Real-world Data Analysis of Battery Electric Trucks operating in Germany

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

ELV LIVE

Erneuerbar mobil

Results of the ELV-LIVE Research Project

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Supported by:

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Oeko-Institut

… is a leading independent European research and consultancy institute for a sustainable future.

- Non-profit association founded in 1977
- Three offices in Germany
- 210 staff members

Current activities in the field of heavy-duty vehicles:

- **Research project ELV-LIVE** and the preceeding projects StratES and StratON
- **Study on depot charging for heavy-duty vehicles** comparing Spain, France, the UK and Germany
- **Evaluation of the German funding program** on climate-friendly HDVs **(KsNI)**
- Multiple **consulting projects for the German government and the EU Commission** on relevant regulations (including EU CO_2 standards)

Outline

- Background
- Data and Methodology
- Analysis of Energy Consumption
- Analysis of Activity Patterns
- Conclusion

Background

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The ELV-LIVE Project in a Nutshell

Title:

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

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

Aims of the Project and Key Research Questions

What is the main topic ?

- Providing scientific support to accompany the market launch of battery electric trucks for the **first users** between 2023 and 2025
- **Analysing** real world data on the **energy consumption of BET**
- **Analysing real world activity** pattern to understand the use and the potential of BET in regional freight transport

Key research questions

- Does the **energy consumption comply** with the figures provided by manufactures?
- What **parameters influence** the consumption?
- What are the **orders of magnitude** of the variations?
- How long are **standing and charging times** at the depot?
- Is there **potential for improved charging**?

Background

- This study is based on the **everyday use of Daimler's eActros 300/400**
- **Range** of available BET (2023-2024): **300-400 km**
- **Range of BET** is one of the most **important aspects when purchasing** a BET:
  - depending on battery capacity and energy consumption
- **Energy consumption is influenced by many factors** and was analysed in first studies on real-world applications

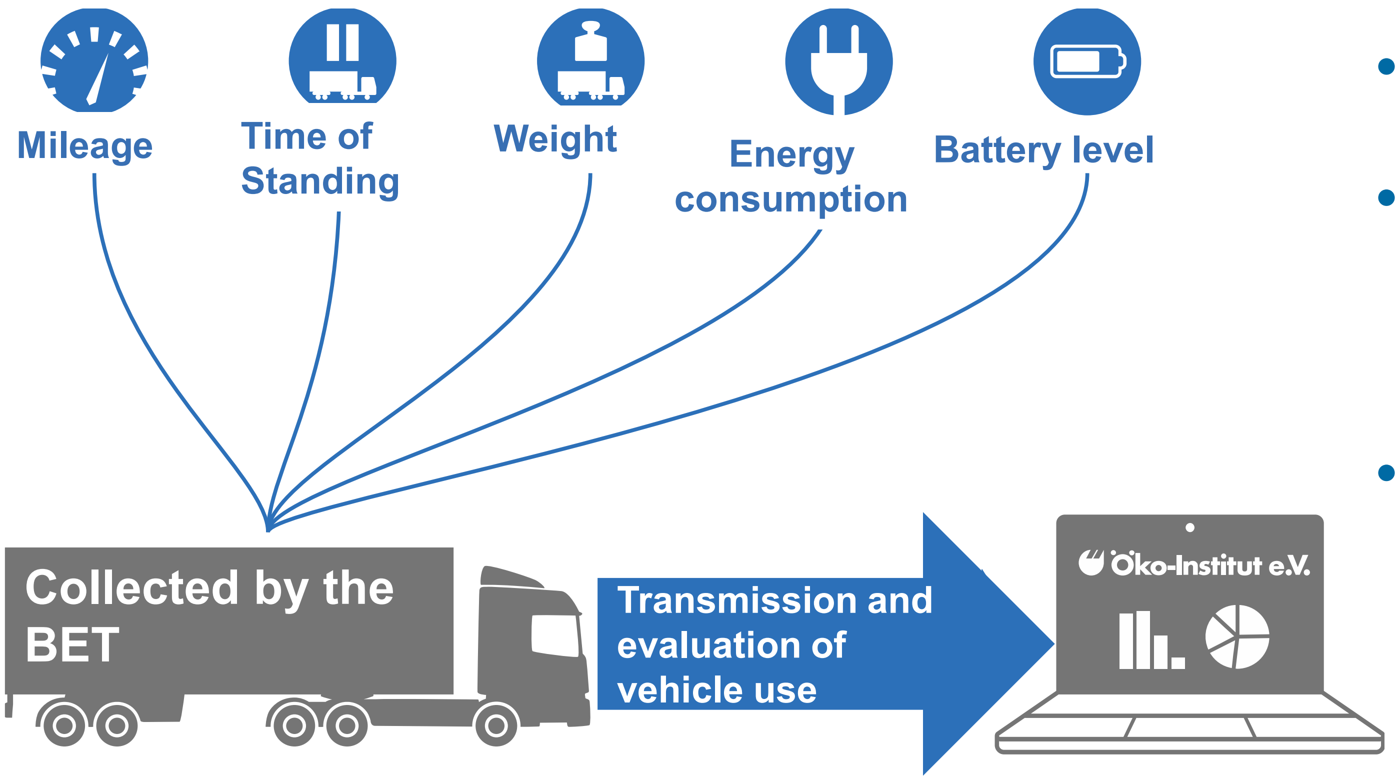
Data and Methodology

BET Characteristics, Operation and Case Study Partners

- Rigid lorries of **N3 category** (maximum mass exceeding 12 tonnes)
- Vehicles with **different axle combinations**: 4x2, 6x2, and lorries carrying a trailer
- **Used for regional delivery transport**

