Analysing Vehicle Cost Dynamics: How CO_2 Pricing Drives Electrification in Road Transport

Kai Kindsgrab M.Sc.
Muenster School of Business (MSB), FH Muenster, Germany, kai.kindsgrab@fh-muenster.de

Co-Autor: Prof. Dr. Michael Dircksen
Muenster School of Business (MSB), FH Muenster, Germany

Co-Autor: Univ. Prof. Dr.-Ing. Hartmut Zadek
Institute of Logistics and Material Handling Systems, Otto von Guericke University Magdeburg, Germany

DOI: http://dx.doi.org/10.25673/116279

Abstract

Globally, logistics activities contribute between 11% and 12% of emissions. In 2021, the EU27 transportation sector emitted 782 MtCO2e, with 21% from heavy goods vehicles. This paper analyses the effects of environmental policies on road freight transport costs. Therefore the BGL cost calculation scheme was used and sharped in order to calculate sustainable total cost of ownership (STCO), which includes compensation cost for CO2 emissions and break even points for Battery electrical vehicles (BEV). It suggests that a price of >= €291 per ton CO2 with toll rates from 2023 or €96 with toll reforms including a CO2 component could justify transitioning to BEVs provided TCO remains below €225,000. The results gain transparency for practitioners and academics to identify break even points in transport cost calculation as well as show policy makers financial effect of environmental measures.

1. Introduction

The latest IPCC report underscores the significant impact of global warming and the urgency of transitioning to a green economy [11]. In 2021, the EU27 domestic transportation sector emitted 782 MtCO2e, with 21% attributed to heavy goods vehicles and approximately 5% of all EU27 emissions are from HGVs [7]. Globally, logistics activities contribute between 11% and 12% of emissions [21]. To incentivize freight companies to reduce CO2 emissions, governments are increasingly relying on market-based environmental policies. One of these measures is the introduction of a CO2 component in the truck toll and the associated exemption of BEV trucks. Of the approximately 800,000 trucks on German roads, only 400 are currently electrically powered, which corresponds to a share of 0.05%. In the coming years, however, this proportion is to be increased. In the realm of battery electric vehicles (BEVs), two primary types exist: battery trucks, which rely solely on their internal batteries for power, and overhead line trucks, where energy is continuously supplied to the truck via an overhead power line along the road [12]. Logistics service providers (LSP) now have the challenge of making an economic decision for themselves as to when it makes sense to switch to a BEV truck. The following research question arises from this problem:

> **RQ: What level must a national CO2 price reach to ensure the economic viability of battery-electric (BEV) trucks over internal combustion engine (ICEV) trucks?**

To answer this question, the lead author continues his investigations and draws on the results already calculated in the last IDWL paper [18]. These results are compared with new values for a BEV truck and a variance analysis is carried out. The author thus continues to show which results can be calculated with his TCO model based on VDI standard 3633 and supports this in his dissertation project. The study is divided into five chapters. Chapter 2 identifies the interactions of environmental policy measures on the individual cost units and provides an overview of various BEV truck types. Chapter 3 presents the main results of the variant analysis. Chapter 4 identifies the limitations and further research opportunities.

2. Methods or experimental part

Various TCO calculations were carried out to perform this calculation. Goeckeler et al 2023 calculated TCO costs based on tolls, energy costs, energy infrastructure costs, administrative costs, purchasing costs and other costs [10]. Rosenberg et al 2023 compare different technologies and their applications and costs [22]. Bongrad et al 2023 also calculates the economics of BEV trucks [5]. Joehrens et al 2022 also calculate different cost levels for different powertrain technologies depending on annual mileage [14]. Together with Andersson, Joehrens also discussed different TCO cost levels in different countries [1]. The basis for this paper was the BGL cost model [3]. Current legal framework conditions as well as the technical and economic environment of a BEV trucks were considered.

