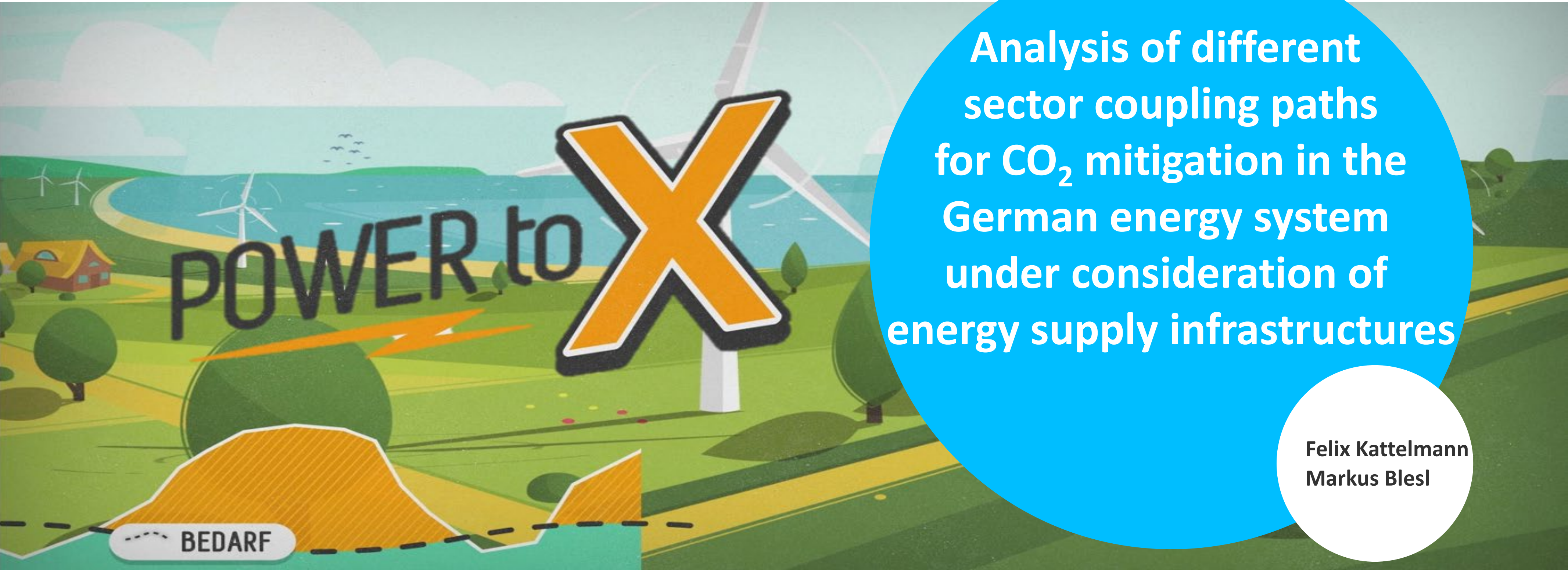
University of Stuttgart
IER Institute of Energy Economics
and Rational Energy Use



Analysis of different sector coupling paths for CO_2 mitigation in the German energy system under consideration of energy supply infrastructures

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Source: Forschungszentrum Jülich/Tricklabor for the Kopernikus project “Power-to-X”

Outline

1. Introduction
2. TIMES Model
    - General modelling approach
    - Implementation of trolley trucks
    - E-Mobility
    - Scenario Analyses
3. Results
4. Conclusion

Motivation

German national targets for reducing the Greenhouse Gas emissions compared to 1990 [1]

	2015	2020	2030	2040	2050
overall GHG emissions	-27.2%	-40%	-55%	-70%	-80% to -95%

- ambitious goals for GHG emission reductions
- almost complete decarbonisation of the entire German energy system necessary
- need of renewables in heat and transport sector
- potentials of renewables mostly in electricity sector

