Dresden University of Technology
"Friedrich List" Faculty of Transport and Traffic Sciences

ERS with Overhead Contact Lines – infrastructure needs, costs and synergies with BEV

Speaker/Author:
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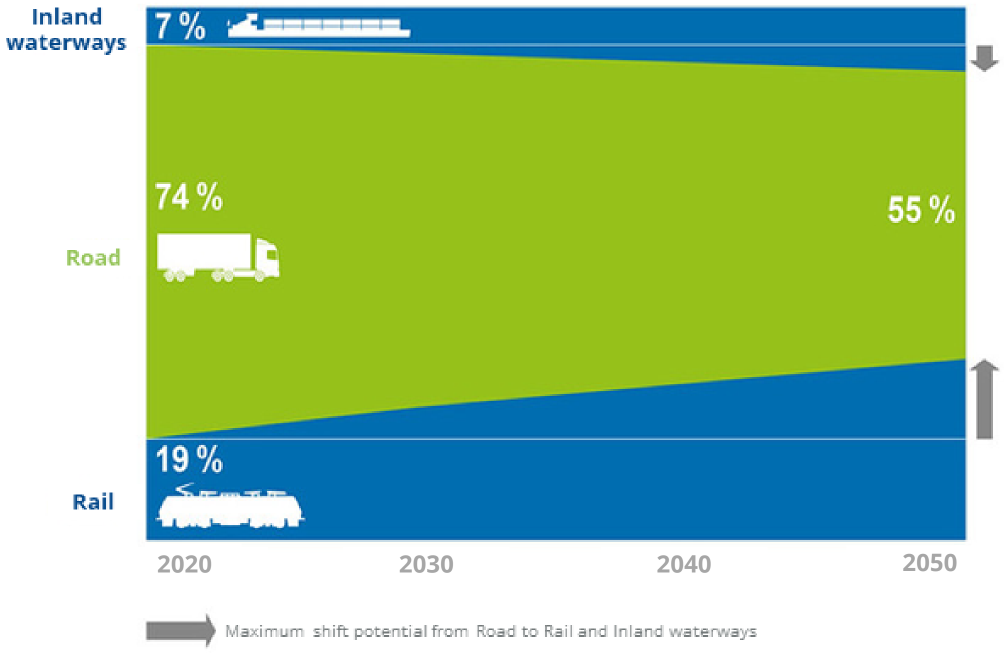
BEE final event in Aachen // Tuesday, 9th December 2025

Motivation
Why electrification of roads?

- Road freight transport causes 1/3 of the emissions in the transport sector in Germany
- 60 % of these are caused by heavy duty vehicles (HDV)
- Heavy road freight transport will account for large share of total freight transport performance in future, even with the greatest possible shift to rail

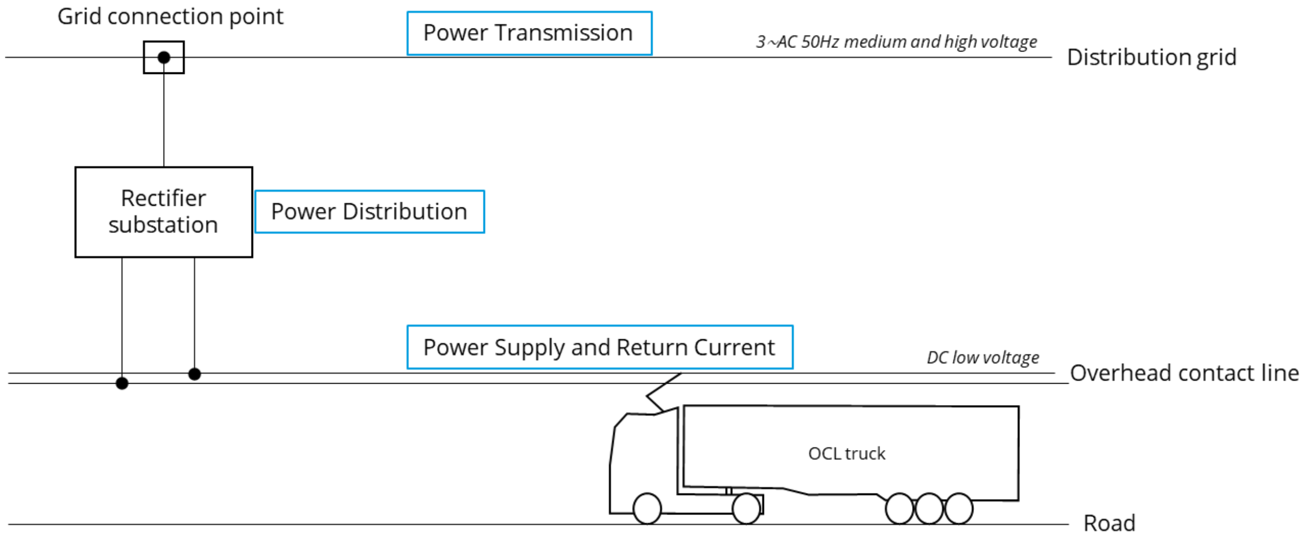


Shares of the transport modes in freight transport performance, Germany. Source: [1]