2.1. CO2 Truck toll and national CO2 Price

Since December 2023, toll charges in Germany have increased by more than 80%. This primarily stems from the introduction of a novel toll rate component, valuing CO2 emissions at €200 per ton of CO2 [23]. Consequently, toll charges now comprise components including noise pollution, air pollution, infrastructure, and CO2 emissions. Both heavy goods vehicles (HGVs) are classified as Euro 6, with the battery electric vehicle (BEV) HGV assigned CO2 class 5 and the diesel HGV assigned CO2 class 1.

Presently, BEVs enjoy exemption from the CO2 toll charges. However, commencing 2026, they too will become subject to tolls, albeit to a limited extent [2]. Nevertheless, they will accrue savings on a portion of the noise pollution costs, 75% of the infrastructure costs, and 100% of the CO2 emission costs. Consequently, commencing 2026, BEVs will incur 0.2 cents for noise pollution costs, 2.3 cents for air pollution costs, and 25% of the 19 cents for infrastructure costs [4].

In addition, BEV trucks are also exempt from motor vehicle tax. This exemption initially applies until the end of the year 2030 or for a maximum of ten years after purchase [19]. Normally, the tax for trailers pulled by an electrically powered vehicle is reduced by 50%.

The global adoption of carbon pricing mechanisms has witnessed a progressive rise, with CO2e pricing schemes encompassing an increasing proportion of greenhouse gas emissions. In 2020, these schemes covered 15.1% of global emissions, escalating to 21.7% by 2021 [27] . This surge is chiefly attributable to the implementation of diverse carbon pricing mechanisms worldwide, including the Chinese Emissions Trading Scheme, the BEHG in Germany, an ETS in the UK, and CO2e taxes in Luxembourg and the Netherlands [17].

Concurrently, the EU has fortified its decarbonization endeavours via initiatives like the European Green Deal, which aims to achieve a 95% reduction in greenhouse gas emissions by 2050, aligning with the Paris climate targets. Notably, the EU has instituted the EU-ETS, a certificate trading system targeting major emitters, particularly in the energy sector. However, the transportation sector, expected to witness burgeoning demand and emissions, remains excluded from the EU-ETS. Efforts have been underway to explore the integration of logistics service providers into carbon pricing mechanisms to mitigate emissions [16].

In Germany, a synthesis of the Pigou tax and certificate trading scheme culminated in the establishment of a national emissions trading system under the BEHG. This system features a fixed price for the initial five years, incrementally rising from €25 per ton of CO2e in 2021 to €55 by 2025 [6]. The EU intends to incorporate the transportation sector into the EU-ETS by 2026 (ETS2); however, the specific mechanisms for offsetting emissions, whether via downstream or upstream principles, remain ambiguous. This transition could significantly impact national freight forwarders, particularly in terms of cost implications. Furthermore, with only a limited number of countries currently implementing carbon pricing mechanisms, carriers may exploit strategic tour calculation methods to minimize fuel costs. Concurrently, discussions persist regarding additional political instruments, such as the modification of truck tolls or the fortification of fleet regulations, to align with national climate laws [20].

These unfolding developments necessitate adjustments in the transport cost calculation schemes of national carriers.

2.2. System analysis BEV truck

There are two main types of BEV. One is the battery truck, and the other is the overhead line truck. In the case of the overhead line truck, the truck is constantly supplied with energy via a power line above the road. The first trials have already been carried out in the Frankfurt area and near Hamburg. Here, a single-lane road was equipped with overhead lines over a length of 5 km. The advantage of such a system is that the battery does not add weight to the truck, and the truck can carry the same or even more payload than an ICEV truck. A major disadvantage, apart from the high infrastructure costs, is that the cables are in the way during a potential air rescue and can only be attached to the left or right outer