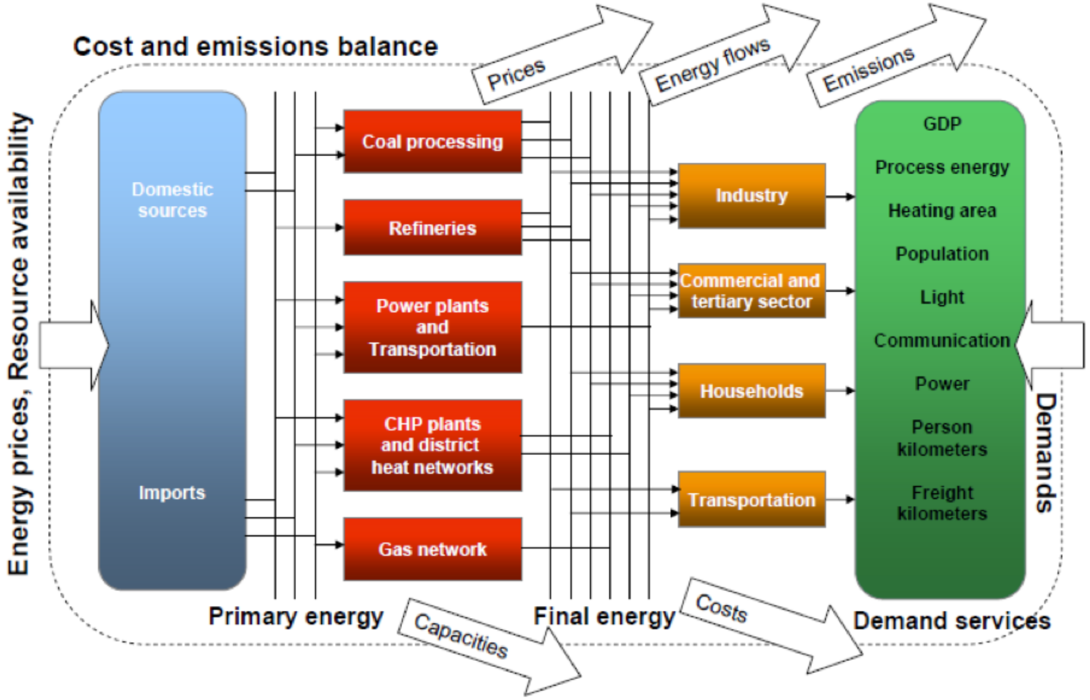
→ sector coupling

TIMES-D model

TIMES-D model

General modelling approach

- depiction of the **entire German energy system**
- **linear optimization**: total system costs minimized
- complete competition between different technologies assumed
- **GHG emissions** of the system are recorded
- division into **280 time segments of 3 hours** each
- model horizon: **2010-2050**
- determination of the **economically optimal energy supply structure** for a given target



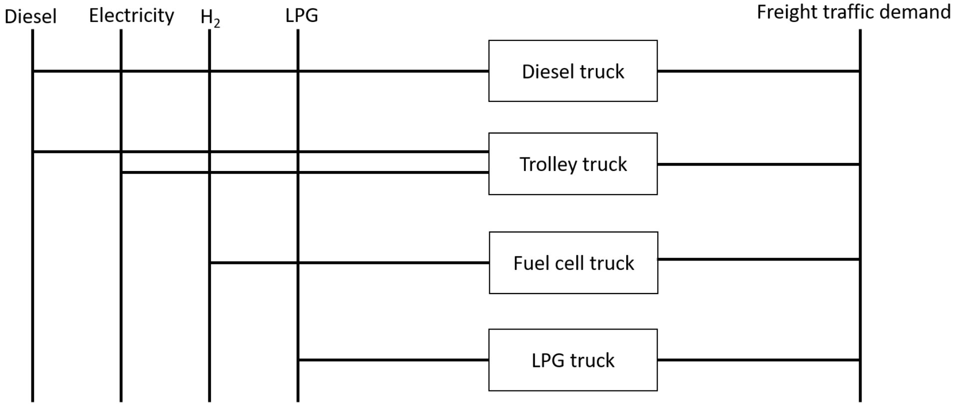
TIMES-D model

Implementation of Trolley Trucks

technology characteristics

- electrically powered trucks
- energy supply via pantograph and **overhead lines**
- **construction of the necessary infrastructure** over motorways (as discussed) **cost-intensive**

