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Electric roads for the German climate protection strategy for freight transport? A review and synthesis of market diffusion and electrification studies

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Summary

The contribution of overhead catenary-based (OC) trucks to the reduction of transport-related greenhouse gas emissions depends largely on the speed of market ramp-up and the achievable electric driving performance as well as the carbon intensity of the energy used. This contribution discusses and compares the methodological approaches and the results of three comprehensive studies on modelling the market ramp-up for Germany. It compares possible market ramp-up scenarios and their greenhouse gas (GHG) reduction potential, identifies key influencing variables and formulates recommendations for action for the market success of the technology, which can be derived from the study comparison. The results are put into the context of other possible technical options for the decarbonization of road freight transport.

1 Research Questions

Road freight transport in Germany is responsible for about 1/3 of transport-related greenhouse gas (GHG) emissions and shows a further increasing trend. About 60 % of this can be attributed to heavy-duty vehicles, mainly operating in long-haul transport. So far, no alternatives to diesel trucks have been able to become established on the market.

The German government has set a 40% GHG reduction target by 2030 (compared to 1990 levels) for the transport sector. The German government's recently adopted climate package formulates the goal of achieving one-third of road freight transport performance on electricity (directly or via eFuels) by 2030. So far, instruments to achieve this target have been specified only to a limited extend, though.

Overhead catenary-based (OC) trucks are one possible approach to achieving this goal. Three comprehensive studies on the potentials of overhead catenary trucks in Germany have been carried out in the past three years within the framework of multi-year research projects (Study within the framework of the mobility and fuel strategy of the German government (MKS study) [1], Roadmap OH-Lkw Project [2], StratON Project [3,4]), of which the two latter ones are currently in press. The aim of this contribution is to compare the main findings of the three studies. Based on these findings, recommendations for policy instruments will be developed in order to ensure market success and thus also a relevant GHG reduction contribution of catenary-based trucks. Furthermore, the results will be discussed in the context of possible technological alternatives.

2 Methodology

This contribution will focus on possible market ramp-up scenarios for catenary-based trucks in Germany. These are discussed in the context of potential technology alternatives and classified in terms of their technical and economic feasibility. In all three studies, the market ramp-up simulation is essentially based on a TCO approach and an assumed network expansion of the infrastructure. The differences between the methodological approaches to simulate the market ramp-up of OC trucks are first analyzed.

The following parameters are considered:

- the respective assumed overhead line network and its expansion speed,
- the assumed technology configurations and their development,
- the defined vehicle use profiles,
- the representation of different user groups (e.g. with different profitability calculations),
- regulatory / fiscal framework conditions.

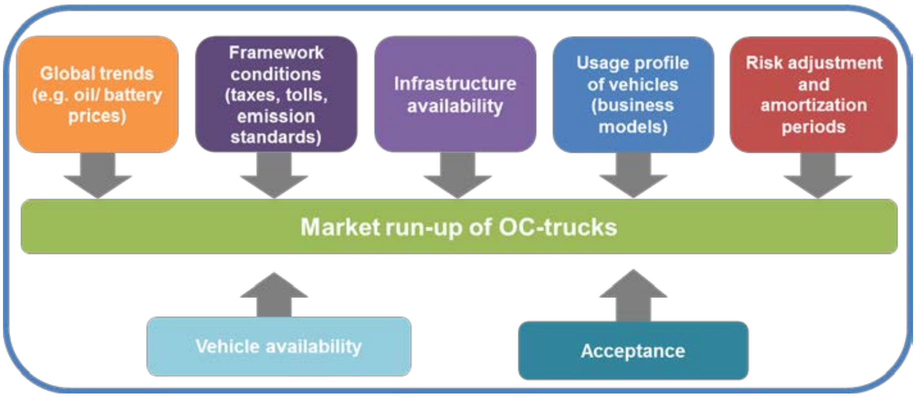

Figure 1: Influencing factors considered for OC truck market ramp-up in the TEMPS model (StratON project)

An understanding of the methodological approaches and the framework conditions applied form the basis for the comparison across the three research projects and the interpretation of the modelled market ramp-ups. In the following, the model results are discussed in comparison and key influencing factors are identified.

Central target variables that are considered in our comparison are

- the achieved number of OC trucks and the achieved electric mileage for different network expansion stages and target years,
- the GHG emission savings achieved through the operation of OC trucks,
- the economy of vehicle use and system costs,
- and the influence of changed framework conditions (e.g. changed kilometer costs, amortization periods) on the market uptake speed.

