WHERE TO CHARGE ELECTRIC TRUCKS IN EUROPE – MODELLING A CHARGING INFRASTRUCTURE NETWORK

Fraunhofer Institute for Systems and Innovation Research ISI

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Image source: https://www.spektrum.de/news/lastwagen-gut-geeignet-fuer-elektromobilitaet/1517061

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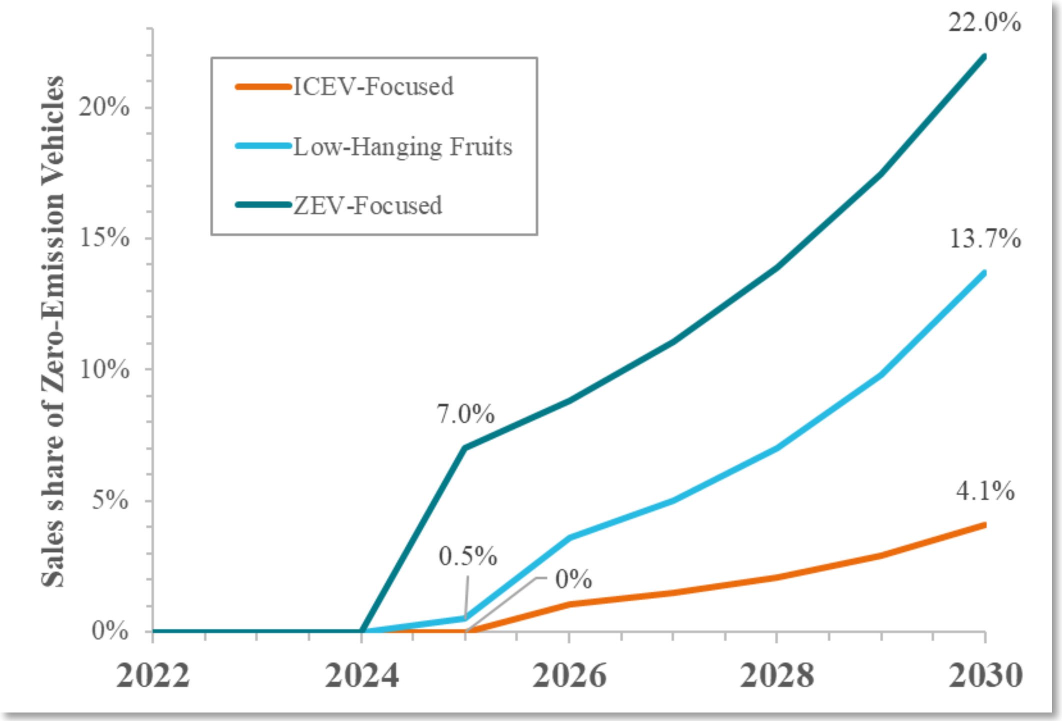
Motivation

Necessity for zero emission vehicles (ZEV): Regulation (EU) 2019/1242



Source: Own figure, based on Breed et al. (2021): CO2 fleet regulation and the future market diffusion of zero-emission trucks in Europe. https://doi.org/10.1016/j.enpol.2021.112640

Necessity for charging infrastructure: AFIR proposal

Proposal for a [...] regulation on the deployment of alternative fuels infrastructure [...] (EC 2021)

Article 4

1. Member States shall ensure a minimum coverage of publicly accessible recharging points dedicated to **heavy-duty vehicles** in their territory. [...]

(a) along the **TEN-T core network**, publicly accessible recharging pools dedicated to heavy-duty vehicles [...] are deployed in each direction of travel with a maximum distance of **60 km in between them**:

(i) by 31 December **2025**, [...] a power output of at least **1400 kW** and [..] at least one recharging station with [...] at least 350 kW

(ii) by 31 December **2030**, [...] a power output of at least **3500 kW** and [...] at least two recharging stations with [...] at least 350 kW

Reduction of CO_2 emissions of newly registered trucks by 30% compared to 2020 requires ZEV. The AFIR proposal promotes the necessary infrastructure development. Remaining question: Where to built how much charging infrastructure for 2030?