side, as the cables need to be supported every 10 metres to prevent sagging. This not only limits the number of trucks that can use such a cable, but also prevents individual trucks from overtaking on another lane. A traffic jam or accident on the overhead line in question would mean that all the trucks behind would have to wait. Because of these drawbacks, the current literature tends to focus on pure battery electric trucks or hybrid models with internal combustion engines, which cannot run long time without overline electricity.
A battery electric truck is operated in the same way as a battery electric car, with permanently installed or replaceable batteries on board. As technology has progressed, different battery sizes with different ranges have become available. In the case of a battery-powered truck, the conflicting objectives are that a larger battery, usually a larger number of individual batteries, not only increases the purchase cost, but also the total weight, which results in a lower available payload, a larger tyre footprint and thus higher power consumption. Currently, BEVs can travel more than 500 kilometres without stopping to recharge [13]. They can carry payloads of up to 18 tonnes and need only 45 minutes to recharge their batteries for another trip of a similar distance. Despite these advances, there is still a considerable gap to close with ICEVs, which can achieve ranges between 600 and 1000 km on a 15-minute charge. To compensate for the competitive disadvantage of low payload due to the additional weight of the battery, the EU discuss at the moment to increase for battery-powered trucks the gross vehicle weight from 42 to 44 tonnes [15].

The purchase price of a BEV is currently three times higher than that of an ICEV. The decision to purchase BEVs depends heavily on government subsidies, which can subsidise up to 80% of the additional costs for electric drive systems (as of October 2023). All new commercial vehicles in EC vehicle classes N1, N2 and N3 that have an electric drive and no conventional drive were subsidised until last year [4]. BEV trucks fall into the EC commercial vehicle category N3 and would be procured as new vehicles so that they remain eligible for subsidies. Due to the reduction in the fiscal budget, funding has been suspended in 2024 until further notice [26]. Table 1 summarizes all the relevant subsidies.
The higher acquisition costs of BEVs compared to ICEVs are mainly due to the currently high manufacturing costs. It is expected that these costs will fall over time, both due to falling battery prices and due to efficiency improvements in the production facilities based on experience and learning effects, which will lead to more costeffective manufacturing processes. Future economies of scale should also help to reduce the production costs of BEVs in the coming years. By 2030, BEVs are expected to have an overall cost advantage over ICEVs in all weight classes.

Table 1: Relevant subsidies and laws

Description	**Time**	**Source**
Act on national certificate trading for fuel emissions (Fuel Emissions Trading Act - BEHG).	Since 2021 – today (currently discussed if it would be integrated in a EU-ETS2 in 2027).	[9]
Act on the levying of distance-related charges for the use of federal motorways and federal roads (Federal Trunk Road Toll Act - BFStrMG).	Since 2011. Updated frequently. Last update December 2023. Introduction of CO2 Component	[2]
Announcement of the directive on the promotion of light and heavy commercial vehicles with alternative, climate-friendly drive systems and associated refueling and charging infrastructure for electrically powered commercial vehicles (pure battery electric vehicles, externally chargeable hybrid electric vehicles and fuel cell vehicles).	Since 2021. Suspended since 2024	[4]

To illustrate the effect of CO2 pricing and subsidies, two trucks were compared with real costs in a case study.

2.3. Data acquisition

There are different figures in the literature for the price of a BEV truck and different future scenarios. However, all prices are currently higher than for an ICEV. A price of €381,600 for a Volvo FH 42 Electric was obtained from an internal dealer quote [25]. The government subsidy results in an actual purchase cost of €174,120. In addition to the purchase cost of a BEV truck, the cost of installing charging points and any route adjustments must also be considered. After deducting the subsidy, these amount to €31,052 for the installation of a

charging point at the ramp, €4,000 for underground engineering and €1,907 for the engineering office. All cost items could be allocated to several BEVs, as the infrastructure may not be used by just one BEV. However, to simplify the calculation, a TCO in the first year of €200,000 was assumed, in line with a study by PWC [8].
The results of the Kindsgrab et al. 2023 study were used to calculate the ICEV truck costs. Annual TCO of €172,834.35 were calculated based on various public databases [18]. A potential CO2 price, indicating a break-even point, can now be calculated using the available data.

