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Strategic Infrastructure Investment and Policy Support: Key Drivers in Reducing the Total Cost of Ownership for Zero-Emission Heavy-Duty Vehicles

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Executive Summary

This study evaluates the economic viability of transitioning to zero-emission heavy-duty vehicles (zHDVs), specifically battery electric trucks (bHDV), for long-haul freight in Germany, France, and the United Kingdom. Using a refined levelized cost methodology, the research highlights the pivotal role of infrastructure investment and supportive fiscal policies in achieving Total Cost of Ownership (TCO) competitiveness compared to diesel trucks. Strategic infrastructure deployment, enhanced utilisation of charging facilities, targeted operational expenditure incentives, and technological advancements are identified as critical factors. The study concludes that coordinated policy support and infrastructure optimisation can decisively accelerate cost parity for battery electric trucks within this decade.

Keywords: Fast and Megawatt charging Infrastructure, Charging Business Models, Optimal Charging Locations, Heavy Duty Electric Vehicles & Buses, Public Policy & Promotion

1 Introduction

The decarbonization of road freight stands as a cornerstone in the global effort to meet stringent climate targets, such as those enshrined in the Paris Agreement and the European Green Deal [1]. With the European Union (EU) committing to a 55% reduction in greenhouse gas (GHG) emissions by 2030 and climate neutrality by 2050 [2], the transport sector that is a major contributor to global emissions and must undergo a radical transformation. In 2021, transport accounted for 20.2% of global CO_2 emissions [4], and within this sector, road freight, particularly heavy-duty vehicles (HDVs), plays an outsized role. Defined as commercial trucks and buses with a gross vehicle weight rating (GVWR) exceeding 3.5 tonnes, HDVs represent less than 5% of vehicles on European roads yet contributed between 15% and 22% of road transport CO_2 emissions in 2019 [5]. This figure is projected to grow, potentially positioning HDVs as the largest source of transport-related emissions by 2040 if other sectors decarbonize more rapidly [6]. The urgency to address HDV emissions is thus undeniable, as failure to act could undermine broader climate goals.

Amid this challenge, battery electric heavy-duty vehicles (bHDVs) have emerged as a promising solution to reduce the carbon footprint of road freight. These zero-emission vehicles are increasingly viable for urban and regional operations, with technological advancements in battery capacity and charging infrastructure beginning to extend their feasibility to long-haul applications [5,7]. The potential of bHDVs lies not only in their ability to eliminate tailpipe emissions but also in their alignment with renewable energy systems, offering a pathway to integrate clean energy into freight transport. Market trends further support this shift, with manufacturers scaling production and battery costs declining due to economies of scale [6]. However, despite their environmental promise, the widespread adoption of bHDVs hinges on overcoming significant economic barriers that currently limit their competitiveness against conventional diesel trucks.

The primary economic challenge for bHDVs revolves around their Total Cost of Ownership (TCO), which encompasses both initial capital expenditures (CAPEX) and ongoing operational expenditures (OPEX). Diesel trucks benefit from a mature ecosystem, including lower upfront costs that are typically a fraction of the 1 to 3 times higher purchase price of bHDVs [8] and a ubiquitous refuelling network. In contrast, bHDVs require substantial investments in both the vehicles themselves and the charging infrastructure necessary to support their operation. For long-haul freight, fast-charging stations are critical, yet their deployment costs can range from $70,000 to $113,000 per tractor in early phases [6]. These costs, whether absorbed by fleet operators, third-party providers, or public entities, elevate the lifetime TCO of bHDVs, posing a significant hurdle to their adoption. Moreover, the lack of standardized charging networks and uncertainties around infrastructure scalability further complicate the economic case for electrification.

Nevertheless, recent analyses suggest that bHDVs could achieve TCO parity with diesel trucks before 2030, particularly in regions with proactive policy frameworks and strategic infrastructure investments [1,9]. Incentives such as toll exemptions and reduced electricity tariffs have already demonstrated their ability to lower OPEX, making bHDVs more financially attractive [1]. Coupled with anticipated reductions in battery costs and improvements in charging efficiency, these developments signal a potential tipping point for bHDV adoption. Yet, achieving this parity requires a detailed understanding of how infrastructure costs, policy interventions, and technological progress interact—a gap this study seeks to address.

