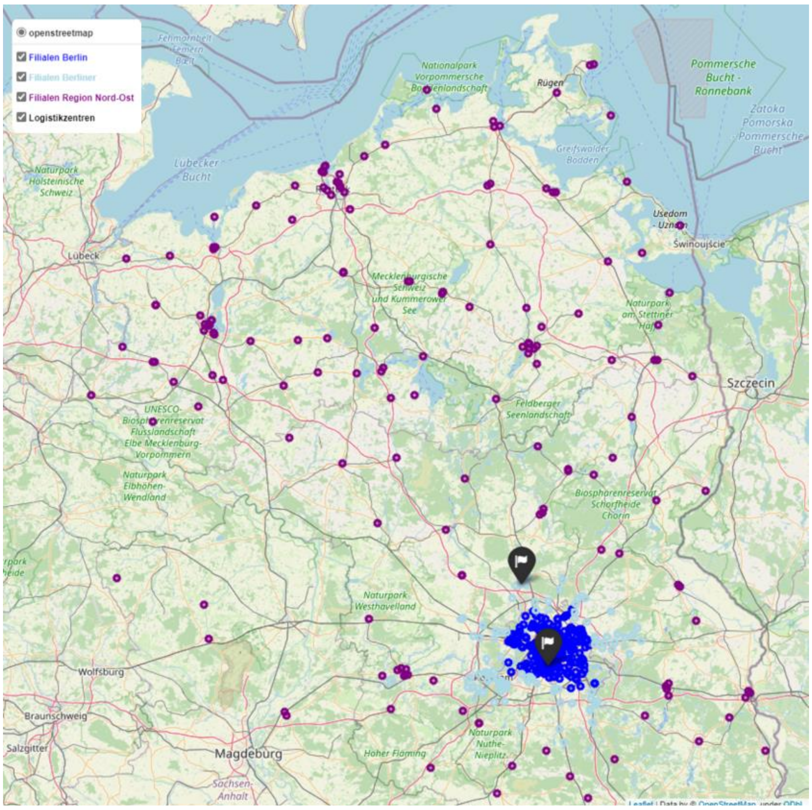


Lieferverkehr mit Batterie-Lkw: Machbarkeit 2021

Fallbeispiel REWE Group - Region Nordost

Ort: Karlsruhe

Datum: 11.11.2021

Final

Impressum

Lieferverkehr mit Batterie-Lkw: Machbarkeit 2021

Projektleitung

Fraunhofer-Institut für System- und Innovationsforschung ISI
Breslauer Straße 48, 76139 Karlsruhe
Patrick Plötz, Patrick.Ploetz@isi.fraunhofer.de

Autoren

Fraunhofer-Institut für System- und Innovationsforschung ISI
Breslauer Straße 48, 76139 Karlsruhe
Steffen Link, Steffen.Link@isi.fraunhofer.de
Patrick Plötz, Patrick.Ploetz@isi.fraunhofer.de
Janik Griener, Janik.Griener@isi.fraunhofer.de
Cornelius Moll, Cornelius.Moll@isi.fraunhofer.de

Auftraggeber

Transport & Environment (T&E) / European Climate Foundation (ECF)
T&E Deutschland: Neue Promenade 6, 10178 Berlin, Deutschland
ECF: Riviervismarkt 5, 2513 AM The Hague, Niederlande

Bildnachweis

Deckblatt: Eigene Abbildung - Leaflet | Data by © OpenStreetMap, under ODbL

Zitierempfehlung

Link, S.; Plötz, P.; Griener, J.; Moll, C. (2021): Lieferverkehr mit Batterie-Lkw: Machbarkeit 2021 – Fallbeispiel REWE Group - Region Nordost. Karlsruhe: Fraunhofer-Institut für System- und Innovationsforschung ISI

Veröffentlicht

November 2021

Danksagung

Die Autoren bedanken sich bei allen internen und externen Gutachtern dieses Berichts, insbesondere bei Fedor Unterlohner und Jekaterina Boening (beide T&E), Martin Wietschel und Daniel Speth (beide Fraunhofer ISI) sowie der REWE Group für die Begutachtung und Freigabe des Berichts. Ein besonderer Dank gilt weiterhin der gesamten Projektgruppe und den Mitgliedern des Beirats für den fachlichen Austausch und die konstruktiven Diskussionen.