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Agenda

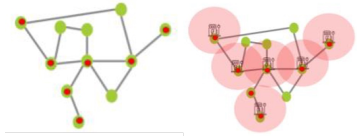
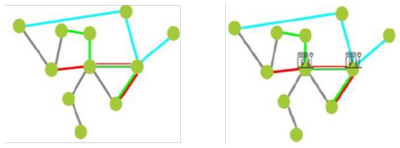
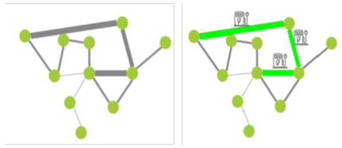
Methodology:
- approaches for infrastructure location modelling
- node-based coverage approach

Data and Scenarios:
- traffic data: updated ETISplus dataset
- scenario description

Results:
- distribution of charging locations and charging points
- sensitivity analysis

Outlook:
- future research needs
- Optimization as an alternative

Methdology: Different approaches for infrastructure location planning

	node-based	journies / activities / tours	flow-based
Approach	• p-Median • MCLM • SCLM (MCLM and SCLM: *coverage approach*)	❯ ***hybrid models*** ❮	• FRLM • FCLM
Schematic			
Data	traffic count, transport statistics	traffic flow data, transport statistics, GPS, logbooks Challenges: Representativeness, Data quantity, Effort, Confidentiality	traffic flow data, transport statistics
Performance urban traffic	+	+	−
highway	o	+	+
driving behaviour	−	+	o
computational power	+	−	o
data availability	+	−	o

suggested by AFIR proposal (node-based)

Source: Based on M. Metais et al. (2021): Too much or not enough? Planning electric vehicle charging infrastructure: a review of modeling options. 2021.hal-03127266

Methodology: Two-stage approach for infrastructure design: (1) charging location determination and (2) sizing

node-based coverage approach (heuristic)

Ensure that **charging locations** are available at **regular intervals** and that an even distribution of charging infrastructure is achieved.

$$CL_L = \begin{cases} 1, if\ d_{CL,L} \geq d_{avg} \\ 0, else \end{cases}$$

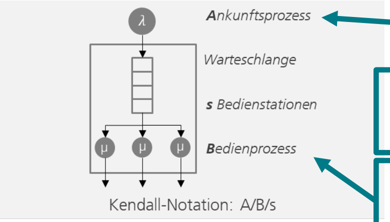
location every d_{avg} km

$$CE_{CL_i} = CE_{EU27+3} * \frac{MAX_{CL_{i-0.5}}^{CL_{i+0.5}}(TV_j)}{\sum_{CL} MAX_{CL_{i-0.5}}^{CL_{i+0.5}}(TV_j)}$$

share of charging events on one specific station CL

Queuing model for the calculation of charging points at one location

Determine the required number of charging points at a location with a given number of charging operations in order not to exceed a given maxi-mum average waiting time in general (e.g. 95%).



