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Market- and Grid-Friendly Integration of Public Charging Infrastructure for Electrified Heavy-Duty Transport into the Future Energy System

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Extended Abstract

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Abstract Summary

The decarbonization of heavy-duty road freight transport is a key requirement for achieving Germany's climate targets. In response, a nationwide public charging network for battery-electric trucks is being deployed along federal highways. While enabling transport electrification, this infrastructure introduces significant new electricity demand into a power system increasingly characterized by renewable variability and congestion challenges. This work investigates whether such infrastructure can also serve as a source of demand-side flexibility and support both market- and grid-oriented charging strategies.

A three-step modeling framework is applied. First, charging demand at 352 planned locations is derived from synthetic European freight flows using a trip-chain approach consistent with EU driving regulations and scaled to 2035. Second, charging hubs are dimensioned using a graph-based optimization model, with locations clustered into three representative demand types and equipped with NCS, HPC, and MCS charging technologies. Third, flexibility is quantified using generalizable indicators (EFI, EFC, APFI, MPFI), complemented by sensitivity analyses and price-based optimization using Day-Ahead and Intraday markets.

The results show that the charging network reaches an installed capacity of approximately 7.6 GW and an annual electricity demand of around 11 TWh, highlighting its system relevance. Significant flexibility potential is identified, though strongly dependent on dwell times and infrastructure design. Overnight charging provides about 92% of total flexible energy, while high-power charging contributes primarily to short-term power flexibility. Grid connection design is critical, with current plans enabling roughly 87% of theoretical flexibility. Economic optimization demonstrates cost reductions of up to 29% using Intraday price signals.

Overall, public heavy-duty charging infrastructure represents not only a major new electricity demand, but also a valuable flexibility resource. Its effective utilization requires

coordinated operation, appropriate incentives, and integration into energy markets and grid planning.

Presenting Author Biography

Philipp Daun studied Business Administration and Electrical Engineering at RWTH Aachen University with a focus on electrical energy engineering and innovation management. After his studies, he first worked as a project engineer in the field of calculation and certification of electric power plants. Since October 2022, he has been working as a research associate and PhD student at the Chair for Energy System Economics (FCN-ESE).