TOTAL COST OF OWNERSHIP OF E-HDT VS. ICE-HDT

Parking position or ready for take-off?

Can battery-electric heavy-duty trucks lead the transition to sustainable road freight transport?

- A scenario analysis of total cost of ownership -

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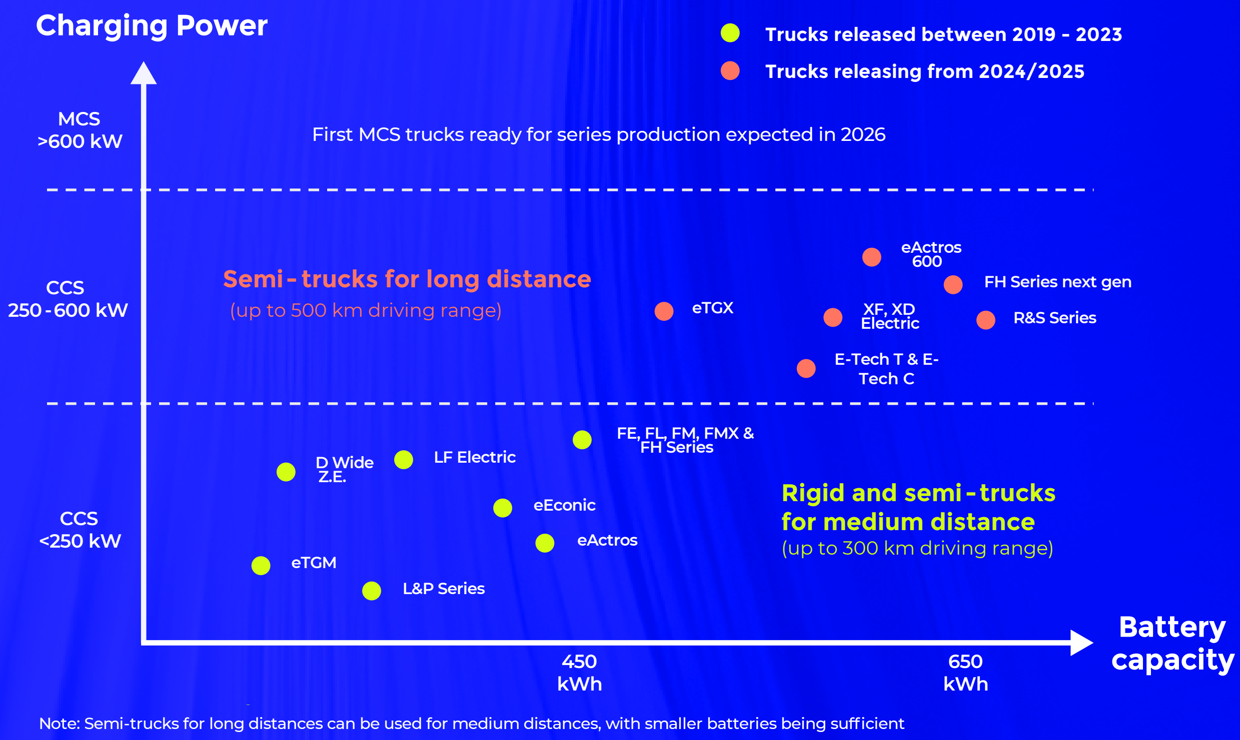
1. EDITORIAL

After years of "technology openness" and exploration of alternative fuels and fuel cell technology, most truck manufacturers have built up their portfolio of zero-emission vehicles around the battery-electric powertrain. Based on the success of electrifying light commercial vehicles and busses and backed by political commitment, the focus is now shifting to **heavy-duty trucks as the next area of large-scale electrification.** Besides the attractiveness of toll charge exemptions and reduced vehicle taxes, the regulatory fleet emission thresholds of the EU Commission have given the topic a new impetus. The obligation for manufacturers to achieve a 45% reduction in CO_2 emissions of trucks above 7.5t by 2030 and a 90% reduction by 2040 compared to 2020 levels can only be met through massive electrification.

Nevertheless, battery-electric heavy-duty trucks (e-HDT) are still in the process of positioning as a viable and low-emission alternative to diesel trucks with internal combustion engine (ICE). While early e-HDT models were limited in terms of range, charging speed, and longevity of their batteries, recently introduced models demonstrate significantly higher capability, enabling a wider range of use cases from **regional-haul transport to long-haul applications** (see Graphic 1). Despite this progress, e-HDT sales numbers grow slowly, and the electrification of the commercial vehicle sector is still in its early stages: only around 2% of newly registered rigid trucks and semi-trailers >16t in Germany in Q1/2024 were battery-electric.[1] However, new registrations are expected to grow in the coming years due to stricter regulation, the expansion of vehicle

[1]Acea (2024): https://www.acea.auto/files/Press_release_commercial_vehicle_registrations_Q1-2024.pdf

portfolios and large-scale production of truck manufacturers enabling lower vehicle acquisition costs.



Graphic 1: Extract of battery-electric truck models

The primary application of e-HDT lies in the logistics industry, which is characterized by narrow margins and, correspondingly, high cost-sensitivity of fleet owners. This makes cost over lifetime one of customers' key requirements. Until February 2024, the KsNI-funding compensated for up to 80% of the difference between e-HDT and ICE-HDT sales prices, as well as the associated charging infrastructure. After its suspension on short notice, transport and logistic associations demanded for a reactivation of the program in their open letter to chancellor Olaf Scholz, declaring the ambitious European climate targets as well as the technology and drive revolution in road freight transport to be unattainable if supporting measures are withdrawn. In June 2024, another funding program was launched, which targets the installation of charging infrastructure of corporate customers specifically.