Poisson distributed arrival

Calculate # charging points

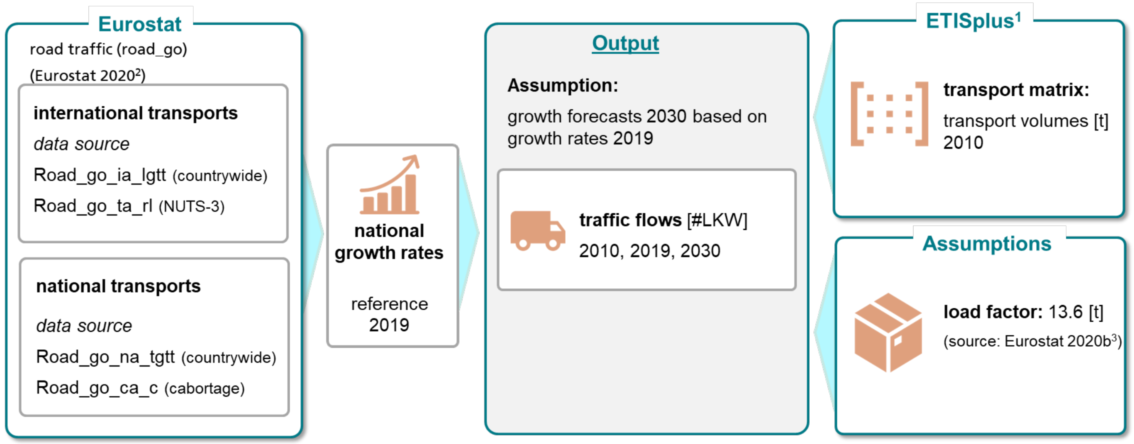
Normally distributed operating process

Source: Based on D. Speth et al. (2022): Public fast charging infrastructure for battery electric trucks – a model-based network for Germany. https://doi.org/10.1088/2634-4505/ac6442.

Icons: Francesco Terzini, Maxim Kulikov from Noun Project

Data and scenarios: Updated ETISplus dataset as basis for modelling

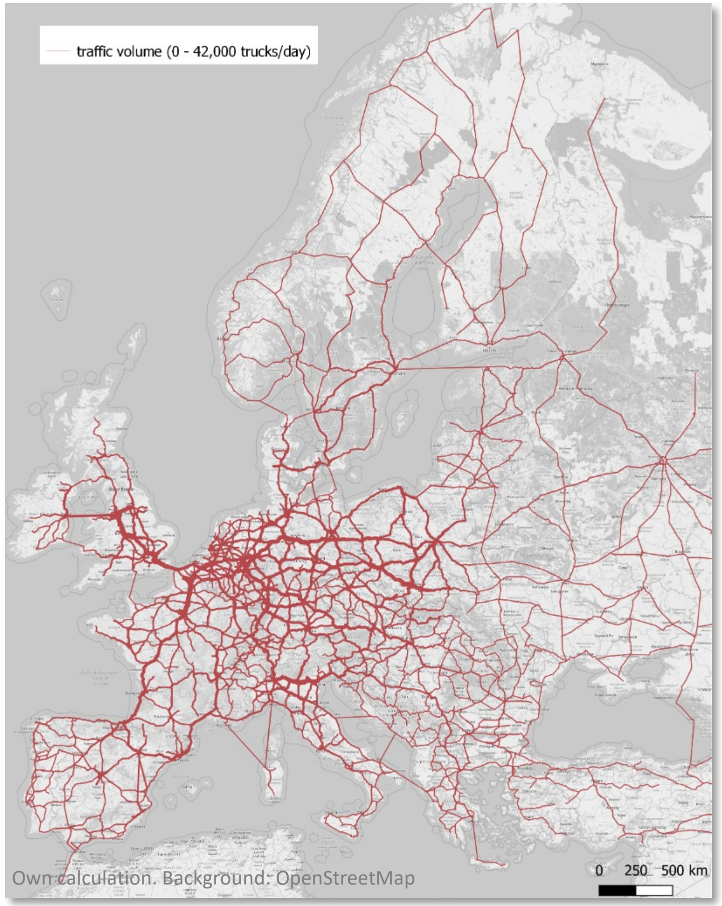
data preparation



resulting dataset:

- traffic flows between 1,675 regions in Europe
- 1,514,573 individual paths in Europe
- → published dataset: 0.17632/py2zkrb65h.1
- → published description: 10.1016/j.dib.2021.107786

traffic flows in Europe 2030



[1] E. Szimba et al. (2013), ETISplus Database Content and Methodology: ETISplus Deliverable D6. Zoetermeer. https://doi.org/10.13140/RG.2.2.16768.25605.