This research focuses on the TCO of bHDVs for long-haul freight operations in Germany, France, and the United Kingdom, three countries selected for their significant road freight volumes and ambitious decarbonization commitments [1]. By employing a levelized cost methodology, the study offers a sophisticated financial analysis that accounts for infrastructure depreciation and technological advancements over a five-year horizon. Unlike traditional TCO models, which often provide static snapshots, the levelized cost approach normalizes lifecycle costs—CAPEX and OPEX—over the energy delivered, enabling a dynamic comparison of bHDVs and diesel trucks. This methodology reveals how economies of scale in infrastructure utilization and declining technology costs can narrow the TCO gap, providing a clearer picture of economic viability.

Beyond economics, the study integrates sustainability and performance considerations into its framework, tailoring the analysis to the unique demands of zero-emission heavy-duty fleets. This holistic approach distinguishes it from broader electric vehicle studies, offering insights specific to the HDV sector. The findings highlight the critical role of infrastructure investment—such as optimizing charger utilization and minimizing grid connection costs—and supportive policies, like OPEX-focused incentives, in driving TCO competitiveness. For instance, the research demonstrates that policies reducing operational costs are often more impactful than upfront subsidies, a nuance with significant implications for policymakers.

In conclusion, this study provides a robust, multi-country assessment of bHDV economics, emphasizing the interplay between infrastructure, policy, and technology. By elucidating how coordinated efforts can bridge the cost divide with diesel trucks, it offers actionable guidance for fleet operators, infrastructure providers, manufacturers, and policymakers committed to decarbonizing road freight. These insights are vital as Europe accelerates its transition to a sustainable transport future.

2 Methodology

The Levelized Cost of Infrastructure (LCI) for bHDV charging is defined here as the total annualised expenditure associated with the procurement, installation, commissioning, ongoing operation, routine maintenance, periodic upgrades, and eventual decommissioning of the necessary charging infrastructure. This comprehensive cost calculation spans the entire lifecycle of the infrastructure assets, ensuring all relevant financial impacts are captured and accounted for in a coherent manner. The resulting figure is subsequently normalised by the total net quantity of electrical energy delivered (expressed as £ per kilowatt-hour dispensed, £/kWh). By consolidating a diverse range of both capital investments and recurring operational expenses into a unified cost metric, the LCI provides policymakers, infrastructure investors, industry practitioners, and academic researchers with a reliable and transparent means to evaluate, compare, and benchmark the long-term economic viability and sustainability of various infrastructure deployment models and investment scenarios. This approach allows stakeholders to systematically assess trade-offs, optimise investment decisions, and strategically plan infrastructure expansions in response to evolving technological developments and regulatory requirements. The formal expression employed in this study is:

$$LCI = \frac{CRF_1 \times C_{Chargers} + CRF_2 \times C_{EI} + CRF_3 \times C_{C\&G} + CRF_4 \times C_{L\&O} + CRF_{inf} \times O_{Total}}{P_{max} \times u \times t} \quad (1)$$

The LCI methodology was selected over static TCO approaches because it captures the lifecycle costs of infrastructure, including depreciation and operational dynamics, offering a more robust framework for evaluating long-term economic viability in the context of evolving bHDV infrastructure deployment. The numerator in this expression represents the summation of annualised capital investments and recurrent operational expenses, using a suitable capital-recovery factor (CRF) for each distinct asset group, whereas the denominator symbolises the annual energy throughput of the infrastructure (expressed as kWh/year). Each variable involved in this comprehensive formulation is clearly delineated in subsequent sections.

The formula systematically integrates both fixed and variable costs associated with establishing and running charging infrastructure. By separating costs into logical capital and operational categories, stakeholders gain enhanced visibility into how specific investments contribute to overall costs. This enables more strategic planning and precise budget management, essential for large-scale infrastructure projects.

