridors in particular. At the same time, the pressure on space at these locations is already very high and there is already a shortage of parking spaces, which will be further exacerbated by the space required for charging stations. Long-term concession agreements and a secure grid connection are prerequisites for the economic development of space for charging locations. The limited availability of sites that meet these criteria is an obstacle to the rapid development of charging parks, which in turn are essential for establishing battery electric trucks in long-distance transport. Greater political and administrative commitment is considered necessary for the acquisition of additional truck parking spaces along the highway network. In particular, the high demand for public overnight charging should also be taken into account. For the prompt implementation of public charging parks, it is also proposed that more available information on suitable areas, expected charging requirements and grid connection conditions be made publicly available.

Change management for vehicle users

The extent of the transformation requires change management among all stakeholder groups. In this context, however, the particular importance of transport companies is highlighted. A rapid technology change can

only succeed if the users also actively tackle it. Currently, relevant knowledge deficits and a reluctance to procure vehicles are still being observed, partly due to the high proportion of small companies. For smaller companies in particular, reference is made to the more difficult financing conditions for additional investments in vehicle procurement and the development of charging infrastructure. The lack of continuity in public funding and the design of further framework conditions with regard to alternative drive systems is seen as extremely counterproductive, as it increases the risks for investments for transport companies. There are fears that delayed action, particularly among smaller companies, could slow down the transformation and, above all, significantly worsen the competitive position of these companies in the future. Sound advice for transport companies is seen as particularly important for acceptance and the switch to e-trucks in practice. It is pointed out that it is almost impossible to develop blueprint solutions due to the individual framework conditions and that highly individualized advice is required.

3.2 Perspective of vehicle users

3.2.1 Practical experience and views on market development

The results of the 2024/2025 survey show that the early adopters of e-trucks in the transport industry also assign the highest market potential to battery-electric trucks. Over 40% of the companies surveyed expect e-trucks to be in 'standard use' by 2030, while a further 40 % expect them to be at least 'largely in use' (Figure 1). Alternative fuels (biofuels and efuels) and the hydrogen fuel cell powertrain (8 % 'as standard in use') follow far behind. Nevertheless, all technologies are rated at least "partly in use" by individual companies indicating a still heterogeneous view on future powertrains. This tendency is also confirmed by the six case study partners. In particular, the management and fleet managers see the highest market potential for BET. In some cases, other drive technologies are expected to complement it, while some companies already rule this out. Among the employees (dispatchers, drivers), the doubts are sometimes more pronounced. Here, particular reference is made to the challenges with regard to long-distance transport and the lack of public charging infrastructure.

The picture is different in the survey of transport companies with no compelling e-truck experience. In a 2021 survey [16], more than 80 % of them stated that they expect the hydrogen fuel cell powertrain to be 'standard in use' (41 %) or 'partially in use' (41 %) in 2030. Similarly high expectations were associated with hydrogen-based combustion engines. Only 5 % saw battery electric trucks as 'standard in use', while 53 % assumed this type of powertrain to be at least 'partially in use'.

One reason for this discrepancy lies likely in the high contentment of early adopters with battery-electric trucks. A vast majority of 88 % of companies in the survey evaluates their experience with battery-electric trucks as either "satisfying" or "very satisfying". In the complementary free text answers, most keywords refer to the high comfort in driving battery-electric trucks (top 3 plus top 4 "quite driving") resulting in a high acceptance by drivers (top 1). Also, in the mission profiles of early adopters, the electric range is sufficient (top 2). On the contrary, main issues in negative feedback answers are an insufficient range (top 1), technical difficulties with the vehicle (top 2) or charging infrastructure (3), as well as a false display of the remaining range (top 4).

The high level of satisfaction with the technology is also confirmed by the experiences of the case study partners. Beyond a few individual technical failures, which occurred particularly in the early phase when the service centers were not yet prepared for e-trucks, resulting in some cases in longer downtimes, a high level of satisfaction and technical reliability of the vehicles is reported. The interviews with the drivers revealed an outstanding level of satisfaction with the technology. In addition to the BET's improved driving behavior, an innovative technology, the improved working conditions resulting from lower noise emissions and vibrations, as well as the lower maintenance requirements, are highly valued. Companies are now deliberately using those factors in the recruitment of professional drivers and seeing it as a strategic advantage in attracting employees. In the current main area of application for BET in regional transport, the electric range does not yet represent a major restriction for route planning and the available charging infrastructure at depots can meet today's needs.

