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Time to charge - Simulating charging strategies for a German battery electric truck fleet

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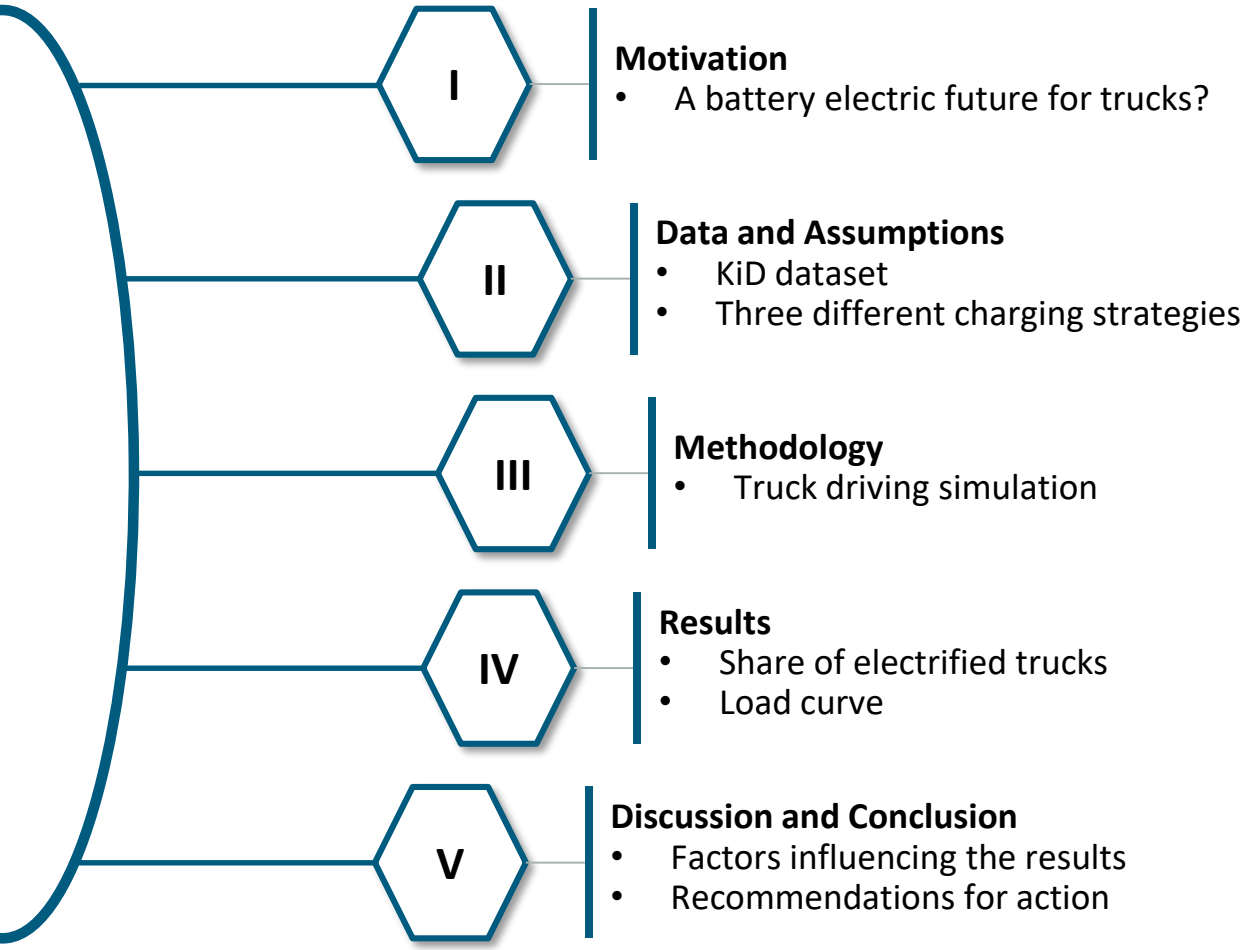
HoLa Hochleistungsladen Lkw-Fernverkehr