[2] road traffic (road_go) 2020. https://ec.europa.eu/eurostat/web/transport/data/database

[3] load factor 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php/Road_freight_transport_by_journey_characteristics#Road_transport_by_type_of_operation

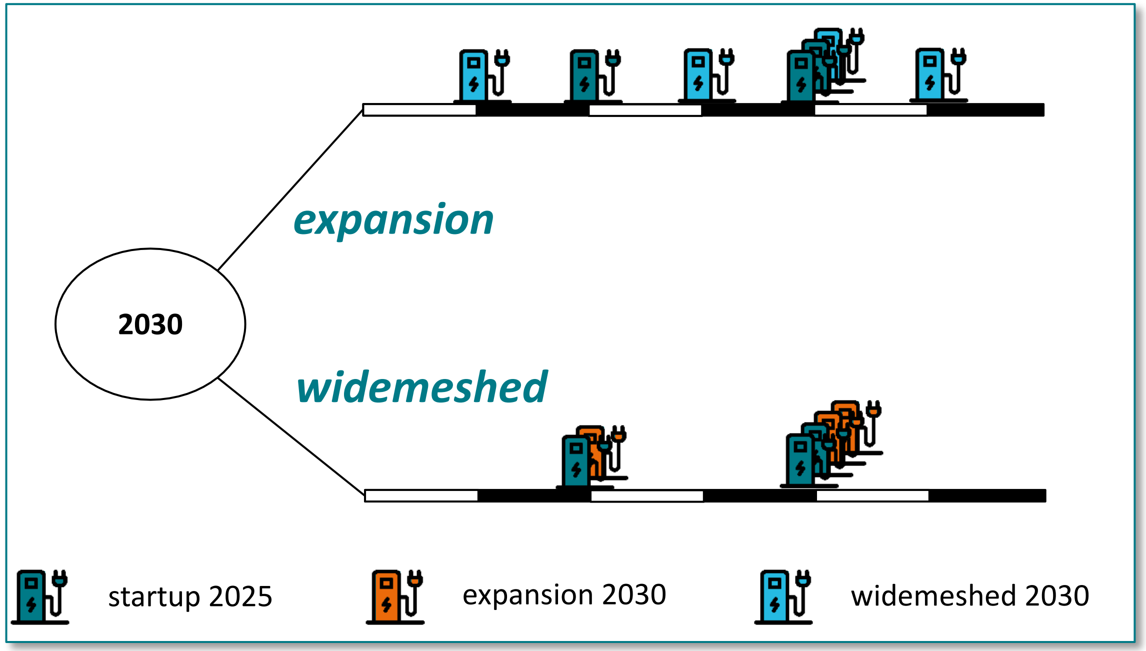
Data and scenarios: Basic assumptions for the design of three scenarios

general parameters

parameter	value
cumulative annual mileage	188,719 Mio. km (2025)[1] 215,042 Mio. km (2030)[1]
range in 4.5 h	300 km[2]
share of public charging	25%[2,3]
average charging time	30 min[2]
average waiting time	5 min[2]
share of daily charging events in most trafficked hour	6%[2]

scenarios	distance	share BET
startup 2025	100 km	5%
expansion 2030	50 km	15%
widemeshed 2030	100 km	15%

simplified draft



The scenarios consider an initial network for 2025 and describe two options for further development for 2030.

[1] D. Speth, V. Sauter, P. Plötz, and T. Signer, "Synthetic European road freight transport flow data," Data in brief, vol. 40, 2022, http://doi.org/10.1016/j.dib.2021.107786
[2] D. Speth et al. (2022): Public fast charging infrastructure for battery electric trucks – a model-based network for Germany. https://doi.org/10.1088/2634-4505/ac6442.
[3] Expert opinion from HoLa, HoLa-Hochleistungsladen Lkw-Fernverkehr: Construction, operation and accompanying research for the first megawatt charging systems for trucks in Europe. [Online]. Available: https://www.hochleistungsladen-lkw.de/hola-en/ (accessed: Oct. 6 2021)
Iconquelle: NounProject by Ayub Irawan

