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

Florian Hacker
Brussels, 19.02.2020
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

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

<table>
<thead>
<tr>
<th>Vehicle stock</th>
<th>Total mileage [bn VKT]</th>
<th>Total emissions [Mt CO₂e/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVW:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 3.5t</td>
<td>3.5-7.5t</td>
<td>7.5-12t</td>
</tr>
<tr>
<td>12-26t</td>
<td>26-40t</td>
<td>40t</td>
</tr>
</tbody>
</table>

*in Germany

**Source:** Fraunhofer-ISI, Öko-Institut, ifeu (2018): Alternative Drives and Fuels in the Road Freight Transport – Recommendations for Action for Germany
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)
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


Getting ZE trucks on the road | Florian Hacker | Brussels | 19.02.2020
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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*Energy supply infrastructure: hydrogen filling station, overhead line system or station-based charging infrastructure

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Diesel</th>
<th>FCEV</th>
<th>OC-HEV</th>
<th>OC-BEV 100</th>
<th>BEV 800</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Direct use of electricity is by far the most energy efficient option for climate-neutral long-haul HDV operation

*in the exploitation of efficiency potentials in electrolysis, fuel synthesis and fuel cells
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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2010</th>
<th>2050</th>
<th>Diesel efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICEV - Diesel</td>
<td>109</td>
<td>4</td>
<td>95%</td>
</tr>
<tr>
<td>ICEV - PtL</td>
<td>226</td>
<td>193</td>
<td>49%</td>
</tr>
<tr>
<td>FCEV</td>
<td></td>
<td></td>
<td>48%</td>
</tr>
<tr>
<td>EV (catenary)</td>
<td>4</td>
<td>47</td>
<td>85%</td>
</tr>
</tbody>
</table>

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

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

*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

**Three scenarios with different toll designs and network expansion rates**

<table>
<thead>
<tr>
<th>Year</th>
<th>Truck toll</th>
</tr>
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<tbody>
<tr>
<td>2020</td>
<td>Toll without exemption for OC-Trucks</td>
</tr>
<tr>
<td>2025</td>
<td>additional CO₂-based toll component of €80 per tonne CO₂ (from 2023)</td>
</tr>
<tr>
<td>2030</td>
<td>additional CO₂-based toll component of €200 per tonne CO₂ (from 2026)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Network expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>Length of cenetenary network</td>
</tr>
<tr>
<td>2035</td>
<td>2025: 500 km</td>
</tr>
<tr>
<td>2040</td>
<td>2035: 3.000 km</td>
</tr>
<tr>
<td>2045</td>
<td>2040: 3.800 km</td>
</tr>
<tr>
<td>2050</td>
<td>2045: 3.800 km</td>
</tr>
</tbody>
</table>
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 and forthcoming 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

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

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

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