The outcry of the main affected industries in response to the cancellation of the KsNI-funding shows that costs, beside insufficient range for long-haul use and lack of public charging options, remain the main argument against e-HDT. However, the vehicle portfolio of long-haul e-HDT models is increasing, and a comprehensive public charging network is being actively pushed by both government and industry. The tender for the initial charging network for trucks gives reason to expect widespread coverage of charging infrastructure within the next 2-3 years. Cost, as one of the most significant decision criteria of fleet owners, remain of concern and require a more thorough evaluation. Beyond initial acquisition expenses, a detailed analysis of total costs incurring over the truck's operational lifespan is necessary.

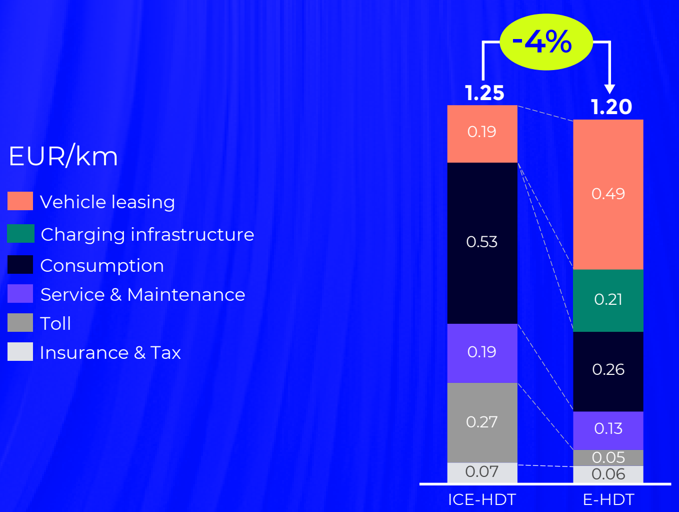
Based on our knowledge of truck technology and operations of logistic fleets, **P3 has developed a comprehensive tool to evaluate the total cost of ownership (TCO) for ICE-HDT and e-HDT.** The following analysis delves into the customer's perspective on the cost comparison of both drive technologies. While P3's TCO tool itself provides high adaptability to international markets, this whitepaper focuses on Germany as the largest market for electric mobility of trucks in Europe.

2. EXECUTIVE SUMMARY

P3´s in-depth comparison of the TCO between a conventional ICE-HDT and an average e-HDT in the German market shows **cost advantages for the electric model** under the defined framework conditions, refuting the common argument of higher cost of e-HDT.

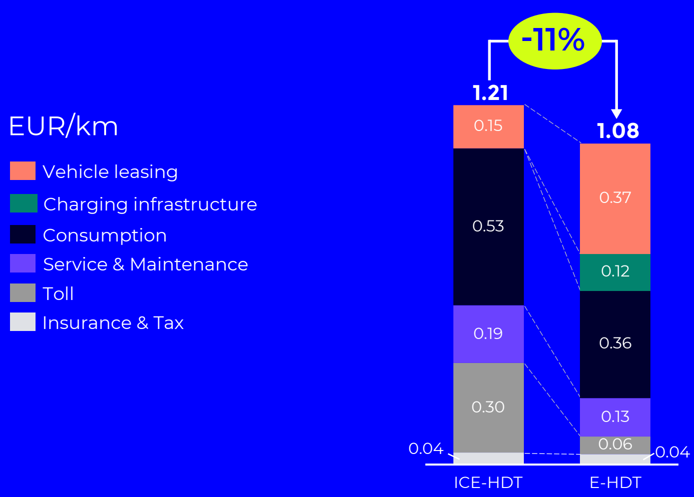
For the regional-haul scenario (60,000 km annual mileage, 100% depot charging), e-HDT reach a slight cost advantage in the six-year holding period. For the long-haul scenario (100,000 km annual mileage; 50:50 depot and highway charging), the e-HDT can achieve an even more significant **cost advantage of 11%, equivalent to 13 ct/km.** However, the feasibility of daily routes of around 500 km is limited due to the lack of a public fast charging network and can currently only be realized in a hub-to-hub use case.

Regional-haul scenario:
60,000 km/a
100% depot charging



Graphic 2: Total Cost of Ownership over holding period 2025-2030 [EUR/km]

Long-haul scenario:
100,000 km/a
50% depot charging, 50% highway charging



Graphic 3: Total Cost of Ownership over holding period 2025-2030 [EUR/km]

The primary reason for the e-HDT's superior performance in long-haul scenarios is its higher mileage, whereby the break-even point is already reached at 63,000 km per year based on the underlying premises. Superiority for the e-HDT in the regional-haul scenario is reached at 52,000 km annual mileage.

The most significant cost advantages - lower energy cost and reduced toll rates - scale with the distance traveled, amplifying the benefits over longer routes. Additionally, the e-HDT benefits from decreased service and repair expenses and CO_2 tax benefits. These cost savings are sufficient to offset the main advantages of the ICE-HDT: lower acquisition cost for the truck and the omission of investment in depot charging infrastructure. Depending on how battery aging over time will turn out in practice, the residual value of the e-HDT may be higher, further improving its TCO result.

In summary, **e-HDT emerge as an attractive alternative for fleet owners in both long-haul and regional-haul scenario, being well-suited for routes below 500 km/day.** Beside annual mileage, the level of advantageousness of e-HDT depends on low electricity costs, adequate grid connection for depot charging infrastructure, and route lengths within current capabilities. If these conditions cannot be met, ICE-HDT may remain the better choice from a cost perspective.

