Electrification potential of an existing heavy-duty vehicle fleet – a techno-economic analysis

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

ELV LIVE

Erneuerbar mobil

Results of the ELV-LIVE Research Project

Theresa Dolinga – Öko Institut e.V.

EVS 38, Göteborg, Sweden, June 15-18, 2025

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Study Overview

- Part of ELV-LIVE research project
- Based on a real use case:
  - Access to real route data
  - Access to realistic costs
- **Research questions:**
  - What proportion of the vehicle fleet is electrifiable?
    What technical requirements are necessary for this?
  - How economical viable is the electrification of the vehicle fleet?
    Which vehicle configurations and operational scenarios offer the greatest potential?

ELV-LIVE in a nutshell

Title:

ELV-LIVE – Accompanying research on the use of battery-electric heavy-duty vehicles in regular logistics operations

Partners:

Oeko-Institut (research), Daimler Truck (associated partner), six case study partners

Duration:

1.1.2023 – 31.12.2025

Funding:

"Erneuerbar mobil", German Federal Ministry of Economics and Climate Protection (BMWK)

More Information:

Project website: Link

Background to Electrification

Political Framework Condition, State of Research and Technology in Germany

Basis for technical feasibility analysis

Background of HDV Electrification in Germany

- **Political Goals:**
  - 2030: Reduction of GHG by 65% + 1/3 of heavy-duty vehicle mileage to be based on electricity
  - Reality (2023): 1.3% of all medium- and heavy-duty vehicles run on alternative fuels
- **Policial Measures:**
  - CO_2 Emission trading (2024: $45\ €/\ t_{CO_2}$(2,6 ct/km) → 2040: 182 $€/\ t_{CO_2}$)
  - CO_2-Component of truck toll on federal highways (2024: 200 $€/\ t_{CO_2}$ (11,6 ct/km))
  - Expansion of public charging infrastructure (AFIR):
    - Public charging infrastructure in 2024: only few truck charging points in Germany and strong price variation

Presentation: Case Study Partner

Badische Staatsbrauerei Rothaus AG

Basis for technical feasibility analyis

Company and its Truck Fleet

- Main business activity: **Brewery** (since 1791)
- 2 Locations: Rothaus, Umkirch
- 20 trucks with 18 drivers
- Trucks in operation for at least **8 years**
- Single-shift operation
- Existing charging infrastructure at the depot
  - **Construction costs:** 805 €/kW
  - **Electricity price:** 5-20 ct/kWh
    (Literature: 2025: 22.8 ct/kWh, 2030: 20.4 ct/kWh)

	„Small Fleet“	„Big Fleet“
Total weight	26 t	40 t
⌀ Distance	100 km	200 km
Price Diesel truck	188.000 € (incl. Truck body)	320.000 € (inkl. Truck body and trailer)
Price BET	308,000 €	450,000 €

Operating Area of the Trucks

- Brewery at an altitude of 1,000 m
  - Mountainous region
  - Low temperatures
- Routes on rural roads and villages
  - Poor expansion of public charging infrastructure
  - Charging at restaurants, shops in the region: 22 kW
  - Around 60 % toll roads

Methodology

Literature Research and methodology

Basis for technical feasibility analysis

Database

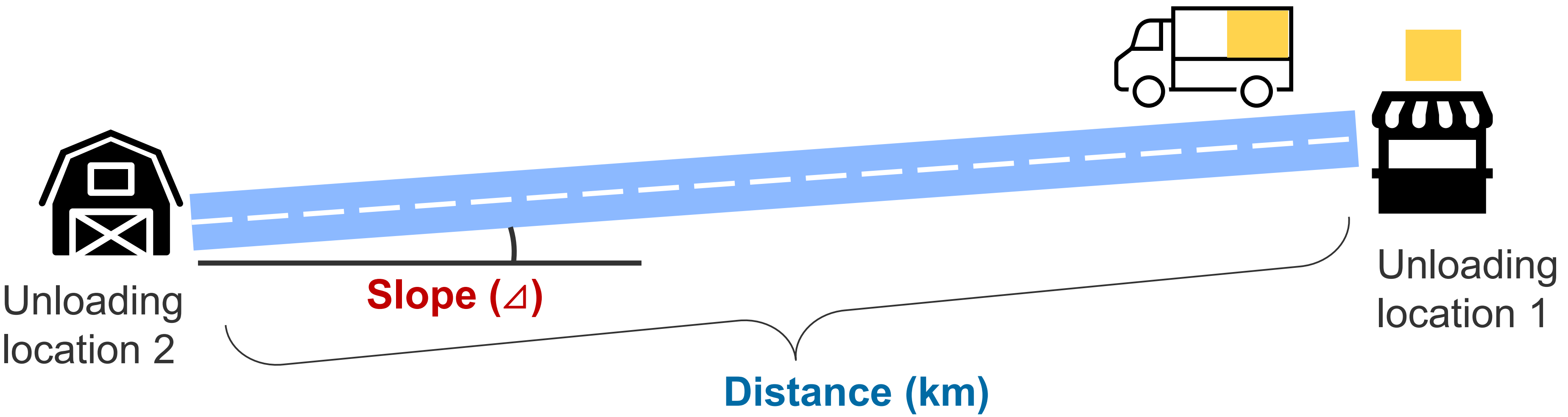
- **Source:** Excel spreadsheet with log of trips and exchange with case study partners
  - Database: 13 vehicles (5-10 days each) = 99 usable days
  - Each day includes all stops (time, address, unloading weight)
- **Editing in Python:** Creating an Address Matrix
  - Calculating distances and altitude difference
  - Calculating time duration of stops, journeys, driving breaks
  - Calculating loading weight

Technical Feasability Analysis

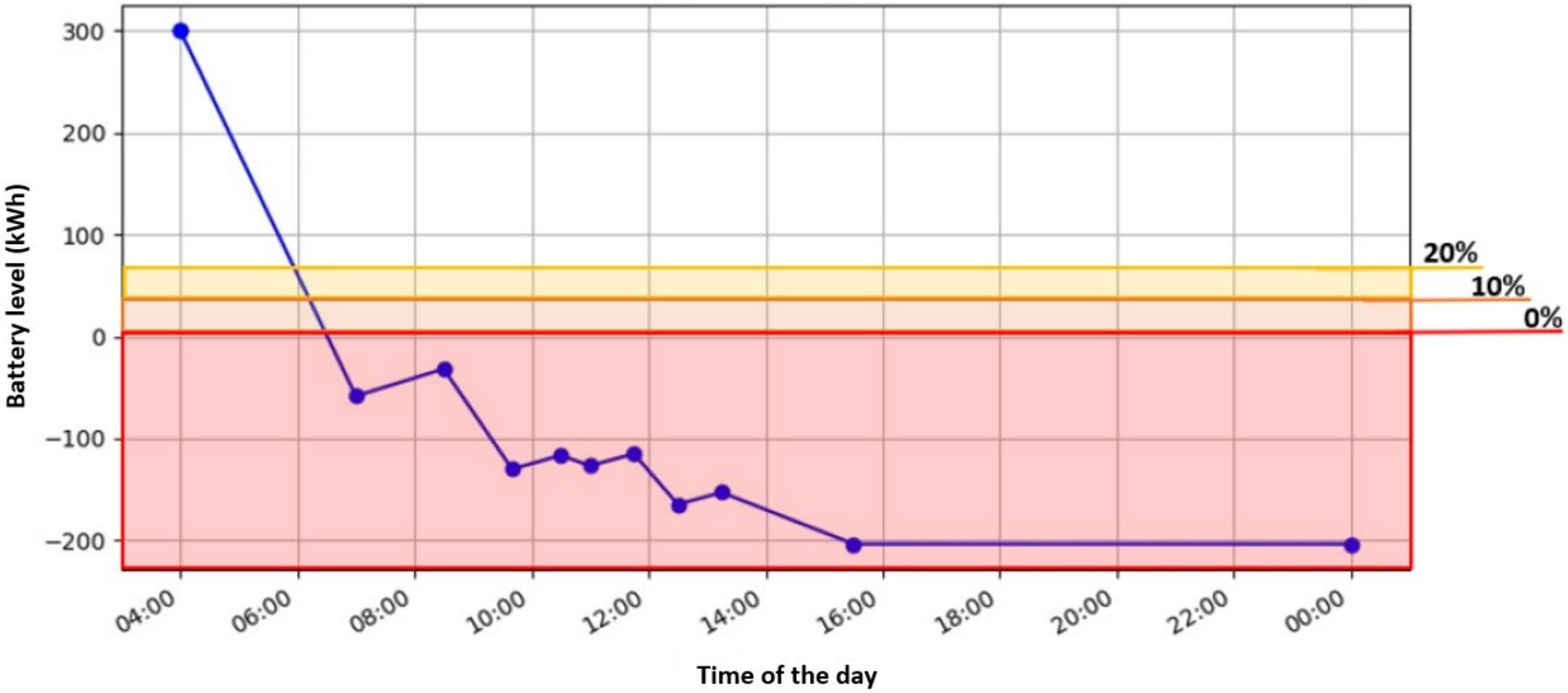
- **Research question:** What proportion of vehicles/tours are electrifiable?
- Based on a broad literature review
- **Different scenarios:**
  - Battery scenario
    - 300 kWh
    - 450 kWh
    - 650 kWh
  - Charging scenario:
    - With intermediate charging (driving breaks: 100 kW; stops: 20 kW)
    - Without intermediate charging
  - Temperature scenario (extreme temperatures)
    - Battery capacity: 75 %
    - Charging power: 83 %