One solution for the decarbonisation of road freight transport can be:
Electric Road Systems with Overhead Contact Lines

Source: FuE Zentrum FH Kiel GmbH

Electric Road Systems with Overhead Contact Lines
System design

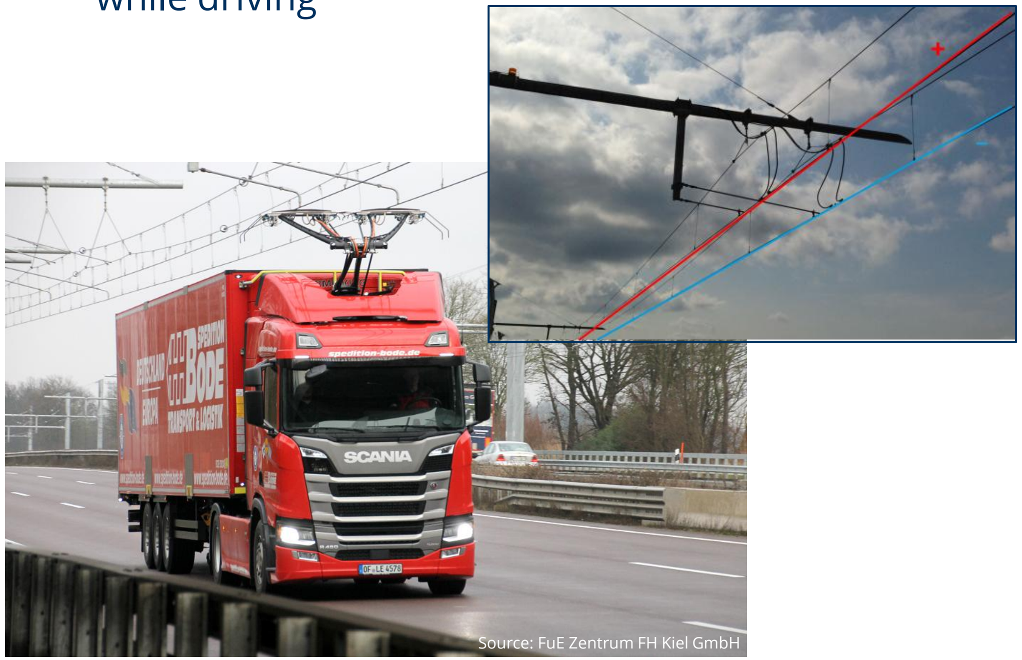


Contact line system und traction power supply system

- Bipolar DC overhead contact line, up to 100 km/h
- Nominal voltage in field tests: DC 670 V (future: DC 1.500 V)
- Substations with passive diode rectifiers (standard)

Vehicles

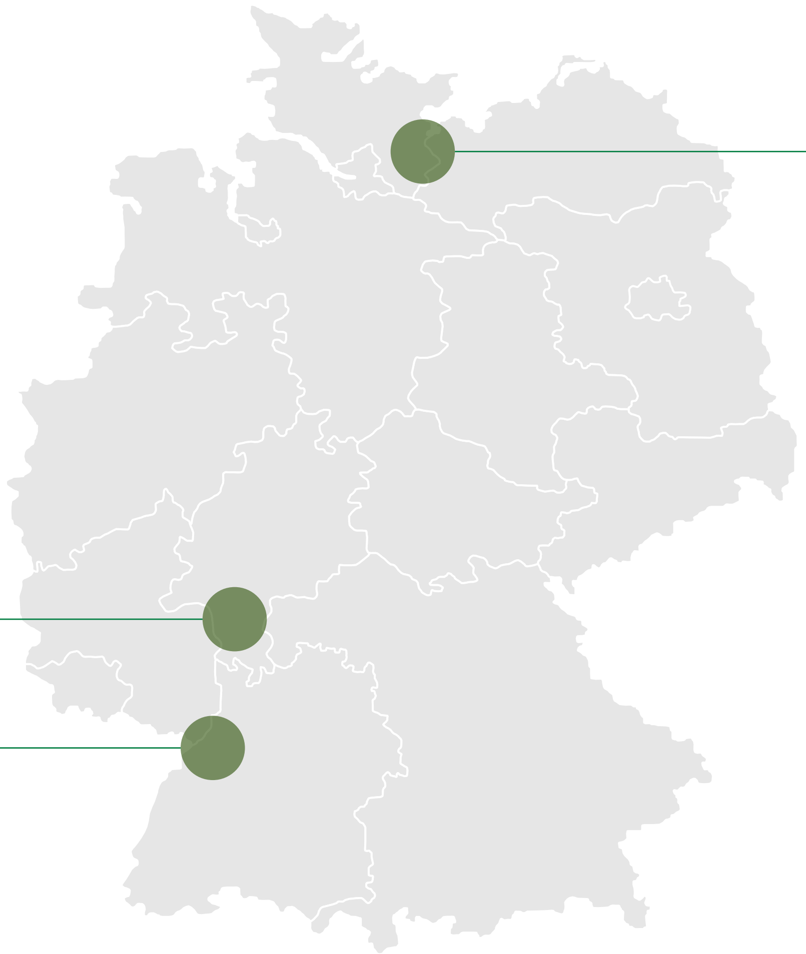
- Overhead contact line trucks with pantographs
- Fully electric battery trucks or hybrid trucks
- Semi-automated connection and disconnection while driving