3. Results and Discussion

To determine this CO2 price, the CO2-independent cost types must first be deducted from the TCO price of a BEV truck of €200,000 (see figure 1). At 40.8%, driver costs and other fixed costs form the largest value in the TCO calculation. At €41,406.25, driver costs account for the largest share. The proportionate administrative costs of €15,000 and other fixed costs such as repairs, vehicle tax, cleaning and imputed interest make up the smaller part at €20,134.10. After deducting these costs, €118,459.65 remains. If the variable costs, such as tire costs or depreciation costs, are deducted, €103,507.65 remains. Depending on the toll rate to be applied, this results in a diesel budget of €76,907.65 for a EURO VI under the old toll regulation (2023) and a budget of €54,787.65 under the new regulation (Dec. 2023) with a toll rate of 34.8 cents per km. With these diesel budgets, the potential CO2 price can now be calculated using the formulas as follows:

$$CP = \left(\left(\frac{Db}{Jkm/100} \times dk\right) - dp\right) \div \frac{Cf}{1000} \qquad (1)$$

With:

CP	CO2 price [€/t]
Db	diesel budget [€]
Jkm	Annual mileage [km]
dk	Diesel consumption [l/100]
dp	Diesel price [€/l]
cf	CO2 consumption [kg CO2/ L Diesel]

As shown in the figure 1 this results in a CO2 price of €70.38 for the old toll rule and a negative price of -€125.44 for the new toll rule. This means that under the old toll rule, a BEV truck would be financially better off from a CO2 price of €70.38, which would lead to a diesel price of €195 per 100 litres of diesel (initial value €170). According to the new toll rule, only a subsidization of the diesel price through a negative CO2 price could generate the cost advantage for the ICEV truck.
With the help of a variance analysis and this formular, various tipping points of the solution can now be determined. Following the same logic, these values can also be converted into a CO2 price per tonne using the tank-to-wheel (TTW) value of 2.67 kg per litre of diesel, for example, in order to evaluate the steering effect of potential CO2 price paths in.