Modelling Energy Consumption

$$\Delta\, \boldsymbol{Battery\ charging\ level} = \boldsymbol{Consumption}(\boldsymbol{Base\ Consmption}, \boldsymbol{m}, \boldsymbol{\measuredangle}, \boldsymbol{T}) * \mathbf{Distance}$$



Modelling Battery Charging Level



Source: Dolinga & Hacker (2025)

Assumptions

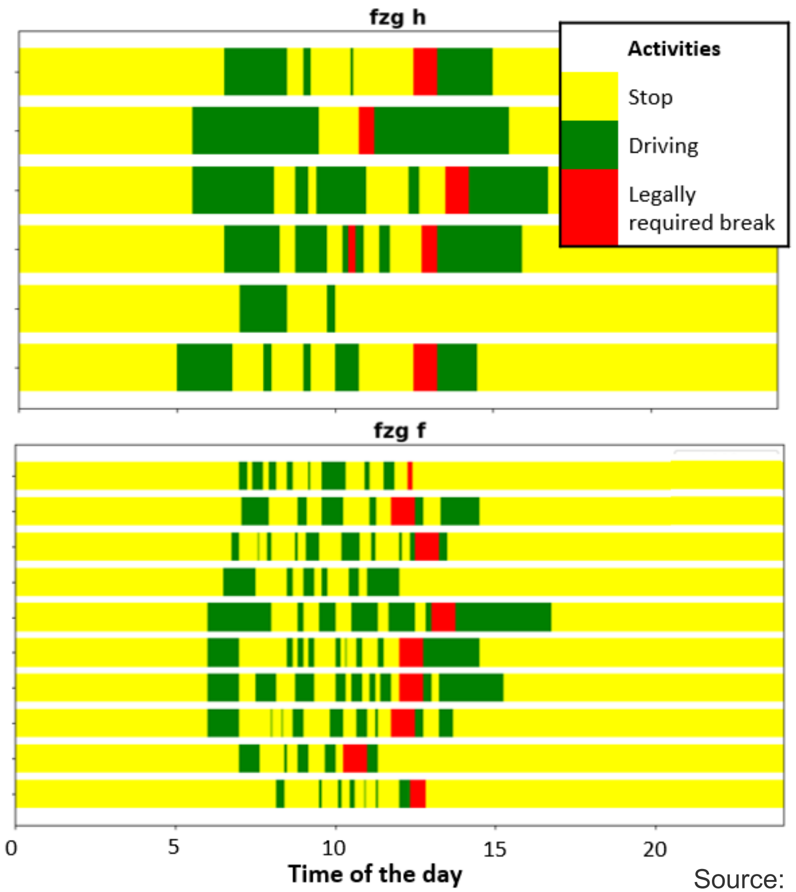
Category	Assumption
Base Consumption	1.1 kWh/km
Weight factor	(Loading weight - ⌀ Load)*4.6%/ton Dead weight of trucks neglected
Incline upwards (incl. recuperation)	Once slope >1%: consumption*1.57
Incline downwards (incl. recuperation)	Once slope >-1%: consumption*0.51
Extreme-**Temperature**	Battery capacity*0.75, charging power*0.83
Time lost during charging (stops and driving breaks)	10 min
Trucks drive off with a full battery	

Technical Feasibility Analysis

What proportion of the vehicle fleet is electrifiable?

What technical requirements are necessary for this?

Descriptive – Potential for Charging



Source: Dolinga & Hacker (2025)

Night break (Greatest potential)

- Very long period (reliably long: 15-18 h)
- Location: Good energy supply (especially at the brewery)

Stops (Medium Potential)

- There are many (3-8)
- Long period (25 min-1 h)
- Location: especially for inns and shops in the countryside = low charging capacity, hardly developed infrastructure

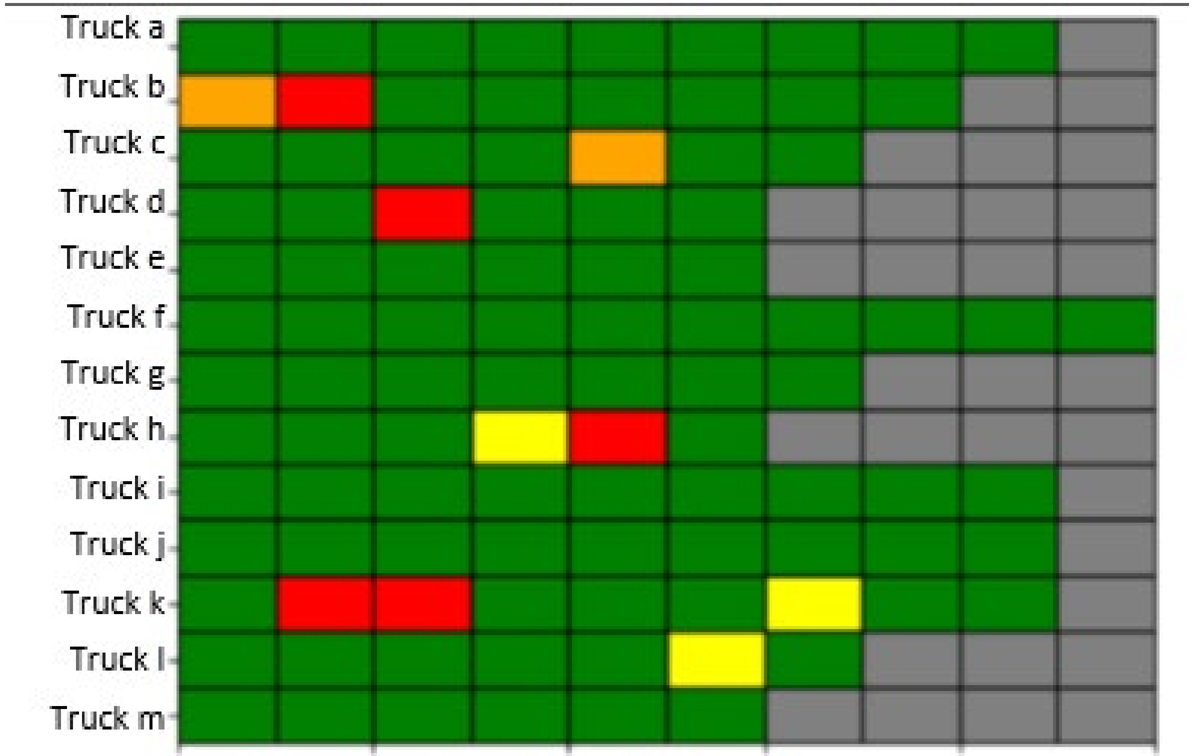
Driving breaks (Medium potential)

- Almost every tour (0.7-1.7 times per day)
- Long period (31-49 min)
- Location: In the countryside, not necessarily near large charging infrastructure

Battery Level for each Trip

Electrifiable without risk → Battery level >20%

(green)	Battery level >20%
(yellow)	Battery level <20%
(orange)	Battery level <10%
(red)	Battery level <0%
(grey)	No data