Source: FuE Zentrum FH Kiel GmbH

Field tests in Germany

Testing the practicality in real operation over several years



➢ **Hesse**

- Project: ELISA
- Motorway A5
  Langen/Mörfelden – Weiterstadt
- Contact line section: 2 x 5 km,
  with extension 1 x 7 km
- Operation from 05/2019
  to 12/2024

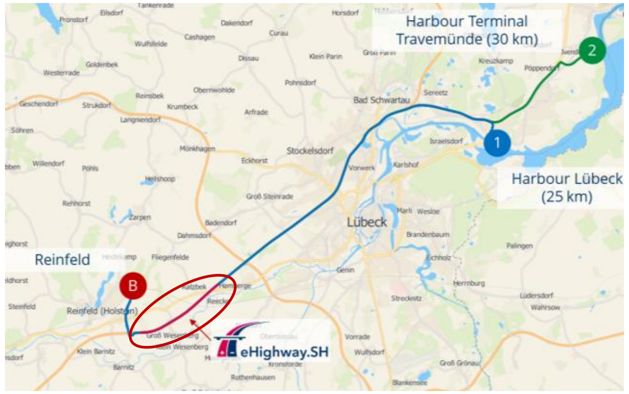
➢ **Baden-Württemberg**

- Project: eWayBW
- Federal road B 462
  Kuppenheim – Gaggenau
- Contact line section: 2 x 4 km
- Operation from 09/2021 to 12/2024

Backround map: ©Slidesgo, 2021.

➢ **Schleswig-Holstein**

- Project: FeSH
- Motorway A1
  Reinfeld – Lübeck
- Contact line section: 2 x 5 km
- Operation from 12/2019
  to 12/2024



Source: FuE Zentrum FH Kiel GmbH, OSM; Editing: M. Werner

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Research project
Main objective


Possible core network for ERS in Germany (4000 km), source: [1]

Status quo and findings from the field trial FeSH

- Electric Road Systems (ERS) with Overhead Contact Lines (OCL) work reliably under real conditions
- High technical maturity and proven logistical and ecological potential in heavy road freight transport, especially in synergy with stationary charging

Important for roll-out scenarios

- Electrical infrastructure must reliably meet high power requirements of heavy duty trucks
- Initial investment in a core network

Main objective

- Determine the traffic-dependent infrastructure needs and associated costs for ERS with OCL taking into account technical feasibility

Road Traffic ⟷ Required Infrastructure ⟷ Infrastructure Costs

Research project
Methodological core

Note on use: Current publications in preparation. When citing, please name the speaker.

Develop techno-physical simulation model for ERS with OCL

Validate against real-world data from field test FeSH

Run comprehensive simulations to create an infrastructure catalogue with specific performance capabilities → Traffic-dependent infrastructure needs

Link traffic-dependent infrastructure needs with cost calculation tool → Traffic-dependent infrastructure costs

Building up the simulation model
Simulation principle

Note on use: Current publications in preparation. When citing, please name the speaker.

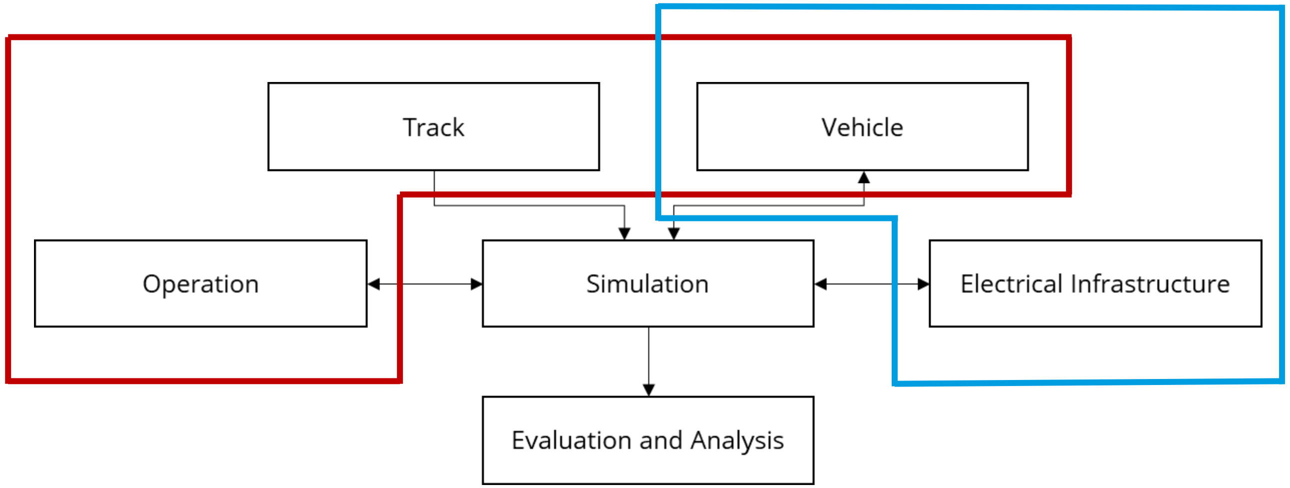
- Modelling the **operation** of Electric Road Systems with electric power supply as an **electrical transport system** with all subsystems and their interactions
- Principle: Operation simulation with combined electrical network calculation with **OpenTrack** and **OpenPowerNet** ("co-simulation")
- **Results**: Detailed information about key **electrical** and **operational parameters** and dimensioning of electrical infrastructure components