CRF transforms initial capital expenditures into an equivalent uniform annual payment spread over the useful lifetime of an asset. This transformation accounts for both asset depreciation and the time-value of money, reflecting an appropriate real discount rate. Formally, the factor is expressed as follows:

$$CRF_x = \frac{r(1+r)^{N_x}}{(1+r)^{N_x} - 1} \quad (2)$$

where r represents the real discount rate applied, and N denotes the asset lifetime measured in years. Assets with distinct lifespans utilise separate CRFs to maintain accuracy in reflecting actual amortisation and depreciation schedules.

This factor is essential for accurately representing how capital costs are distributed over time. By converting initial investment into a stream of annual costs, decision-makers can better evaluate and compare investments on equal footing, ensuring consistent and transparent cost accounting across diverse infrastructure components.

2.1 Infrastructure Capital Expenditure (CAPEX)

These components represent the fundamental hardware and electrical systems necessary for delivering electrical power consistently and efficiently to bHDV charging stations. Each of these elements plays a distinct yet interconnected role in ensuring the operational reliability, safety, and overall functionality of the charging infrastructure. The detailed categorisation and explicit definition of each component facilitate accurate financial forecasting, transparent budgeting, and rigorous economic analysis. Moreover, this structured delineation aids stakeholders in comprehensively understanding cost allocations, optimising capital expenditures, and assessing the financial viability and strategic effectiveness of infrastructure projects.

$C_{Chargers}$ includes the procurement and installation of charging units, such as high-power fast chargers or megawatt-scale systems designed for bHDVs. These units are essential for delivering electricity to the vehicles and vary in cost based on power output and installation complexity.

C_{EI} encompasses the supporting electrical systems, including transformers, switchgear, metering equipment, and grid connection upgrades. For bHDVs, which demand significant power, this category often requires substantial investments to reinforce local distribution networks or install dedicated substations.

$C_{C\&G}$ covers the physical construction and regulatory preparation of charging sites, including land grading, pavement installation, drainage systems, road access improvements, permitting, environmental assessments, and project management fees.

$C_{L\&O}$ include expenses for acquiring or leasing land, which can vary significantly based on location, as well as overhead costs such as communication networks, cybersecurity measures, and administrative support.

2.2 Recurring Operating Expenditure (OPEX)

The term O_{Total} represents the total annual operational expenditures, which are crucial for maintaining the infrastructure's functionality. Operating costs include preventive and corrective maintenance for the power-conversion equipment, annual electrical safety inspections, software licences, network service fees, insurance premiums and land-related outgoings such as lease payments and local business rates. Although several line items escalate with equipment age or labour rates, the current framework employs the expected real arithmetic mean over the project horizon. To maintain consistency with the real-value analysis, operational costs are adjusted for inflation using an inflation-adjusted CRF_{inf}, ensuring all expenses are expressed in present-day terms.

2.3 Throughput Normalisation

The performance of the charging infrastructure is further characterised by key utilisation parameters. P_{max} defines the contracted maximum import capacity in kilowatts, delineating the peak power level that the infrastructure can legally and technically draw from the grid. The parameter u represents the long-run utilisation factor, expressed as the ratio of the infrastructure's average power draw to its maximum rated capacity. Projections for European battery-electric heavy-duty vehicle hubs suggest that utilisation rates may approach 20% by 2035, depending on the density of route electrification. Finally, t denotes the number of operational hours in a non-leap year, conventionally set at 8,760 hours, which is used to convert rated power into annual energy throughput expressed in kilowatt-hours. Together, these parameters enable a precise estimation of annual infrastructure use, critical for cost amortisation and economic feasibility analyses.

