Getting zero emission trucks on the road
From regional to long-haul

Comparing the costs and benefits of different technologies: A case study for Germany

Moritz Mottschall
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Our Profile

Oeko-Institut is a leading European research and consultancy institute working for a sustainable future.

- A non-profit association founded in 1977
- Offices in Freiburg, Darmstadt and Berlin
- Clients: European Union, national and state-level ministries, companies, foundations and non-governmental organizations
Decarbonisation of road freight transport: Long-haul transport of particular importance

- Light & heavy-duty vehicles responsible for about 35 % of EU transport GHG emissions
- Long-distance trucks particularly relevant in terms of GHG emissions due to high annual mileage and high fuel consumption

**Vehicle stock, total mileage and CO₂ emissions of commercial vehicles***

![Graph showing vehicle stock, total mileage, and CO₂ emissions by GVW category]

The challenge of zero emissions freight transport has a number of dimensions

- **GHG emissions** from road freight transport continue to rise in the EU
- In **regional freight transport** the **battery electric** drive is emerging as a possible solution
- In long-haul transport there is **no clear favourite** powertrain alternative to the diesel engine yet
- Long-distance transport requires **cross-border solutions**
- New propulsion technologies must enable **zero-emission** road freight transport in the **long term** – at the lowest possible economic cost
What are the propulsion and fuel options for zero emission long-haul transport?

**Direct use of electricity**

- **Battery-electric (BEV):** electric drive; large battery in combination with ultra fast charger

- **Overhead catenary electric (OC):** electric drive; electricity uptake from overhead catenary line, second drive / energy supply via hybrid powertrain (HEV) or smaller battery (BEV)

**Indirect use of electricity**

- **Fuel cell electric (FCEV):** electric drive; electricity is generated in an on-board fuel cell based on hydrogen

- **Internal combustion engine (ICEV):** conventional propulsion with hydrocarbon synthetic fuel (so-called efuel)
Excursus: LNG as an option to reduce GHG emissions?

- LNG has a better CH ratio than diesel and therefore leads to lower direct CO₂ emissions (SI -5% to HPDI -20%),
- Is massively promoted in Germany (vehicle acquisition, energy tax relief, toll exemption),
- Offers the possibility to use Bio-LNG and PtG-LNG in the long term.

But

- LNG leads to high upstream GHG-emissions (e.g. production, liquefaction, transportation).
- The use of fossil LNG leads to no or only a small reduction in WtW emissions and, depending on the source of the LNG, can also lead to higher emissions.
- The potential for Bio-LNG and especially PtG-LNG by 2030 is very low in relation to total natural gas consumption.
Electric propulsion systems in long-haul transport offer near-term cost advantages

- Lower operating costs compensate for higher vehicle costs
- **BUT:** uncertainties remain regarding the development of technology costs, energy prices and regulatory / fiscal framework

**Case study: TCO of long-haul truck in Germany**

Assumptions of TCO: operation of a long-haul truck in Germany, user costs excl. VAT, 3.5% discount rate, 5 years of vehicle operation, annual mileage of 120,000 km

FCEV – fuel cell electric vehicle, OC – overhead catenary, HEV – hybrid electric vehicle, BEV 100 – battery electric vehicle 100 km electric range

The roll-out of alternative energy supply infrastructure needs to be pre-financed

Assumptions of TCO: operation of a long-haul truck in Germany, user costs excl. VAT, 3.5% discount rate, 5 years of vehicle operation, annual mileage of 120,000 km

*Energy supply infrastructure: hydrogen filling station, overhead line system or station-based charging infrastructure
The roll-out of alternative energy supply infrastructure needs to be pre-financed

- Availability of energy supply infrastructure is key to market ramp-up of alternative drives
- If early users fully carry infrastructure cost, this will hinder economic operation

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Direct use of electricity is by far the most energy efficient option for climate-neutral long-haul HDV operation.
Decarbonisation of the freight transport sector by 2050: Demand of renewable energy depends on propulsion system

- Decarbonisation of long-haul freight transport requires high amount of renewable energy
- Highest energy efficiency for direct use of electricity results in lowest additional demand
- Use of synthetic fuels (PtL, H₂) requires energy imports
- Use of synthetic fuels must be combined with sustainability criteria at an early stage