OPENTRACK

Source: [2]

OpenPowerNet

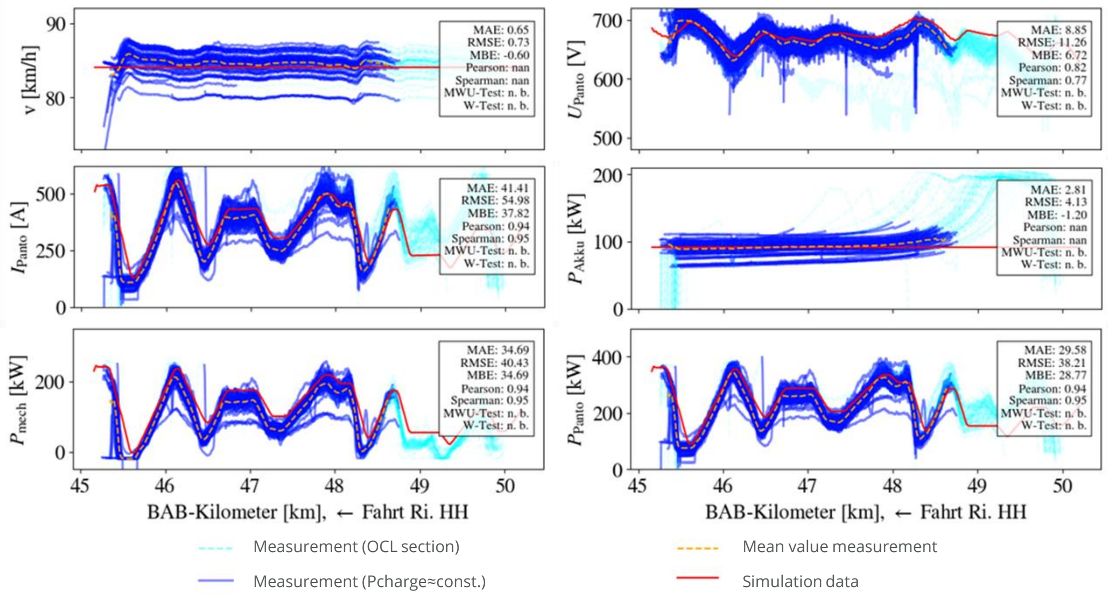
Source: [3]



Validation against real measurement data

Principle and result

- **Simulation** scenarios with **realistic boundary conditions** for replicating the test operation in the **field test FeSH**
- **Comparison** of **simulation results** with processed **measurement data** from >10.000 OCL-truck trips:
  - OCL truck data (current, voltage, power, energy demand, charging behaviour of batteries, etc.)
  - Environment data
  - Infrastructure data
- **Evaluation** using methods of descriptive and inferential statistics with developed python tool



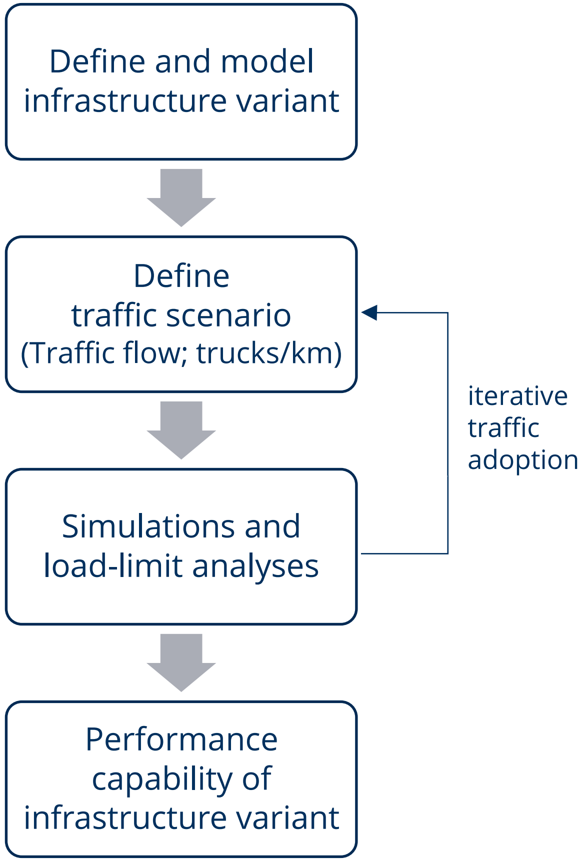
Example of validation; TU Dresden 2024.