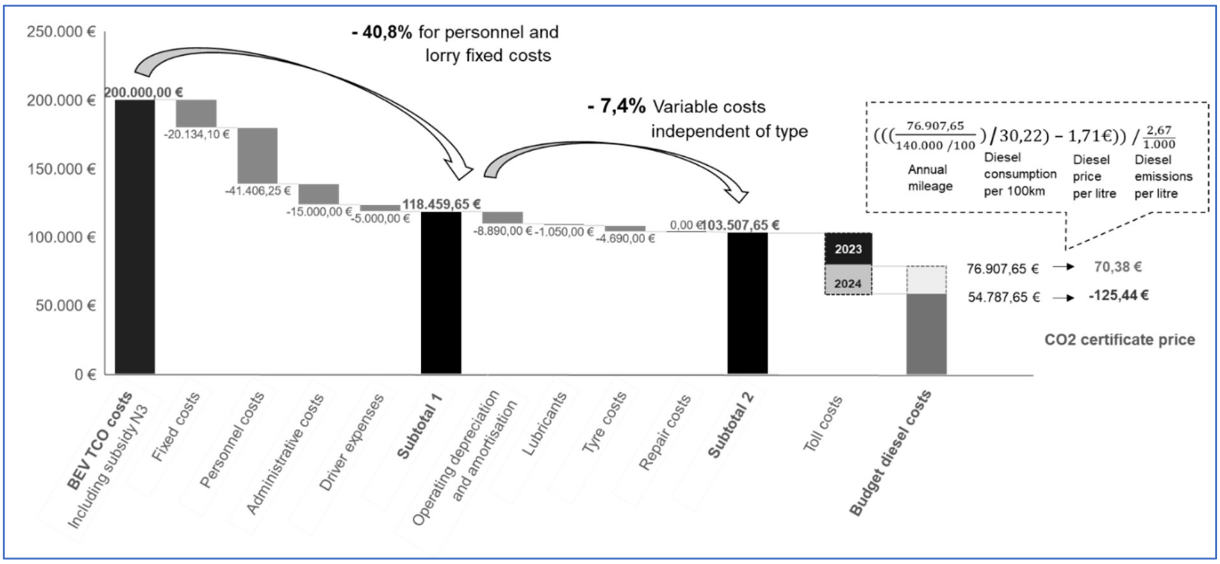

Figure 1: Illustration of Diesel budget.

3.1. Different level of diesel price

First, an analysis can determine the diesel price per litre at which different TCO costs for a BEV truck become more economically viable compared to the purchase of a EURO VI ICEV truck. The results are presented according to toll regulations (see Table 2). Notably, under the previous toll regulations without a CO2 component, a BEV would only become economically viable at a TCO value of less than €200,000. At a TCO value of €250,000, the diesel price would need to be nearly doubled for the BEV to be economically sensible. These values are revised downwards under the new market regulations. For example, a TCO value of €225,000 at a diesel price of €1.89 per litre is no longer unrealistic. Furthermore, with a TCO value of €180,000, as forecasted by PWC for the year 2030, the diesel price could be halved, and the BEV would still be more economically viable. This transition underscores the impact of regulatory changes and market evolution on the economic feasibility of BEV trucks, indicating a significant potential for cost savings and environmental benefits as market conditions evolve.

3.2. Different level of CO2 prices

Under the old toll system, a BEV truck became economically viable with a TCO value of less than €180,000, as this would have effectively resulted in a notional negative CO2 price. In contrast, under the new toll system, BEV trucks remain economically viable even with a TCO value exceeding €200,000. This demonstrates the impact of updated toll regulations on the economic feasibility of BEVs compared to traditional internal combustion engine vehicles. Looking ahead to 2026, when the national CO2 trading system is expected to integrate into the European Emissions Trading System (EU-ETS2), the economic case for BEV trucks strengthens further. At a projected CO2 price of €100 per tonne, a BEV truck would present a more economically advantageous option than a new EURO VI truck. This shift highlights the increasing financial incentives for adopting BEVs as regulatory frameworks and market conditions evolve, potentially leading to significant cost savings and environmental benefits for fleet operators.

3.3. Cost advantages for BEV truck

The results indicate a significant dependency on TCO values. For a BEV with a TCO value of €250,000, the cost advantage of ICEVs diminishes notably as diesel prices rise (see Table 3). At a diesel price of €1.60 per litre, the ICEV has a cost advantage of €0.88 per litre. This advantage gradually decreases with higher diesel prices, becoming negative beyond €1.90 per litre, which signifies that a BEV becomes more cost-effective at this point. As diesel prices increase, the economic benefit shifts more markedly towards BEVs. For instance, at a diesel price of €2.00 per litre, the cost advantage of an ICEV over a BEV with a TCO of €250,000 drops to €0.48 per litre. This trend is more pronounced at higher diesel prices, reflecting increased savings with BEVs. For BEVs with lower TCO values, such as €180,000, economic advantages manifest at even lower diesel prices.

Table 2: Variance analysis of different BEV costs, toll rates and CO2 prices

Diesel price per litre for break-even		TCO BEV				
		250.000,00 €	**225.000,00 €**	**200.000,00 €**	**180.000,00 €**	**150.000,00 €**
Toll rate	**without CO2 Component**	3,00 €	2,41 €	1,82 €	1,35 €	0,64 €
	with CO2 Component	2,48 €	1,89 €	1,29 €	0,82 €	0,11 €