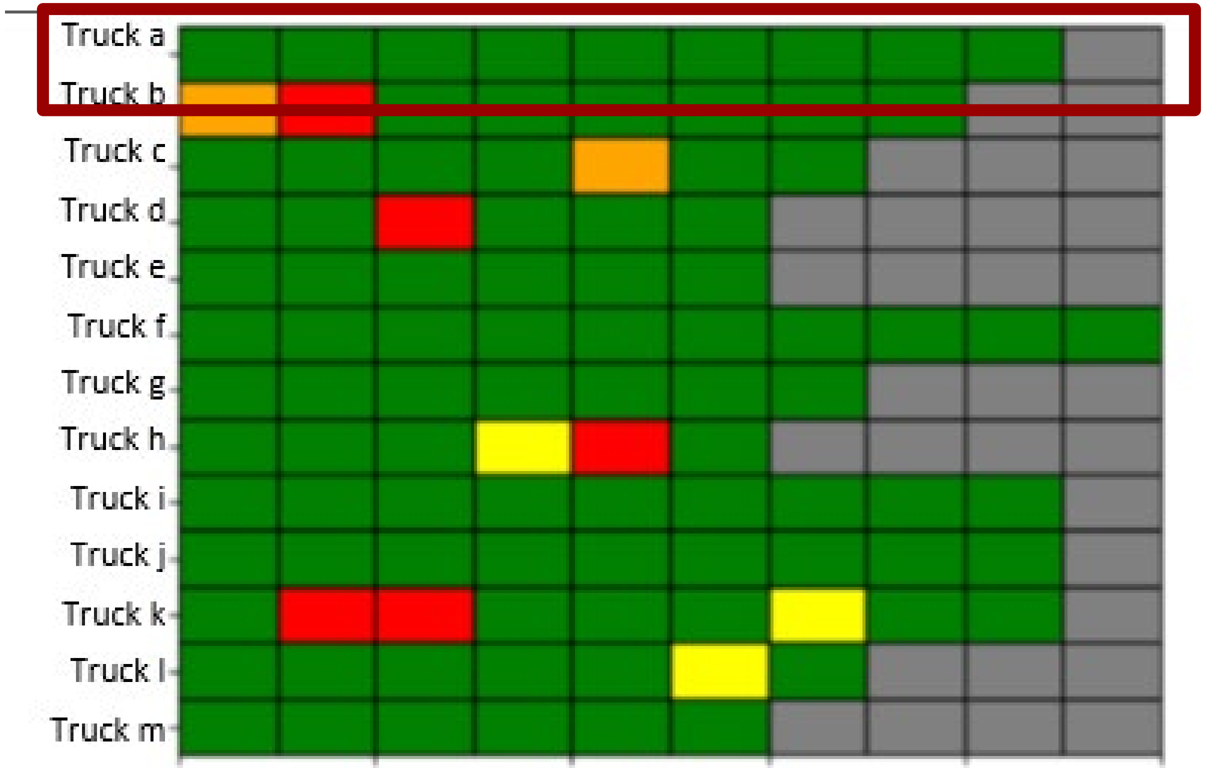


Battery Level for each Trip

Electrifiable without risk →

(green)	Battery level >20%
(yellow)	Battery level <20%
(orange)	Battery level <10%
(red)	Battery level <0%
(grey)	No data

One truck

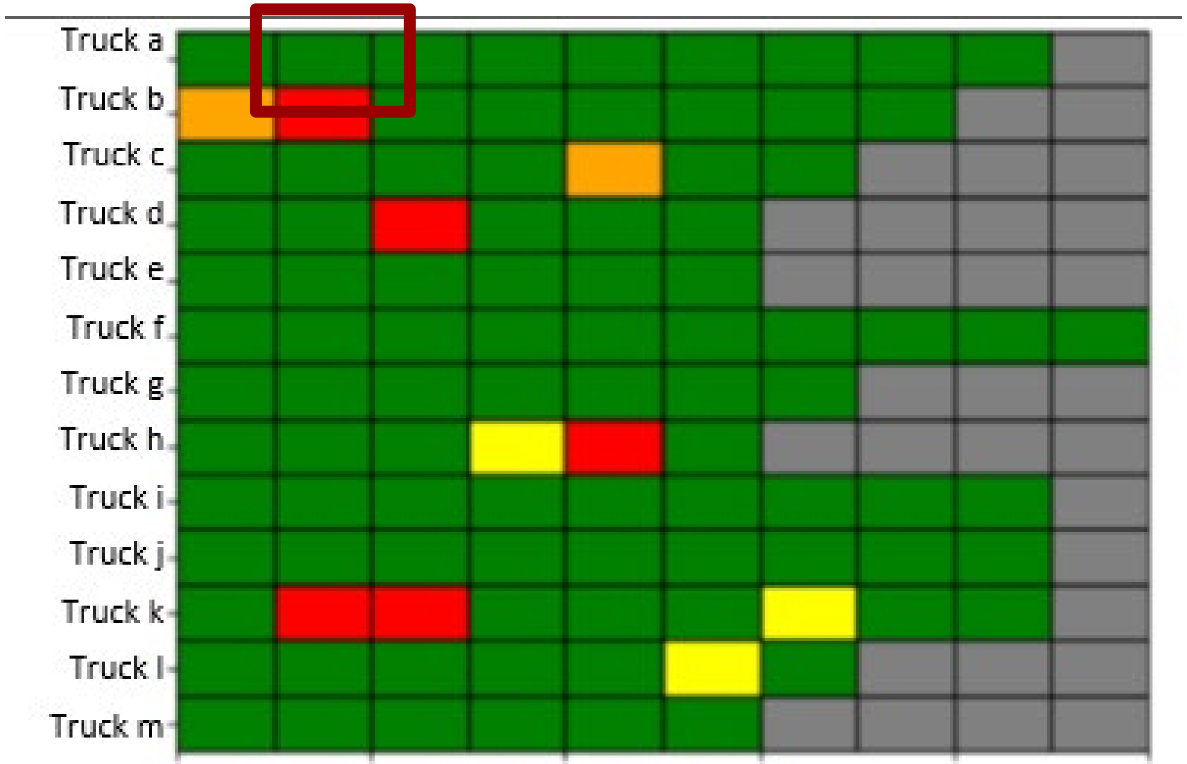


Battery Level for each Trip

Electrifiable without risk

(dark green)	Battery level >20%
(yellow)	Battery level <20%
(orange)	Battery level <10%
(red)	Battery level <0%
(grey)	No data

One day trip

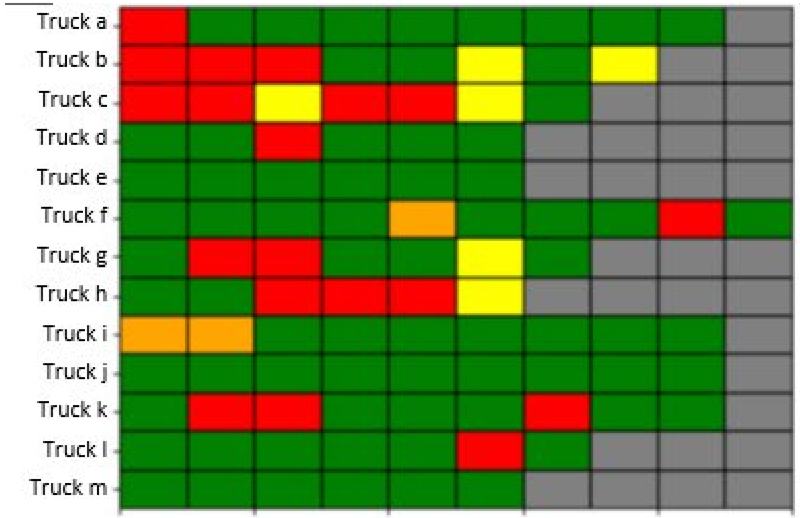


Battery Level with Depot Charging only (no Intermediate Charging)

Electrifiable without risk →

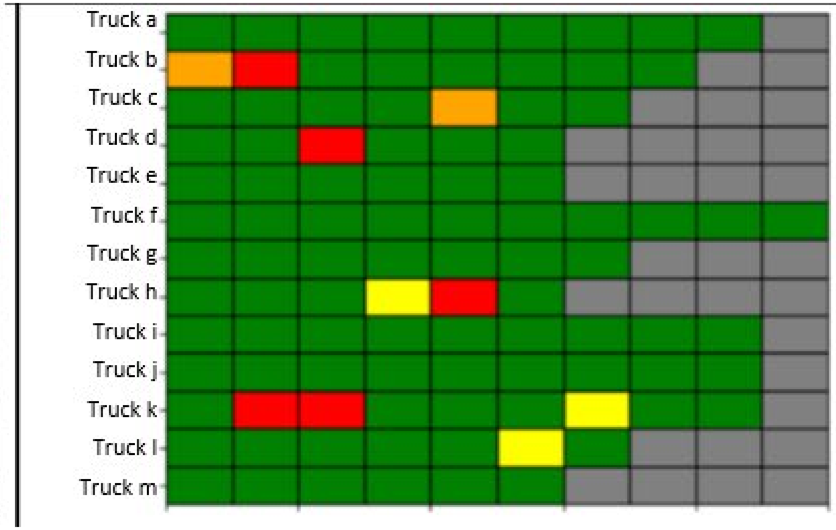
(green)	Battery level >20%
(yellow)	Battery level <20%
(orange)	Battery level <10%
(red)	Battery level <0%
(grey)	No data