- **5 Case study partners** all over Germany (different company size and use pattern)
- **Companies**: some transport their own goods, **most provide hire or reward transport services** and carry goods on behalf of third parties
- **Operation mainly in flat or slightly hilly areas**, with a single partner operating in a mountainous region

Data Recording and Collection via Fleetboard



+ Exchange with Case Study Partners

- Data of up to 19 BET in the period 09/2023 to 01/2025
- **Activities observed:**
  - Vehicle driving
  - Vehicle standing
  - Vehicle charging
- **Parameters collected:**
  - Weight (t)
  - GPS Coordinates (start and end)
  - Time Stamp (start and end)
  - Distance covered (km)
  - Total Energy Consumption in kWh per Event
  - Battery's State of Charge (start and end)

Data Treatment – Energy Consumption

Recorded and Calculated Parameters:

- Average **Energy consumption** per driving event
- Average **Speed** per driving event
- **Altitude difference** between starting- and end point
- **Ambient Temperature** of starting point location
- Equipment with of **Cooling Unit**

Data-quality & corrections:

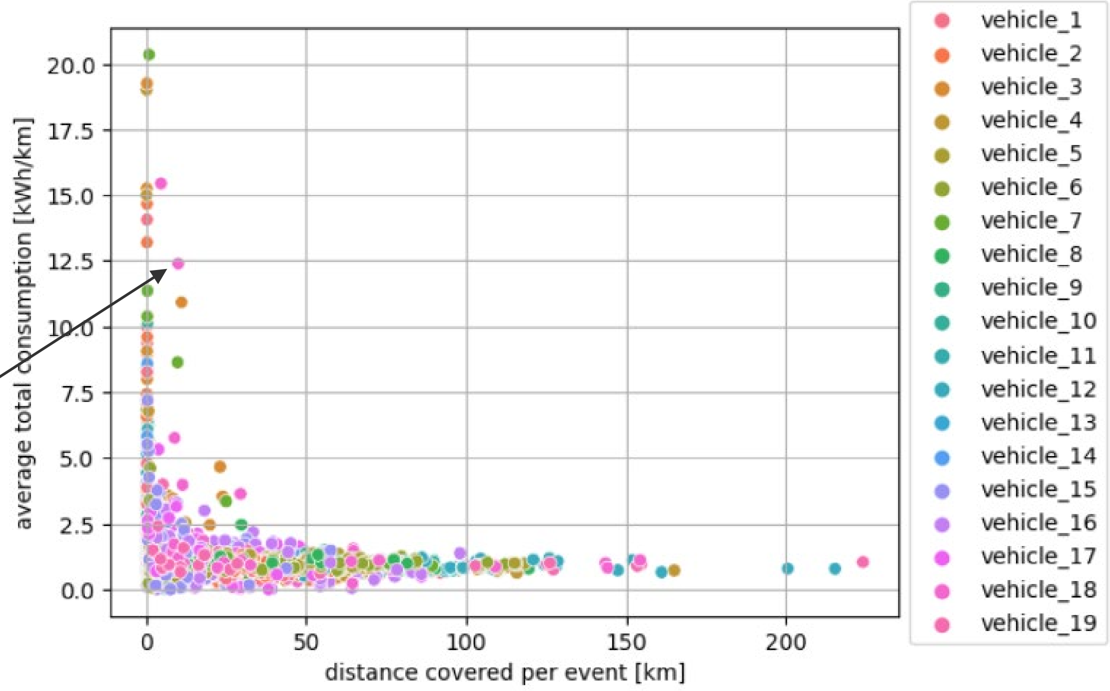
- Limited reliability of primary data (many inplausible entries)
- Exclude data: missing values, outliers (speed > 90 km/h)
- Exchange with:
  - Case study partner – context information of truck operation
  - Fleetboard team – data understanding and error correction

Final Dataset	
Number of vehicles	19
Total number of weeks	16
Number of vehicle weeks (days)	37 (119)
Number of trips	807
Average number of trips per day	6.8

Methodology – Energy Consumption

- **Step 1:** Calculate average consumption
- **Step 2:** Analyse influencing parameters on energy consumption (regression analysis)
- **Step 3:** Check model fit
- **Step 4:** Comparing results with other studies and measurements

Average energy consumption per driving event [km]



Each data point corresponds to one driving event

Source: Öko-Institut (2025) – Real-world data analysis of battery electric trucks operating in Germany (in publication)