- ➢ **Validation** demonstrated a **high agreement** between **measurement data** and **simulation results**
- ➢ Ensures reliability of simulation results and predictions

Traffic-dependent infrastructure catalogue

How much infrastructure is needed?

- Development of a **traffic-dependent infrastructure catalogue** trough comprehensive simulations
- **Catalogue** contains >110 infrastructure variants **with** their specific **performance capabilities** (in kW/km)
- **Infrastructure variants** with different ERS parameters like:
  - Substation spacing
  - System voltage
  - OCL configuration
- **Load-limit analyses** to determine the performance capabilities of the infrastructure variants taking into account **normative requirements** for electrical infrastructure (“design criteria”):
  - Voltage stability
  - Current-carrying capacity (thermal dimensioning)
  - Protection criteria
  - Electromagnetic compatibility (EMC)

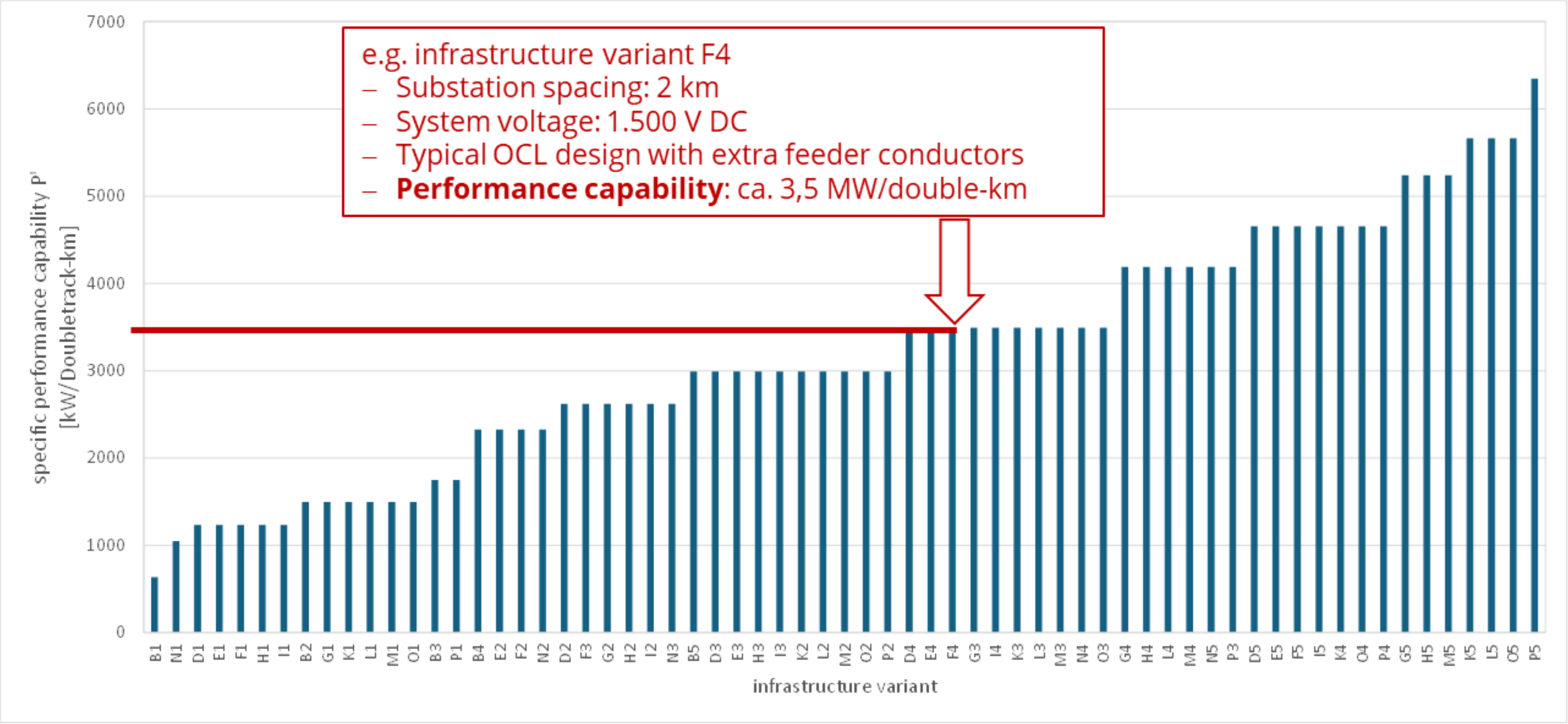


Performance capability of OCL infrastructure

Note on use:
Current publications in preparation. When citing, please name the speaker.