300 kWh



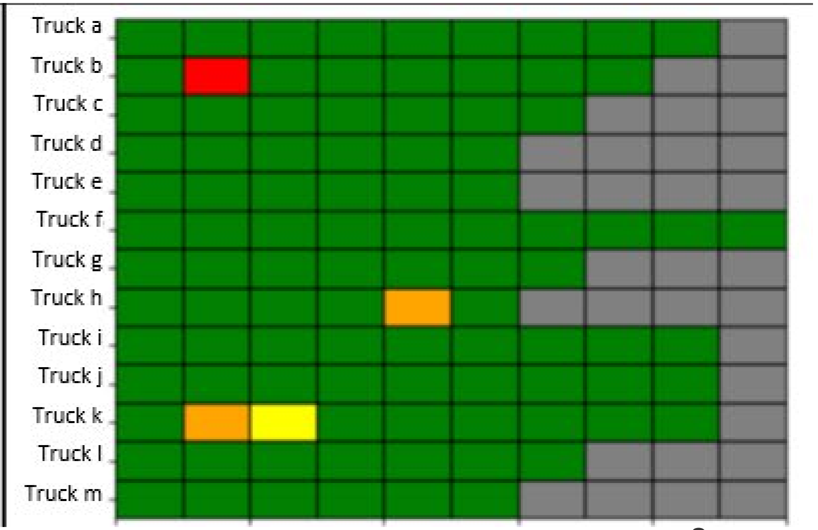
Electrifiable:
- 3 of the trucks
- 72% of the tours

450 kWh



Electrifiable:
- 7 of the trucks
- 90% of the tours

650 kWh



Electrifiable:
- 10 of the trucks
- 96% of the tours

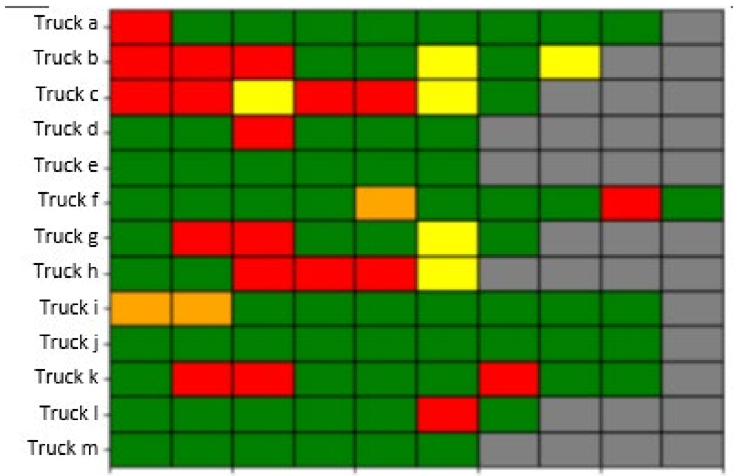
Source: Dolinga & Hacker (2025)

Electrifiable without risk →

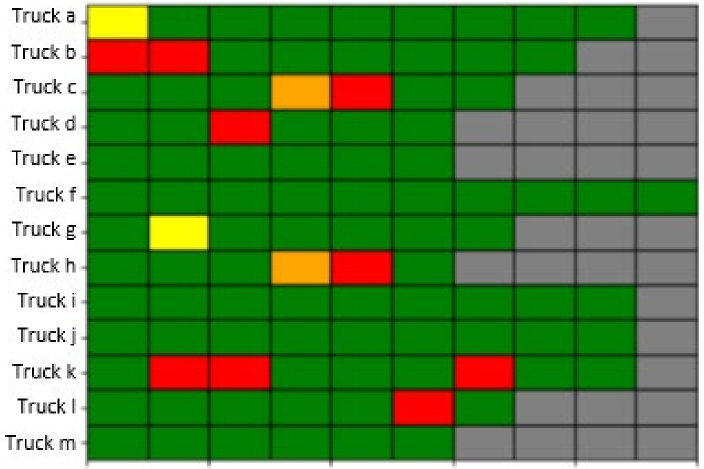
(dark green)	Battery level >20%
(yellow)	Battery level <20%
(orange)	Battery level <10%
(red)	Battery level <0%
(grey)	No data

Comparison (300kWh)

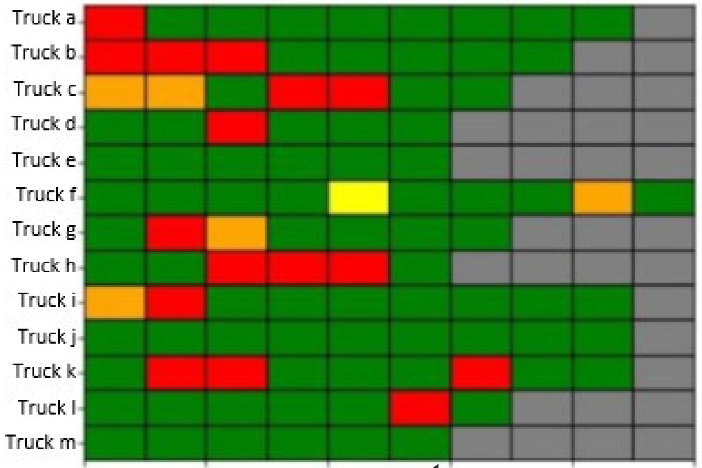
With Depot Charging only (no Intermediate Charging)



With Depot and Intermediate Charging



With Depot and Intermediate Charging and Low Temperature



Source: Dolinga & Hacker (2025)

15 percentage points difference

9 percentage points difference

Summery of Results

- Most of the tours and trucks are technically electrifiable!
- Intermediate charging at stops: Many routes with lower battery capacity electrifiable
- Electrification problems mostly due to 1-2 tours

Solution:

- Restructure tours by length
- many trucks with low battery capacity
- few with high battery capacity
- Extra charging stops on some routes (extreme temperature)

Required battery capacity according to charging strategy

Scenario with Depot Charging Intermediate Charging		
6 Trucks with 300 kWh	6 Trucks with 450 kWh	1 Truck with 650 kWh

Scenario with Depot Charging only (no Intermediate Charging)		
3 Trucks with 300kWh	9 Trucks with 450 kWh	2 Trucks with 650 kWh

→ Assignment is base for the economic viability analysis

Economic Viability Analysis

Accumulated Total cost of ownership

- For time interval up to 16 years
- For whole fleet and each vehicle (electric and diesel)
- Based on Assumptions and Scenarios

Scenarios

Accumulated Total cost of ownership:

- For time interval up to 16 years
- For whole fleet and each vehicle (electric and diesel)
- Based on Assumptions and Scenarios

		Vehicle purchase price	
		Rothaus (base) case	Optimistic case
Smaller batteries, more expensive Energy	Intermediate charging	1) Same residual value 2) Same residual curve	3) Same residual value 4) Same residual curve
Bigger batteries, cheaper Energy	No intermediate charging	5) Same residual value 6) Same residual curve	7) Same residual value 8) Same residual curve

Source: Dolinga & Hacker (2025)

Assumptions

Variable	Assumption		
Vehicle purchase price without battery Rothaus (cheaper)	Diesel	26t	128,000€ (89,500€)
		40t	140,000€ (103,000€)
	Electric	27t	192,064€ (104,800€)
		40t	204,516€ (126,900€)
Diesel costs f(year, CO_2 price, toll)	1.15 €/l (2030) 1.42 €/l (2040) + 0.53 €/l (toll)		
Electricity costs f(year)	Own depot charging	0.2 €/kWh (2025), 0.18 €/kWh (2030)	
	Charging at other depot	0.26 €/kWh (2025), 0.23 €/kWh (2030)	
	Public charging	0.3 €/kWh (2025), 0.27 €/kWh (2030)	
Depreciation (30% taxes)	Vehicle	9 years	
	Battery	10 years	
	Charging infrastructure	19 years	
Residual value	Vehicle f(years, km, vehicle size) after 8 years	40 t	-27 %
		27t	-51 %
	battery	- 2,3 %/year	
	Charging infrastructure	Linear, 5% left after 19 years	