Analysed Parameters influencing Energy Consumption

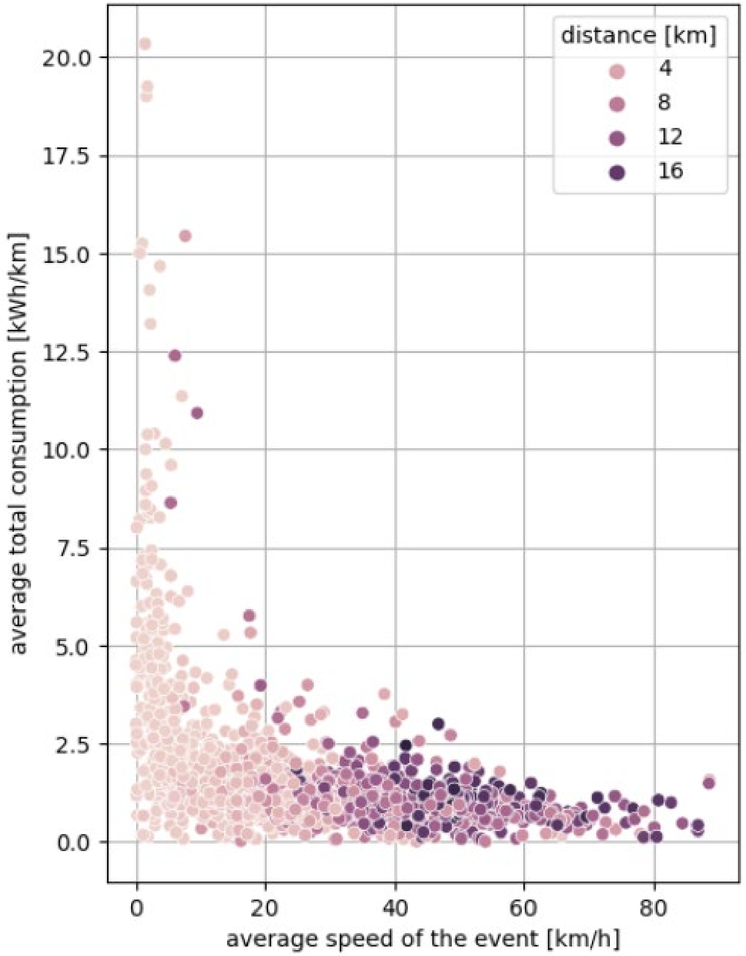
Temperature, Weight, Altitude, Speed

Analysed Parameters influencing Energy Consumption

Temperature, Weight, Altitude, **Speed**:

- Speed has strong impact on energy consumption
- Non-linear relation to driving distance:
  - Low speed → short distance
  - Short distance → high consumption (kWh/km)
- Modelled with exponential function

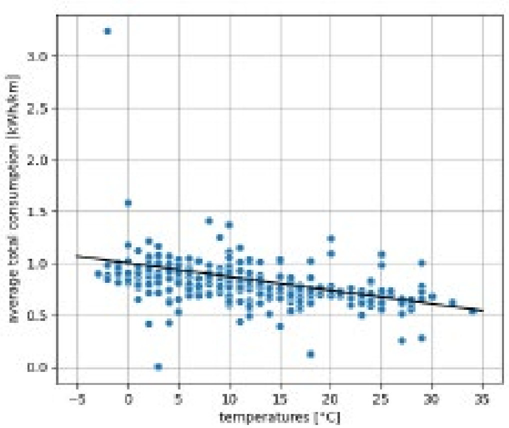
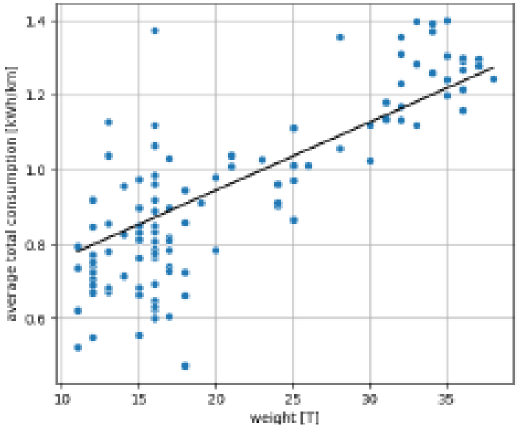
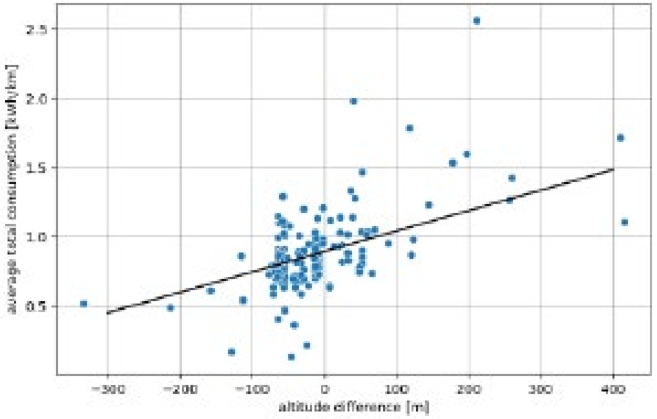
Average energy consumption depending on average speed of driving event [km]



Source: Öko-Institut (2025) – Real-world data analysis of battery electric trucks operating in Germany (in publication)

Analysed Parameters influencing Energy Consumption

Temperature, Weight, Altitude, Speed: $Energy\ Consumption\ (C) = m_1 * \exp(-k_1 * s) + m_2 * t + m_3 * w + m_4 * a + m_5$