KAMO KARLSRUHE MOBILITY HIGH PERFORMANCE CENTER / PROFILREGION

Overview



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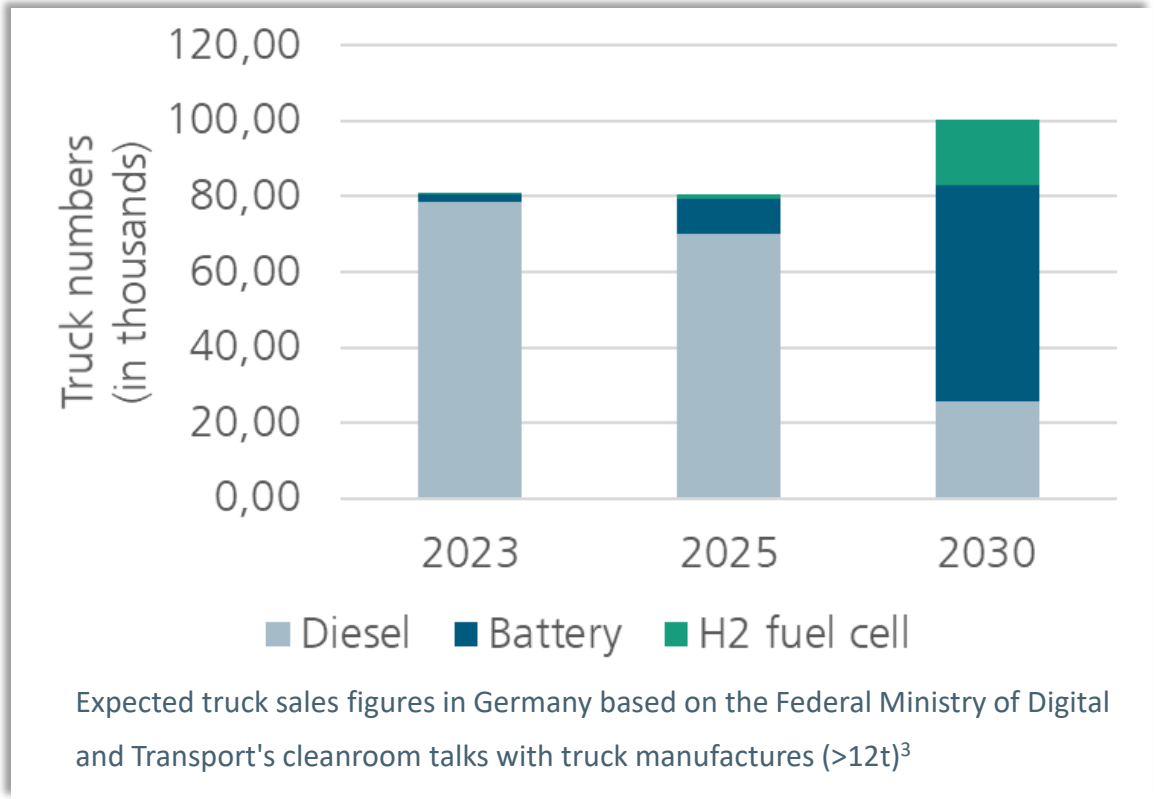
Motivation

Battery electric trucks are a promising option to reduce greenhouse gas emissions in the transport sector.

Reducing greenhouse gas emissions in transport sector?

- Heavy-duty vehicle represent less than 5% of the European vehicle fleet, but are responsible for up to 22% of CO_2 emissions from road transport[1,2].
- Truck manufacturers announced alternative drivetrains, especially battery electric trucks, for coming years[3].
- Megawatt charging will allow to charge a truck within 45 minutes (mandatory break)[4].



Expected truck sales figures in Germany based on the Federal Ministry of Digital and Transport's cleanroom talks with truck manufactures (>12t)[3]

[1]Umweltbundesamt (2023): Klimaschutz im Verkehr. https://www.umweltbundesamt.de/themen/verkehr-laerm/klimaschutz-im-verkehr.
[2]Eurostat (2024): Greenhouse gas emissions by source sector. https://ec.europa.eu/eurostat/databrowser/view/env_air_gge/default/table?lang=en.
[3]NOW (2023): Market development of climate-friendly technologies in heavy-duty road freight transport in Germany and Europe. Evaluation of the 2022 cleanroom talks with truck manufacturers
[4]CharIn (2024): Megawatt Charging System (MCS). https://www.charin.global/technology/mcs/.