1,71 €	Current diesel price

CO2 price for break-even per litre of diesel		TCO BEV				
		250.000,00 €	**225.000,00 €**	**200.000,00 €**	**180.000,00 €**	**150.000,00 €**
Toll rate	**without CO2 Component**	513,00 €	291,69 €	70,38 €	-106,67 €	-372,25 €
	with CO2 Component	317,18 €	95,87 €	-125,44 €	-302,49 €	-568,07 €

30,00 €	Current CO2 price (2023), 45€ pro tonne CO2e in 2024

At a diesel price of €1.60 per litre, the BEV with a TCO of €180,000 already exhibits a cost advantage of €0.31 per litre. This advantage expands as diesel prices rise, underscoring the economic feasibility of BEVs in scenarios with reduced TCO. Negative cost advantages, indicated by negative values, reveal scenarios where BEVs have a lower cost per litre of diesel compared to ICEVs. For example, at a diesel price of €2.00 per litre and a TCO of €150,000 for the BEV, the cost advantage is -€1.89, indicating significant savings for BEVs. The toll rate of €34.80 significantly impacts the overall cost dynamics, making BEVs more competitive under the new toll regulations that account for CO2 emissions. This regulatory shift further enhances the economic attractiveness of BEVs over ICEVs.

Table 3: Cost Advance BEV Truck per litre Diesel in the new toll system

Cost advantage of ICEV over BEV per litre of diesel with toll rate *		TCO BEV				
		250.000,00 €	225.000,00 €	200.000,00 €	180.000,00 €	150.000,00 €
Diesel price	1,60 €	0,88 €	0,29 €	-0,31 €	-0,78 €	-1,49 €
	1,65 €	0,83 €	0,24 €	-0,36 €	-0,83 €	-1,54 €
	1,70 €	0,78 €	0,19 €	-0,41 €	-0,88 €	-1,59 €
	1,75 €	0,73 €	0,14 €	-0,46 €	-0,93 €	-1,64 €
	1,80 €	0,68 €	0,09 €	-0,51 €	-0,98 €	-1,69 €
	1,85 €	0,63 €	0,04 €	-0,56 €	-1,03 €	-1,74 €
	1,90 €	0,58 €	-0,01 €	-0,61 €	-1,08 €	-1,79 €
	1,95 €	0,53 €	-0,06 €	-0,66 €	-1,13 €	-1,84 €
	2,00 €	0,48 €	-0,11 €	-0,71 €	-1,18 €	-1,89 €
	2,05 €	0,43 €	-0,16 €	-0,76 €	-1,23 €	-1,94 €
	2,10 €	0,38 €	-0,21 €	-0,81 €	-1,28 €	-1,99 €
	2,15 €	0,33 €	-0,26 €	-0,86 €	-1,33 €	-2,04 €
	2,20 €	0,28 €	-0,31 €	-0,91 €	-1,38 €	-2,09 €
	2,25 €	0,23 €	-0,36 €	-0,96 €	-1,43 €	-2,14 €
	2,30 €	0,18 €	-0,41 €	-1,01 €	-1,48 €	-2,19 €
	2,35 €	0,13 €	-0,46 €	-1,06 €	-1,53 €	-2,24 €
	2,40 €	0,08 €	-0,51 €	-1,11 €	-1,58 €	-2,29 €
	2,45 €	0,03 €	-0,56 €	-1,16 €	-1,63 €	-2,34 €
	2,50 €	-0,02 €	-0,61 €	-1,21 €	-1,68 €	-2,39 €
	2,55 €	-0,07 €	-0,66 €	-1,26 €	-1,73 €	-2,44 €
	2,60 €	-0,12 €	-0,71 €	-1,31 €	-1,78 €	-2,49 €
	2,65 €	-0,17 €	-0,76 €	-1,36 €	-1,83 €	-2,54 €
	2,70 €	-0,22 €	-0,81 €	-1,41 €	-1,88 €	-2,59 €
	2,75 €	-0,27 €	-0,86 €	-1,46 €	-1,93 €	-2,64 €
	2,80 €	-0,32 €	-0,91 €	-1,51 €	-1,98 €	-2,69 €
	2,85 €	-0,37 €	-0,96 €	-1,56 €	-2,03 €	-2,74 €
	2,90 €	-0,42 €	-1,01 €	-1,61 €	-2,08 €	-2,79 €
	2,95 €	-0,47 €	-1,06 €	-1,66 €	-2,13 €	-2,84 €
	3,00 €	- 0,52 €	-1,11 €	-1,71 €	-2,18 €	-2,89 €
			34,80 €	Toll rate		