Variable name	**Temperature (°C)**	**Weight (t)**	**Altitude difference (m)**	**Average speed (km/h)**
Var	*t*	*w*	*a*	*s*
Range	-7 to 36	11 to 40	-785 to 786	0.02-90
Mean	11.8	20.4	-0.2	44
Standard deviation	8.5	7,5	94.9	17.6
				

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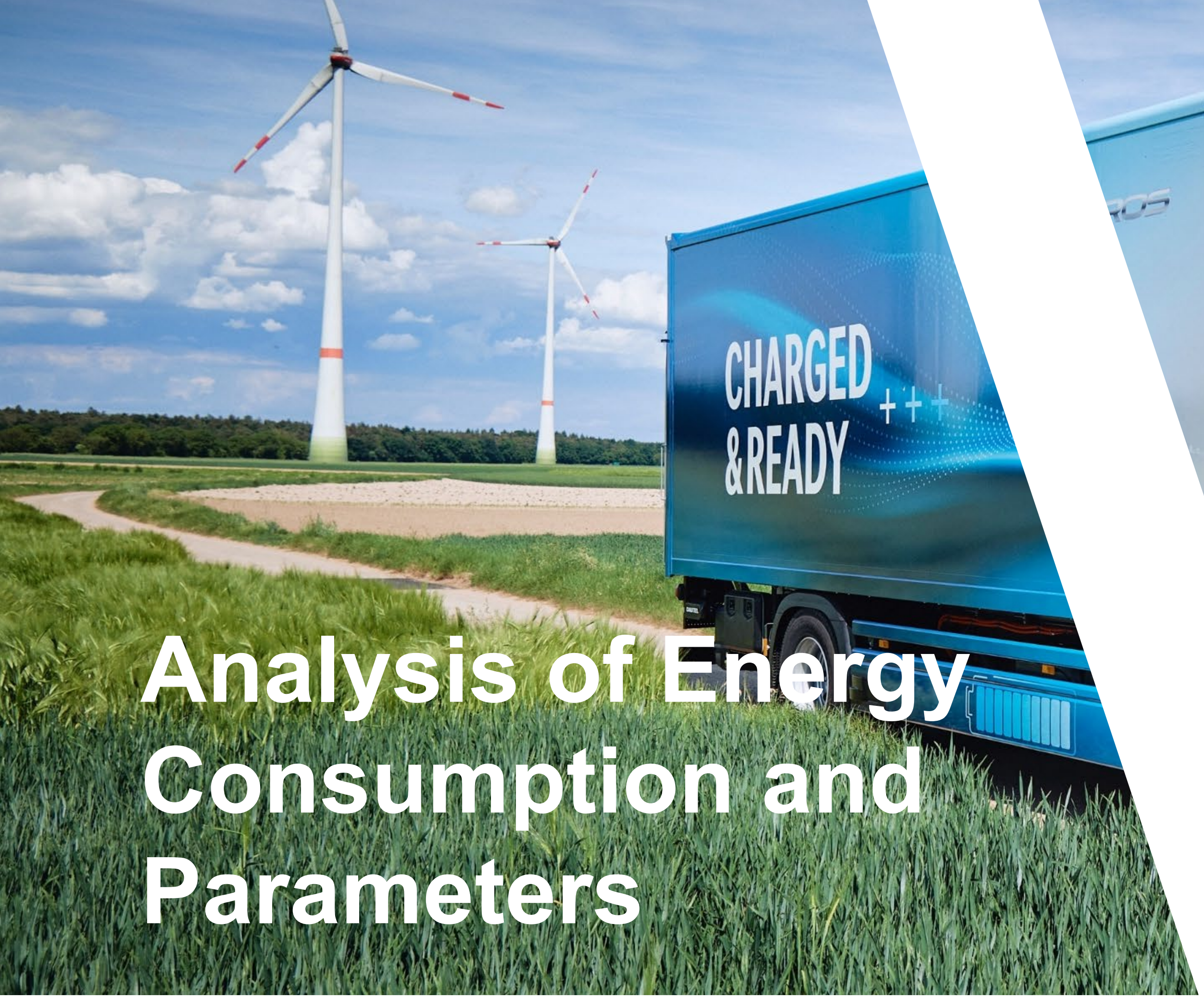

Analysis of Energy Consumption and Parameters

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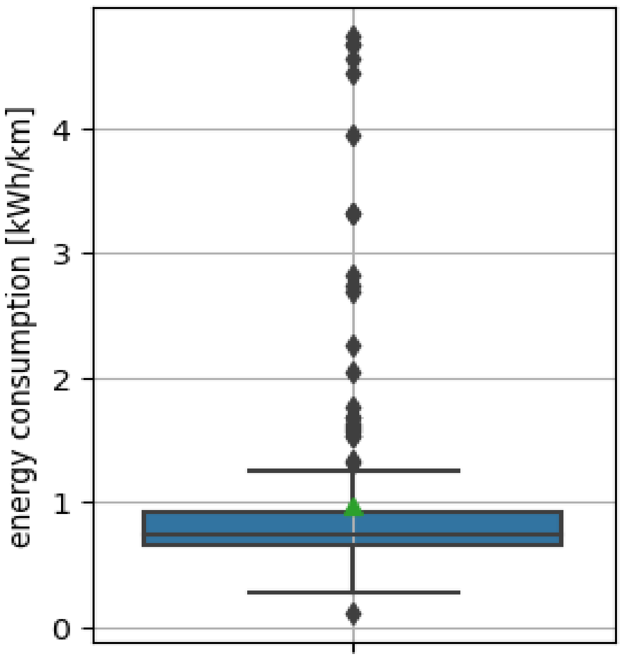
Results:
Real-World Energy Consumption vs. Manufacturer Information