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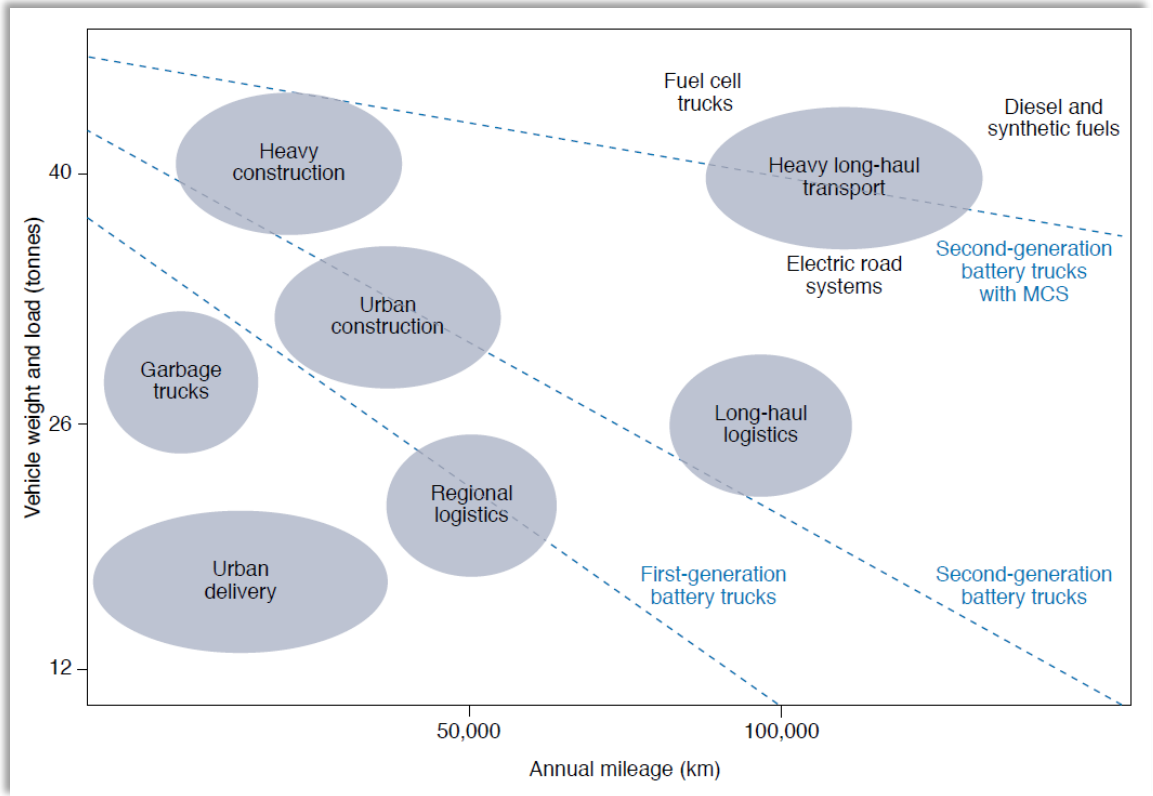
Motivation

Battery electric trucks are likely in the future. Today, their charging behavior is still uncertain.

A battery-electric future for trucks?

Battery electric trucks can be used in urban and regional transport and (with MCS or ERS) on long-distance routes. The second and third generation of battery electric trucks are expected to cover over 80% of all journeys.

- Which proportion of all trucks can be electrified?
- When will battery-electric trucks be charged in the future?
- Which additional power demand can be expected?