Hinweise

Key Findings

- Heavy-duty battery-electric trucks (BET) offer tremendous potential for greenhouse gas emission reduction in transport. However, owing to limited electric range and high acquisition costs, their current feasibility in logistics is under discussion.
- The present study examines the current techno-economic feasibility of BET for a large logistics company based on real tours during one month. The tour data sample consists of 9,500 real tours to 543 retail stores executed by 224 heavy trucks over 12 t gross vehicle weight (GVW). For each vehicle, the individual energy demand is simulated based on its operating profile including auxiliaries, and the total costs of ownership (TCO) are calculated for vehicle purchase in 2021 and eight year service life.
- Given currently available battery truck ranges (model years 2021 - 2023), all trucks in urban delivery and almost half of the trucks in regional delivery are technically feasible with BET. Charging at night is almost always sufficient. Especially very heavy trucks with GVW over 26 t and very long daily trips pose a challenge given the announced ranges up to 2023. In future, however, these are likely to become feasible with extended battery capacities, additional opportunity charging or optimized route planning.
- Even in 2021, BETs may be economically viable compared to diesel trucks if they exhibit high mileage. The cost advantage of BET increases with mileage, as higher purchase costs amortize through lower operating costs. In urban delivery, the annual mileage is often insufficient for an overall cost advantage, even under the current German purchase subsidies for BET. However, especially in regional delivery, many vehicles already achieve significant cost advantages. Overall, around 42% of the considered vehicles and 21% of their transport activity are both technically feasible and more cost-effective with BET as of today.
- Key factors affecting the current economic viability of BET are the 80% purchase subsidy for the additional vehicle costs (as compared to a diesel truck) and infrastructure as well as the increasing CO_2 price for diesel fuel or a corresponding CO_2-based road toll. In future, decreasing prices for BET will enable economic operation even with decreasing subsidies, particularly safeguarded and enhanced by significant CO_2 pricing.
- Due to the high feasibility and possible cost-effectiveness, logistics operators and fleet owners are advised to evaluate their fleet with respect to a switch to battery electric trucks for city logistics and regional delivery as of today. The current policy framework offers not only cost saving opportunities but allows to gain valuable experience for the transition to electric trucks in future.

Summary

Motivation and scope

Heavy-duty battery-electric trucks (BET) offer tremendous potential for reducing greenhouse gas emissions in transport. However, owing to the limited electric range and high acquisition costs, their techno-economic feasibility in logistics is still under discussion. Thus, this study aims to evaluate the technical feasibility and economic viability of BET above 12 t gross vehicle weight (GVW) for city and regional delivery under current conditions in Germany. Food retail logistics serves as a case study. Based on these findings, this study provides recommendations and knowledge for policy-makers and the industry.

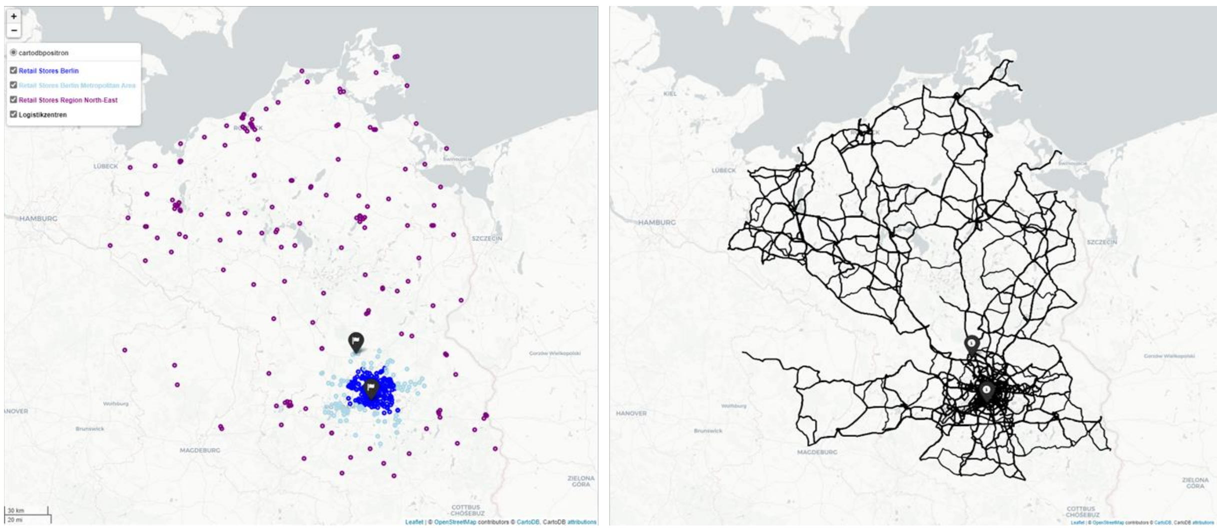
Data: 9,500 real tours to 543 retail stores by 224 trucks other one month period

This study utilizes real-world tour data from commercial tour scheduling software provided by the REWE Group for two depots in the northeast region of Germany. The smaller depot in Mariendorf is mainly used for city deliveries in Berlin and the metropolitan area. The larger depot in Oranienburg is additionally and predominantly used for regional deliveries to the entire northeast region. The tour data comprises all tours of February 2021 and provides information on, among others, chronological sequence, distance, and payload per tour and for each vehicle.