Variable	Assumption
Operation of charging infrastructure	2 % of purchase price
Battery price	107 €/kWh
Purchase price charging infrastructure	804 €/kW
Inflation	2.4 %/year
Calculation interest	1.1 %/year

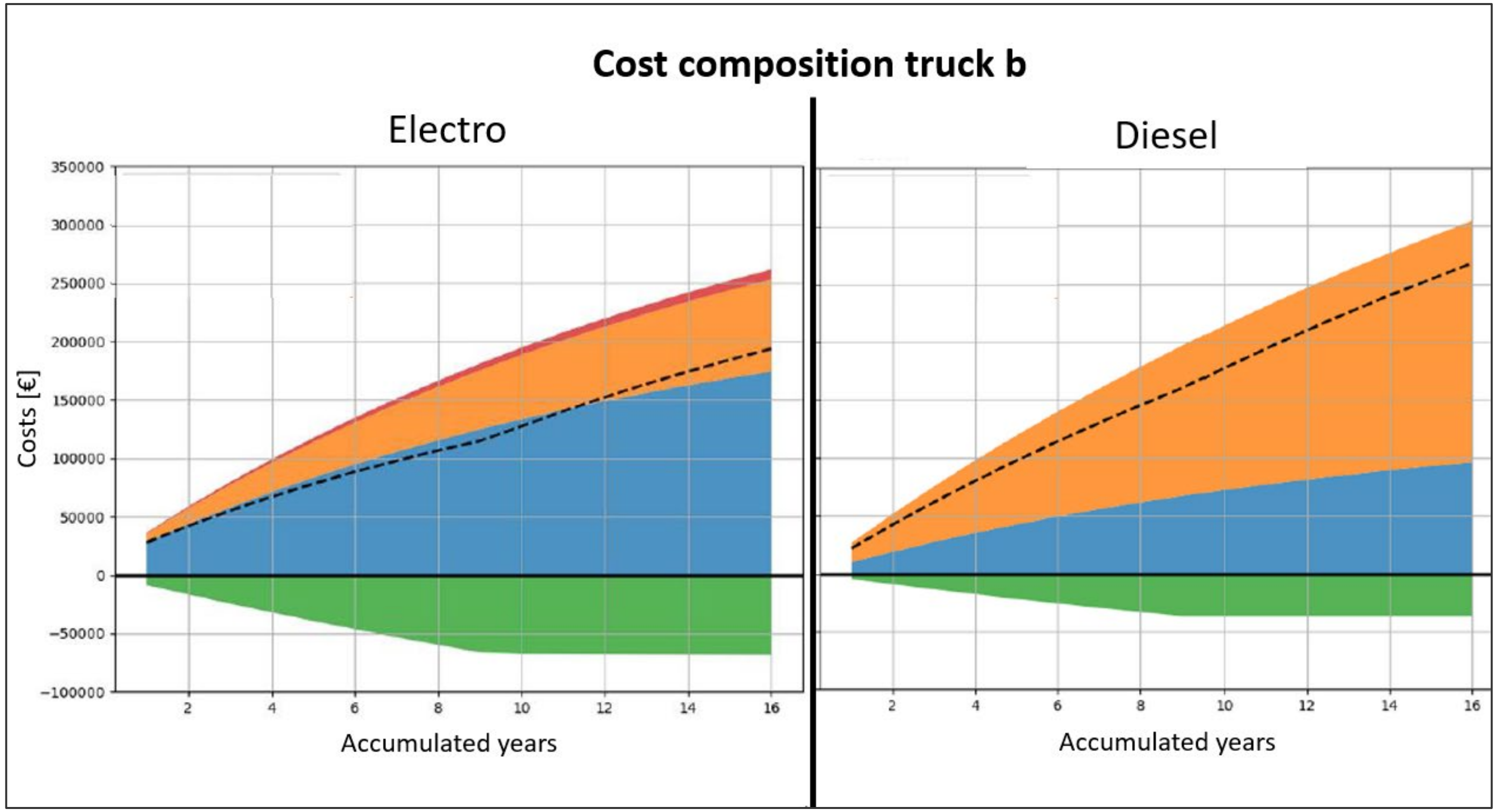
Economic Viability Analysis

How economical is the electrification of the vehicle fleet?

Which vehicles and scenarios offer the greatest potential?

Cost Composition

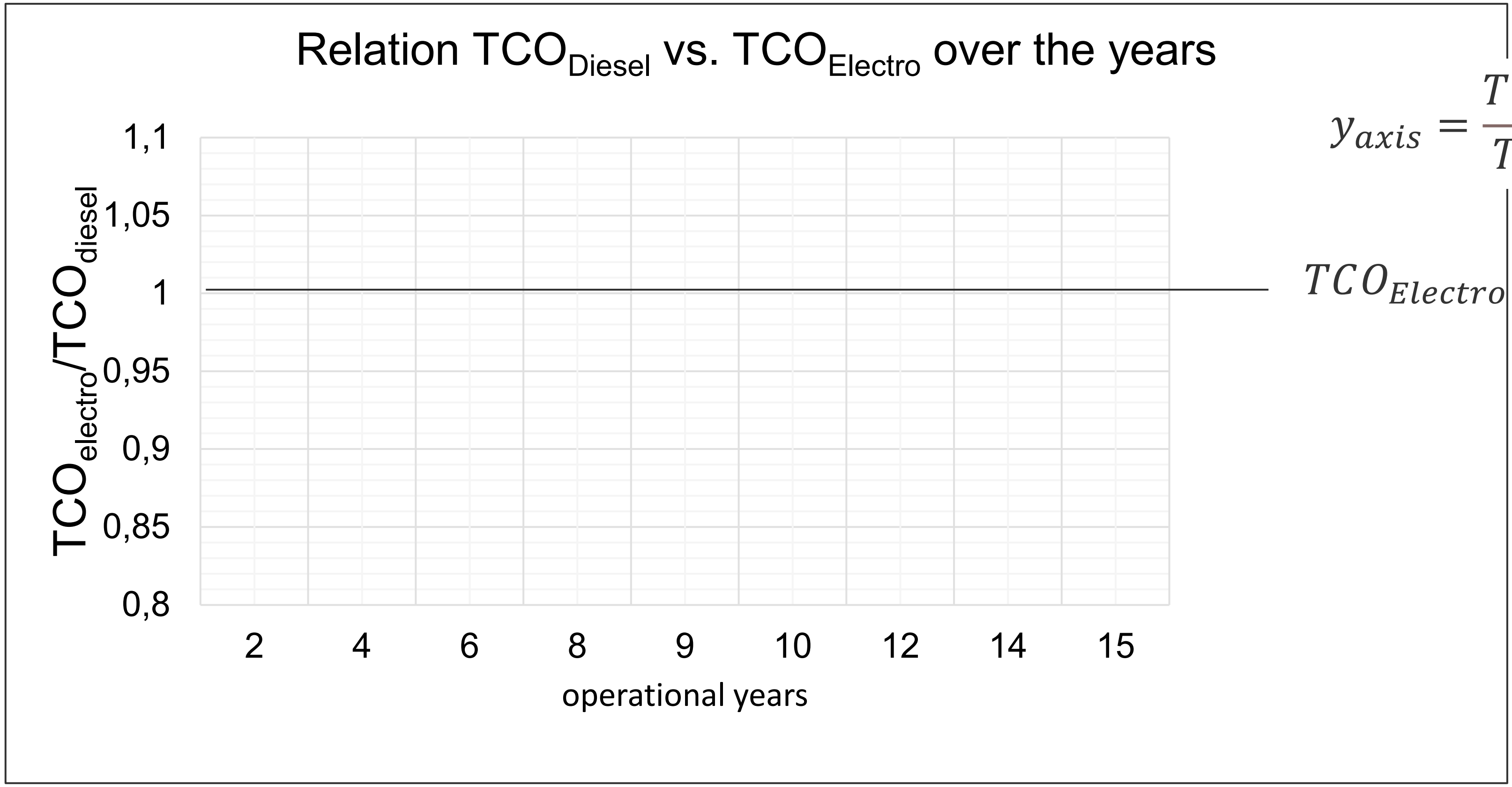
(blue)	Purchase price truck – residual value
(orange)	Operational costs
(green)	Depreciation
(red)	Purchase price charging infrastructure – residual value
– – –	Total sum