2.4 Analytical Implications

The LCI methodology provides a robust framework for evaluating the economic viability of bHDV charging infrastructure by synthesizing diverse cost elements into a single, comparable metric. By integrating CAPEX and OPEX and normalizing them over energy throughput, it mirrors the levelized cost of energy (LCOE) used in power generation, adapted here for transportation infrastructure. This approach highlights the importance of utilization rates in achieving cost parity with diesel trucks and offers transparency through detailed cost categorization and explicit assumptions about asset lifetimes and discount rates. Consequently, the LCI serves as a valuable tool for policymakers, infrastructure investors, and fleet operators, equipping them with the data needed to make informed decisions in the decarbonization of heavy-duty freight transport.

3 Scenario Definition and Deterministic TCO Comparison

This subsection extends the methodological framework by: (i) defining four counterfactual scenarios; (ii) describing the country-specific calibration procedure; and (iii) illustrating how the levelized cost of infrastructure (LCI) integrates with a deterministic TCO model for 40 t bHDV. The analysis concentrates on long-haul duty cycles exceeding 400 km in Germany, France and the United Kingdom and uses best-in-class Euro VI diesels as the benchmark. Where numerical values are stated, they represent real-2024 euros, exclusive of refundable VAT.

3.1 Scenario set-up

The four archetypes are designed to isolate the marginal influence of infrastructure deployment, fiscal intervention and technology learning. Each builds cumulatively on the Baseline while keeping driver wages, maintenance schedules and annual distance constant at 140 000 km.

Table 1: Definition of Counterfactual Scenarios for bHDV TCO Analysis

Scenario	Summary description	Infrastructure assumption	Policy treatment	Technology trajectory
S_1 Baseline	Continuation of 2023 market and policy conditions	Sparse motorway megawatt hubs with utilisation circa 8 % and depot charging adopted only by first movers	Existing purchase grants and partial toll rebates remain unchanged	Present-generation battery packs at 240 Wh/kg and 140 €/kWh; standard power-train efficiency
S_2 Investment push	Accelerated public–private corridor roll-out financed through blended capital	TEN-T rest areas equipped with 1 MW chargers every 50 km; average hub utilisation rises to 25 %; depot grid-connection costs partly underwritten by energy-network funds	No additional vehicle incentives or tax relief	Same battery cost and efficiency as S_1
S_3 Policy boost	Strong OPEX-oriented fiscal stimulus	Charging landscape as S_1	40 % subsidy on the incremental BHDV purchase price; complete motorway toll exemption for zHDVs; electricity excise reduced by 50 % for dedicated charging	Same technology as S_1
S_4 Tech advance	Rapid learning in cell chemistry and drive-line design	Physical network identical to S_2	No supplementary fiscal support beyond the Baseline	Battery specific cost falls by 25 %; pack energy density improves by 15 %; rolling and drivetrain efficiency gains reduce electricity use per km by 8 %

Although listed separately, the scenario elements are not mutually exclusive in practice. Their segregation here enables the relative weight of each lever to be assessed transparently.

3.2 Integration of levelized charging cost

The LCI is added to the bHDV electricity cost line as an annuitized €/kWh surcharge. Equation (1) is applied to two charger classes, namely 150 kW overnight dispensers and 1 MW daytime corridor units, using cost coefficients from Hall and Lutsey [6] that are updated via the Eurostat civil engineering price index. Hardware prices have softened by 11 % in real terms since 2019, a trajectory confirmed by 2024 tenders in Germany and the Netherlands. Fixed operation and maintenance are modelled at 1 % of total equipment CAPEX per annum. Utilisation, defined as mean power divided by rated power, is the dominant scalar: increasing the load factor from 8 % to 25 % halves the annuity. Scenario specific LCIs therefore range from 0·19 €/kWh for S_1 and S_3 to 0·10 €/kWh for S_2 and 0·07 €/kWh for S_4. A weighted average is applied where the depot and corridor energy split is 80 : 20. Under the infrastructure assumptions in S_2 and S_4, a fleet of 1 000 vehicles requires roughly 125 depot dispensers and 40 corridor chargers, a ratio consistent with Shoman et al. [1].