How much and which infrastructure is needed to reliably supply a certain amount of trucks/traffic (per km or time)?

Performance capability in kW/double-km (implicit: possible traffic)

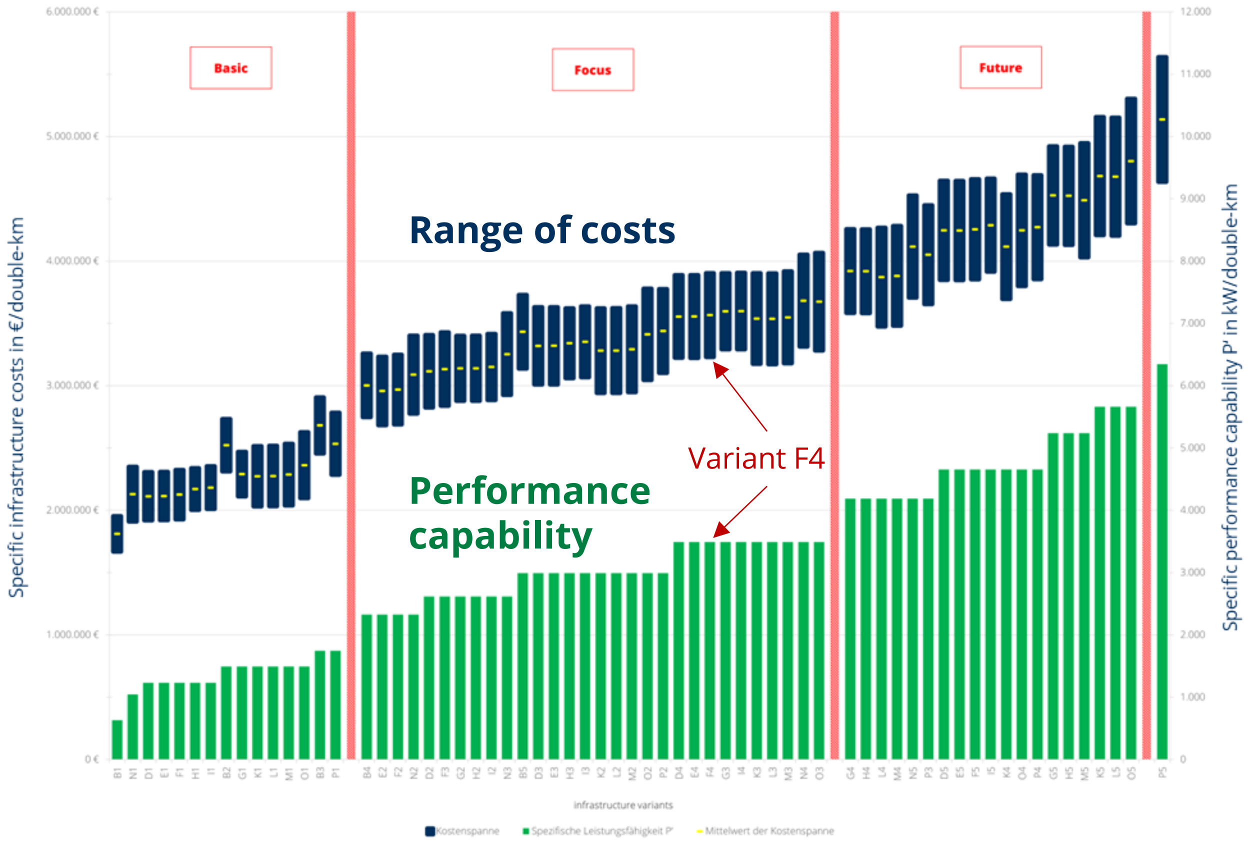


Exemplary results; TU Dresden

Infrastructure variant

Required infrastructure and associated costs

- **Linking the infrastructure catalogue with cost calculation tool for infrastructure costs**
- Relevant here: Costs for planning and construction, using cost ranges for more realistic estimation
- Granular cost data for electrical infrastructure components (OCL, substations, grid connections, etc.)
- **Result:** Infrastructure variants, their performance capability and range for specific infrastructure costs
- Enabling:
  - Forecasts of traffic-dependent infrastructure costs
  - Identification of cost-optimised infrastructure designs



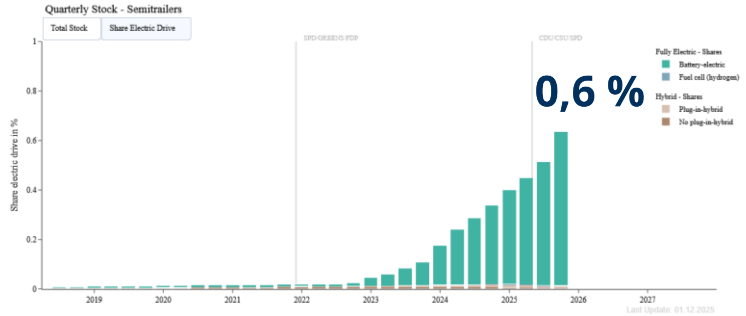
Infrastructure variants, performance capability and range for infrastructure cost

Exemplary results; costs in $€_{2024}$; TU Dresden 2024.

