Dynamic simulation of bus emissions in urban transport

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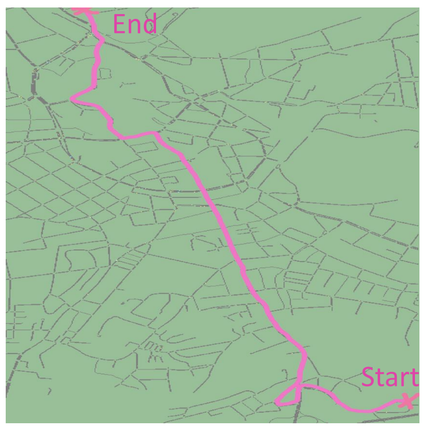
Research questions:

To what extent does the traffic and passenger load as well as the type of drive affect bus emissions ?

Which emissions calculation model associated with SUMO provides more realistic values ?



Motivation:

- Increase in motorized passenger transport in Germany
- Increase of the CO_2, NO_x and PM_x emissions
- Environmental and health impacts

→ Promoting environmentally-friendly transport

Assumptions:

- 18 m articulated bus (diesel or electric drive)
- Area of investigation: Osnabrück (bus route length: 6,25 km)
- 3 different times of the day using real traffic counts
- passenger count, average holding times and speeds

Methods:

	Density of traffic	Type of drive	Passenger load
Database	Real traffic counting data using TEU detectors	Diesel and electric articulated buses, acceleration and braking values based on bus test runs	Passenger load counted on bus test runs
Implementation in SUMO	route sampler with cars only as XY, trips for bus route	Parameters set in SUMO (e.g. emission class)	Passengers emission impact is neglected in SUMO therefore the impact of passenger weight on emissions calculated manually

Density of traffic:

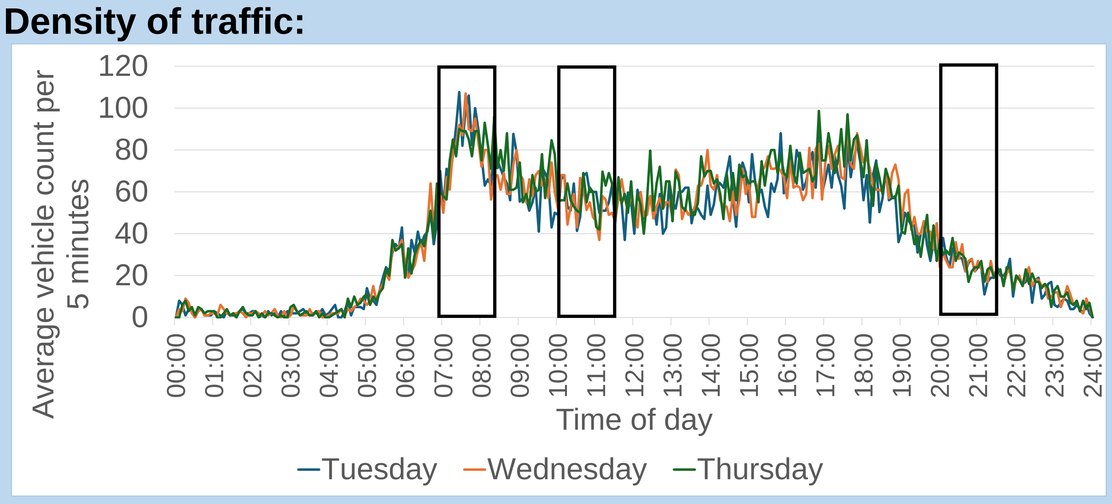
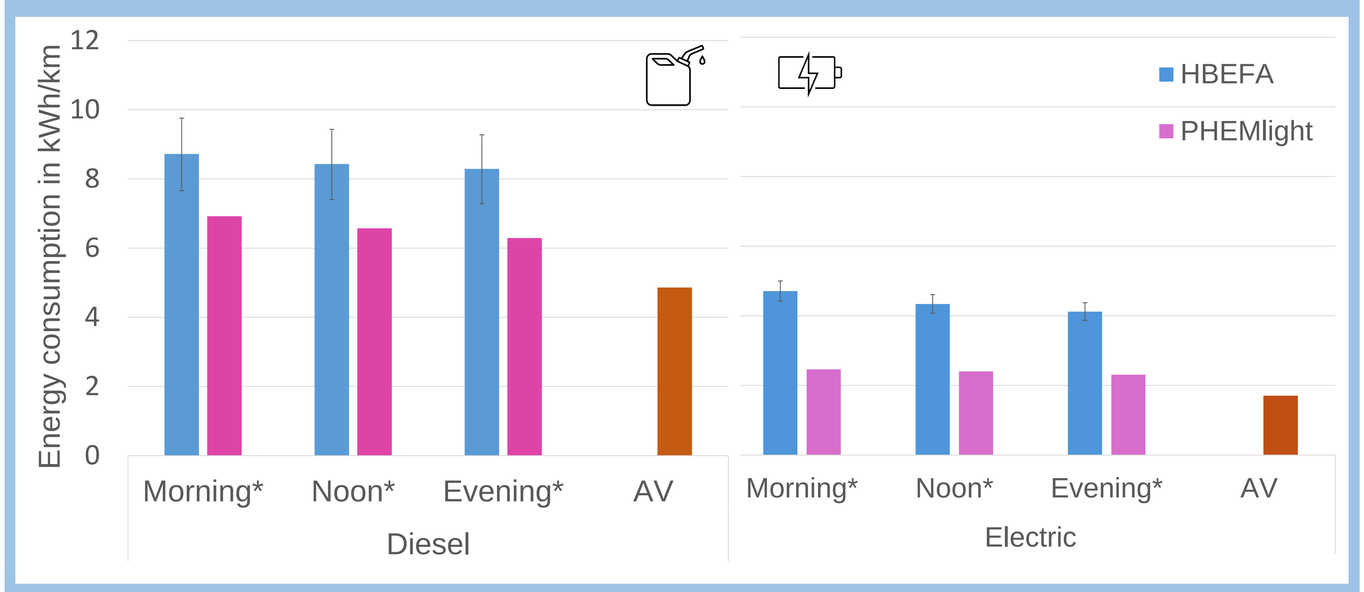