Plötz, P. (2022): Hydrogen technology is unlikely to play a major role in sustainable road transport. Nature Electronics https://doi.org/10.1038/s41928-021-00706-6

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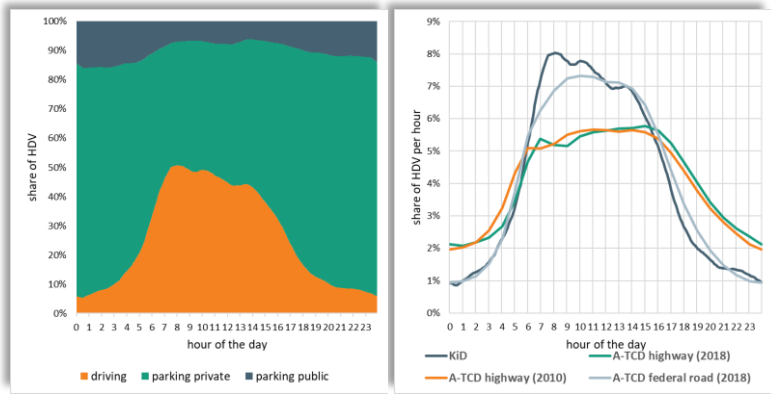
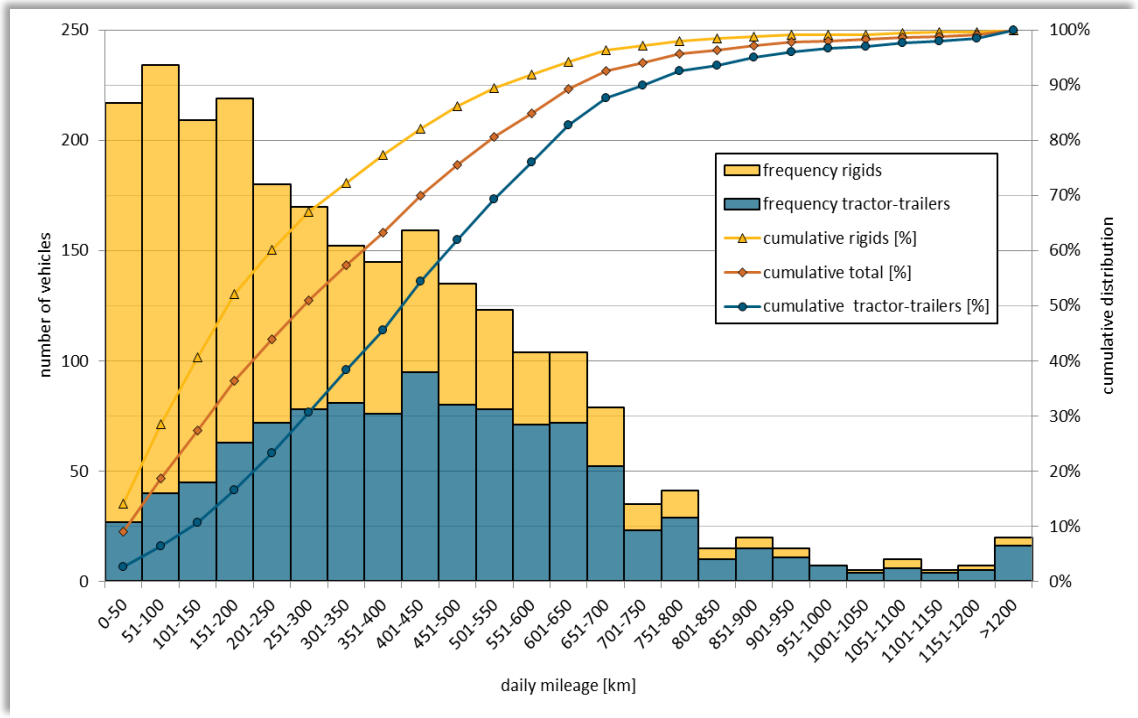
Data and Assumptions

KiD 2010 provides 2,410 single-day driving profiles from German diesel trucks.

- Sample (KiD 2010) contains ~2,800 randomly selected single-day profiles from German diesel trucks (>12 t GVW)
- After cleaning, 2,410 driving profiles (1,350 rigids, 1,060 tractor-trailer) remain
- Driving profile contains:
  - trips (start, end, distance travelled)
  - parking locations (public, private)
- Sample considered representative, possibly with a slightly too high share of regional transport





Speth, D. & Plötz, P. (2024): Depot slow charging is sufficient for most electric trucks in Germany. Transportation Research D. https://doi.org/10.1016/j.trd.2024.104078

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Data and Assumptions

Three charging strategies show possible impacts of different charging behavior.