Our final data set includes 8,300 of the 9,500 total tours, with the difference filtered out as non-relevant. This covers 224 trucks and a total mileage of around 1 million km. Four different truck classes are distinguished. These are trucks with a GVW of 18 or 26 tons as solo refrigerated trucks and as truck-trailer combinations as well as tractor and refrigerated semitrailer combinations (48% of the total fleet). Solo trucks are primarily used for city logistics. Truck-trailer and tractor-trailer combinations are used in both city logistics and regional delivery. 162 of the 224 trucks are used in Oranienburg.

The northeast region comprises 543 retail stores in total. Figure 7 shows the depot locations and individual customer locations (left) as well as associated tours across the northeast region (right). Around 50% of customers are located in the Berlin zip code area (blue). Together with the metropolitan area of Berlin, this results in a local concentration of 70% (light blue). The remaining retail stores are spread across the northeast region (purple).

Figure 7: Summary - Northeast Region: Customers (Left) and Tours (Right)



Source: Own illustration with Leaflet | Data by © OpenStreetMap

Methodology: Defining the current techno-economic feasibility of BET

The technical feasibility involves an individual energy simulation for each truck and market research for currently and near-term available BET. The simulation uses a simplified mathematical-physical vehicle model to derive the specific energy consumption for each tour and accounts for additional energy requirements such as accessories or payload cooling. In total, this results in the theoretical yet specific energy demand for each truck. In addition, a possible intermediate depot charging within the depot premises - e.g., directly at the cargo terminals - is investigated to secure tours and extend vehicle coverage. Tour schedule is presumed to be exactly as of February 2021, without any potential from optimized tour scheduling or truck re-allocation. Plus, note that this study assumes that all tours of the respective truck must be feasible to confirm its technical feasibility in total. The average battery size for all trucks in the respective class is determined for each location by matching the theoretical necessary battery capacity and the available battery sizes. For convenience, a truck-specific battery choice is neglected.

The economic analysis compares the total cost of ownership (TCO) for BET versus diesel trucks over an eight-year service life and for truck acquisition in 2021. Apart from acquisition costs, truck resale, and operating costs, costs for charging infrastructure at the depots are included. Infrastructure costs for overnight charging are assessed per truck, while further charging infrastructure for intermediate depot charging is averaged over the entire potentially electrified truck fleet per depot. Current subsidies for climate-friendly commercial vehicles and the associated charging infrastructure are accounted. This study uses an equivalent CO_2 tax for diesel and the current German toll regulation rather than a CO_2-based toll charge as proposed by the Eurovignette Directive. In total, the cost-effectiveness of BET versus diesel trucks is determined individually for each truck.