The comparison of the modelling approaches and analysis of the model results forms the basis for deriving recommendations for action to enable a successful market ramp-up OC trucks and ensure a significant contribution to Germany's climate protection goals. In this context, the competition and possible synergies with possible technological alternatives, such as battery electric trucks, are also discussed.

3 Results

In the three studies considered, a largely congruent target network of about 4,000 km length for the overhead line infrastructure is a key project result (figure 2). This target network comprises the most frequented motorways in Germany. The studies and the scenarios under consideration differ about the speed and possible stages of network expansion. These discrepancies are due to differences in the methodological approach and the assumptions made, which are discussed in more detail in the discussion of the results.

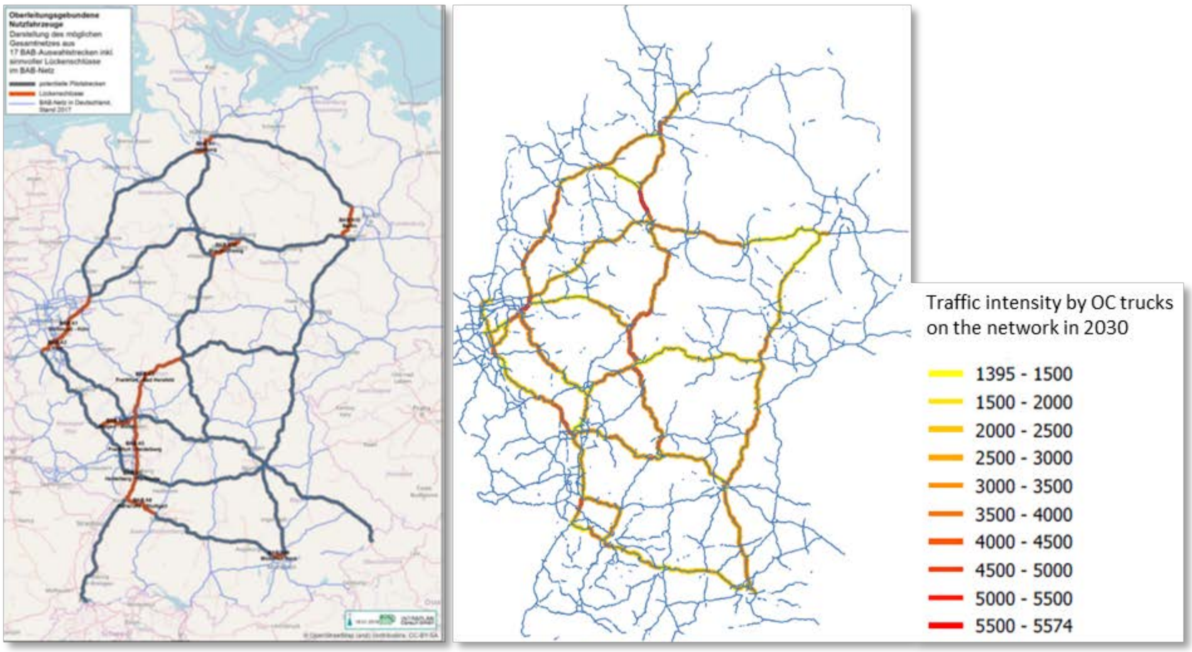

Figure 2: Target network for the overhead catenary infrastructure in the projects “StratON” and “Roadmap OH-Lkw” (example)

The results of the market ramp-up modelling vary significantly between the scenarios considered about the number of vehicles realized, the proportion of different OC truck configurations and the electrical driving performance achieved (figure 3). In addition to the network expansion speed, the main influencing factors are the available technology configurations and their costs as well as variables that influence the cost per kilometer. In the model results of the StratON project as well as of Roadmap OH-Lkw, a CO_2-based truck toll system shows a particularly positive effect on the total electrical driving performance of OC trucks and high cost-efficiency. The achieved greenhouse gas reduction depends on the achieved electrical driving performance and the development of the CO_2 intensity of the power generation. Therefore, in the scenarios with advancing infrastructure expansion and increasing decarbonization of the power system, especially after 2030, the reduction is significantly increased.