4. Limitations and Conclusion

In order to reduce complexity and due to the lack of data, assumptions are made to calculate the results of this paper. Therefore have some limitations. Nevertheless, some conclusions can be drawn from it.

4.1. Limitation

The findings of this computation are partially derived from publicly available data that has been standardized and harmonized for the analysis. Diligence has been exercised to ensure the generalizability of the calculations; however, variations in TCO between BEVs and ICEVs may arise due to company-specific data, potentially leading to divergent break-even points. Nonetheless, the results align with existing literature indicating that, in numerous instances, BEV trucks are already economically advantageous relative to ICEV trucks within the prevailing regulatory environment, inclusive of subsidies and toll exemptions. Any alterations to these regulatory frameworks would necessitate corresponding adjustments to the break-even analysis.

Moreover, beyond the economic assessment of TCO expenses, the logistical viability within the individual customer's network must also be considered. Presently, BEVs exhibit constrained range capabilities, and access to charging infrastructure, either at public stations or at customer loading bays, may not always be feasible, necessitating meticulous route planning for BEV utilization.

Lastly, ensuring the market availability of BEVs is imperative. Currently, extended waiting periods exceeding a year are not uncommon.

4.2. Conclusion and further search

In conclusion, the results demonstrate the economic viability of BEVs over ICEVs under various diesel prices and TCO scenarios. As diesel prices rise, BEVs become increasingly cost-effective, particularly when supported by favourable toll regulations incorporating CO2 pricing. Fleet operators should consider these factors when evaluating the transition to BEVs, as long-term cost benefits and regulatory incentives are likely to improve the overall economic and environmental performance of their vehicle fleets. Furthermore, the paper aims to assess the effectiveness and efficiency of environmental policies in the logistics sector and to uncover potential challenges associated with their implementation. It seeks to foster discussions on integrating environmentally friendly practices into the business models of logistics companies and identifying best practices for sustainable logistics. Additionally, it endeavours to raise awareness about the necessity of a green transformation within the logistics industry and to incentivize innovation and investment in ecofriendly technologies and practices. Lastly, the paper aims to expedite the transition to a lowcarbon economy and enhance the long-term competitiveness of logistics companies and gain further transparency for the financial implication of CO2 pricing [24].

5. References

[1] IPCC, "Synthesis Report of the IPCC sixth assessment report (AR6): Summary for Policymakers," 2023.

[2] EEA, European Environment Agency greenhouse gases — data viewer. [Online]. Available: https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

[3] A. C. McKinnon, Net Zero Road Freight Transport. [Online]. Available: https://www.alanmckinnon.co.uk/uploaded/PDFs/Presentations/Net%20Zero%20Road%20Freight%20%20(McKinnon%20-%20Green%20Freight%20Summit)%20final%20(17-5-2023)%20final%20version.pdf (accessed: Sep. 4 2023).

[4] ITF, "Decarbonisation and the Pricing of Road Transport: ITF Roundtable Reports, No. 191," 2023.

[5] K. Kindsgrab, M. Dircksen, and H. Zadek, "Effects of CO2e measures for the transport logistics sector," doi: 10.25673/103480.

[6] K. Goeckeler, I. S. Wolf, K. Görz, F. Hacker, and M. Mottschall, "StratES - Scenarios for the electrification of road freight transport: Study based on market ramp-up modeling," 2023.