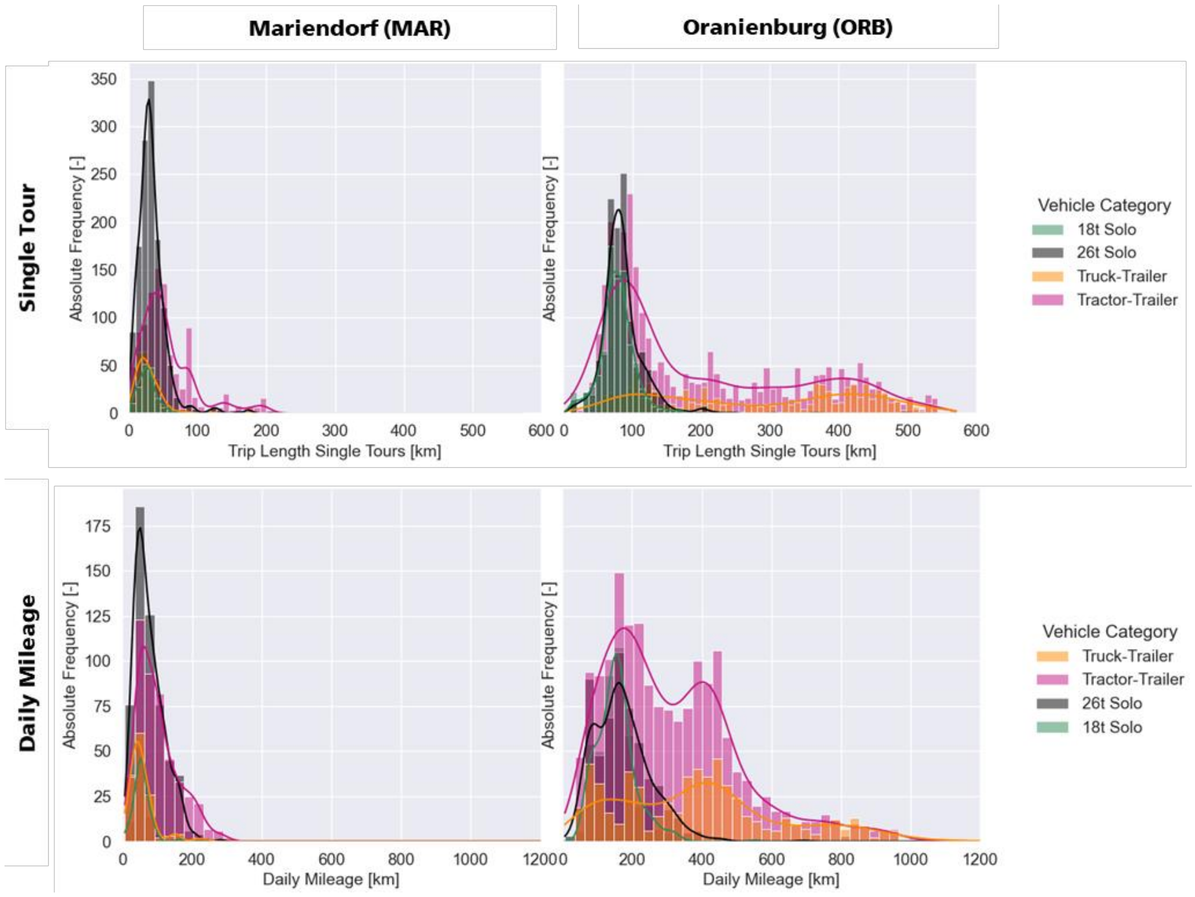
Daily mileages in city delivery generally less than 200 km and less than 500 km in regional delivery

Figure 8 shows the absolute number and estimated probability density distributions of single tours and daily mileage by truck class and depot location. The upper row shows single tours, the lower row daily mileage. The latter is composed of one to five individual tours per day and truck, whereas one and two tours per day are most common.

The analysis of ***individual tours*** shows that for city delivery from Mariendorf, almost all tours (99%) in all classes are under 200 km. Trucks from Oranienburg have higher overall mileages. Solo trucks are mainly used in Berlin and the metropolitan area. Accordingly, the share of tours under 200 km is 99%. Truck-trailer and tractor-semitrailer combinations are additionally and predominantly used to supply the entire northeast region. Around a quarter of all tours for the tractor-semitrailer and half of all tours for the truck-trailer are over 300 km. The longest single tour is 570 km for Oranienburg and 220 km for Mariendorf.

The analysis of ***daily mileage*** identifies a maximum of 320 km for Mariendorf and a high proportion (96%) with less than 200 km. In Oranienburg, this proportion is only 45 %. Similar to the individual tours, total mileage is higher. For solo trucks, the maximum daily mileage is around 400 km while a high proportion (85%) is already below 200 km per day. For truck-trailer and tractor-semitrailer combinations, only 54% (truck-trailer) and 36% (tractor-trailer) of daily mileage is under 300 km per day. For truck-trailers, about 20% of daily mileage is over 600 km per day. For tractor-trailers, this share is only 10%. In multi-shift operation, the maximum daily mileage is 1,280 km for Oranienburg.

Figure 8: Summary - Analysis of single tours and daily mileage



Source: Own illustration

Representativeness

Owing to highly varying truck applications and specifics per sector, industry, and even fleet company and due to only a few comprehensive truck datasets with sufficient observation periods available, it is difficult to assess the representativeness of this study compared to the entire German truck fleet. However, to better classify the data and generalize our findings, the following points are helpful:

1) By examining food retail logistics as part of the distribution logistics, this study covers up to a quarter of Germany's total road freight transport activity. Furthermore, this study covers about 15% of Germany's total area and about 9% of the total population, and the four truck classes cover about 87% of the German N3 truck stock.
2) The comparison to the KiD driving profiles (Wermuth et al. 2012) indicates a disproportionate share of annual mileage below 100,000 km in our data set, but overall a similar mileage distribution for tours from Oranienburg. Urban tours from Mariendorf are significantly shorter than the mean for all trucks of the same class.
3) Different Eurostat transport statistics suggest a similar distribution of transported payload across truck classes and a similar distribution of transport activity across different distance levels.

Overall, this study assesses urban and regional delivery as two essential parts of German road freight transport. Although a clear distinction and classification is not possible, we conclude that the Oranienburg depot, in particular, reflects urban and regional delivery traffic in Germany well. Plus, some findings may be applied to the whole road freight transport as well.