Source: Dolinga & Hacker (2025)

- Charging infrastructure to be neglected
- **Diesel trucks:** operating costs (diesel) largest share
- **Electric trucks:** Vehicle costs largest share

TCO – Comparison (Diesel vs. Electric Fleet)

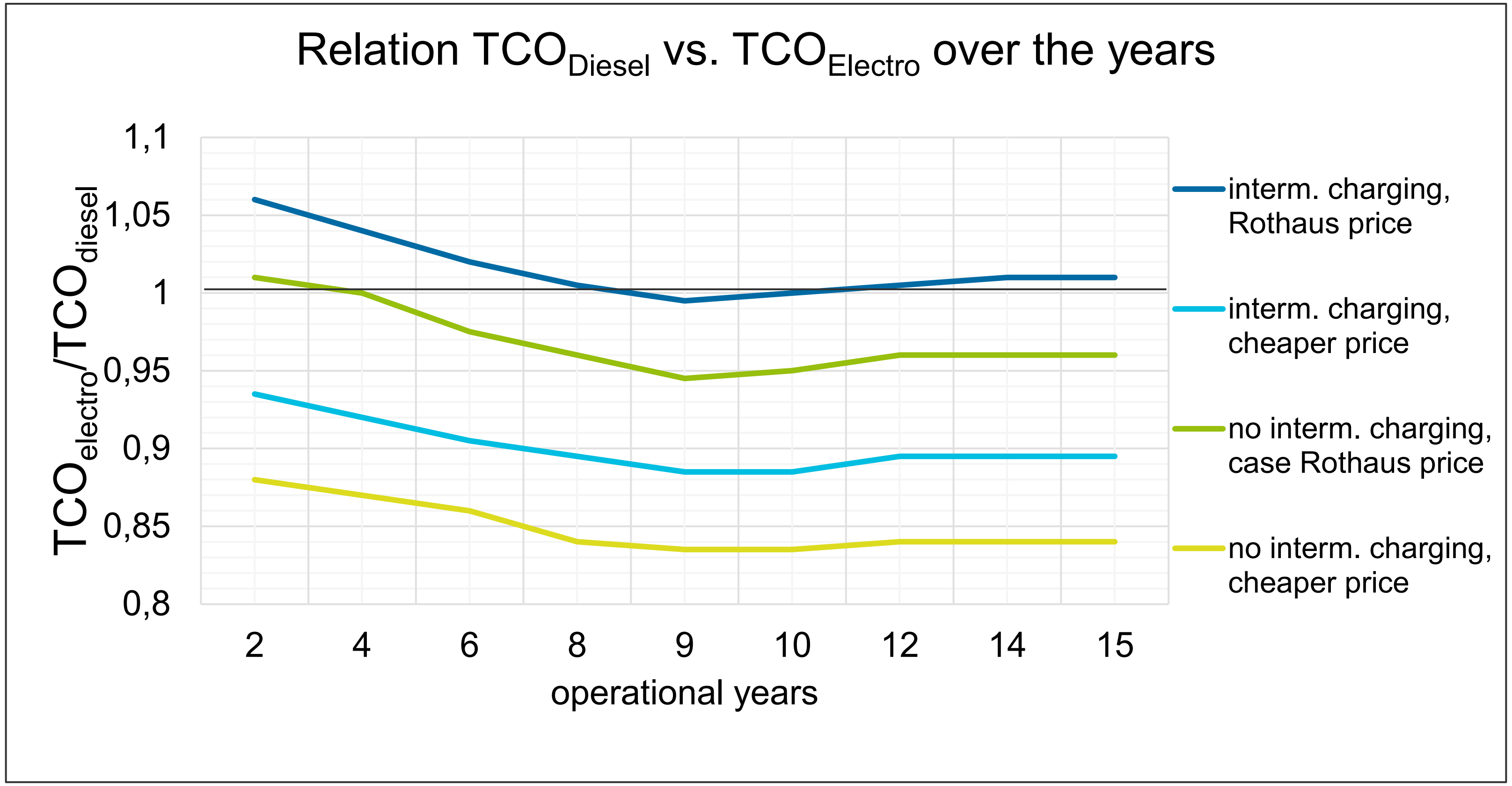


$$y_{axis} = \frac{TCO_{Electro}}{TCO_{Diesel}}$$

$$TCO_{Electro} = TCO_{Diesel}$$

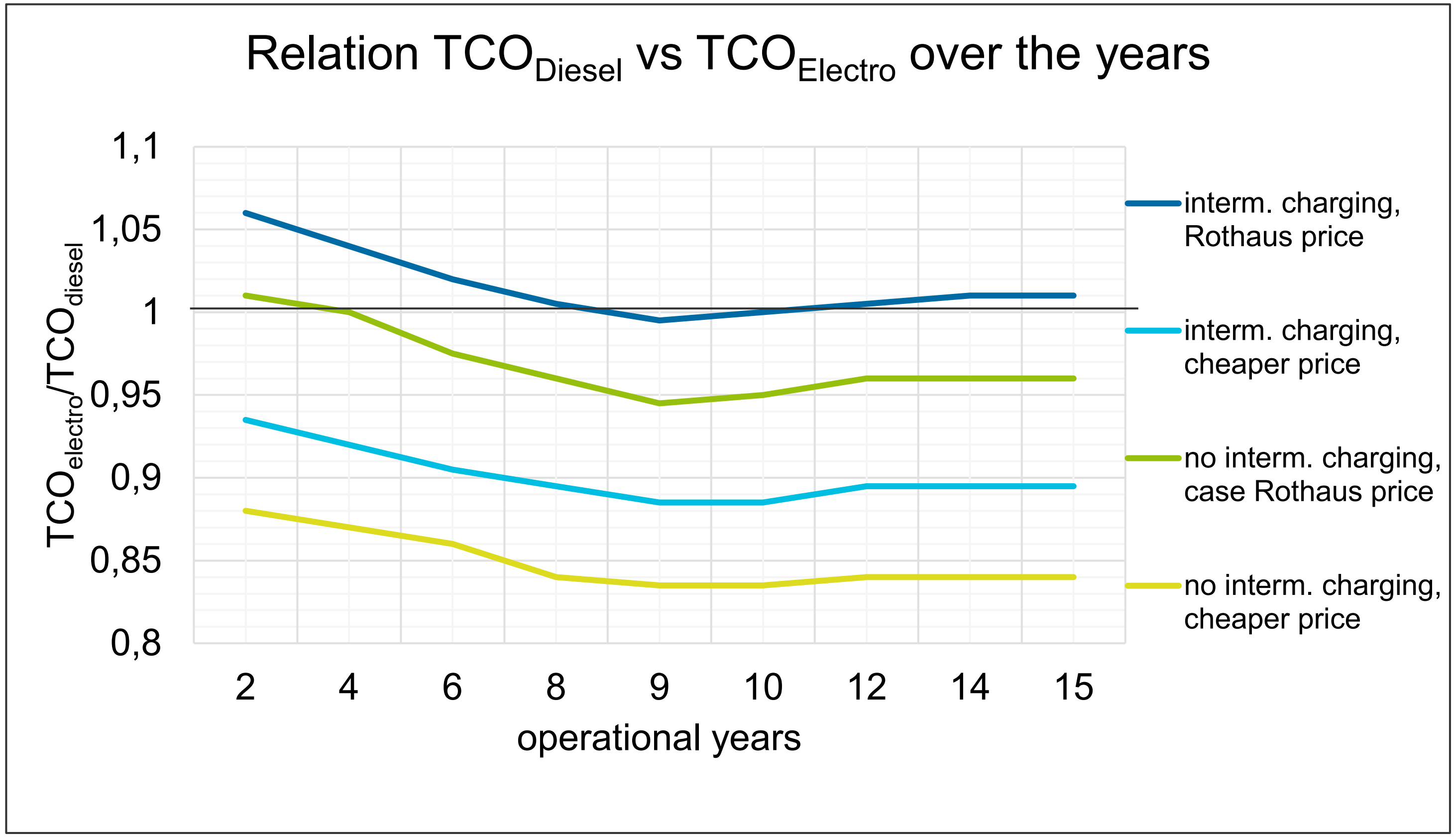
Source: Dolinga & Hacker (2025)

TCO – Comparison (Diesel vs. Electric Fleet) Same residual curve



Source: Dolinga & Hacker (2025)