3.3 Interpretation and policy take-aways

Infrastructure utilisation emerges as the single most decisive determinant of cost convergence. Elevating hub throughput from 8 % to 25 % halves the LCI and trims approximately €0.07 from every bHDV kilometre, implying that fleet co-location, dynamic tariffs and interoperable payment systems are as valuable as physical charger deployment. In parallel, OPEX-based instruments, principally differentiated tolling, outperform blanket purchase grants; a corridor-wide toll holiday induces a larger TCO swing than a 40 % capital subsidy, yet does so without a direct fiscal outlay and while preserving the polluter-pays principle for residual diesel mileage. Accelerated technology learning catalysed through advance purchase commitments or other risk sharing mechanisms remains essential, particularly in electricity price sensitive markets such as the United Kingdom where wholesale rates erode energy cost advantages. Finally, the temporal sequencing of interventions matters, early investment in high utilisation corridors creates the preconditions for subsequent fiscal or technological gains, whereas premature incentives risk capital lock in and protracted underutilisation.

4 Discussion

The present analysis confirms that zHDVs can reach TCO parity with best-in-class diesel tractors within the current decade, if infrastructure utilisation and supportive fiscal measures improve in tandem. In the baseline scenario, an average TCO premium of 0.22 to 0.24 €/km persists across Germany, France and the United Kingdom, chiefly because charger capital is spread over low throughput. Raising hub utilisation to 25% (Scenario S_2) halves the levelized cost of infrastructure and narrows the gap to below 0.12 €/km. When combined with operating-expenditure-oriented incentives such as differentiated tolls and reduced electricity excise (Scenario S_3), the electric option becomes decisively cheaper than diesel, delivering a net present saving of 55 to 70 k€ per tractor. These findings highlight that infrastructure investment and policy support are not peripheral; they are the fulcrum of competitiveness for long-haul battery electric trucks.

Comparison with existing work shows broad alignment but also important nuances. Earlier European studies projected parity for regional applications at 300 to 500 km ranges [2]; our results demonstrate cost advantage at over 400 km, reflecting recent declines in charger hardware prices and modest gains in pack energy density. Noll et al. [3] reported cost competitiveness only in countries with heavy tolls and generous purchase grants. The present study indicates that high-utilisation infrastructure can substitute for part of that fiscal effort, a divergence explained by our explicit treatment of levelized charging costs. Conversely, our conclusions concur with Basma et al. [4] that OPEX-focused measures out-perform pure capital grants. Remaining discrepancies with Mareev et al. [5], who found longer payback periods, stem from their assumption of depot-only charging that locks utilisation below 10%.

The policy implications are clear. First, the forthcoming revision of the Alternative Fuels Infrastructure Regulation should set binding targets for truck-capable charging stations along the TEN-T core and at urban freight nodes. A minimum of one megawatt charger every 50 kilometres, rising to full corridor coverage by 2030, would favour early utilisation and accelerate cost convergence. Second, financial incentives should prioritise operating expenditure. A 20-30% reduction in electricity taxes for bHDV charging, phased over 5 years, could offset initial TCO gaps by approximately 0.05 €/km based on S_3 modelling. and full toll exemptions for zero-emission axles can be calibrated to restore price symmetry with diesel at utilisation rates still below maturity; modelling suggests an optimal OPEX subsidy of approximately 0.08 €/km during the first 5 years of market scaling. Third, transmission-level grid preparation warrants urgent attention. Designating high-demand logistics hubs as strategic connection points and simplifying permitting for sub-station upgrades will mitigate long lead times. Fourth, Member States should coordinate investment towards ports, consolidation centres and major distribution warehouses where dwell times enable overnight charging, thereby reducing the need for oversized batteries. A collaborative governance framework that obliges electricity network operators, charge-point operators and fleet consortia to share load forecasts and infrastructure data would further raise utilisation. Finally, binding national targets for both charger density and utilisation rates would harmonise deployment across the Single Market and avoid the emergence of charging deserts.

Several limitations temper these conclusions. Cost projections for battery packs, charger hardware and grid connections remain uncertain; a 10% variance in any of these inputs can shift the TCO break-even point by 1 to 2 years. Technological learning curves were modelled as deterministic rather than stochastic, potentially under-stating downside risk. The levelized cost formulation assumes constant discount and inflation rates, yet macro-economic volatility could alter capital recovery factors. Moreover, the analysis treats driving patterns and energy prices as country averages, overlooking sub-national diversity that may affect individual fleet economics.