With further technological advancements, including increasing battery capacities, faster charging speeds, and decreasing vehicle costs with scaling of production, the competitiveness of e-HDT is rapidly increasing across a wider range of applications. Moreover, the truck market is expected to be shaken up with the potential market entry of the Tesla Semi truck: a highly competitive price coupled with outstanding technical performance in range and efficiency give rise to the expectation of an outstanding TCO result below 1 EUR/km.

3. INTRODUCTION

Today, the German truck market is largely dominated by established players. Big manufacturers have not been jeopardized in the last years due to their solid performance with the diesel powertrain.

With electrification of trucks gaining momentum, manufacturers are now facing new challenges – not only technology-wise, but also **with an increasingly multifaceted competitive landscape** with aspiring US companies like Tesla, and emerging contenders from the East, for instance the Chinese electric mobility giant BYD, competing for market share.

Meeting customer requirements is becoming even more important for manufacturers to retain relevance in the market and drive sales numbers. The **high cost-sensitivity of the logistics industry** as the main customer group in the truck industry dictates the **minimization of operational expenses** as a decisive argument for vehicle acquisition. Today more than ever, battery technology is on the verge of replacing diesel drives. Whether this will extend to the heavy-duty sector crucially depends on financial attractiveness. The cost comparison of ICE-HDT and e-HDT evaluates whether e-HDT have the potential to disrupt the German truck market and take the lead in the transition towards sustainable road freight transportation.

Excursus: Tesla

Today's e-HDT models in Germany differ only marginally in electricity consumption, battery size and range. However, another truck model has the potential to stir up the market as soon as being homologated and authorized for the German market: **Tesla´s Semi Truck.**

The Semi's factsheet makes an exciting reading: Tesla's flagship truck stands out from competitors with a 900-kWh battery, enabling, according to Tesla, exceptional ranges of up to 800 km depending on load. Field testing of electric trucks under the roof of the North American Council for Freight Efficiency (NACFE) further solidified the **Semi's position as "best-in-class"** in the US with demonstrating the long-haul capability by driving more than 1,700 km in one day with only three charging breaks. On top, the Tesla Semi also offers an **unbeatable price** far below e-HDT competition.

The concept of a fully electric HDT was already introduced in the Tesla Master Plan of 2016. Despite the initial market launch date being set for 2019, the delivery of the first vehicles only took place in late 2022, revealing production challenges such as battery supply constraints and manufacturing complexities. While the US market anticipates increased production volumes, Tesla has already turned its attention to Europe, where orders have already been placed in countries like Norway and the Netherlands. Notably absent from this list is Germany, presumably due to regulatory concerns. Nevertheless, Tesla CEO Elon Musk has expressed interest in producing the Semi at the Grünheide Gigafactory in Germany.

From a global view, the Tesla Semi already presents a **strong competitor for truck manufacturers** today due to its excellent price-performance ratio and increasing availability in the major US sales market. A launch of the Semi in Germany could further intensify competition and cause European manufacturers to lose their national customers.

4. METHODOLOGY AND BASE ASSUMPTIONS

To enable a substantiated evaluation on the TCO of e-HDT compared to ICE-HDT, P3 has developed a comprehensive calculat v ion tool – which has been used to conduct the comparative analysis in this report.

4.1. Truck models in focus

P3's calculation tool catalogues the technical specifications of different reference truck models in a database for selection. As there are only minor differences in technical characteristics of truck models registered in the German market, this analysis takes an **average of technical specifications among the most modern and common HDT models** in compliance with highest emission standards. Table 1 displays the main specifications for the truck models under investigation.

Table 1: Vehicle specifications per drive type

	e-HDT	ICE-HDT
Body type	Semi-Truck	Semi-Truck
Model year	2024	2024
Date of acquisition	01/01/2025	01/01/2025
Net vehicle purchase price [EUR]	280,000	110,000
Gross vehicle weight [t]	42	40
Emission class	5	3
Gross battery size [kW]	600	/
Power Class [kW]	500-600	300-400
Electricity consumption [kW/km]	1.3	/
Fuel consumption [l/km]	/	0.33

4.2. Input parameters for TCO calculation

The calculation tool divides total expenditures (TOTEX) into capital expenditures (CAPEX) and operational expenditures (OPEX).

To draw an objective comparison between e-HDT and ICE-HDT, the configurations of the calculation tool were set to reflect reality as accurately as possible. Table 2 shows the consideration of main input parameters in the analysis of e-HDT to ICE-HDT.

Table 2: Consideration of input parameters in TCO calculation

CAPEX		
Vehicle-related	Vehicle leasing considering residual value	☑
Vehicle-related	Battery replacement within holding period	☒
Charging infrastructure related	Depot charging infrastructure installation	☑
OPEX		
Distance-related	Fuel, ad-blue and electricity cost	☑
Distance-related	Highway toll	☑
Distance-related	Lubricants and oil	☑
Distance-related	Tires	☑
Distance-related	Repair and service	☑
Distance-related	Charging losses	☑
Distance-related	Vehicle insurance	☑
Time-related	Depot charging infrastructure operation	☑
Time-related	Vehicle tax	☑
Time-related	Driver cost	☒
Revenue streams		
Vehicle-related	Vehicle subsidies	☒
Charging infrastructure related	Depot charging infrastructure subsidies	☒
Time-related	Greenhouse gas quota	☑

All input factors used in the calculation tool were corroborated by official sources including publications by truck manufacturers and independent research institutions. Forecasts on energy price trends and cost developments are based on P3 assumptions.