[7] E. Rosenberg, K. Espegren, J. Danebergs, L. Fridstrøm, I. Beate Hovi, and A. Madslien, "Modelling the interaction between the energy system and road freight in Norway," Transportation Research Part D: Transport and Environment, vol. 114, p. 103569, 2023, doi: 10.1016/j.trd.2022.103569.

[8] S. Bongard, S. Schröder, and S. Kreuzwieser, "Wirtschaftlichkeit und Nachhaltigkeit der Elektromobilität in ausgewählten logistischen Lkw-Fahrzeugklassen," 2023.

[9] J. Jöhrens et al., "Vergleichende Analyse der Potentiale von Antriebstechnologien für Lkw im Zeithorizont 2030: Teilbericht im Rahmen des Vorhabens „Elektrifizierungspotential des Güter- und Busverkehrs - My eRoads“," 2022.

[10] M. Andersson, Johansson, J. Jöhrens, and M. Mottschall, "Opportunities for electric road systems in road freight economics," 2023.

[11] BGL, Modellrechnungen zur Kostenentwicklung im Güterkraftverkehr. [Online]. Available: https://www.bgl-ev.de/web/der_bgl/informationen/branchen kostenentwicklung.htm&v=2#form (accessed: Dec. 6 2021).
[12] SVG, "Neue Mauttarife ab dem 01.12.2023," 2023.
[13] BFStrMG, "Bundesfernstraßenmautgesetz," 2011.
[14] BMVI, "Bekanntmachung der Richtlinie über die Förderung von leichten und schweren Nutzfahrzeugen mit alternativen, klimaschonenden Antrieben und dazugehöriger Tank- und Ladeinfrastruktur für elektrisch betriebene Nutzfahrzeuge," 2021.
[15] KraftStG, "Kraftfahrzeugsteuergesetz," 2002.
[16] World Bank Group, "State and Trends of Carbon Pricing 2020," 2020.
[17] F. Kattelmann, A. Burkhardt, P. D. M. Blesl, D. U. Fahl, and P. D. K. Hufendiek, "Einfluss der CO2 - Bepreisung auf den Wärmemarkt," 2022.
[18] A. Kaiser and H. Zadek, "Leitfaden für Transportdienstleister zur Vorbereitung auf CO2-Lenkungsinstrumente, insbesondere den Emissionshandel, im Straßengüterverkehr," 2012.
[19] DEHSt, "Hintergrundpapier - Nationales Emissionshandelssystem," 2020.
[20] D. S. Levi, I. Wolf, P. D. C. Flachsland, D. N. Koch, D. F. Koller, and D. Edmondson, "Klimaschutz und Verkehr: Zielerreichung nur mit unbequemen Maßnahmen möglich," 2021.
[21] J. Jöhrens, M. Allekotte, and F. Heining, "My eRoads - Der Weg zu einem klimaneutralen Lkw-Verkehr," 2023.
[22] I. Jüngst, "Zugeständnisse für den Klimaschutz," 12 Jan., 2023. https://www.eurotransport.de/artikel/mehr-gewicht-fuer-null-emissionen-fahrzeuge-zugestaendnisse-fuer-den-klimaschutz-11233527.html (accessed: May 20 2024).
[23] C. Werwitzke, "Jetzt offiziell: Bund fördert keine elektrischen Lkw und Busse mehr | electrive.net," 2024.
[24] Gesetz über einen nationalen Zertifikatenhandel für Brennstoffemissionen (Brennstoffemissionshandelsgesetz - BEHG): BEHG, 2019.
[25] L. Tombers, "BEV gegen Diesel: Welche Haltungskosten sind am Beispiel der Joh. Tombers GmbH geringer?," 2023.
[26] C. Foltz, P. Rose, and J. Neuhausen, "The Dawn of electrified Trucking," 2023.
[27] M. Toelke and A. C. McKinnon, "Decarbonizing the operations of small and medium-sized road carriers in Europe," 2021.