Manufacturer information on energy consumption:

- 4x2 axle configuration
- 20°C outside temperature
- Energy consumption: 0.97 kWh/km

Data Selection (n=211):

- All axle configurations
- Vehicle weight from 11-18 t
- 19-21°C outside temperature
- Maximum altitude difference of 200 m

Average energy consumption:

- **⌀ 0.96 kWh/km**
  - ➢ -1.03 % deviation from manufacturer information

Parameter	kWh/km
Mean energy consumption	0.96
Standard deviation	0.75
First quartile (25 %-percentile)	0.66
Median (50 %-percentile)	0.74
Third quartile (75 %-percentile)	0.92
Sample size	*211*

Source: Öko-Institut (2025) – Real-world data analysis of battery electric trucks operating in Germany (in publication)

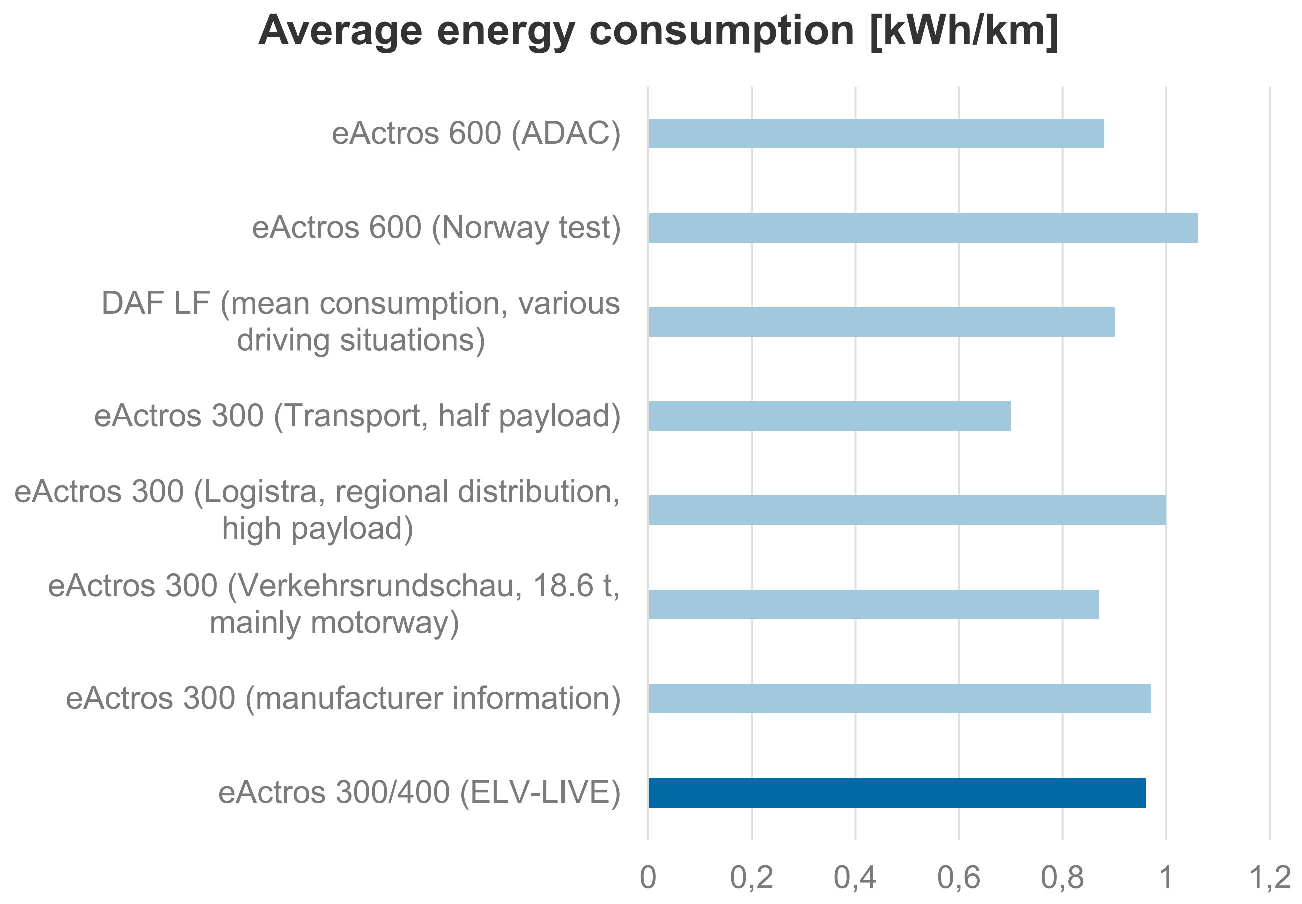
Results:
Parameters influencing Energy Consumption

$$Energy\ Consumption\ (C) = m_1 * \exp(-k_1 * s) + m_2 * t + m_3 * w + m_4 * a + m_5$$