picture: dpa/picture-alliance



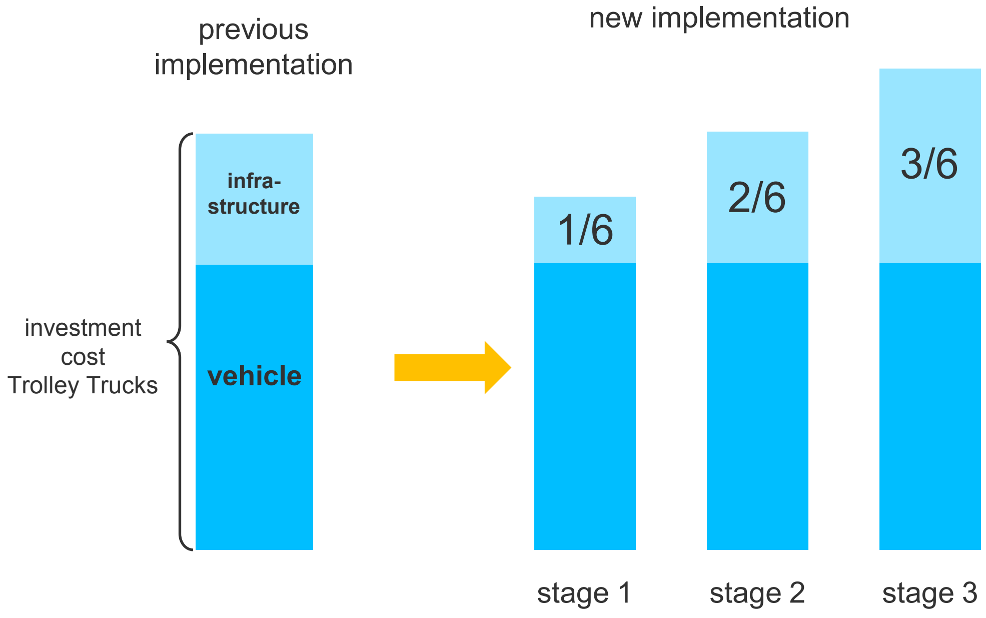
modelling

- one of multiple technologies in transport sector
- selection of technologies in model dependent on process-costs (amongst other things) e.g. investment or maintenance costs
- contribution to meeting the freight traffic demand limited to **90%**

TIMES-D model

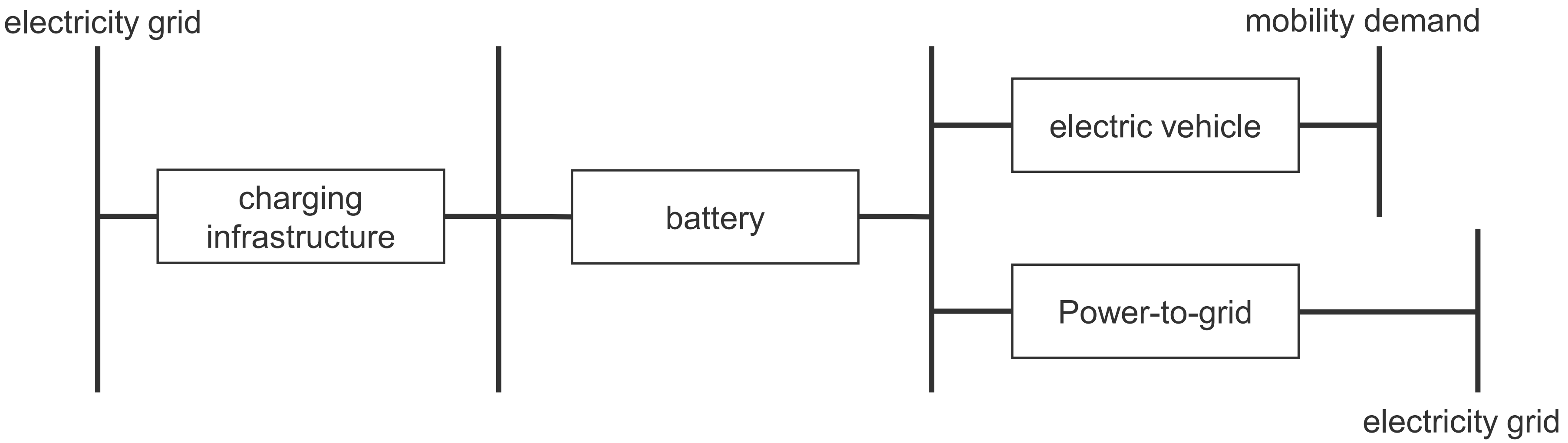
Implementation of Trolley Trucks – more accurate modelling of infrastructure

