CATENARY HYBRID ELECTRIC TRUCKS (E-TRUCKS): EUROPEAN MARKET DIFFUSION AND IMPACT ON THE ENERGY SYSTEM

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Outline

1. Introduction
2. Methods and Data
3. Results
4. Discussion and findings
Heavy-duty vehicles have small stock shares...


...but high shares on CO₂ emissions.

Here, we analyze the market diffusion and energy impact of e-trucks in Europe in 2040.

Two possible execution variants

**Overhead line or catenary trucks**
- Established technology for rail
- Modifications needed

**Conductor rail-truck**
- New technology
- Difficult in bad weather

**Inductive charged-truck**
- Rather low efficiency

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**Diesel hybrid** with small traction battery as buffer (~10 kWh) → Today preferred for full flexibility

**Electric motor + battery** → long-term electrification

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Just briefly - why not...

...**BEV**: range/weight and charging issues
...**FCEV**: range/volume and refueling issues
...**e-Fuels**: for reasons of energy efficiency

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Determination of market diffusion for e-trucks

**A) Individual Analysis of vehicles**
1. simulation of truck usage
2. comparison of total cost of ownership (TCO)
3. determination of cost based market share $p_{r,s}$ of drive train $s$ and size $r$

**B) Limitation of vehicle and infrastructure availability**

$$p^2_{r,s} = p_{r,s} \times b_{r,s}$$

**C) Calculation of new vehicle registrations**

$$N_{r,s} = p^2_{r,s} \times N_r$$

**D) Determination of total vehicle stock**

**Data sets**
- truck dataset with 5,729 annual vehicle kilometres travelled
- vehicle database (9 drive trains, 5 size classes)

**Assumptions**
- energy prices
- electrified highway kilometres
- limited vehicle availability
- vehicle stock development

**Model steps**

www.aladin-model.eu
Impact of overhead line construction on electric driving share in Germany

- Car and truck traffic concentrated on some highways
  - Highways with higher loads should electrified first
  - 33% expansion electrify 50% of truck VKT


Simulation of truck electrification

\[ u_{BAB} = 1 - \Phi \left( \Phi^{-1} \left( 1 - \frac{\text{km}_{el}}{12980} \right) - 1.19^2 \right) \]

Some key assumptions for transfer to Europe

For electric trucks

- **country-specific new vehicle registrations** considered
- distribution of **annual driving assumed to be equal for Germany and Europe** (tests with Eurostat data showed no usable distinction)
- **market shares** in Germany and Europe assumed to be **equal**
- **electric driving** assumed to **increase** with growing infrastructure
- energy demand:
  \[
  W_{t}^{HDV} = s_{t}^{el} \sum_{t-t-T}^{t} M S_{t}^{HDV} \cdot V K T_{t}^{HDV} \cdot c_{t}^{el,HDV}
  \]

For passenger cars

- **country-specific diffusion** according to historic PEV market shares and energy prices
- **electric driving** assumed to be **constant** due to given battery sizes
- energy demand:
  \[
  W_{t}^{PEV} = \sum_{t-t-T}^{t} M S_{t}^{PEV} \cdot V K T_{t}^{PEV} \cdot c_{t}^{el,PEV} \cdot s_{t}^{el,PEV}
  \]
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Electric vehicles and electric trucks can have significant market shares until 2040.

Market shares of electric vehicles and e-trucks can reach 50-70% in 2040.

The energy demand would then amount to ~500 TWh (~15% of EU electricity production).
Energy consumption of e-trucks by country

TOP5 in energy consumption

- Germany
- France
- Spain
- Poland
- United Kingdom

2040 annual electricity consumption through e-trucks [TWh/a]

Source: Plötz et al. (in preparation)
Electric trucks can reduce GHG emissions from road transport sector

-40 Mt

-50 Mt
### Assumptions for electricity generation

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- Increase of energy demand due to electric vehicles and trucks
- Existing power plant capacities used for electricity generation
Electric trucks can reduce total GHG emissions

1. Decrease of GHG in transport sector
2. Increase of GHG in energy sector
3. Total GHG decrease with optimistic assumptions and marginal emissions of electricity mix
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Is the electrification of European highways a viable solution?

- High share of heavy duty transport in Europe is cross-national
- About one third of the European highway grid are approx. 25,000 km
- Trans-European traffic corridors best start
- Alternative fuels infrastructure directive for joint European system

→ Debate is still in an early phase and likelihood of European overhead line grid unclear
Summary and further research

Findings

- Market diffusion of electric vehicles and e-trucks could increase electricity demand in western and central Europe
- Even under pessimistic assumptions, this diffusion only slightly increases total GHG emissions
- Passenger cars with higher total impact, but solutions in heavy-duty vehicle sector are rare

Further research

- Only marginal electricity mix considered – GHG reduction even better with average emissions
- TtW emissions of conventional vehicles not considered – about +15-20% for WtT emissions
- No flexibility options considered - could smoothen electricity demand peaks with high emissions.
Thank you for your attention!

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Further reading:
- Wietschel et al. (2017): Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw (LINK, German)