Three different charging strategies:

As slow as possible	*As fast as possible*	*Combination*
• Entire available time used for charging event • Minimize additional load on the grid	• Charging starts immediately after arrival with maximum available power • Probably most challenging in terms of additional load	• Charging at depots limited to 44 kW and based on ASAP strategy • Public charging available at full power, but also ASAP strategy • Real-world oriented approach

Framework parameters:

Parameter	***2030***	***2045***
Share of electrification	30%	Technically possible share
Max. distance	350 km	590 km
Max. avg. charging power	430 kW	810 kW
Min. break time for charging	30 min	30 min
Min. SOC for charging	20% (280 km)	20% (472 km)

Strategies based on:
Gschwendtner et al. (2023): Mind the goal: Trade-offs between flexibility goals for controlled electric vehicle charging strategies. IScience, 26(2), 105937. https://doi.org/10.1016/j.isci.2023.105937
Borlaug et al. (2022): Charging needs for electric semi-trailer trucks. Renewable and Sustainable Energy Transition, 2, 100038. https://doi.org/10.1016/j.rset.2022.100038
Parameters based on:
Speth, D. & Plötz, P. (2024): Depot slow charging is sufficient for most electric trucks in Germany. Transportation Research D. https://doi.org/10.1016/j.trd.2024.104078
NOW (2023): Market development of climate-friendly technologies in heavy-duty road freight transport in Germany and Europe. Evaluation of the 2022 cleanroom talks with truck manufacturers

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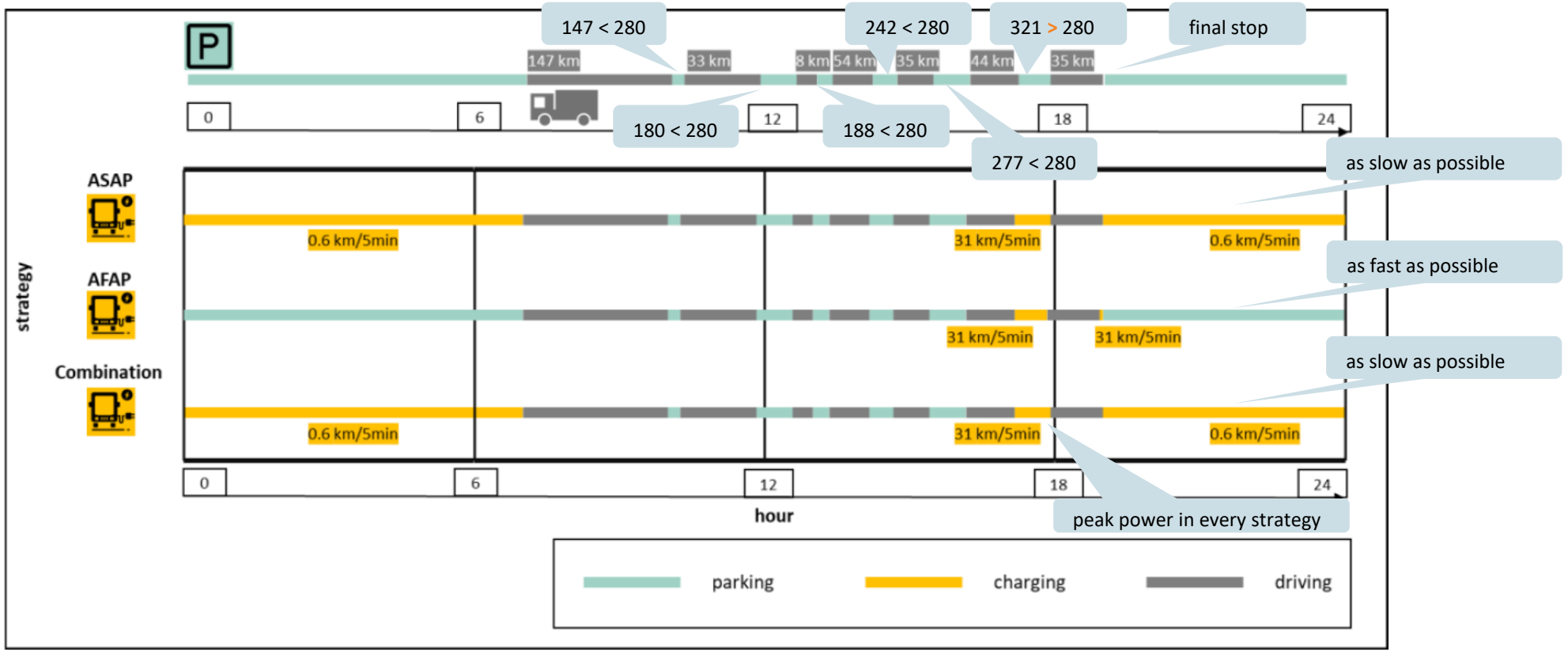
Methodology

Simulation of one day of driving and charging.