Parameter	Coefficient	Interpretation
Speed $\exp(-k_1 * s)$	5.130	Increasing the speed from **20km/h to 30km/h** reduces consumption by **0.138 kWh/km**
Temperature t	-0.013	Temperature **increase by 10 °C**, reduces consumption by **0.13 kWh/km**
Weight w	0.018	If the truck becomes **10 t heavier**, consumption increases **by 0.18 kWh/km**
Altitude difference a	0.002	If an altitude difference of **100m** is added, consumption increases by **0.15 kWh/km**
Constant k	0.709	

- Influence of all parameters is significant
- R^2 0.47: 47 % of the deviation from the mean of consumption can be explained by the parameters
- Model fit best at 40 km/h and 14.5 t
- BET with cooling units:
  - Independent of outside temperature
  - Additional energy consumption of 0.092 kWh/km

Comparison with other current Analyses of BET's Energy Consumption

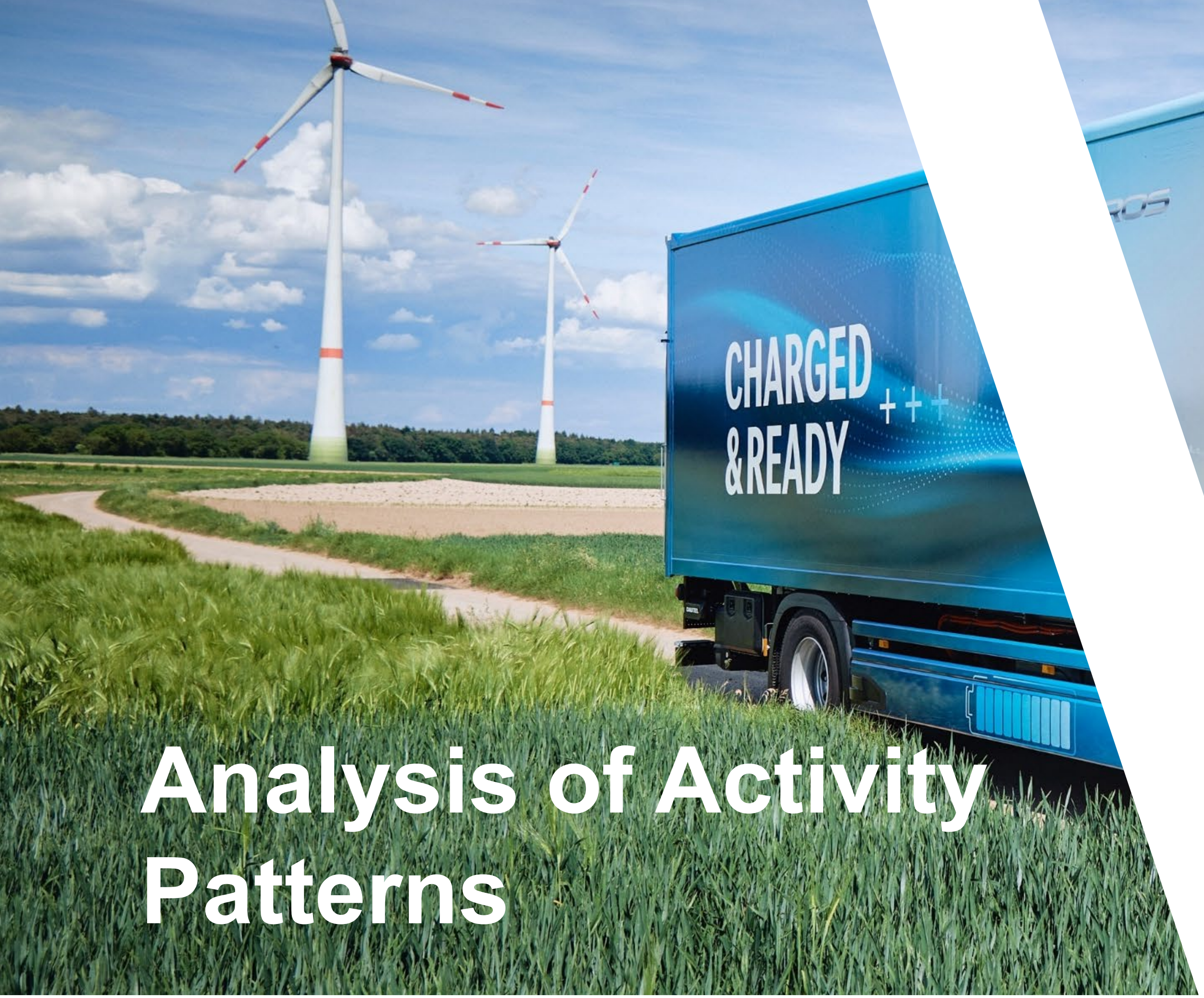


Main findings:

- Studies with different preconditions: weight, speed, slope, temperature
- Energy Consumption in comparable range
- Other eActros300 studies:
  - consumption of 0.87 kWh/km (18,6 t, speed 85 km/h),
  - 1.0 kWh/km (high payload)
  - 0.7 kWh/km (low payload)
  - extreme slope changes consumption by a factor of 1.16-1.5

Source: Öko-Institut – own illustration

Analysis of Activity Patterns



Data Treatment and Methodology – Activity Pattern

- **Goal of Treatment:**
  - Define start and end time of each activity for each day
- **Data Cleaning:**
  - Implausible activity data (e.g. activity overlap, unrealistic speed, missing values)
  - Implausible daily data (e.g. less than 10 hours of data, no/only little driving or charging)
- **Methodology:**
  - Quantitative: Calculated statistics for each activity and overall activities for each truck
  - Qualitative: interpretation of daily activity patterns with additional background information from interviews and on-site visits

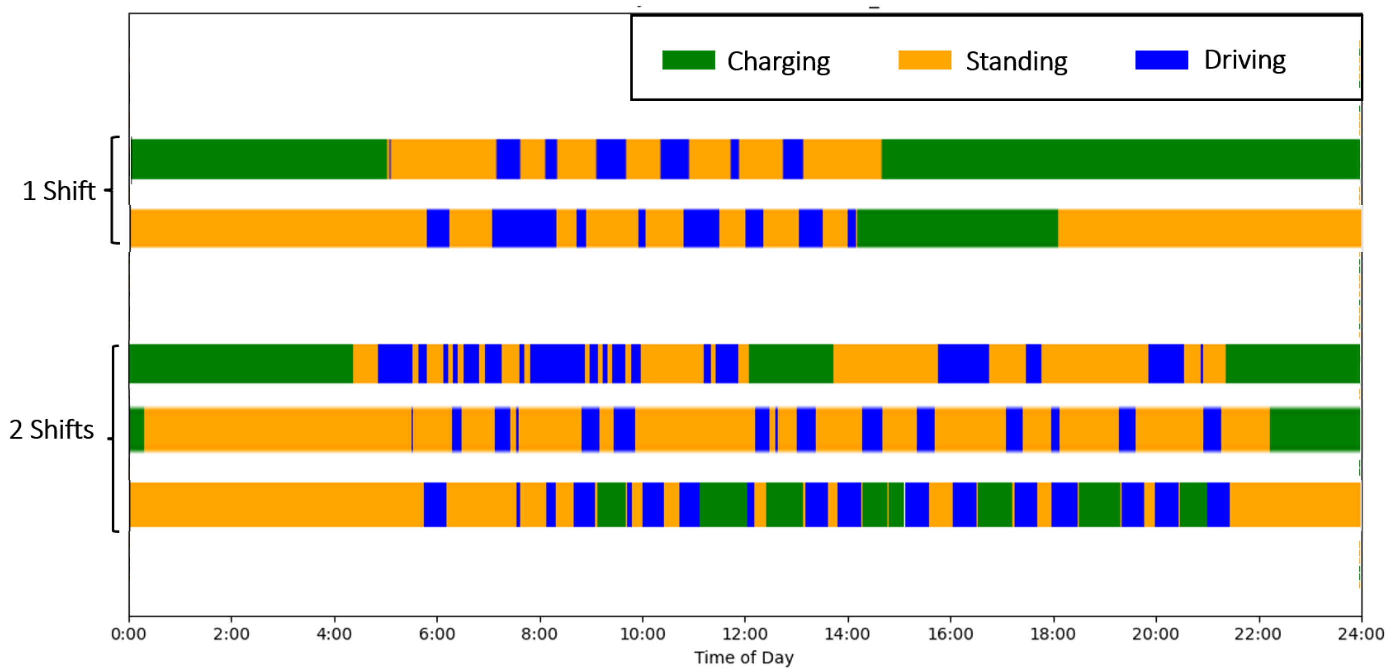
	Energy consumption data	Activity pattern data
Number of vehicles	19	19
Total number of weeks	16	16
Number of vehicle weeks (days)	37 (119)	166 (688)
Number of trips	807	-
Average number of trips per day	6.8	-

Results: Activity Pattern of BET (Usage Cases)

- Vehicle **operation mostly on weekdays**
- All **vehicles return to depot** at the end of the day
- **Average daily mileage of 220 kilometres**
  - Single-shift operation: 160 km
  - Two-shift operation: 280 km
  - The range of average daily mileage for the 19 vehicles ranges from 115 to 350 km
- **Charging infrastructure:**
  - All vehicles have **access to depot charging**, but varies regarding location and power
  - **Public charging is the exception**
  - The vehicles often follow a **fixed "charging schedule"**

Results: Activity Pattern of BET in Regional Transport

Vehicle usage by activity in 1- and 2-shift operation



Observations:

- **Many stops** a day, shift starts around 5 a.m.
- **Battery charging:**
  - **Single-shift operation:**
    - Usually **once a day**, after the **end of the shift**
    - Average of **1.4 charges per day**
  - **Two-shift operation:**
    - Often **several times**, even **during the day**
    - In some cases only during the day
    - Average of **4.1 charges per day**