An essential assumption in the TCO calculation is the selection of **leasing as prevalent acquisition** form. This was chosen based on P3's market insights showing most commercial fleet owners being deterred from or not capable of affording the high purchase cost for e-HDT today. The higher acquisition cost for the e-HDT are reflected in a higher leasing rate.

Battery replacement costs are not included in the TCO calculation as battery lifespans are expected to exceed both the considered holding period and projected mileage. Manufacturer warranties of 6-8 years further justify this exclusion.

In contrast to the dense network of public diesel stations and private refueling options in Germany and abroad, there are only **limited public charging options for e-HDT today.** Coupled with the higher cost of electricity for on-route charging, it makes sense for fleet owners to install **depot charging infrastructure.** In principle, CAPEX can be reduced by installing charging stations below 150 kW per charging point which are sufficient for recharging the big truck battery overnight or even within long parking times. In the present calculation, the installation of a 200-kW station in depot is assumed to enable faster recharging. Besides charging hardware, CAPEX for depot charging infrastructure also include planning, installation and grid connection.

Driver costs are not included in the TCO as they are differing by company, are independent from drive type and carry the associated risk of distorting TCO results.

Due to the lack of nationwide subsidies for e-HDT in Germany since the latest cancellation of the KsNI-funding, **subsidies for the truck are not considered** in the TCO calculation. Although there are active subsidies for charging infrastructure available today, they will not be considered due to the lack of continuous availability and the limited size of funding pots.

Today, trading based on the greenhouse gas quota enables an upside revenue potential for e-HDT owners. In the future, a declining trend is assumed with increasing electrification in the market, thus having only small impact on the TCO calculation.

4.3. Scenario Simulation

To consider the TCO effects depending on different use cases, two scenarios were set up.

“Regional-haul scenario”, representing the standard application of e-HDT in distribution transport around depot today (no last mile delivery in cities): daily route distance of 200-300 km, 100% charging in depot of fleet owner.

“Long-haul scenario”, representing the standard long-haul application of ICE-HDT today: daily route distance of 350-500 km, 50:50 split into depot and highway charging.

For the calculation of annual mileage, 50 weeks per year with 5 working days each are assumed as a typical shift system. The share of mileage on toll roads is generally set high due to the geographical proximity of most logistic depots to highways and main traffic axes.

Table 3: Scenario assumptions

	Long-haul scenario	Regional-haul scenario
Mileage [km/a]	100.000	60.000
Mileage on toll roads [%]	90%	80%
Holding period vehicle [years]	6	6
Lifetime of charging infrastructure [years]	8	8
Charging behavior [% of kWh charged]	50% depot (DC: 200 kW) 50% highway (HPC: 400 kW)	100% depot (DC: 200 kW)

Although HDT electrification is of relevance for most customers in the long-term, the analysis focuses specifically on the customer type with highest interest in e-HDT today: medium and large companies with 50+ HDT in their fleet and commitment to sustainability reporting (ESG) typically prioritize fleet charging and are used as a baseline in this analysis.

Table 4: Customer specification

	Minimum requirements
Daily routes [km]	250
Charging points in depot	8 charging points

4.4. Cost forecast for diesel and electricity

Assumptions about the development of diesel and electricity cost are considered to be decisive factors for the TCO analysis.

Based on the announcements of constant increases in the next years, P3 expects **CO_2-taxes to drive up diesel prices in the future.** Electricity prices on the other hand, set to be around 20 ct/kWh for medium-sized companies, are expected to remain stable over the next years due to the opposing effects of rising grid charges and falling costs for (renewable) electricity generation. Hence, the gap between diesel and electricity prices will increase (see Table 5).

Nevertheless, as sharp increases in energy prices during the Ukraine war have shown, both diesel and electricity can be subject to significant and hard-to-predict price fluctuations. Accordingly, a sensitivity analysis at the end of this report elaborates upon the TCO effects of lowering/raising electricity and diesel costs.

Table 5: Scenario assumptions

	Net electricity prices [EUR/kWh]		Net diesel prices [EUR/l]
	Depot charging	Public charging	
2025	0.20	0.33	1.47
2026	0.20	0.33	1.48
2027	0.20	0.33	1.52
2028	0.20	0.33	1.56
2029	0.20	0.33	1.60
2030	0.20	0.33	1.64

Excursus: Customization options in P3's TCO tool

To evaluate the effects of different assumptions and to test diverse scenarios in the calculation of TCO and CO_2-equivalents for HDT, P3 has developed its tool with several customization options stretching far beyond basic calculations.

Firstly, core assumptions on the calculation can be set within the **"configurator".** Next to the definition of the holding period for HDT, yearly mileage and charging behavior split into depot/public can be specified. The consideration of subsidies and driver cost as well as acquisition type (purchase/leasing) can be selected.

Secondly, the tool accesses a **database of different vehicles** which allows the feed-in of concrete manufacturers and truck models from light-duty to heavy-duty segment for comparison. Vehicle-specific data is automatically inserted for calculation, such as diesel/electricity consumption, CO_2-emission class, and acquisition cost. Cost for battery replacement can be defined including the overall mileage after which replacement is needed.