Future research should therefore adopt dynamic system-dynamics or agent-based models that capture feedback between infrastructure roll-out, utilisation, and technology cost reductions. A comprehensive sensitivity assessment, varying battery prices, electricity tariffs and charger lifetimes, would refine confidence intervals around break-even dates. Investigating alternative business models, including hub-and-spoke charging co-operatives and utility-owned infrastructure, could reveal pathways to higher utilisation sooner. Finally, integrating vehicle-to-grid revenue streams and carbon pricing into the TCO framework would offer a holistic view of the economic potential of electric long-haul freight under deep decarbonisation scenarios.

In conclusion, the study substantiates that strategic infrastructure investment, coupled with well-targeted operating-expenditure incentives, can deliver cost-competitive zero-emission haulage. Aligning regulatory obligations, fiscal instruments and collaborative planning is likely to prove decisive in realising the full economic and environmental benefits of battery electric heavy-duty vehicles.

5 Conclusion

This study advances prior research by integrating a levelized cost of infrastructure framework with a multi-country TCO model, offering a pioneering analysis of bHDV competitiveness across Germany, France, and the UK, and revealing utilization as a critical substitute for fiscal subsidies and demonstrates that bHDV 40t tractors can achieve and, under favourable conditions, exceed cost parity with Euro VI diesel benchmarks before 2030. The baseline TCO premium of 0.22 to 0.24 €/km falls below 0.12 €/km once hub utilisation reaches 25% and disappears altogether when differentiated tolls and reduced electricity excise are added. Infrastructure throughput is the single most influential lever: tripling average utilisation halves the levelized cost of charging and removes roughly 0.07 €/km from operating expenditure. OPEX-oriented incentives outperform capital grants, while battery cost learning and modest efficiency gains provide an additional, but secondary, boost to competitiveness.

The paper extends existing work in three ways. First, it introduces a levelized cost of infrastructure framework that assigns asset-specific lifetimes and inflation-adjusted recovery factors, offering a more precise treatment of charging costs than static TCO approaches. Second, it links that framework to a tri-national TCO model calibrated for Germany, France and the United Kingdom, thereby exposing geographic sensitivities that have been overlooked in pan-European averages. Third, by isolating infrastructure, fiscal and technological levers in four counterfactual scenarios, the analysis quantifies the relative weight of each policy instrument, showing that utilisation-driven cost reduction can substitute for part of the fiscal outlay traditionally assumed necessary.

Provided that Member States enact binding targets for megawatt chargers along the TEN-T core and align electricity taxation with decarbonisation goals, long-haul battery-electric freight can become the economically rational choice within the next fleet-renewal cycle. Coordinated investment at ports, consolidation hubs and motorway rest areas will lift utilisation and accelerate break-even dates, while transparent data-sharing between grid operators and fleets will optimise connection sizing and defer costly upgrades. For policymakers, the results underscore the efficiency of shifting support from purchase subsidies towards road-use charges and energy-tax differentials that reward zero-emission kilometres. For industry, the findings highlight the commercial value of collaborative charging consortia and advance-purchase commitments that pull battery costs down the learning curve. Overall, the study affirms that a judicious blend of infrastructure planning, demand-based fiscal measures and continued technological progress can deliver a credible, cost-effective pathway to fully decarbonised heavy-duty road transport.

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References

[1] B. Noll, S. Del Val, T. S. Schmidt, and B. Steffen, *Analyzing the competitiveness of low-carbon drive-technologies in road-freight: A total cost of ownership analysis in Europe*, Applied Energy, vol. 306, p. 118079, Jan. 2022, doi: 10.1016/j.apenergy.2021.118079.