Source: Öko-Institut (2025) – Real-world data analysis of battery electric trucks operating in Germany (in publication)

Results: Activity Patterns – Potential

- **Application** of vehicles currently **based on the electric range of BET**
- **Single-shift operation**: BET **downtime of 14-18 hours** and charge only about a third of the time
- **Two-shift operation**: BET stand for **7-8 hours**
- **Potential for grid-optimized charging**
- BUT: potential for **optimized charging in two-shift operation is already more limited** and is often further reduced by operational restrictions related to available charging infrastructure
- **Outlook:** Further fleet electrification and expansion to **long-distance use of BET**

  → **Optimisation approaches and existing depot charging infrastructure not sufficient to cover demand**

Conclusion

Conclusion

- **Average energy consumption of 0.96 kWh/km** determined for 19 BET in regional operation confirms available data on real-world consumption
- **Strong influence of outside temperature and vehicle weight** could be determined
- **Influence of topography and cooling unit** could also be shown. Additional data is necessary for a robust assessment
- Activity patterns show **clear differences in BET use** and charging patterns **between single-shift and multi-shift operation**
- **Potential for optimising vehicle charging**, but **insufficient in the context of further fleet electrification**

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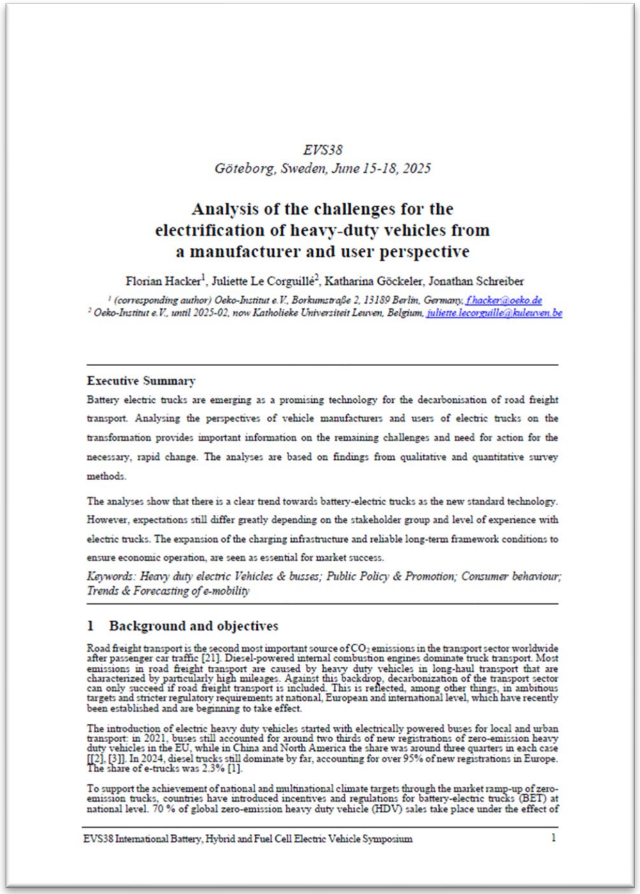

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Analysis of the challenges for the electrification of heavy-duty vehicles from a manufacturer and user perspective

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Executive Summary

Battery electric trucks are emerging as a promising technology for the decarbonisation of road freight transport. Analysing the perspectives of vehicle manufacturers and users of electric trucks on the transformation provides important information on the remaining challenges and need for action for the necessary, rapid change. The analyses are based on findings from qualitative and quantitative survey methods.

The analyses show that there is a clear trend towards battery-electric trucks as the new standard technology. However, expectations still differ greatly depending on the stakeholder group and level of experience with electric trucks. The expansion of the charging infrastructure and reliable long-term framework conditions to ensure economic operation, are seen as essential for market success.

Keywords: Heavy duty electric Vehicles & busses; Public Policy & Promotion; Consumer behaviour; Trends & Forecasting of e-mobility

1 Background and objectives

Road freight transport is the second most important source of CO_2 emissions in the transport sector worldwide after passenger car traffic [21]. Diesel-powered internal combustion engines dominate truck transport. Most emissions in road freight transport are caused by heavy duty vehicles in long-haul transport that are characterized by particularly high mileages. Against this backdrop, decarbonization of the transport sector can only succeed if road freight transport is included. This is reflected, among other things, in ambitious targets and stricter regulatory requirements at national, European and international level, which have recently been established and are beginning to take effect.

The introduction of electric heavy duty vehicles started with electrically powered buses for local and urban transport: in 2021, buses still accounted for around two thirds of new registrations of zero-emission heavy duty vehicles in the EU, while in China and North America the share was around three quarters in each case [[2], [3]]. In 2024, diesel trucks still dominate by far, accounting for over 95% of new registrations in Europe. The share of e-trucks was 2.3% [1].

To support the achievement of national and multinational climate targets through the market ramp-up of zero-emission trucks, countries have introduced incentives and regulations for battery-electric trucks (BET) at national level. 70 % of global zero-emission heavy duty vehicle (HDV) sales take place under the effect of

EVS38 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium 1

Juliette Le Corguillé, Florian Hacker, Theresa Dolinga (2025):
Real-world data analysis of battery electric trucks operating in Germany.