Figure 1: The average number of vehicles in the period 01.09.22 to 29.02.23, at the TEU detector 23 depending on the time from 0 to 24 hours for the weekdays Tuesday, Wednesday and Thursday, excluding holidays

Results with PHEMlight based emission data:

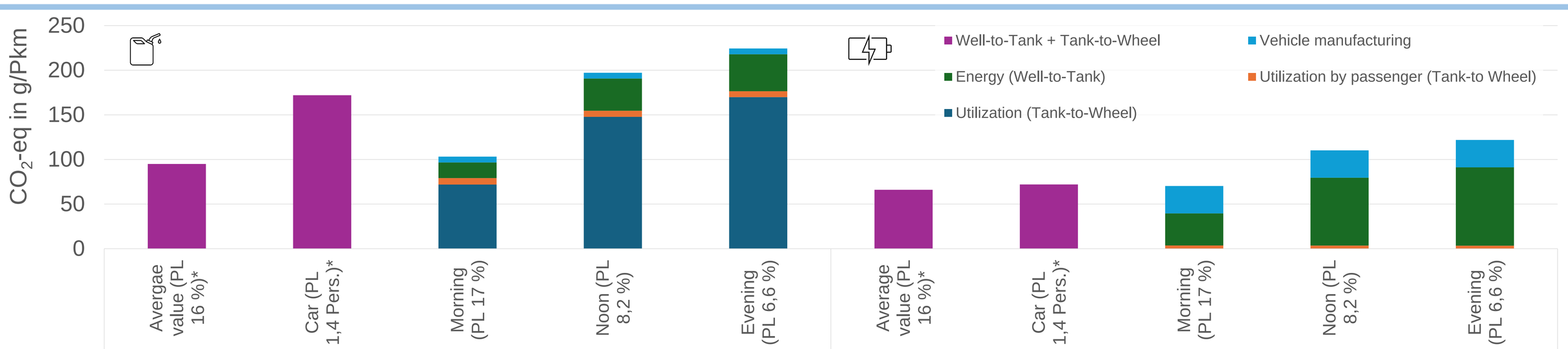
Due to the fact that the PHEMlight values are closer to the average values, the further evaluation was carried out with this emission calculation model.