- costs for complete electrification of motorways **distributed over assumed max. number of vehicles**
- problem: clear **differences in the utilisation of motorways** in Germany
- overhead lines over heavily used motorways can **power more vehicles** than over low-frequented ones
- <u>**new implementation**</u>
  - **infrastructure costs distributed unevenly** over three stages
  - stage 1: 1/3 of vehicles but 1/6 of infrastructure
  - **potential of one stage limited** to 1/3 of the max. overall contribution from Trolley Trucks



TIMES-D model

Modelling of e-mobility



- e-mobility: **all electrically operated vehicles in transport sector** (except for heavy goods traffic and trains)
- sufficient charging infrastructure **has to be used** to charge the batteries
- Power-to-grid possible
- one of multiple technology pathways in transport sector

TIMES-D model

scenario analyses

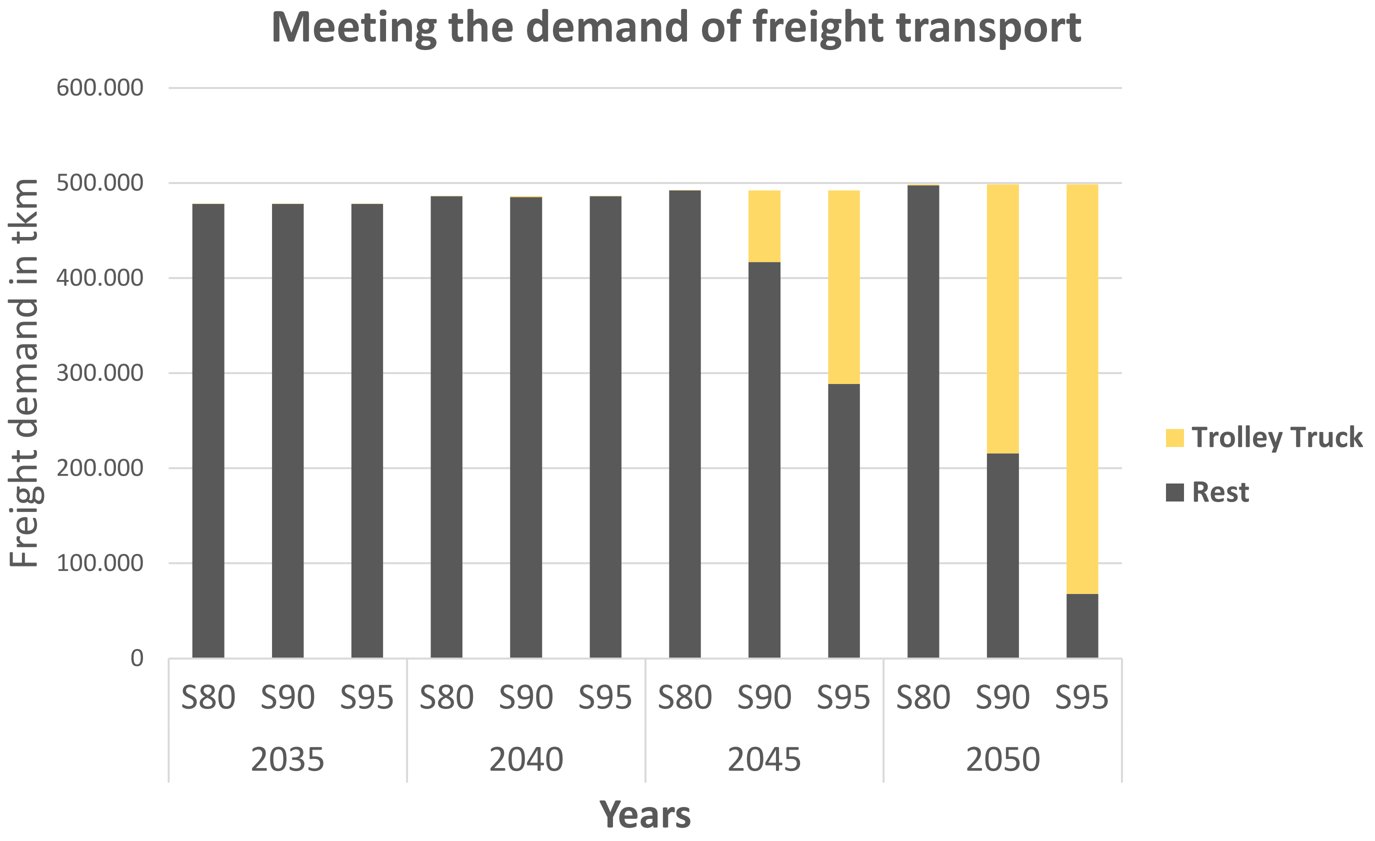
- gradual reduction of the system‘s **GHG emissions**
- three scenarios with great **differences in the long-term reduction targets**
- Trolley Trucks: scenario S90 with and without **disaggregated infrastructure**
- analysis of the charging infrastructure‘s influence
- **share of simultaneously usable infrastructure** limited to 10%, 50% and 90%