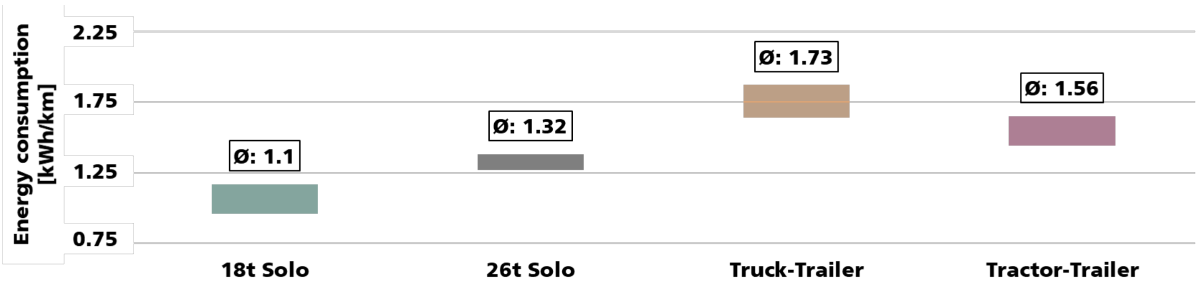
Market research: Variety of models from 250 to 550 kWh in series or pre-series production

The market research focuses on the 2021 to 2023 period and identifies a prevailing share within 250 to 400 kWh gross battery capacity for 18 t and 26 t solo trucks by major European truck manufacturers. For road tractors, this corridor ranges from 350 to 550 kWh. For all classes, initial announcements and near-market models with more than 600 kWh and up to 900 kWh battery capacity - a prerequisite for long-haul transport in the future - are already emerging. Plus, a modular system portfolio with different battery capacities for one model to fit individual customer requirements best is evident.

Vehicle simulation: Energy consumption from 1.1 to 1.7 kWh per km depending on truck class

Figure 9 shows the aggregated simulated energy consumption per segment as median with interquartile range (IQR) across all tours. Higher variation for tractor-trailer and truck-trailer combinations result, among others, from diverse operations in city and regional delivery. Overall, simulation results span from 1.1 kWh/km median for the 18 t solo truck, 1.32 kWh/km for the 26 t solo truck, 1.56 kWh/km for tractor-trailer, to 1.73 kWh/km for the truck-trailer combination. These results are consistent with other studies.

Figure 9: Summary - Simulated energy consumption per distance (battery-to-wheel)



Source: Own illustration

Technical feasibility: 58% of trucks and 25% of transport activity (ton-kilometers)

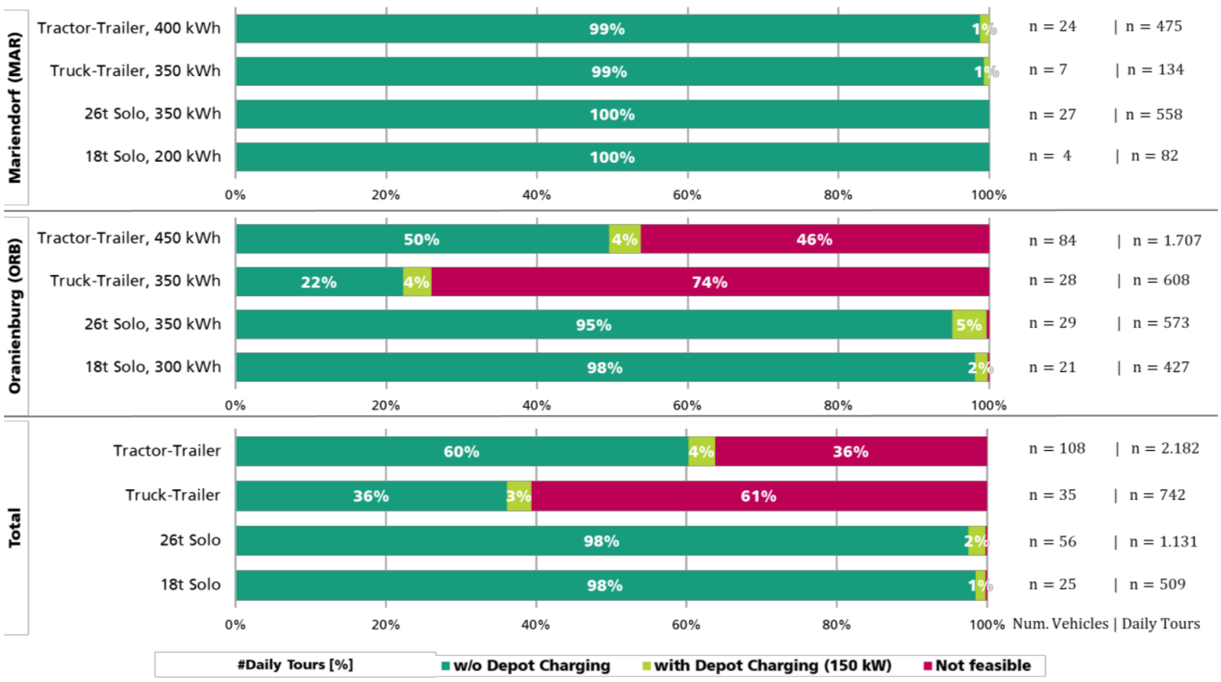
Figure 10 shows the technical feasibility as a proportion of daily trips per class and per location depending on the selected gross battery capacity.