Negative aspects mentioned include the initial lack of technical support for vehicles and charging infrastructure, as well as the insufficient public charging infrastructure and the electricity prices to be paid there. The further expansion of the charging infrastructure in the depot is seen as problematic and a central obstacle to further electrification, particularly with regard to the necessary grid connection.

The case study partners mention the expansion of public charging infrastructure and attractive electricity prices at public charging infrastructure as important prerequisites for the development of long-distance transport with BET.

It should be noted that, beside different target groups and company samples, the time gap between both surveys may explain the observed discrepancies to some extent considering the rapid market development for e-trucks. Nevertheless, the assumption of a structural more optimistic view of early adopters on battery-electric trucks is supported by the case studies. Interviews after and prior to the use of battery-electric trucks show a higher acceptance of the technology and, partly, more confidence regarding a future use in more demanding mission profiles like long-haul transports.

Existing research points towards a high technology acceptance rate of early electric truck adopters. A 2024 study including electric truck users found a high likelihood of future investments in zero-emission vehicles within the next 2 or 7 years with a dominance of battery electric drives [18]. Further research shows that companies with readily identifiable electric trucks, have a more positive attitude towards battery electric trucks than other companies [17].

In this context, it is also relevant that the transport industry is characterized by low margins and a high proportion of small companies with little financial leeway and short contract durations. High investment costs for BET and charging infrastructure therefore represent a major hurdle at this early market stage. Therefore, it is not surprising that the case study partners include, on the one hand, large companies with the financial means to test a few electric trucks at an early stage. On the other hand, small or medium-sized companies are involved that operate in a relatively stable market environment or whose main business is outside the provision of transport services. At the same time, the case study partners report that they too are still encountering a high level of skepticism towards BET in their corporate environment.

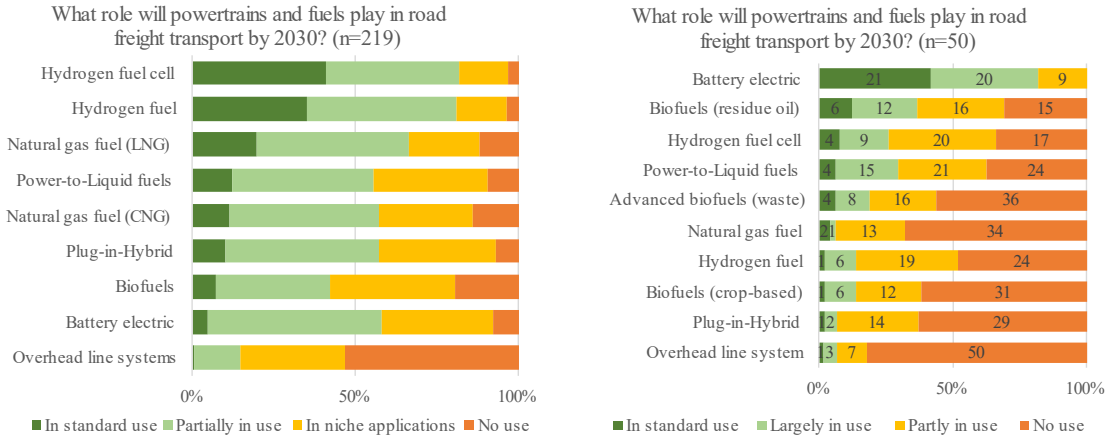

Figure 1: Anticipated relevance of powertrain and fuel technologies in the heavy-duty transport sector in 2030. Left: results from a survey among transport companies in 2021, right: results from a survey of early adopters of battery electric trucks in 2024. Please note the different categories.

After the technical reliability of the vehicles (over 80 % 'fully agree'), the availability of public charging infrastructure (over 70 % 'fully agree') is rated by early adopters as the second most important obstacle to the further procurement of e-trucks.