	scenario	2020	2030	2050
Reduction of overall GHG emissions	S80	-40%	-55%	-80%
	S90	-40%	-55%	-90%
	S95	-40%	-58%	-95%

Results

Results

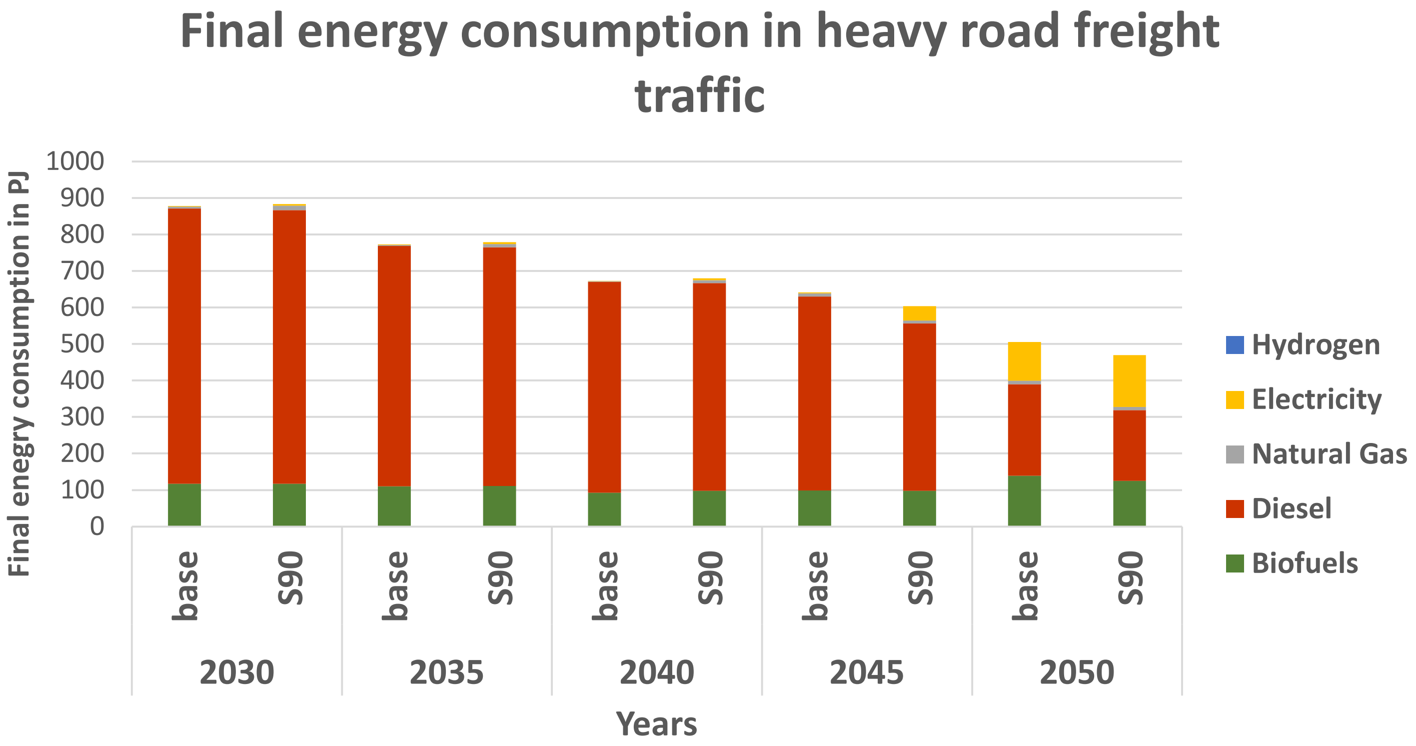
Freight Traffic – potential of the Trolley Truck