Case study: Decarbonisation of German long-haul freight transport

Net electricity generation from renewable energies in Germany 2017: 210 TWh

Scenario assumptions:
- All scenarios: complete decarbonisation of long-haul freight transport
- ICEV – PtL: Diesel replaced by imported synthetic fuel based on renewable energy → WTT efficiency: 49%
- FCEV: imported hydrogen (electrolysis, liquefaction and transport) → WTT efficiency: 48%
- EV (catenary): OC-vehicles with 75% electric mode and 25% conventional mode (PtL); WTT efficiency of electricity: 85%
Overall costs of carbon neutral road freight transport until 2050: energy costs of particular importance

Case study:
Decarbonisation of German long-haul freight transport

Accumulated costs (2020 – 2050) in billion €
(compared to fossil fuels)

Overall costs of carbon neutral road freight transport until 2050: energy costs of particular importance

Case study:
Decarbonisation of German long-haul freight transport

Sensitivity:
Low investment costs for H₂ infrastructure

Overall costs of carbon neutral road freight transport until 2050: energy costs of particular importance

Case study: Decarbonisation of German long-haul freight transport

Sensitivity:
High investment costs for overhead catenary network

- Decarbonisation of freight transport is related to considerable economic costs
- Total costs are determined by the energy costs
- Costs of infrastructure and vehicles are less important from this perspective
- Direct use of electricity shows robust economic cost advantages

Example of overhead catenary core network (4.000 km) in Germany: relatively low investment required

- All alternative propulsion systems require a reliable energy supply infrastructure
- In road freight transport, a relatively low network density along corridors could already be attractive for a variety of applications
- Investment needed is moderate compared to other expenditures for future technologies

*All alternative propulsion systems require a reliable energy supply infrastructure

*In road freight transport, a relatively low network density along corridors could already be attractive for a variety of applications

*Investment needed is moderate compared to other expenditures for future technologies

*Average annual toll revenues or infrastructure investments during the indicated period

Speed of infrastructure development and CO₂ pricing decisive for GHG reduction of ZE trucks – the example of OC-HDV

Three scenarios with different toll designs and network expansion rates

- Rapid infrastructure development is a key requirement for relevant GHG reduction
- CO₂-based truck toll system: establishes a polluter pays relationship, creates a robust user cost advantage, enables infrastructure financing

![Graph showing reduction of direct GHG emissions in million t CO₂ equivalent over time with different scenarios for truck toll and network expansion.](image-url)

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<thead>
<tr>
<th>Truck toll</th>
<th>Network expansion</th>
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<tr>
<td>Toll without exemption for OCE-Trucks</td>
<td>Length of caterenary network</td>
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<td>additional CO₂-based toll component of €80 per tonne CO₂ (from 2023)</td>
<td>2025: 600 km</td>
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<tr>
<td>additional CO₂-based toll component of €200 per tonne CO₂ (from 2026)</td>
<td>2025: 1,500 km</td>
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<td>2035: 3,000 km</td>
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<td>2040: 3,800 km</td>
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Electrification of long-haul road transport: Conclusions

- Electrification enables climate neutrality of road freight transport
- Electric trucks can already be operated economically in the near future
- The direct use of electricity is the most efficient and requires the least expansion of renewable energies
- Infrastructure costs are particularly relevant in the start-up phase, but are of secondary importance in the long term
- The GHG mitigation potential is highly dependent on the speed of infrastructure development
What should happen now?
Plan of action

- **Planning security for market players:** Align freight transport policies with GHG emissions

- **Guarantee infrastructure expansion:** Develop a reliable infrastructure expansion plan and public financing of infrastructure

- **Framework conditions for the supply side:** Set minimum quota for new electric truck registrations

- **Framework conditions for the demand side:** Base truck tolls on CO₂ emissions

- **Practical experience:** Enable and promote larger implementation projects in public road space

- **International cooperation:** Initiate cross-border technology development and start standardization at an early stage
A challenging journey from today's situation to the set targets – decisive action is required!

Targets set in the German government's climate package (09/2019) for the year 2030:

**One third** of road freight transport performance **on the basis of electricity**

Number of electric trucks (>12 t payload) registered in Germany in 2019:

8 out of 120,000

Further reading:
Recent publications of Oeko-Institut

StratON project report (09/2018)
on overhead catenary heavy-duty vehicles

Policy paper (10/2018)
on alternative drive trains and fuels for HDV

Final report (02/2019)
energy supply options of the transport sector

➤ All reports available on our website: www.oeko.de
Further reading:
Recent publications of Oeko-Institut

StratON final report (02/2020)
assessment of overhead catenary trucks

Final report (05/2020)
assessment of LNG trucks

➢ All reports available on our website: www.oeko.de
Thank you for your attention!

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