TCO – Comparison (Diesel vs. Electric Fleet) Same residual curve



Source: Dolinga & Hacker (2025)

- Electrification pays off in most scenarios after a few years (but Rothaus price, interm. Charging)
- The more years, the more worthwhile it is

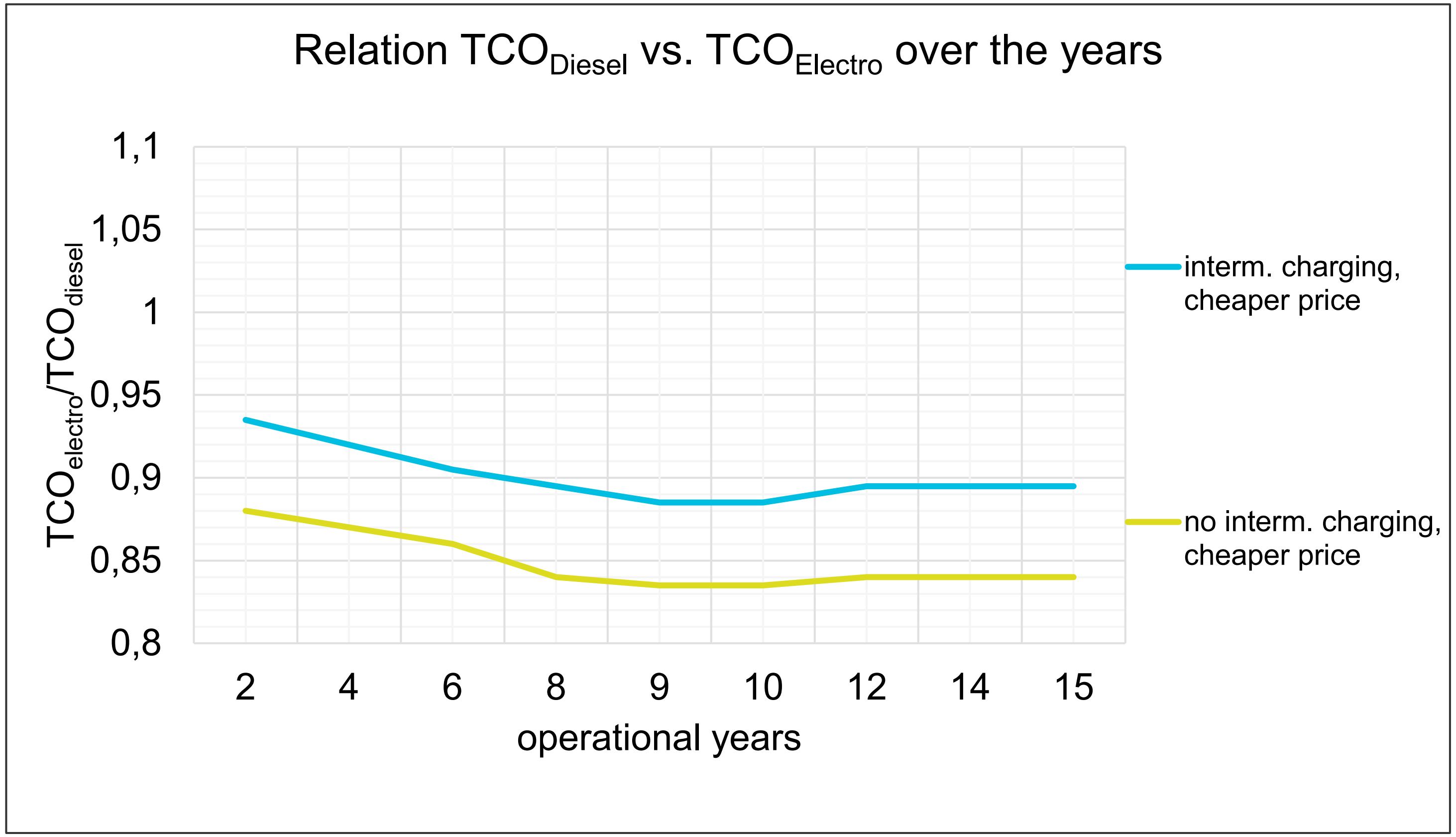
! Same residual value: worse results, pays of after 6, 8 years or not at all

TCO – Comparison (Trucks individually)

Profitability varies per vehicle (30-50 percentage points difference)

- Vehicles that only drive short distances are the least profitable
- Intensively used vehicles with high mileage pay off the most
- Larger trucks are more profitable (because they are relatively cheaper)

Comparison Charging Strategies



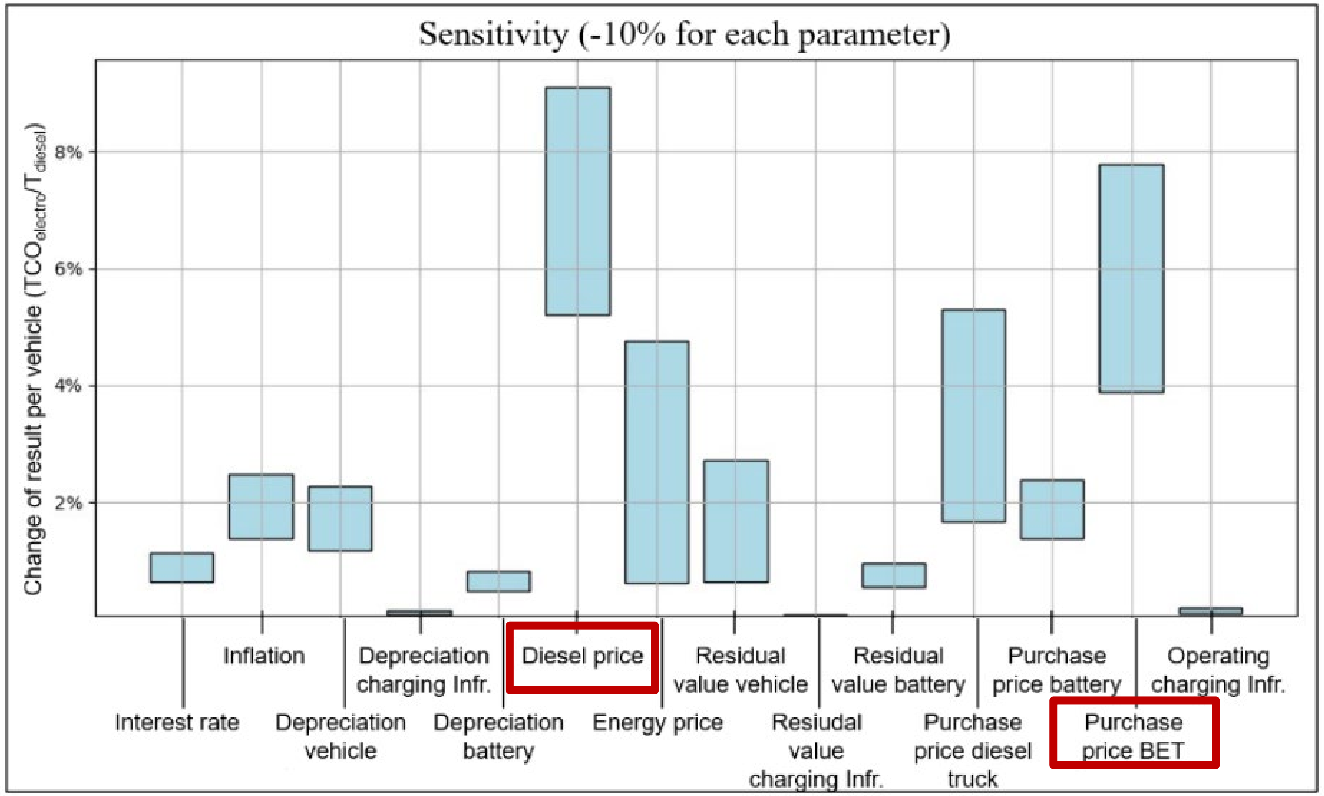
Source: Dolinga & Hacker (2025)

- No intermeadiate charging is cheaper:

  Cheaper depot electricity > More expensive batteries

- Varies depending on the vehicle(0.86-0.89)

Sensitivities



Source: Dolinga & Hacker (2025)

- **Purchase price of e-trucks** likely to change in the future
- **Diesel price** could become higher depending on the political situation
- **Charging infrastructure** to be neglected