3.2.2 Views on challenges and needs for action

Unlike the manufacturers, there is still no clear picture on the user side regarding the dominant drive technologies of the future. The perspectives of early adopters and the large number of transport companies that have not yet gained practical experience with BET therefore also differ greatly in some cases. The following section focuses on the specific challenges and needs for action that can be derived from the analysis of the experiences of the first users. The general challenge of how the entire transport industry can be reached

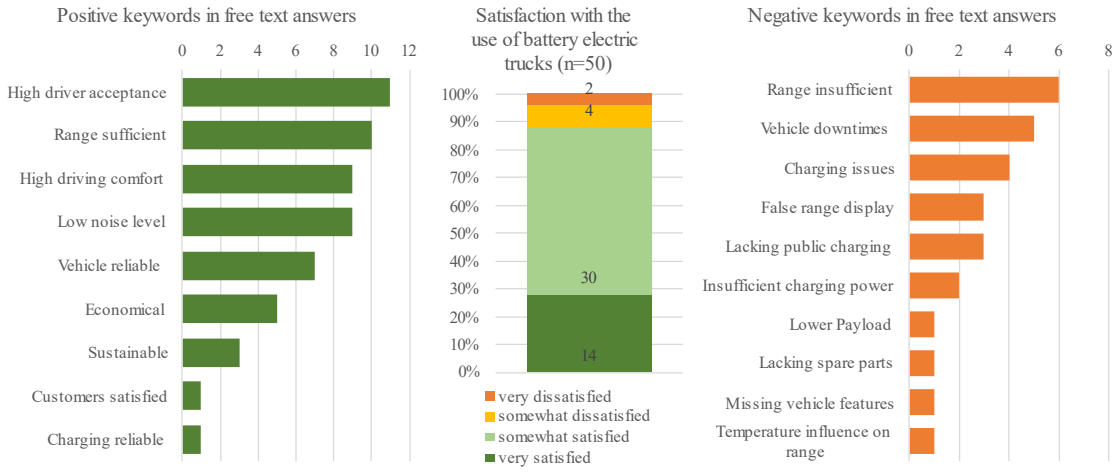

Figure 2: Feedback from early adopters on the contentment with the use of battery electric trucks in a survey in 2024 (middle). Left and right: Frequency of keywords in free text explanations on level of satisfaction.

in view of the change in drive technology is addressed in the conclusions.

In the current applications of BET, the early adopters of the vehicles are very satisfied. With a view to further scaling - in terms of both volume and use cases - numerous challenges are already seen in the short term. Some of them are listed in Figure 3, which presents the results of the survey regarding “reasons for the purchase of battery electric trucks” and “challenges for purchase of further battery electric trucks”.