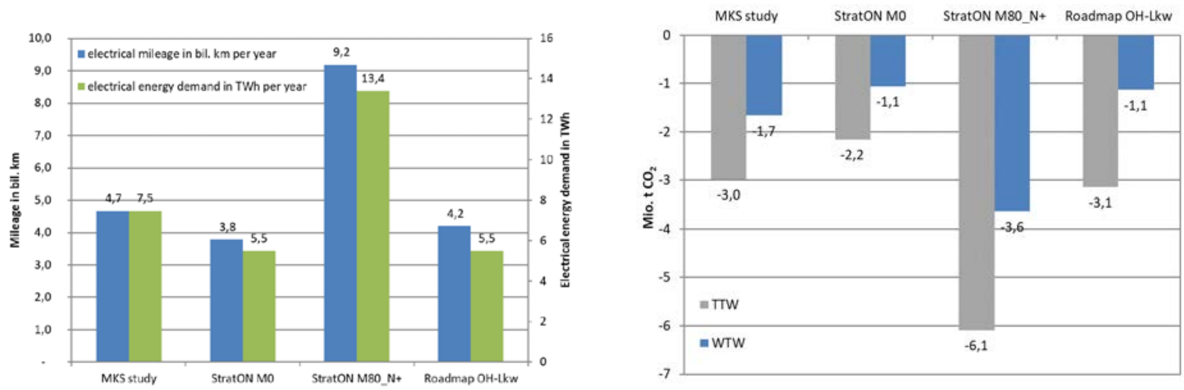

Figure 3: Comparison of the electric mileage / power consumption of OC trucks in the reviewed studies for selected scenarios (left) and realized GHG reduction (right) in 2030.

From the user's perspective, it is shown that an economic operation can often be achieved in the usual payback periods at an early stage, but only if the infrastructure costs are not passed on to the users. An examination of the total system costs shows that although infrastructure costs are associated with high investment costs, in the long term they are more than compensated by lower energy costs compared to a Diesel reference scenario (figure 4).

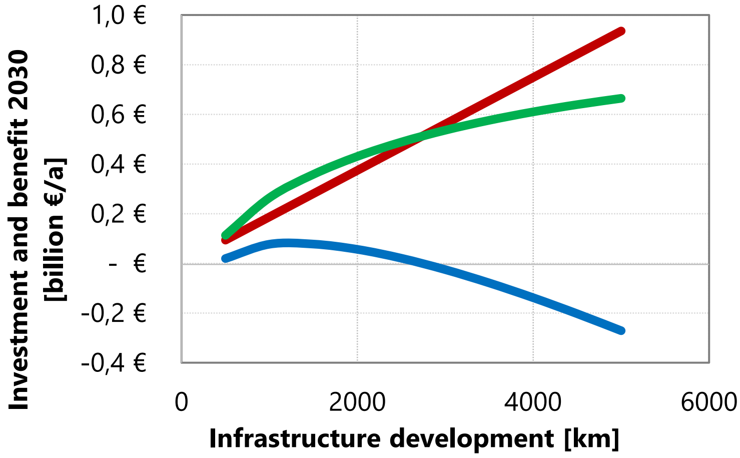

Figure 4: Annuity of investment for overhead lines (red) and annual fuel cost savings (green) as well as the difference, i.e. the total system cost benefit (blue) as a function of the infrastructure development in km.

Technical alternatives for a decarbonisation of road freight transport are trucks with purely battery electric drive or fuel cells as well as the use of synthetic fuels based on renewable electricity in combustion engines. In comparison, the direct use of electricity shows the highest energy efficiency and thus the highest GHG reduction potential for the same amount of available electricity from renewable sources. First total cost analyses also point to the long-term cost advantage of direct electricity use, as higher infrastructure costs are more than compensated by the lowest energy costs in comparison [5,6]. However, battery electric trucks also show potential synergies with OC trucks. On the one hand, this concerns many identical components of the drive train as well as the shared use of stationary charging infrastructure [7]. Against this background, the regional spread of battery-powered trucks could also enable low-threshold and early entry into the electrification of road freight transport.

Based on the preceding analyses, the contribution finally provides recommendations for action that could enable a market ramp-up of OC trucks and a relevant contribution to the achievement of the national GHG reduction target. Central fields of action are to ensure the development of infrastructure and its financing, economical vehicle operation and the highest possible proportion of electric mileage by OC trucks.

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Florian Hacker holds a degree in Geoecology and joined Oeko-Institut in 2007. He is Deputy head of the Resources & Transport Division. His research activities focus on technology assessment from different perspectives, the development of CO_2 reduction strategies for the transport sector and the calculation of transport emissions. His special expertise lies in the examination of alternative propulsion technologies with a focus on electric mobility. He is currently project leader of several projects on the electrification of commercial vehicles, including battery-electric and ERS technology solutions.

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