Further customization options are given within the **calculation input factors.** Besides the specification of general calculation assumptions (e.g., inflation, interest rates for leasing), all incurring cost for ICE-HDT, e-HDT and depot charging infrastructure are listed in detail and can be adjusted. This includes for instance the leasing periods forv charging infrastructure, the second-life value of the e-HDT battery and pricing of diesel/electricity. Although the initial assumptions and calculations are based on German market conditions, the tool's flexibility allows for adaptation to various international contexts by modifying the parameters mentioned previously.

5. RESULTS

The direct comparison of TCO per km driven between ICE-HDT and e-HDT shows an **advantageous result for e-HDT in both scenarios.**

For the r**egional-haul scenario,** a **slight cost advantage of 5 ct/km is observed for the e-HDT.** This is achieved through lower OPEX, which slightly outweighs the higher CAPEX for the vehicle and charging infrastructure.

For the **long-haul scenario,** a significant advantage of the e-HDT compared to its ICE-variant is visible, with the **diesel truck being over 10% more expensive** over the holding period. The substantial cost advantage of 13 ct/km of the e-HDT is mainly based on OPEX savings, including lower energy cost and toll benefits. However, the cost advantage of the e-HDT is contingent upon certain conditions.

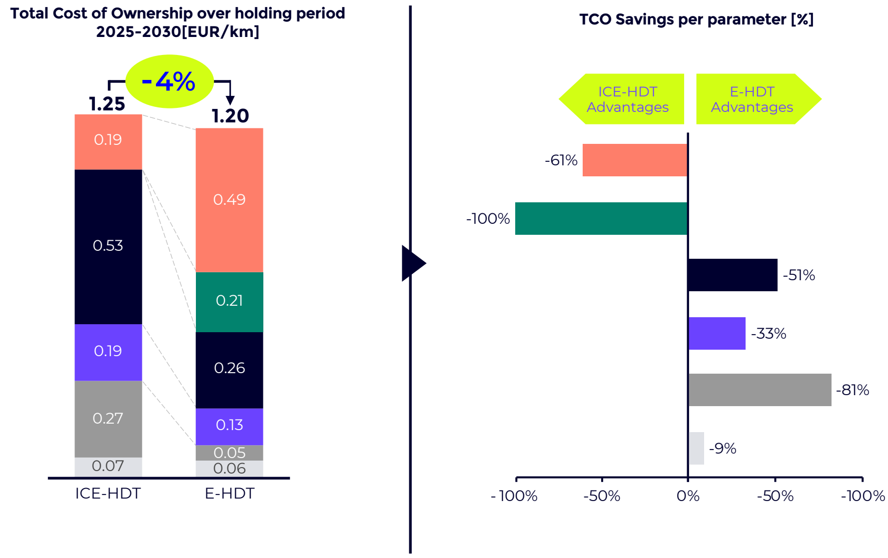
1. **Low electricity costs** via industry tariffs, possibly complemented by decentral renewable production to keep charging cost at depot below diesel cost.
2. **Adequate grid connection** to enable installation of charging infrastructure at depot without big bureaucratic hurdles and long approval times.
3. HDT application within **routes manageable for electric drives** today. Average daily routing of >500 km/day is not (yet) sensibly feasible for e-HDT due to technical constraints.

5.1. Detailed cost breakdown

A closer examination reveals the origin of the e-HDT's significant cost advantage.

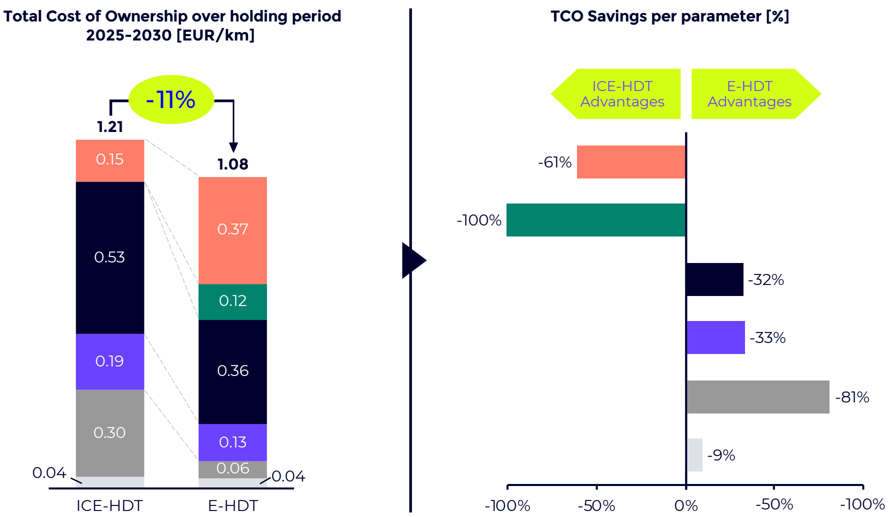
Regional-haul scenario:

60,000 km/a
100% depot charging



Long-haul scenario:

100,000 km/a
50% depot charging, 50% highway charging



Graphic 4: TCO over holding period [EUR/km] and TCO savings per parameter [%]

Firstly, **overall consumption makes up for substantial cost saving of the e-HDT** with 17 ct/km in the long-haul scenario (regional-haul scenario: 27 ct/km). Due to the higher overall efficiency of the e-HDT of up to 95% compared to up to 45% of modern diesel engines, e-HDT require lower energy input per km driven.

Secondly, **e-HDT can achieve significant savings in highway tolls** of up to 24 ct/km in long-haul scenario (regional-haul scenario: 22 ct/km). Today, e-HDT are exempt from tolls until 31.12.2025 and are granted a significantly reduced toll rate of ≈ 25% from 2026 onwards. Although P3 expects this rate reduction to be canceled at some point in the future, the increasing toll rates for ICE-HDT based on the "polluter pays"-principle justify the assumption of a continued toll spread between e-HDT and ICE-HDT.