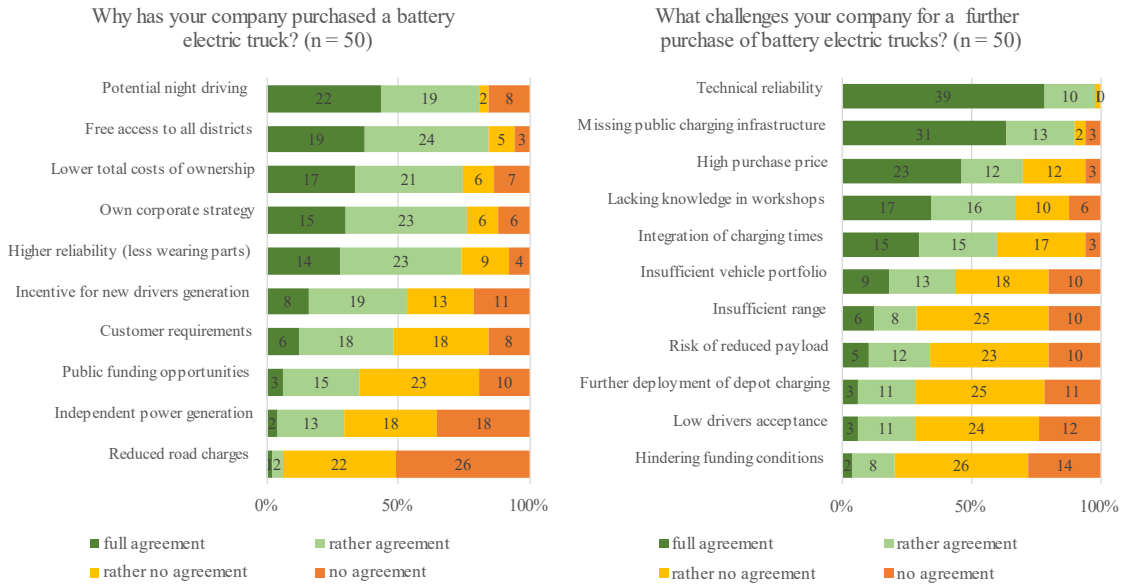

Figure 3: Agreement with pre-formulated items by early adopters in a survey in 2024.

In some cases, the challenges faced by the six case study partners in the project and the standardized survey of users of e-trucks differ. This is particularly the case regarding the development of further charging infrastructure, which is mentioned as a lower hurdle in the standardized survey. Furthermore, the topic of grid connection was not explicitly addressed in the standardized survey. In addition, the technical reliability and the lack of qualification of the workshops are mentioned in the survey as major hurdles. With regard to the charging infrastructure and grid connection, one explanation for the discrepancy could be that the case study partners are companies that are aiming for a very extensive electrification and are therefore already confronted with the challenges on the charging infrastructure side, which do not yet arise when testing the first trucks. In addition, the case study partners have also reported technical malfunctions of the vehicles and a lack of service at the workshops, although they have observed a significant improvement over the course of use.

Technical issues

The technical reliability is the top ranked challenge for further electric truck purchases (Figure 3). Despite a high satisfaction with the use of battery electric trucks, many early adopters faced technical difficulties with the vehicle or the charging infrastructure (Figure 2). Often issues occurred in the early phase of the vehicle use and could be solved. But there remain technical issues with other electric components (e.g. logbooks, refrigeration units) that need to address by manufacturers to ease the transition to electric fleets.

At the same time, the case study partners have observed an increasing reliability of the vehicles and a significant increase in service quality and response times at the workshops over the period of several years of use. In addition, a further significant quality improvement has been noted with the latest generation of vehicles.

Total cost of ownership

For the widespread use of BET in transport companies, total cost advantages are a central economic prerequisite. Early adopters rank “cost benefits” as one of the top reasons for the purchase of battery electric trucks (Figure 3). However, in particular smaller companies are also faced with the challenge of financing the high initial investments for vehicles and energy supply infrastructure. Even early adopters see “high purchase prices” as a main barrier for further expansion of their electric fleet (Figure 3). The case study partners see the long-term safeguarding of operating cost advantages as the central starting point. The introduction of a CO_2-based toll plays a central role in this context. The early termination of the state funding program for climate-friendly trucks and energy supply infrastructure in Germany has led to great uncertainty and a wait-and-see attitude among transport companies from the users' point of view. In addition, reference is made to the wide range of electricity costs among companies, which - unlike diesel - has a strong influence on competition between companies.

With regard to the charging infrastructure and grid connection, government funding programs are still considered useful. Large companies in particular are also increasingly thinking about how they can also give their subcontractors access to BET through new procurement schemes without requiring these companies to finance the high initial investment.

Change management

Both the standardized survey and the case study partners show that a corporate strategy that sets itself ambitious climate targets is a key motivation for testing BET at an early stage. The personal motivation of responsible persons in the company is also often an important driver for the use of BET. At the same time, increasing customer demands for low-CO_2 transportation are also reported and stricter requirements for sustainability reporting are cited as an important influencing factor. However, it is also criticized that these requirements for the use of climate-friendly technologies - at least so far - are not yet accompanied by a significantly higher willingness to pay or another type of participation in the higher investment and operating costs from customers.