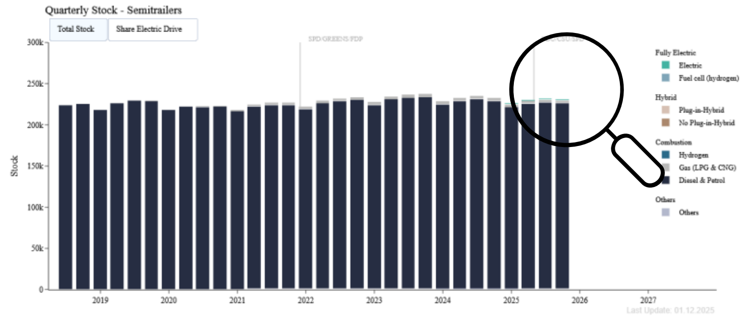
What does the HDV market say? Where are we now?
BEV with stationary charging as the favoured way to go

- Policy and industry focus on battery-electric trucks (**BEV**) **with stationary charging → key role** expected, also in HDT
- In heavy-duty transport, this means combined depot charging and public fast charging
- **Market shows**: Increasing numbers of BEV registrations and available BEV models, but we are at the very beginning
- Political framework, funding programmes for charging infrastructure and instruments for the ramp-up
- Truck OEMs with private initiatives to build charging infrastructure

➢ But: There are **challenges** and risks **in the ramp-up** of this technology, **especially** in **heavy-duty transport**



Share of battery-electric HDVs; 12/2025



Total stock of HDVs; 12/2025

Source: https://openenergytracker.org/en/docs/germany/emobility/#trucks

Battery-electric trucks in heavy-duty transport
Possible challenges and risks in the ramp-up

Space requirements for public charging infrastructure

- Need for much more and larger charging areas along motorways
- Planning, approval and leasing procedures are lengthy + complex
- Identifying and activating suitable areas requires time, political framework and support for local authorities

"**InKo**" model (developed in enERSyn) enables forecasts about stationary charging demand and public charging infrastructure needs.

Grid connections

- Grid expansion is essential for the electrification of HDVs
- Limited available grid capacity along motorways
- Lengthy, non-standardised grid connection procedures (implementation time up to 10 years and more)

Charging infrastructure availability

- Deployment of a nationwide, demand-oriented public fast-charging network (incl. MCS) and large-scale depot electrification on time
- Parallel expansion in other EU countries for intern. traffic

Big and expensive batteries

- Truck investment costs, increased demand of critical resources, further effects for payload and vehicle weight

Operational and logistical requirements

- Challenging charging organisation with synchronised driving and charging breaks, avoiding add. standing times

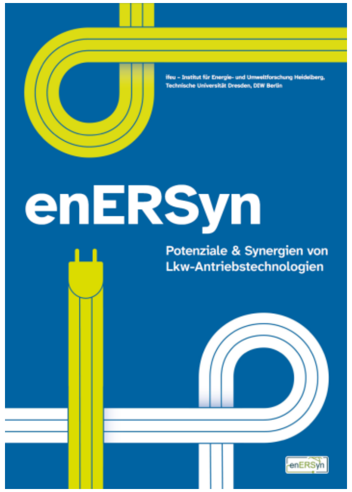
Spotlight: Grid connections for charging infrastructure
One of the key challenges for market ramp-up of BEV

Read more in current and upcoming publications.

- The current situation is as follows:
  - **Grid expansion is essential for** the **electrification** of HDVs
  - **Battery-electric HDV** are still **barely included** in long-term plans of grid operators
  - Due to transformation processes in other sectors, grid operators face **numerous,** partly non-binding **grid connection requests**
  - **Low transparency** on available **grid capacity** makes site selection difficult for CPOs
  - **Expansion** of the charging infrastructure is currently **slowed down** by **lengthy** and inconsistent **grid connection procedures**
  - Tenders for the public fast-charging network for trucks are important, but based on **demand forecast for 2035**