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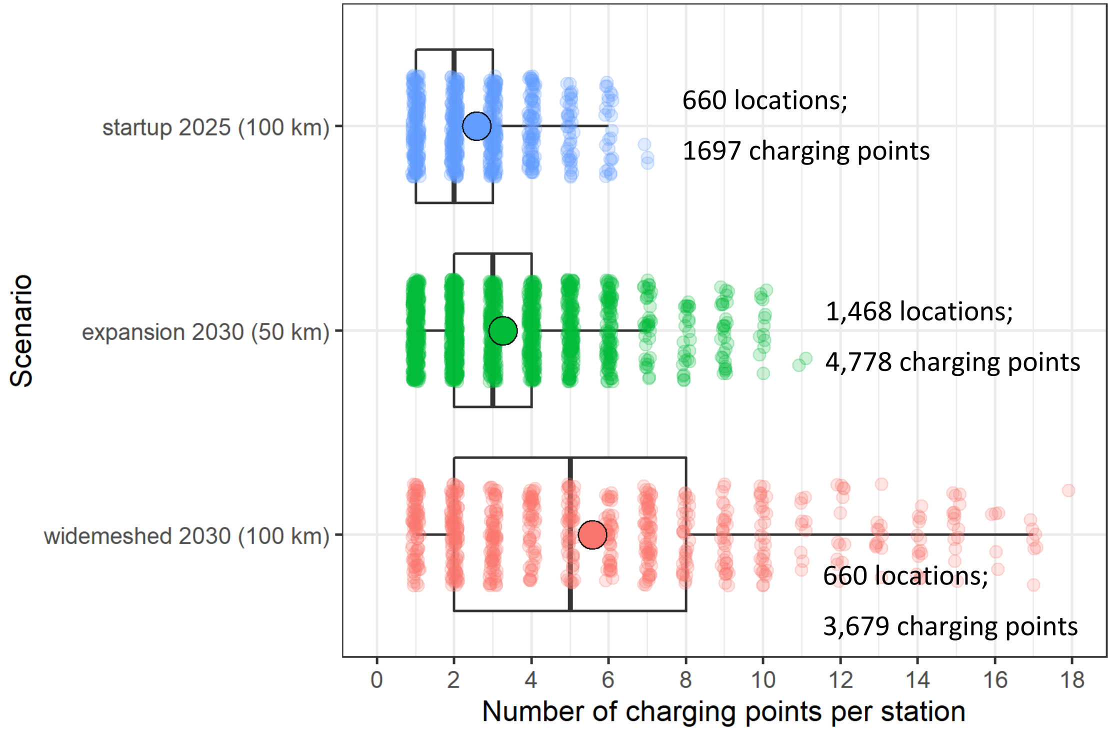
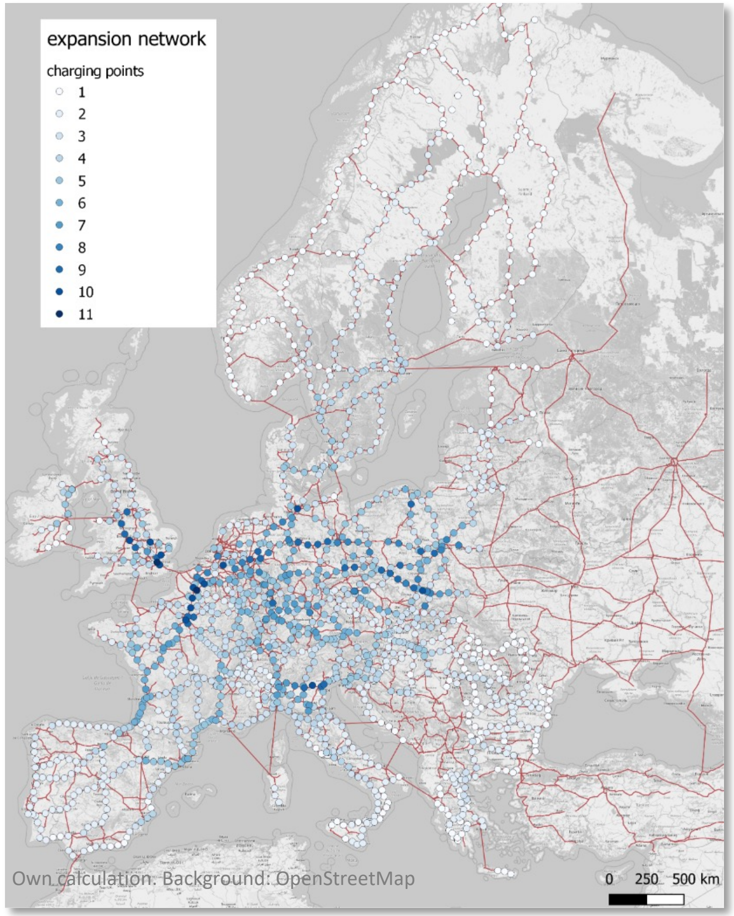
Results: distribution of charging points