Grid connection

The further electrification of vehicle fleets is seen in many companies in connection with the current or soon-to-be-available grid connection capacity at the depot. In many cases, however, this is severely limited or associated with long lead times for upgrading. The processes for applying for an extended grid connection capacity are criticized as complicated and not very standardized, and long implementation times are complained about. In addition, competition between users within an industrial park is increasingly seen as a potential problem. From the users' point of view, simplified application processes and a forward-looking network expansion that is geared to future needs are required.

Public charging infrastructure

The current application of BET in practice is limited to usage profiles that can be managed with the current electric range of the vehicles and without regular public charging. Users consider the availability of public charging infrastructure to be essential for extending the use of BET to long-distance transport, but are comparatively skeptical about its timely availability. The forecast for the further market development of BET is therefore seen strongly in the context of the speed of expansion of public charging infrastructure. The high prices of public charging infrastructure are also problematized in this context. Users cite a maximum price of around 30 cents/kWh at public charging points, which would be necessary for the economic operation of vehicles under the given framework conditions.

Long term framework conditions

In view of the far-reaching investments that are required when switching to BET, users expect long-term predictable framework conditions in order to minimize investment risks. These relate in particular to the development of charging infrastructure and securing the operating cost benefits of BET. Other non-monetary incentives, such as the opportunity to circumvent night-time driving bans and privileges in low/zero emission zones, are also mentioned (Figure 3). Mandatory quotas for the procurement of ZEVs for fleet operators, on the other hand, are rejected - in contrast to the manufacturer side.

The lack of clarity in the current political framework for technology promotion and the technology-neutral approach tends to be seen as counterproductive for the rapid market development of BET.

4 Conclusions

The presented analyses on the assessments of the market development of BET and the associated obstacles and need for action reveal both clear overlaps and clear differences between the manufacturers and the vehicle users, as well as considerable differences within the group of vehicle users.

A clear product strategy and a focus on BET is emerging among manufacturers across the board, following a long period in which there was no clear technology preference. In addition to technological development progress, the regulatory environment with the CO_2 standards is a clear driver for this development. On the user side, the picture is much more ambivalent and the reservations about switching to BET are greater. A distinction must be made between the early adopters, who paint a very positive picture of their experiences to date and are open-minded, and the vast majority of transport and logistics companies, who have hardly any current experience with electric trucks and neither have a clear picture of promising drive alternatives nor show any inclination to switch quickly.

Compared to other recent surveys on the subject [[6], [15]], the manufacturer interviews conducted conveyed a more optimistic view of BET – other alternative fuel and propulsion options are mentioned less frequently. The fundamental assessments of the technologies hardly differ - in particular that H_2 drives can hardly compete economically with BET in the long term. Fears that the charging infrastructure cannot be implemented as quickly as originally expected and the current reluctance of users to adopt BET may be one explanation for the observed gap. At the same time, both analyses show that the risk of losing market share

to new players in the market in the course of electrification is also an important motivation for manufacturers to act decisively and to avoid negative experiences with the electrification of cars and buses and the associated weakening of the overall market. It is also hardly surprising that the charging infrastructure and, in particular, the necessary grid expansion and connection are seen as the key to the market ramp-up. This view and problem is also shared by early users.

Both groups also demand long-term and predictable framework conditions from politicians. In view of the investments required, this is an understandable demand in order to avoid investment risks.

It is interesting to note that for manufacturers, regulation has led to a clear technology roadmap across all manufacturers and it is now considered important for the long-term, plannable further development of regulation and predictable framework conditions - also with regard to carbon pricing.

On the user side, there is a lack of such clear regulatory framework conditions. Depending on their role in the market (and, among other things, the size of the company), market players are influenced to varying degrees by different factors when choosing a drive system and future developments are assessed very differently. At the same time, regulation comparable to that of manufacturers (e.g. through a ZEV quota for large fleets) is viewed very skeptically.

On the user side, it should also be noted that this is a very heterogeneous industry. Small companies in particular face major financial challenges and are often unable to make the high initial investments associated with the introduction of BET. Support programs tailored to their needs or partnerships with contractors appear necessary.

In view of the early market phase, it will be important to monitor the challenges posed by the further market development of BET in future analyses and to pay greater attention to the majority of companies that have not yet gained any experience with BET.

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