For urban delivery in ***Mariendorf***, 100% or 62 of 62 trucks can be electrified due to short single tours and daily mileage. Intermediate depot charging has a minor impact and safeguards a few daily tours.

For urban and regional delivery in ***Oranienburg***, solo trucks and truck combinations operating in Berlin and the metropolitan area may be fully electrified as well. For the entire northeast region, technical feasibility is significantly lower for tractor-trailer and truck-trailer combinations as of today. Intermediate depot charging has a particular impact on this use case. However, individual non-feasible tours that are too long for a single battery charge limit this range-extending effect. Based on the truck allocation to individual tours, we deduce that 43% or 69 of 162 trucks in Oranienburg are technically feasible and, thus, replaced with BET.

This leads to technically feasible electrification of 58% or 131 of 224 trucks with currently available BET models for the ***entire northeast truck fleet***. An allocation of tours to transport activity (ton-kilometers) - excluding any truck allocation - yields a technically feasible electrification of 32% without depot charging and 36% with depot charging. However, only 25% of the total transport activity may be electrified if this truck allocation is included. Note that there is no optimization, truck re-allocation, or adjusted tour schedule. Tours are presumed to be exactly as of February 2021.

Figure 10: Summary - Current technical feasibility



Source: Own illustration

Economic viability: Cost effectiveness of BET versus diesel trucks for 81% of all trucks

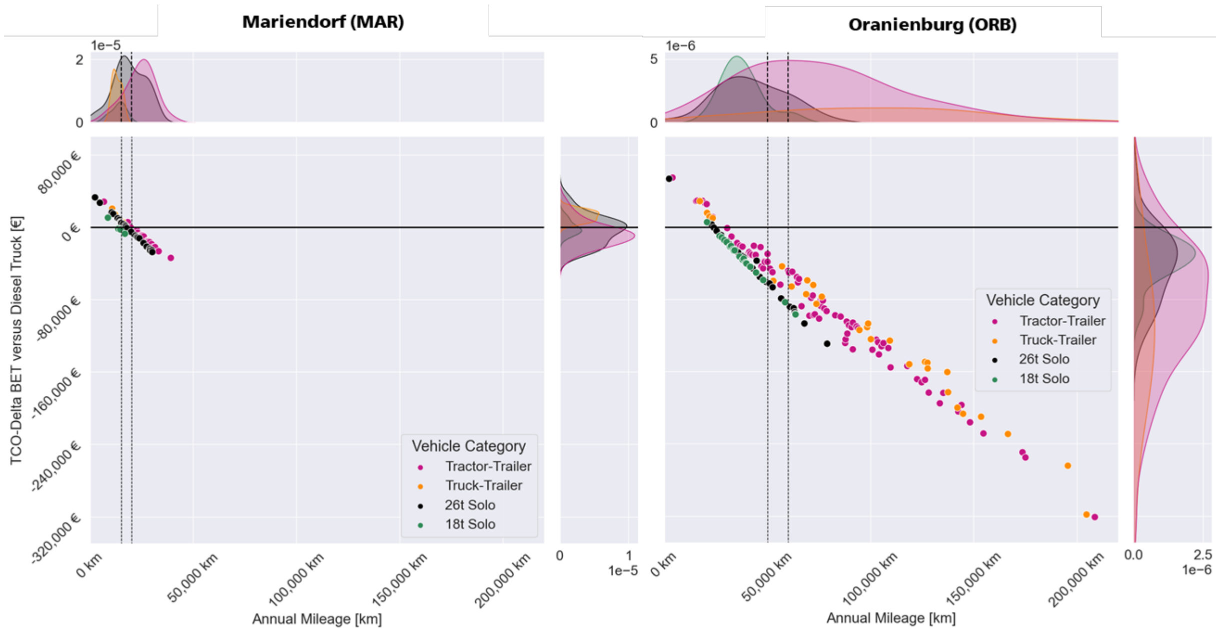
Figure 11 visualizes the TCO difference for BET versus diesel trucks for each truck by depot location and over annual mileage function. A negative cost difference means that a BET purchased in 2021 is more cost-effective than a diesel version. Annual mileage is extrapolated from monthly mileage. This results in an average annual mileage of around 18,000 km in Mariendorf and 60,000 km in Oranienburg. In addition, a mean annual mileage range according to REWE is included for both depots.