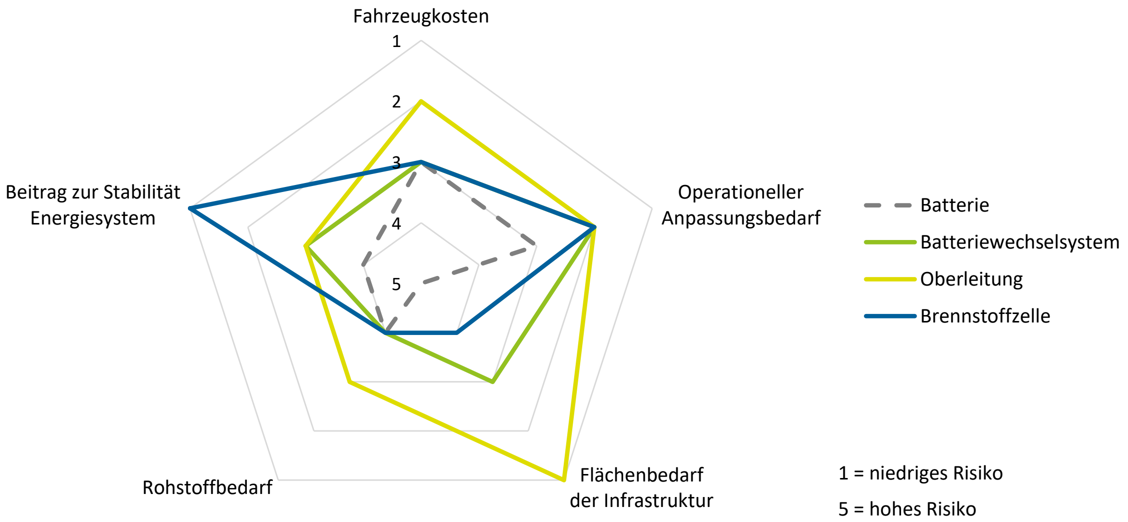
➢ **Recommendations for an effective and sustainable grid expansion:**

1. Thinking about grid expansion 'from the end'.
2. Accelerating grid connection processes through standardisation and transparency.
3. Battery storages to ease the grid connection situation – a differentiated picture.



Electric Road Systems with Overhead Contact Lines
Where could dynamic charging help?

– **Dynamic charging addresses key challenges** of a BEV-only scenario with stationary fast charging and can be economically successful:
  - Low space requirements, space integration essentially solved
  - Operational advantages: Charging while driving
  - Smaller battery sizes: Lower truck investment costs, reduced demand for critical resources, improved weight and payload
  - Reduced need for public fast charging infrastructure
  - Grid connection remains a key challenge, ERS could bring slight advantages



Source: enERSyn results brochure, 12/2025

➢ **But**: Deployment of a core network requires long lead times, high initial investments and clear political decisions. → **A large-scale rollout of ERS is currently not planned or expectable.**

Electric Road Systems with Overhead Contact Lines
What are perspectives?

- **ERS could be further qualified**, e.g. by equipping a suitable high-performance corridor with point-to-point connections
- **If stationary fast-charging** deployment and BEV **falls behind expectations**, ERS should be reconsidered
- **Other factors** support ERS application, such as implementation in other countries, regulatory requirements (like AFIR), EU-wide cooperation and coordination

The BEV retrofit solution developed in the BEE project could help to increase user potential in ramp-up phase.

Source: SMO, H. Grünjes, DCRPS2024

?

Summary and ongoing research

- **Validated simulation model** for Electric Road Systems with Overhead Contact Lines
- **Detailed forecasts** of key electrical and operational parameters for any scenario in larger networks
- New methodology to determine the **traffic-dependent infrastructure needs and costs of ERS** taking into account technical feasibility
- Methodological approach can be transferred to other technologies

➡ Findings and results form a robust basis for:

  - Techno-economic analyses in roll-out scenarios
  - Technical analyses of system design and dimensioning
  - Combined TCO and LCC analyses for electrification worthiness (“break-even”)

Contact

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LinkedIn profile

Find out more on recent and current research projects:

FESH – eHighway field trial on the A1 motorway in Schleswig-Holstein (Germany)
Link: https://ehighway-sh.de/en/

enERSyn – Electric Road Systems as part of truck electrification
Link: https://www.ifeu.de/projekt/enersyn-dynamisches-laden-im-kontext-der-lkw-antriebswende/

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ELEKTRISCHE BAHNEN

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Planning and operation of electric transportation systems

- Power Generation and Transmission
- Power Distribution and Supply
- Electric Vehicles and Drives
- Return Current and Interaction
- Vehicle and Facility Operation


Source: IFB GmbH


Source: TU Dresden


Source: Markus Werner

Sources

[1] Hacker, F./ Bernecker, T./ Röckle, F./ Schubert, M. et al. (StratON), 2020. *Evaluation and Implementation Strategies for Overhead Catenary Heavy Duty Vehicles.* Editing: Markus Werner.

[2] Hürlimann, D. 2017. OpenTrack Manual – Betriebssimulation von Eisenbahnnetzen. Version 1.9. OpenTrack Railway Technology GmbH und ETH Zürich – Institute for Transport Planning and Systems. 2017.

[3] Institut für Bahntechnik GmbH, Branch Office Dresden. 2018. OpenPowerNet: User Manual. Version 1.8.0

Illustrations without separate labelling were produced by the author himself / TU Dresden.