charging point distribution



expansion network EU27+3



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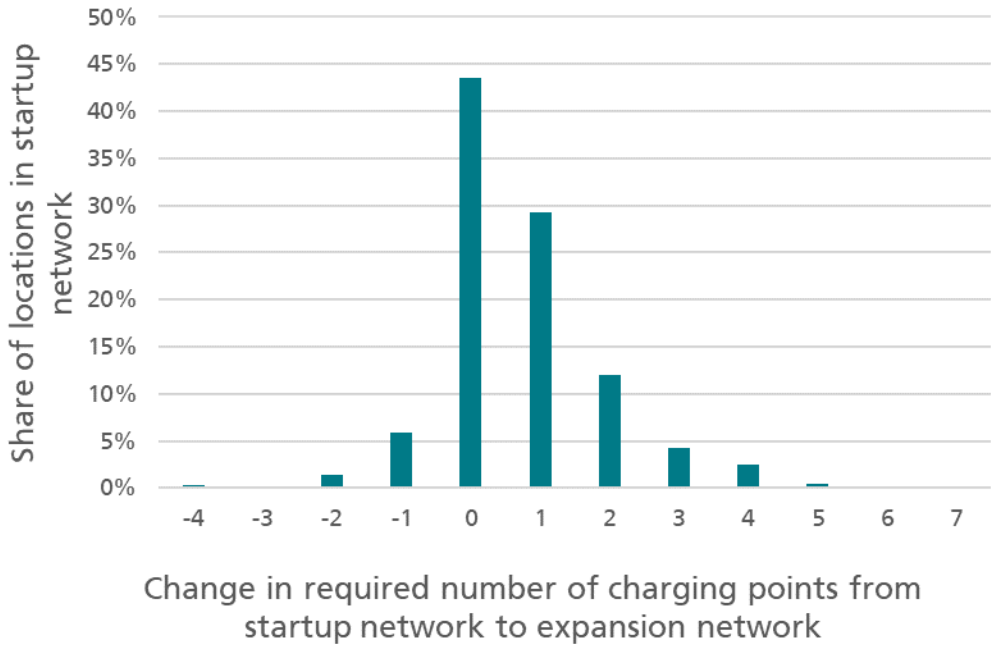
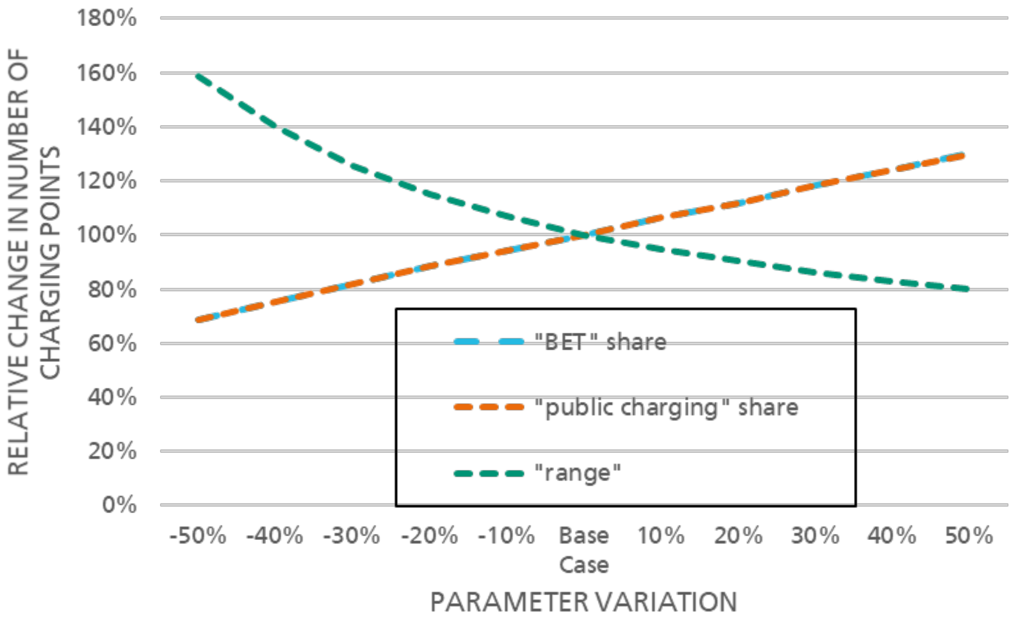
Results: Change of charging points from startup network to expansion network; influence of relevant parameters