Summary of Results

- Electrification is economical:
  - Especially when charging in the depot
  - Especially if the greatest possible distances are driven
  - Especially when vehicles are in use for as many years as possible
- Influencing variables with high relevance:
  - Residual value development
  - Vehicle purchase costs for e-trucks
  - Diesel costs

Discussion and Conclusion

Summary of Results of both Analysis

Electrification pays off

- Charging in the depot is also particularly attractive from an economic point of view
- Intermediate charging is usually not necessary, not attractively priced and often not available at all
- Intensively used vehicles with high mileage particularly economical
- Optimization potential: Intelligently assign tours and vehicles with different battery capacities
- Intermediate charging: especially relevant for exceptional situations (e.g. extreme temperatures) and on long tours in individual cases

Larger batteries as an attractive solution

- Bring more flexibility
- Enable longer trips and loads
- Increase the use of cheap depot electricity

Classification of Findings

- **Limitations**
  - Only one use case of many was considered
  - Calculations are based on uncertain assumptions and forecasts
- **Scientific outlook:**
  - Forecasts are needed about future vehicle prices, charging infrastructure, CO2 price, vehicle residual value
  - More analyses are needed for different use cases
- **Political outlook**:
  - Needs clear communication about future technologies
  - Needs long-term measures
- **Methodological conclusion**: Method and database are fruitful

Acknowledgment

The authors would like to thank the representatives of the vehicle manufacturers and transport companies for their participation in the study.

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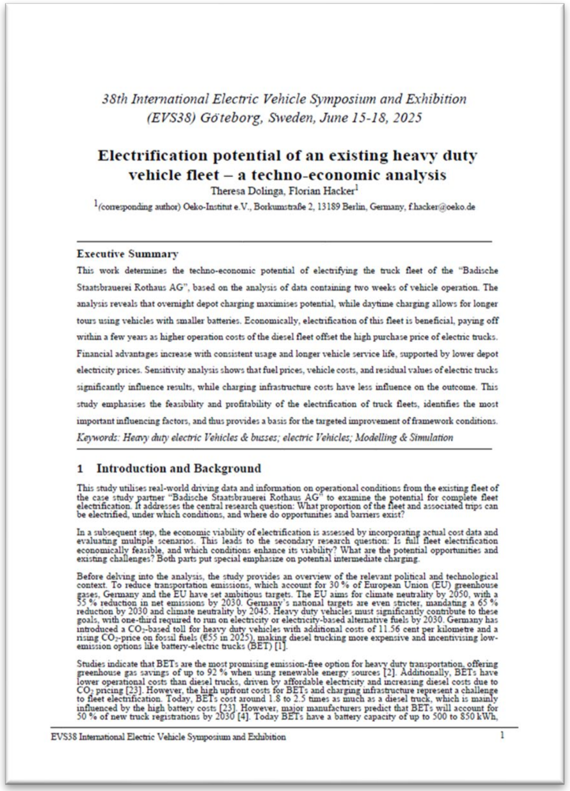

38th International Electric Vehicle Symposium and Exhibition (EVS38) Göteborg, Sweden, June 15-18, 2025

Electrification potential of an existing heavy duty vehicle fleet – a techno-economic analysis

Theresa Dolinga, Florian Hacker[1]

[1](corresponding author) Oeko-Institut e.V., Borkumstraße 2, 13189 Berlin, Germany, f.hacker@oeko.de

Executive Summary

This work determines the techno-economic potential of electrifying the truck fleet of the "Badische Staatsbrauerei Rothaus AG", based on the analysis of data containing two weeks of vehicle operation. The analysis reveals that overnight depot charging maximises potential, while daytime charging allows for longer tours using vehicles with smaller batteries. Economically, electrification of this fleet is beneficial, paying off within a few years as higher operation costs of the diesel fleet offset the high purchase price of electric trucks. Financial advantages increase with consistent usage and longer vehicle service life, supported by lower depot electricity prices. Sensitivity analysis shows that fuel prices, vehicle costs, and residual values of electric trucks significantly influence results, while charging infrastructure costs have less influence on the outcome. This study emphasises the feasibility and profitability of the electrification of truck fleets, identifies the most important influencing factors, and thus provides a basis for the targeted improvement of framework conditions.

Keywords: Heavy duty electric Vehicles & busses; electric Vehicles; Modelling & Simulation

1 Introduction and Background

This study utilises real-world driving data and information on operational conditions from the existing fleet of the case study partner "Badische Staatsbrauerei Rothaus AG" to examine the potential for complete fleet electrification. It addresses the central research question: What proportion of the fleet and associated trips can be electrified, under which conditions, and where do opportunities and barriers exist?

In a subsequent step, the economic viability of electrification is assessed by incorporating actual cost data and evaluating multiple scenarios. This leads to the secondary research question: Is full fleet electrification economically feasible, and which conditions enhance its viability? What are the potential opportunities and existing challenges? Both parts put special emphasize on potential intermediate charging.

Before delving into the analysis, the study provides an overview of the relevant political and technological context. To reduce transportation emissions, which account for 30 % of European Union (EU) greenhouse gases, Germany and the EU have set ambitious targets. The EU aims for climate neutrality by 2050, with a 55 % reduction in net emissions by 2030. Germany's national targets are even stricter, mandating a 65 % reduction by 2030 and climate neutrality by 2045. Heavy duty vehicles must significantly contribute to these goals, with one-third required to run on electricity or electricity-based alternative fuels by 2030. Germany has introduced a CO_2-based toll for heavy duty vehicles with additional costs of 11.56 cent per kilometre and a rising CO_2-price on fossil fuels (€55 in 2025), making diesel trucking more expensive and incentivising low-emission options like battery-electric trucks (BET) [1].

Studies indicate that BETs are the most promising emission-free option for heavy duty transportation, offering greenhouse gas savings of up to 92 % when using renewable energy sources [2]. Additionally, BETs have lower operational costs than diesel trucks, driven by affordable electricity and increasing diesel costs due to CO_2 pricing [23]. However, the high upfront costs for BETs and charging infrastructure represent a challenge to fleet electrification. Today, BETs cost around 1.8 to 2.5 times as much as a diesel truck, which is mainly influenced by the high battery costs [23]. However, major manufacturers predict that BETs will account for 50 % of new truck registrations by 2030 [4]. Today BETs have a battery capacity of up to 500 to 850 kWh,

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Electrification potential of an existing heavy-duty vehicle fleet – a techno-economic analysis.

Residual Value

Fahrzeug 18t-26t: $RW_{rel} = \exp\left(-\frac{1{,}36 \cdot JFL \cdot HD}{1.000.000}\right) \cdot \exp\left(-\frac{876 \cdot HD}{10000}\right)$

Fahrzeug >26t $RW_{rel} = \exp\left(-\frac{1{,}62 \cdot JFL \cdot HD}{1.000.000}\right) \cdot \exp\left(-\frac{354 \cdot HD}{10000}\right)$

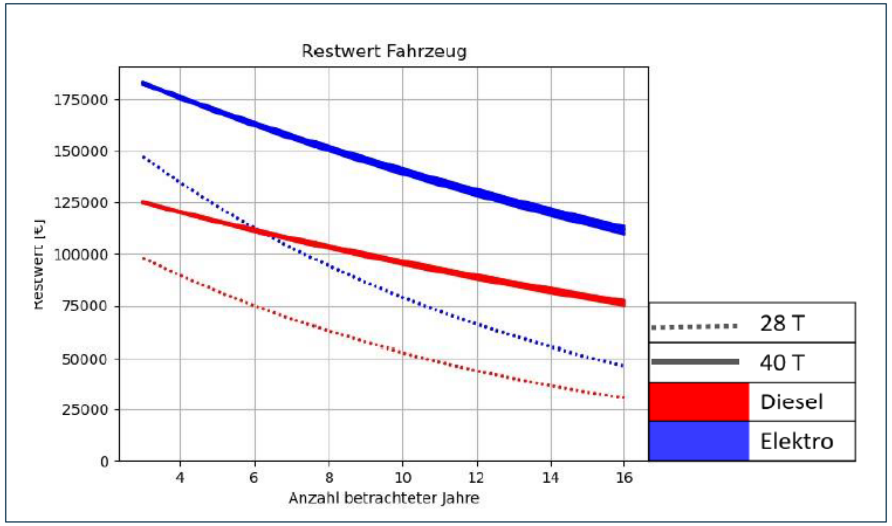

Abbildung 10: Angenommene Restwertkurven Verlauf der Diesel- und e-LKW für Szenario gleicher Restwertkurve.