Thirdly, cost advantages for e-HDT are found in repair and service: **e-HDT incur lower spending on lubricants and maintenance** due to fewer mechanical components, resulting in overall savings of approximately 6 ct/km compared to ICE-HDT. Tire costs show no discernible differences.

The fourth and final advantage for e-HDT are **lower vehicle taxes.** Although total exemption will no longer apply to electric vehicles registered after 2025, they are subject to only half the regular tax rate. However, when calculating annual tax payments for ICE-HDT, the cost amount to <1 ct/km and hence plays only a minor role in the overall assessment.

While e-HDT are advantageous in OPEX, the ICE-HDT brings cost advantages in two categories. Firstly, the omission of the acquisition and operation of charging infrastructure. Secondly, the acquisition or leasing cost for the HDT itself, with the vehicle purchase price of the e-HDT being more than double compared to the ICE-HDT.

5.2. Purchase vs. leasing

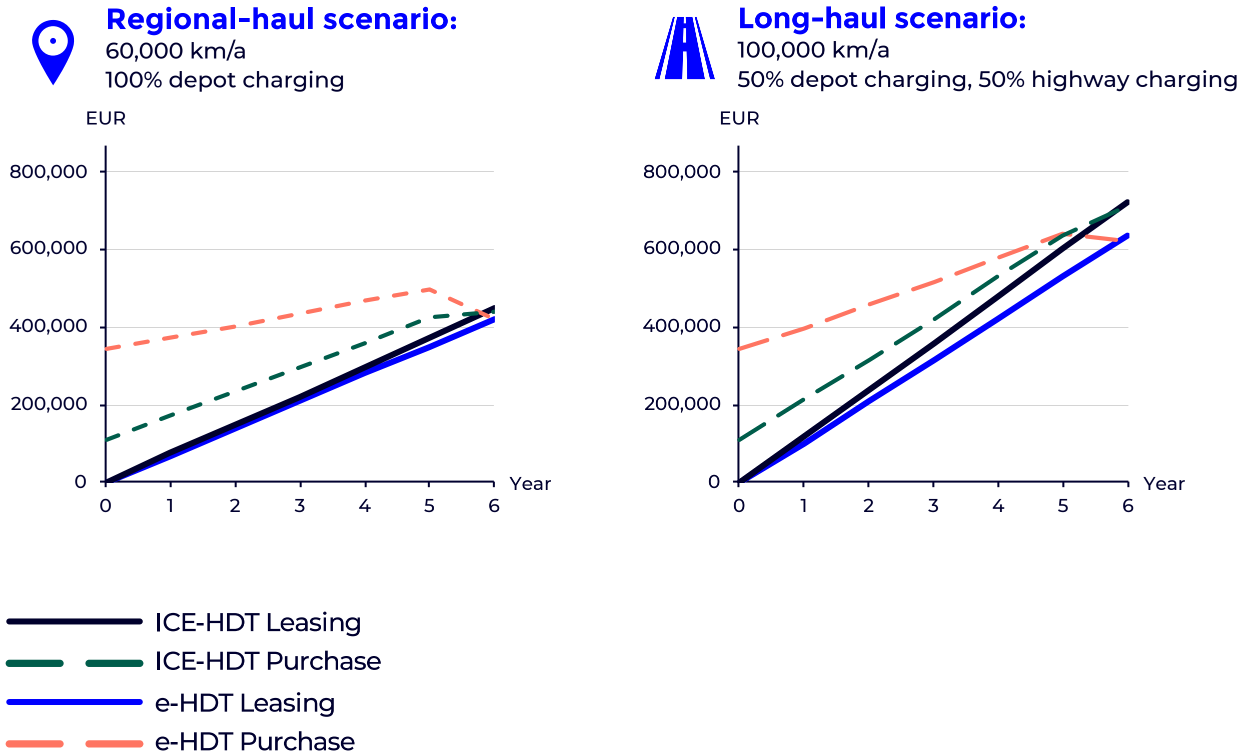
The **2.5 to 3 times higher acquisition costs associated with the purchase of an e-HDT compared to an ICE-HDT** represent a major obstacle for many logistics companies. Leasing and rental models for vehicles and charging infrastructure can help to overcome this hurdle.

In case of **operating leasing,** there is no upfront purchase invest for truck and charging infrastructure as all payments are spread over the entire 6-year holding period. Comparing the cumulative costs for leasing ICE-HDT and e-HDT over the holding period, **there is no point at which the ICE-HDT is more cost-effective,** meaning the e-HDT remains advantageous throughout.

Comparing the purchase variant of ICE-HDT and e-HDT, the diesel variant shows an initial advantage of more than 230k EUR due to lower acquisition cost for truck and the omission of charging infrastructure. Nevertheless, the e-HDT catches up quickly with its significantly lower annual OPEX, ultimately achieving a cost advantage by the end of the fifth year in both scenarios (no discounting assumed).

The assumption of a prolonged holding period increases the economic attractiveness of the e-HDT, as the lower operating costs accumulate over a longer period of time. In addition, the influence of the residual value on the calculation is lower.

In summary, leasing an e-HDT can already be more financially viable than leasing its ICE-equivalent. When it comes to comparing e-HDT and ICE-HDT **in purchase, cumulated costs deflect in favor of the e-HDT only at a late stage of the six-year holding period,** which makes the result more vulnerable to changing assumptions in the calculation.