change from startup network to expansion network



sensitivity analysis (expansion network)



Due to the densification of the startup network to the expansion network, the size of stations already built in the startup network varies only slightly when tripling the electric mileage.

Outlook

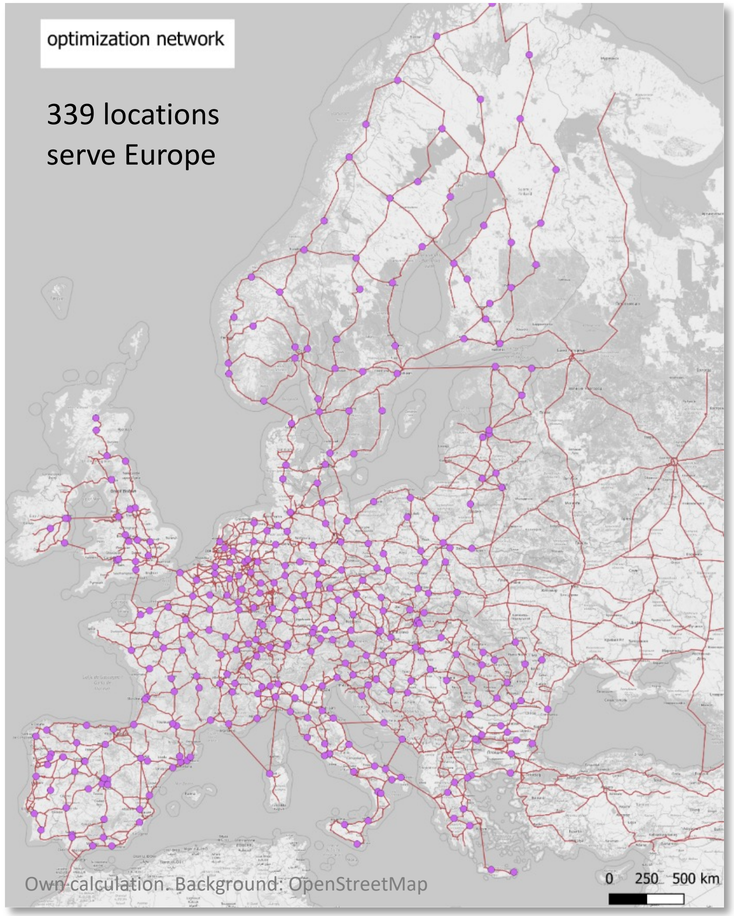
Demand for future research

- Presented models gives a first impression, how a future charging infrastructure for trucks might look like.