Results: Comparison between HBEFA and PHEMlight based emission data



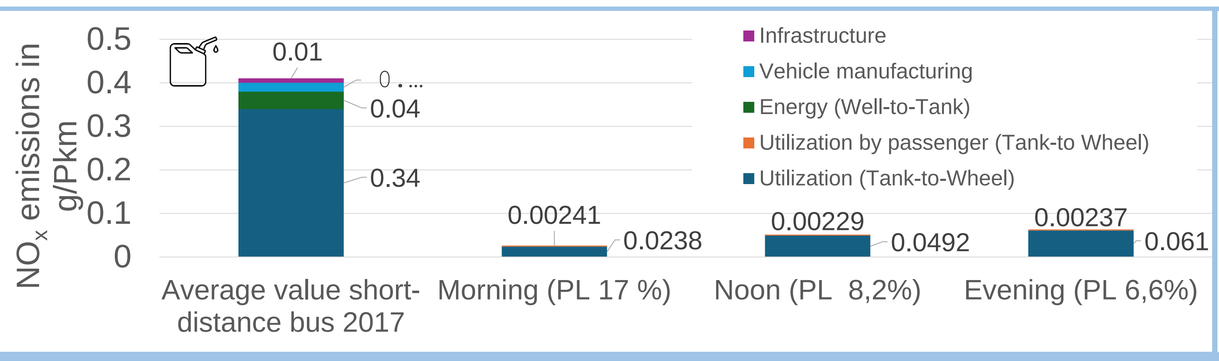
*the given data refer to the average of all 6 electric or rather buses of the respective daytime simulation scenario

Figure 2: The determined average energy consumption of electric and diesel articulated buses in kWh/km depending on the times of day (morning, noon and evening) and the two emission models HBEFA (with a total error value of 24.08 % (diesel) and 12.36 % (electric) and PHEMlight, as well as the average energy consumption of an electric and diesel articulated bus [1] [2]



*Averages refer to data from the Federal Environment Agency [3]

Figure 3: The average CO2-eq of the bus in g/Pkm depending on the type of drive (diesel or electric engine), direct or indirect emissions, time of day (morning, noon and evening) and passenger load (PL) compared with average values (violet)



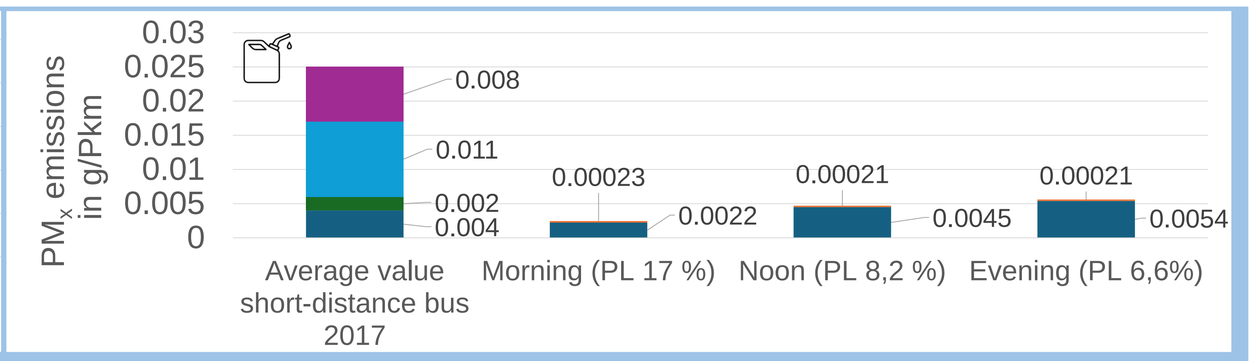


Figure 4+5: Average direct NOx and PMX emissions in g/Pkm depending on time of day (morning, noon and evening), passenger load (FGA) and average direct and indirect emissions of a commuter bus (2017) [4]

Summary:

PHEMlight provides more accurate results compared to HBEFA when used with SUMO in conjunction with buses.

Electric buses emit less CO2-equivalent, NOx, and PMx emissions than their diesel counterparts.

Additionally, a higher traffic volume results in increased direct emissions. However, carrying more passengers can reduce emissions per person.

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[1] ZEIT ONLINE. "Linienbusse unter Strom." https://www.zeit.de/auto/2010-04/linienbusse-strom
[2] PricewaterhouseCoopers GmbH WPG, "Kurzfassung des Abschlussberichts zur Begleituntersuchung der Förderung von Elektrobussen im ÖPNV"
[3] Umweltbundesamt. "Emissionsdaten." https://www.umweltbundesamt.de/themen/verkehr/emissionsdaten#verkehrsmittelvergleich
[4] Umweltbundesamt, "Umweltfreundlich mobil!: Ein ökologischer Verkehrsartenvergleich für den Personen- und Güterverkehr in Deutschland"