[2] A. O'Connell, N. Pavlenko, G. Bieker, and S. Searle, *A Comparison of the Life-Cycle Greenhouse Gas Emissions of European Heavy-Duty Vehicles and Fuels*, International Council on Clean Transportation, 2023, https://theicct.org/publication/lca-ghg-emissions-hdv-fuels-europe-feb23, accessed on 2025-04-24.

[3] T. McPhie and A. Crespo Parrondo, *European Green Deal: Commission proposes 2030 zero-emissions target for new city buses and 90% emissions reductions for new trucks by 2040*, European Commission, 2023, https://ec.europa.eu/commission/presscorner/detail/en/IP_23_762, accessed on 2025-04-24.

[4] U. U. Turkan, E. A. Calado, S. Mamarikas-Itsios, D. Kontses, Z. Samaras, and A. E. Hartavi, *Integrating TCO and Sustainability Requirements: ESCALATE Pro-Active Design and Manufacturing Approach for Enhanced Electric Fleets*, TRA24 Conference, 2024

[5] W. Shoman, S. Yeh, F. Sprei, P. Plötz, and D. Speth, *Battery electric long-haul trucks in Europe: Public charging, energy, and power requirements*, Transportation Research Part D: Transport and Environment, vol. 121, p. 103825, Aug. 2023, doi: 10.1016/j.trd.2023.103825.

[6] D. Hall and N. Lutsey, *Estimating the Infrastructure Needs and Costs for the Launch of Zero-Emission Trucks*, International Council on Clean Transportation, 2021, https://theicct.org/wp-content/uploads/2021/06/ICCT_EV_HDVs_Infrastructure_20190809.pdf, accessed on 2025-04-24.

[7] S. Suzan and L. Mathieu, *Unlocking Electric Trucking in the EU: long-haul trucks*, Transport & Environment, 2021, https://www.transportenvironment.org/wp content/uploads/2021/07/202102_pathways_report_final.pdf, accessed on 2025-04-24.

[8] Shell International B.V., *Decarbonising Road Freight: Getting into Gear*, Shell International B.V., 2021, https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.shell.com/content/dam/shell/assets/en/business-functions/energy-and-innovation/the-energy-future/documents/decarbonising-road-freight-industry-report.pdf&ved=2ahUKEwjBk5fCg9GMAxVQXEEAHWhbPIgQFnoECBQQAQ&usg=AOvVaw1vqDH668J_TUOuljvtwxMW, accessed on 2025-04-24.

[9] H. Basma, C. Buysse, Y. Zhou, and F. Rodríguez, *Total Cost of Ownership of Alternative Powertrain Technologies for Class 8 Long-Haul Trucks in The United States*, International Council on Clean Transportation, 2021, https://theicct.org/wp-content/uploads/2023/04/tco-alt-powertrain-long-haul-trucks-us-apr23.pdf, accessed on 2025-04-24.

[10] B. Al-Hanahi, I. Ahmad, D. Habibi, and M. A. S. Masoum, *Charging Infrastructure for Commercial Electric Vehicles: Challenges and Future Works*, IEEE Access, vol. 9, pp. 121476–121492, 2021, doi: 10.1109/ACCESS.2021.3108817.

[11] W. Shoman, S. Yeh, F. Sprei, P. Plötz, and D. Speth, *Battery electric long-haul trucks in Europe: Public charging, energy, and power requirements*, Transportation Research Part D: Transport and Environment, vol. 121, p. 103825, Aug. 2023, doi: 10.1016/j.trd.2023.103825.

[12] T. Earl, L. Mathieu, S. Cornelis, S. Kenny, C. C. Ambel, and J. Nix, *Analysis of long haul battery electric trucks in EU*, 8th Commercial Vehicle Workshop, 2018, https://www.transportenvironment.org/uploads/files/20180725_T.pdf, accessed on 2025-04-24.

[13] I. Mareev, J. Becker, and D. Sauer, *Battery Dimensioning and Life Cycle Costs Analysis for a Heavy-Duty Truck Considering the Requirements of Long-Haul Transportation*, Energies, vol. 11, no. 1, p. 55, Dec. 2017, doi: 10.3390/en11010055.

Presenter Biography

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