Strategies based on:
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Simulation initially based on:
Speth, D. & Plötz, P. (2024): Depot slow charging is sufficient for most electric trucks in Germany. Transportation Research D. https://doi.org/10.1016/j.trd.2024.104078

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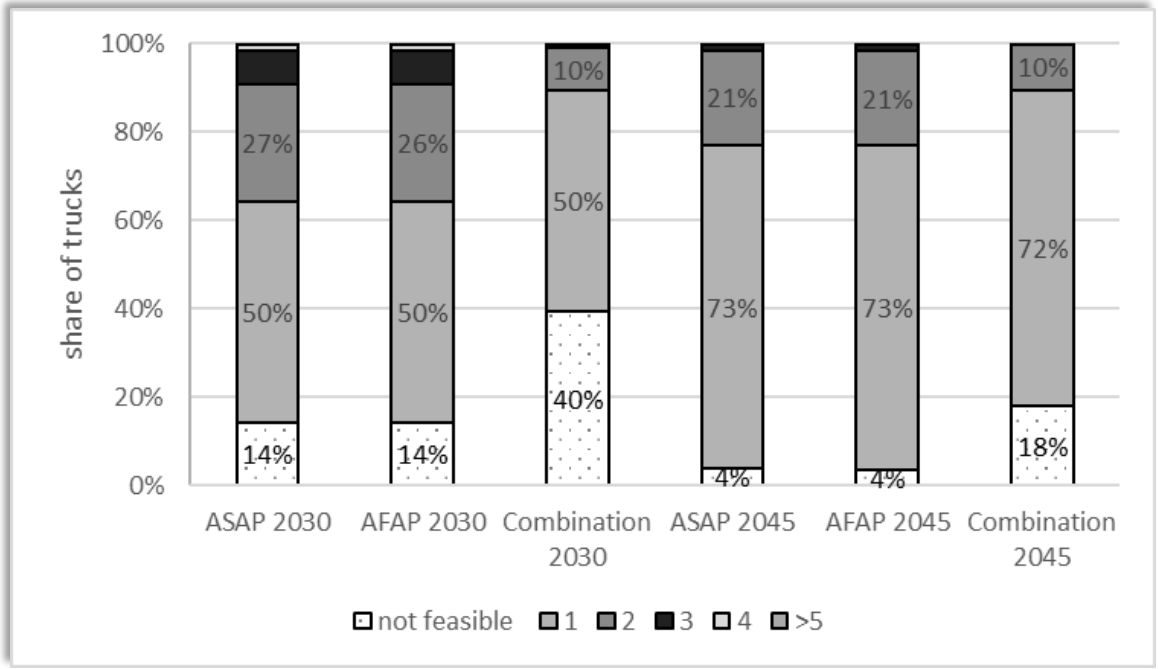
Results

In principle, almost full conversion of the fleet is possible, if semi-fast depot charging will be established.

Which proportion of all trucks can be electrified?

- Driving profiles is considered as “possible”, if the vehicle can be fully recharged after the last trip of the day, before the first trip starts again
- High and similar share of electrification in ASAP and AFAP strategies
- Limited charging power at the depot (< 44 kW) reduces share in combination strategy significantly
- Most vehicles will be charged once or twice a day
- Rising range and charging power enables almost full conversion of the fleet



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Results

the charging strategy highly influences the load curve, especially the peak demand in the evening.