Graphic 5: Cumulated cost for purchase vs. leasing over holding period

5.3. Sensitivity analysis

To illustrate the effects of variation in electricity and diesel prices as key influencing factors in both the long-haul and regional-haul scenario, a sensitivity analysis under existing assumptions is conducted.

In the regional-haul scenario, the tipping point towards advantageousness of e-HDT is already reached in the base case. Even when assuming increasing electricity prices up to 30%, the e-HDT can keep at least cost parity. A clear disadvantage of the e-HDT is only visible in the case of strongly decreasing diesel prices combined with increasing electricity prices, indicating a small actual risk.

In the long-haul scenario, the base case shows e-HDT having a strong cost advantage over ICE-HDT, which is maintained with most sensitivity adjustments. In the improbable cases of electricity prices increasing or diesel prices decreasing, e-HDT and ICE-HDT reach approximate parity. However, **e-HDT only show a clear disadvantage in the most extreme cases when electricity prices rise significantly while diesel prices fall,** indicating a low risk. Overall, e-HDT remain cost-effective in most scenarios for long-haul use.

Regional-haul scenario:

60,000 km/a
100% depot charging

Electricity: ← Increase in electricity price | Decrease in electricity price →

Diesel: ↑ Increase in diesel price | Decrease in diesel price ↓

Diesel \ Electricity	+30%	+15%	BASE CASE TCO in EUR/km e-HDT/ICE-HDT	-15%	-30%
+30%	Δ9%	Δ12%	Δ15% 1.20/1.41	Δ18%	Δ20%
+15%	Δ4%	Δ7%	Δ10% 1.20/1.33	Δ13%	Δ16%
BASE CASE TCO in EUR/km e-HDT/ICE-HDT	Δ-2% 1.27/1.25	Δ1% 1.23/1.25	Δ4% 1.20/1.25	Δ7% 1.16/1.25	Δ10% 1.12/1.25
-15%	Δ-9%	Δ-6%	Δ-2% 1.20/1.17	Δ1%	Δ4%
-30%	Δ-17%	Δ-13%	Δ-10% 1.20/1.09	Δ-6%	Δ-3%

Long-haul scenario:

100,000 km/a
50% depot charging, 50% highway charging

Electricity: ← Increase in electricity price | Decrease in electricity price →

Diesel: ↑ Increase in diesel price | Decrease in diesel price ↓

Diesel \ Electricity	+30%	+15%	BASE CASE TCO in EUR/km e-HDT/ICE-HDT	-15%	-30%
+30%	Δ13%	Δ17%	Δ21% 1.08/1.37	Δ25%	Δ29%
+15%	Δ8%	Δ12%	Δ16% 1.08/1.31	Δ20%	Δ25%
BASE CASE TCO in EUR/km e-HDT/ICE-HDT	Δ2% 0.97/1.21	Δ6% 1.01/1.21	Δ11% 1.08/1.21	Δ15% 1.15/1.21	Δ20% 1.19/1.21
-15%	Δ-5%	Δ0%	Δ4% 1.08/1.10	Δ9%	Δ14%
-30%	Δ-13%	Δ-8%	Δ-3% 1.08/1.05	Δ2%	Δ8%

- Clear TCO advantage of e-HDT (Δ>5%)
- Approx. parity of TCO between e-HDT vs. ICE-HDT (Δ±5%)
- Clear TCO disadvantage of e-HDT compared to ICE-HDT (Δ>5%)
- Δ Difference in TCO between e-HDT vs. ICE-HDT
- Trend scenario

Graphic 6: Sensitivity analysis for electricity and diesel as key influencing factors

Excursus: Analysis of greenhouse gas emissions as additional function in P3's TCO tool

In addition to the assessment of costs, P3's TCO tool also enables an ecological comparison by providing the CO_2 equivalents (CO_2-eq) emitted over the holding period of the respective truck. In a simplified assumption, the comparison covers only the **CO_2-eq by operation of the truck and the production of the LFP battery in Europe.** These two factors are considered due to their **main impact on emissions** of the selected drive types. To make a comprehensive statement on emitted CO_2-eq of e-HDT and ICE-HDT, a full lifecycle analysis must be performed.

The underlying rationale behind including the analysis of CO_2-eq is the Non-Financial Reporting Directive (NFRD), which requires more and more companies in the European Union to monitor their sustainability practices, starting with energy-intensive companies. Transparency is achieved by the publication of a non-financial report together with the annual management report on the company's ESG performance (Environmental, Social, Governance). The scope of the NFRD is gradually expanding to encompass all large and small publicly listed companies in the coming years.

By calculating with CO_2-eq as best practice in the industry, a unit of measurement is used to standardize the climate impact of different greenhouse gases: not only CO_2-emissions are considered, but also other greenhouse gases with even higher climate impact.