Future topics:

- Several assumptions with high influence on the results should be further investigated in the future
- Aspects like available parking areas and power grid connection have to be considered in detailed planning
- Comparison with flow-based and tour-based models will increase the understanding for charging infrastructure for trucks

outlook: optimization EU27+3



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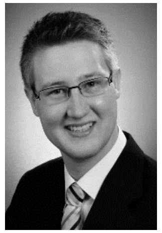
Thank you!



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- High Power Charging for Trucks -

STORM

Smart freight TranspOrt and logistics research Methodologies

Backup

Data quality of the updated ETISplus dataset with Germany as an example

procedure and findings

procedure:

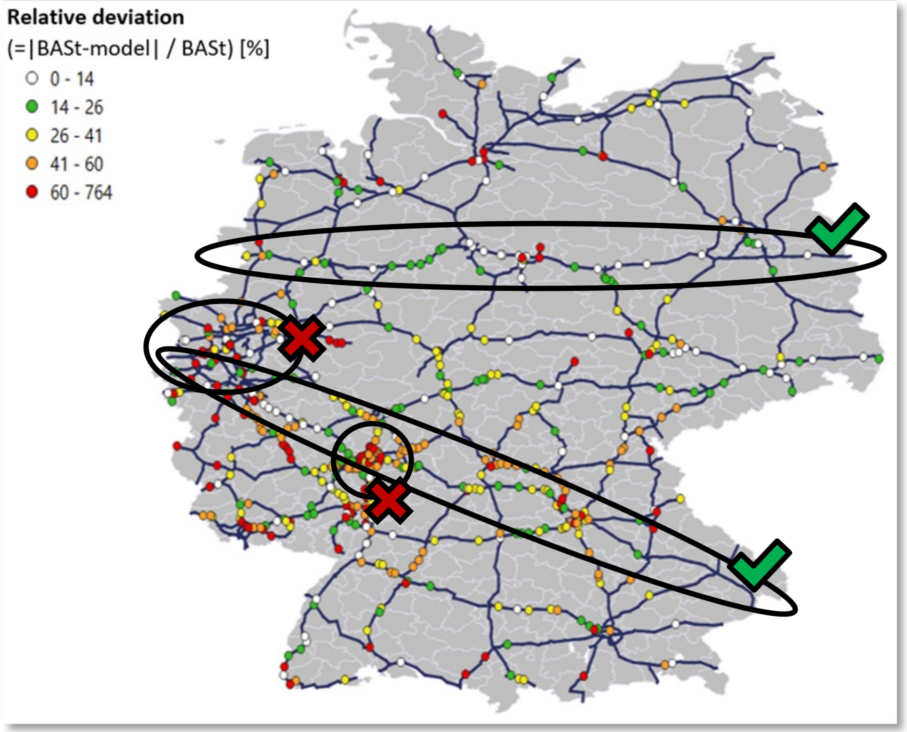
- comparison of synthetic road counts (updated ETISplus dataset) with automated traffic counts[1]

findings:

- high consistency on typical long-haul routes
- low consistency in urban areas where highways are also used for regional traffic

→ updated ETISplus dataset suitable for long-haul modelling and public charging

deviation in Germany



[1] BASt (2019): Automatische Zählstellen 2018. https://www.bast.de/BASt_2017/DE/Verkehrstechnik/Fachthemen/v2-verkehrszaehlung/Aktuell/zaehl_aktuell_node.html.

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regional distribution of charging points in three scenarios