In ***Oranienburg***, diesel trucks offer a current economic advantage for an annual mileage of less than 30,000 km across all segments. At higher mileages, lower operating and maintenance costs amortize higher purchase costs for BET. Overall, BET achieved a cost advantage in 90% or 147 of 162 of the trucks. Cost advantage cumulates to more than €10,000 over eight-year truck service life for 141 trucks, which implies a certain resilience. These are especially 18 t and 26 t solo trucks as well as the tractor-trailers. This economic analysis does not include any technical feasibility but only focuses on cost assessment based on the annual vehicle mileage.

In ***Mariendorf***, higher acquisition costs amortize less frequently due to significantly lower mileage, even though infrastructure expenditures are lower as depot charging has minor relevance. For an annual mileage below 20,000 km, battery trucks achieve no or only a tiny cost advantage across all segments. In total, 58% or 36 out of 62 trucks achieve an advantage, with only 19 trucks showing a significant cost advantage of more than €10,000 over the eight-year truck service life. These are especially 26 t solo trucks and tractor-trailers. This economic analysis does not include any technical feasibility but only focuses on cost assessment based on the annual vehicle mileage.

For the ***entire northeast truck fleet***, this implies economically attractive electrification of up to 82% or 183 of 224 trucks under the current subsidy for climate-friendly commercial vehicles. Note that is based on current vehicle purchase prices (2021) and current policy framework and excludes technical feasibility.

Figure 11: Summary – Current TCO difference



Source: Own illustration

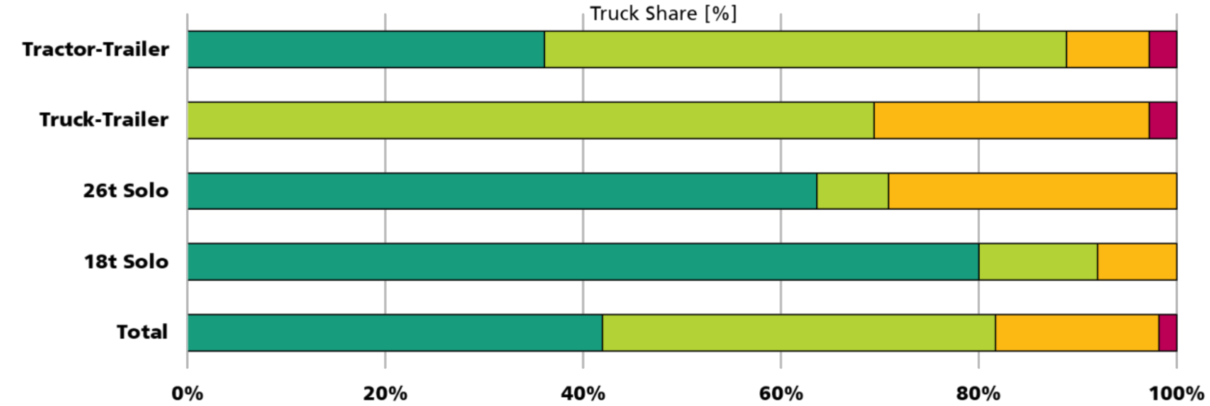
Techno-economic feasibility: 42% of the fleet and 21% of the transport activity (ton-kilometers)

The techno-economic feasibility crosses technical feasibility and economic viability per truck. Overall, a trade-off between technical feasibility and economic viability depending on annual mileage is evident. The cost advantage of BET increases with mileage, as lower operating costs amortize higher acquisition costs that remain even after current subsidy. However, the technical feasibility decreases with increased annual mileage as single or even daily tours - even with intermediate depot charging - cannot be completed i.e., electrified. Thus, the technical feasibility is often high for short trips and correspondingly low annual mileage, yet higher acquisition costs do not amortize.

Figure 12 visualizes the techno-economic electrification potential for the ***entire northeast truck fleet*** as the main result of this study. The bar chart reflects the relative shares per segment and is complemented by a summary in absolute figures. For the northeast region, a total of around 42% of the trucks (94 out of 224) may be electrified from a techno-economic perspective. An allocation to transport activity yields that only 21 % of the total transport activity may be electrified as of today.