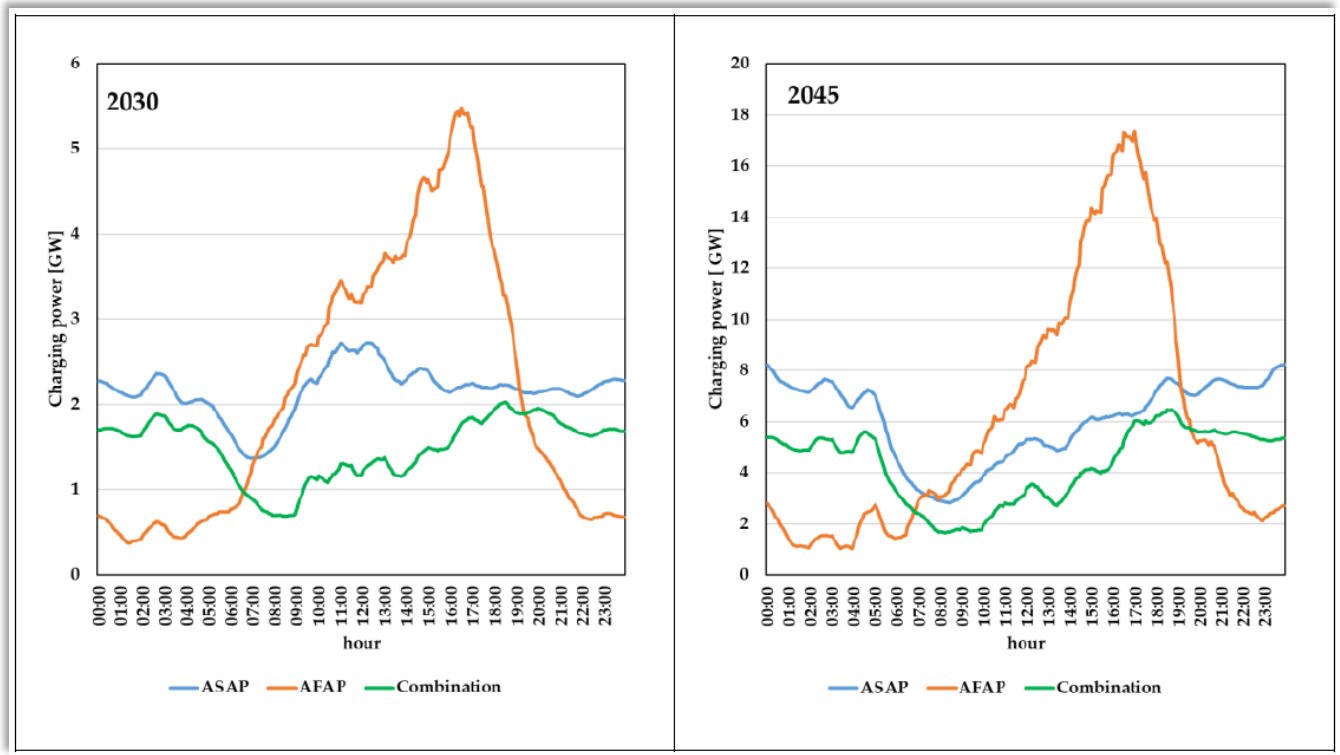
When will battery-electric trucks be charged in the future?

- ASAP and Combination strategies will lead to a almost flat energy demand, with a dip in the morning hours
- AFAP strategy will lead to a significant increase in midday and evening hours
- Short range will lead to a midday peak, which will be reduced with increasing vehicle ranges

Which additional power demand can be expected?

- Depending on strategy, up to 18 GW at full fleet conversion
- Energy demand:

Scenario	*2030*	*2045*
ASAP / AFAP	50 GWh/day	145 GWh/day
Combination	35 GWh/day	100 GWh/day



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Discussion and Conclusion

In principle, almost full conversion of the fleet is possible, if semi-fast depot charging will be established.

Topics to discuss:

- Single day driving profile may overestimate electrification potential, but generally high potential across all profiles opposes this. Larger batteries?
- Larger sample can be more accurate, but identified main effects are plausible.
- Optimization and perfect foresight will strengthen battery electric trucking, compared to the presented simulation, even if infrastructure is missing.

Conclusions:

- Battery electric trucks should be considered in energy system simulation.
- From the beginning, additional load from battery electric trucks should be managed.
- Depot charging is highly relevant in terms of load management.

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Thank you!

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