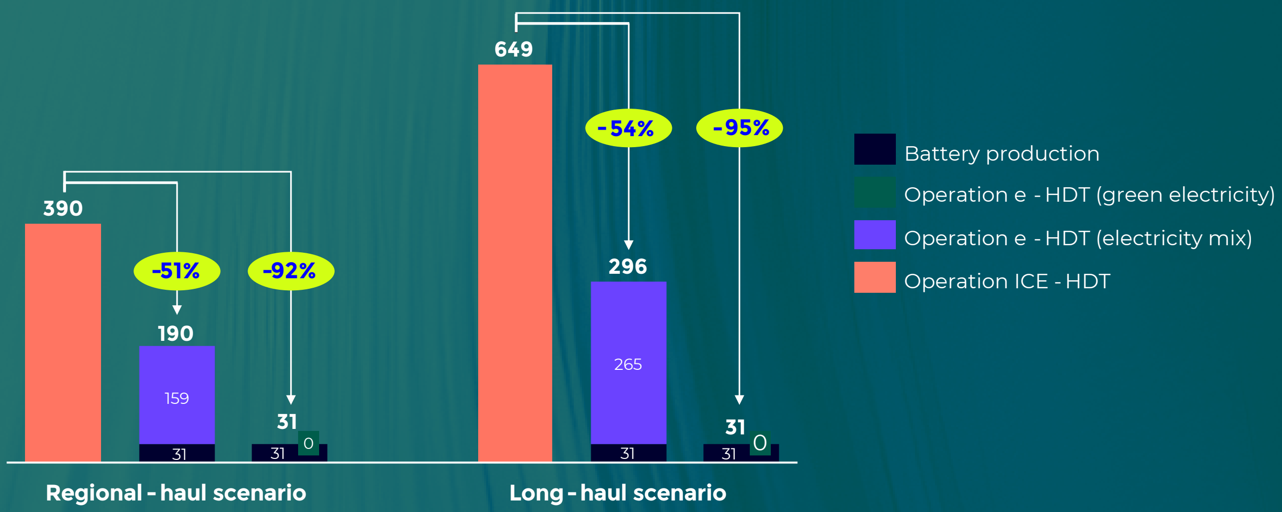
Not surprisingly, **the comparison of CO_2-eq for the operation of trucks over their holding period of six years strike out in favor of the e-HDT.** Decreasing emission factors for electricity over time due to constantly increasing renewable energy production in Germany push the ecological dominance of the electric powertrain in truck operation compared to the diesel variant. Despite being often condemned as huge emission source, the **production of the battery has only a minor impact on the e-HDT's CO_2-eq balance.**

Considering both battery production and truck operation, the **e-HDT can save more than 550 g CO_2-eq per km driven compared to the ICE-HDT,** when calculating with the German electricity mix. This results in a **cumulative 200 tons of CO_2-eq over the entire six-year usage period** compared to the ICE-HDT in the regional-haul scenario, and even 350 t CO_2-eq for the long-haul scenario.

The gap between e-HDT and ICE-HDT further widens when assuming a green electricity tariff, which is already available at minimally higher cost. In this case, companies can already reduce the emissions of their fleet operations to zero. The production of renewable electricity on site can further contribute to the improvement of companies' carbon footprints.

Regional-haul scenario:
60,000 km/a
100% depot charging

Long-haul scenario:
100,000 km/a
50% depot charging, 50% highway charging



Graphic 7: CO_2-eq for battery production and truck operation over holding period 2025-2030 [in t CO_2-eq]

6. CONCLUSION AND OUTLOOK

Although lagging in today’s vehicle registrations, the transition to battery-electric heavy-duty trucks will gain more and more traction within the next years. This momentum can be attributed to the particularly high cost-sensitivity of the truck market, where operational expenses play a pivotal role in decision-making. Market dynamics being heavily influenced by cost considerations coupled with the fierce competition among manufacturers provide fertile ground for disruptive innovations to gain traction swiftly. Now and in the future, energy-intensive sectors, such as logistic companies, must also give greater priority to environmental aspects – transitioning to an electric vehicle park provides high potential to reduce company greenhouse gas emissions.

Depending on the conditions at the operator's depot, there are already use cases today in which e-HDT financially outperform their ICE counterparts. As a result, **e-HDT have become a viable alternative to ICE-HDT in terms of cost, with substantial savings per kilometer compensating for the higher acquisition cost for vehicle and charging infrastructure.**

As the scenarios of this whitepaper have shown, cost advantages for specific use cases already exist. However, many fleet owners remain hesitant due to the significant upfront investments. To overcome this barrier, **a shift towards flexible acquisition models is essential.** In particular, leasing of e-HDT has gained popularity and helps to accelerate market adoption.

Similarly, **financing and rental options for charging infrastructure** are increasingly sought after to spread costs over time. To meet market demands and lower entry barriers, manufacturers and solution providers must expand their offerings to include these flexible models. Alternatives such as **subscription services or pay-per-use agreements** could further enhance accessibility, enabling fleet operators to adapt more easily to market changes and technological advancements.

Beyond flexible acquisition models, the economic viability of e-HDT critically depends on consistently upholding low electricity prices at the depot. This requires a multifaceted approach that combines decentralized electricity production, strategic utilization of favorable electricity market prices, and implementation of intelligent charging systems. The goal is to create a **smart energy ecosystem, where vehicle charging is seamlessly integrated into a comprehensive energy management strategy.** This holistic approach not only enhances the cost-effectiveness of e-HDT but also contributes to the overall sustainability of fleet operations.

Whilst the two scenarios illustrated in this analysis have been chosen deliberately to represent standard use cases, they do not reflect the full spectrum of heavy-duty transport. Accordingly, it is crucial to highlight the importance of conducting individualized assessments. The operating procedures of the vehicle fleets and the special circumstances of each depot must be examined in detail to fully profit from fleet electrification.

7. Contact

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Hermann Pyschny
Partner

hermann.pyschny@p3-group.com

Alina Haller
Senior Consultant

alina.haller@p3-group.com

Disclaimer

Address:
P3 Group GmbH
Heilbronner Str. 86
70191 Stuttgart
Germany

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www.p3-group.com