In detail, techno-economic electrification potential in ***Mariendorf*** is 36 out of 62 trucks (58%) and in ***Oranienburg*** 58 out of 162 trucks (36%). This comprises 20 solo trucks of 18 t, 35 solo trucks of 26 t and 39 road tractors. This potential is significantly higher from an economic perspective, but the technical feasibility limits the potential due to excessive mileage. This share may be improved by optimized tour scheduling but is not investigated.

Figure 12: Summary - Techno-economic feasibility of BET for the entire truck fleet



	Total	18t Solo	26t Solo	Truck-Trailer	Tractor-Trailer
Econ. + Techn.	94	20	35	0	39
Econ. only	89	3	4	25	57
Techn. only	37	2	16	10	9
Not feasible	4	0	0	1	3

Source: Own illustration

Discussion: Higher potential in city logistics and regional delivery in Germany seems reasonable

Tours and accompanying vehicle allocation are presumed to be exactly as of February 2021, without any optimization. Based on this, we simplify by assuming that all trips must be technically feasible to classify one truck as feasible in total. Thus, a few non-feasible tours have a high impact on our final result. Especially tour rescheduling or re-allocation between trucks may further improve technical feasibility. Intermediate charging at public charging stations or at selected retail stores may further increase technical feasibility.

Uncertainties for total costs of ownership arise from current acquisition costs, resale values, and energy prices. Our energy policy framework includes the current 80% subsidy for trucks and infrastructure and the CO_2-based levies. Initial truck subsidy and the operating cost benefit from the CO_2 levy have a high impact on the economic viability of BET. If future costs for battery trucks decrease, cost-effective operations will likely become feasible even with lower subsidies.

In total, our assumptions reflect the current regulatory framework and focus on series and pre-series truck models that are already available. As all tours of over 200 trucks are analyzed over one month, our results are likely robust and realistic for current city logistics and regional delivery.

Conclusion: City logistics can be fully electrified and significant proportions in regional delivery can be electrified. In total, over one-quarter of transport activity can be electrified within a few years.

Current BET are already sufficient to electrify significant parts of German road freight transport. In our case study, around 42% of the fleet can be electrified from a techno-economic perspective. This corresponds to 21% of the transport activity, whereas up to 36% seem possible from a technical perspective by tour rescheduling and re-allocating.

Recommendations for REWE: 58 of 224 trucks may be replaced by today

In our case study, up to 42% of the truck fleet (94 out of 224) can be electrified from a technical perspective and should be electrified from an economic perspective. This appears technically feasible and should reduce overall costs.

In the future, and apart from truck availability only, tour scheduling should integrate vehicle range and battery SoC when assigning subsequent tours to ease fleet electrification. Equipping cargo terminals with charging points could be a potential hurdle due to additional costs, space, and other limitations. Therefore, we recommend first electrifying trucks that do not rely on intermediate depot charging. For the Northeast region, this comprises 58 of the 224 trucks.

Recommendations for fleet owners and shippers: Start examining your transition to climate-friendly commercial vehicles

All logistics companies should already examine the transition to BET in city logistics and regional delivery today. The provision of depot infrastructure for overnight charging is crucial. Furthermore, an individualized vehicle analysis is recommended to select an appropriate battery size in line with the modular battery sizes offered by the manufacturers for each application and tour schedule. Payload restrictions for trucks with battery sizes suitable for city logistics and regional delivery are unlikely due to the current exemption for increasing the permissible GVW. Logistics companies should work closely with their local energy provider on grid network expansion, as costs and effort depend heavily on local conditions.

Policy recommendations: subsidies, toll system, and regulation

The 80% subsidy for zero-emission vehicles and their infrastructure is decisive for the economic viability of battery trucks during this early market phase. The importance of charging infrastructure at depots should be emphasized. At the same time, additional measures such as tolls and CO_2 taxes are crucial for securing the economic viability of battery-electric trucks compared to diesel - especially in city logistics.

In light of the identified technical feasibility and, in most cases, economic viability of BET for urban and regional delivery, an upcoming roll-out of zero-emission zones in large metropolitan areas seems reasonable. Furthermore, according to our results, one third of electrified road transport in 2030 according seems reachable though very ambitious. However, this requires corresponding model availability. Although the announcements on market shares and sales targets for battery trucks by all truck manufacturers are promising, current delivery times are extremely long and might even cause problems with the truck subsidy. To accelerate market diffusion, the aforementioned zero-emission zones may help to further increase customer demand for BET. Plus, stricter CO_2 fleet targets and zero-emission vehicle mandates may help to boost model offers and increase availability of climate-friendly commercial vehicles and, meanwhile, reduce vehicle costs more quickly.