- huge discrepancy between the scenarios:
  - **entire possible demand** provided by Trolley Trucks in S95
  - **no usage** at all in S80
- deployment of trolley trucks **highly dependent** on the selection of **GHG reduction targets**

Results

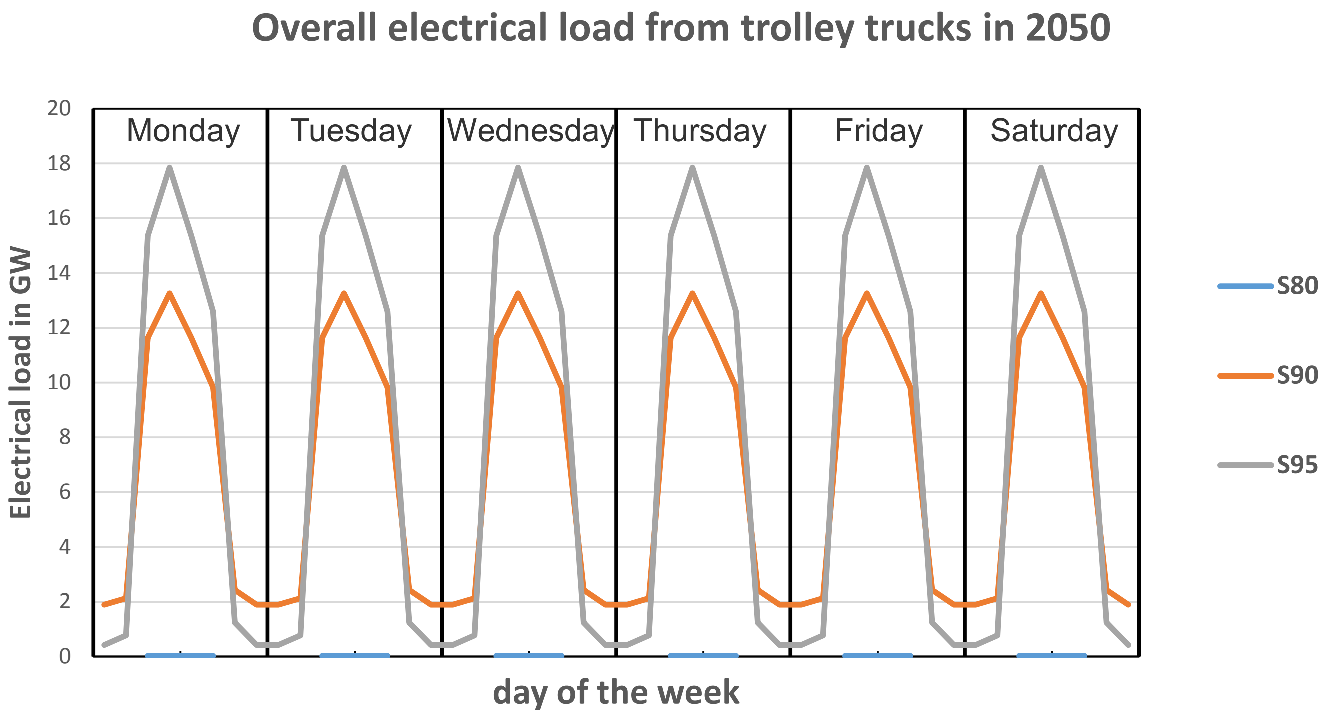
Freight Traffic – influence of disaggregated infrastructure modelling



- share of electricity:
  - **30%** (disaggregated infrastructure)
  - **21%** (base)
- usage of Trolley Trucks **depends strongly** on the **modelling of infrastructure**

Results

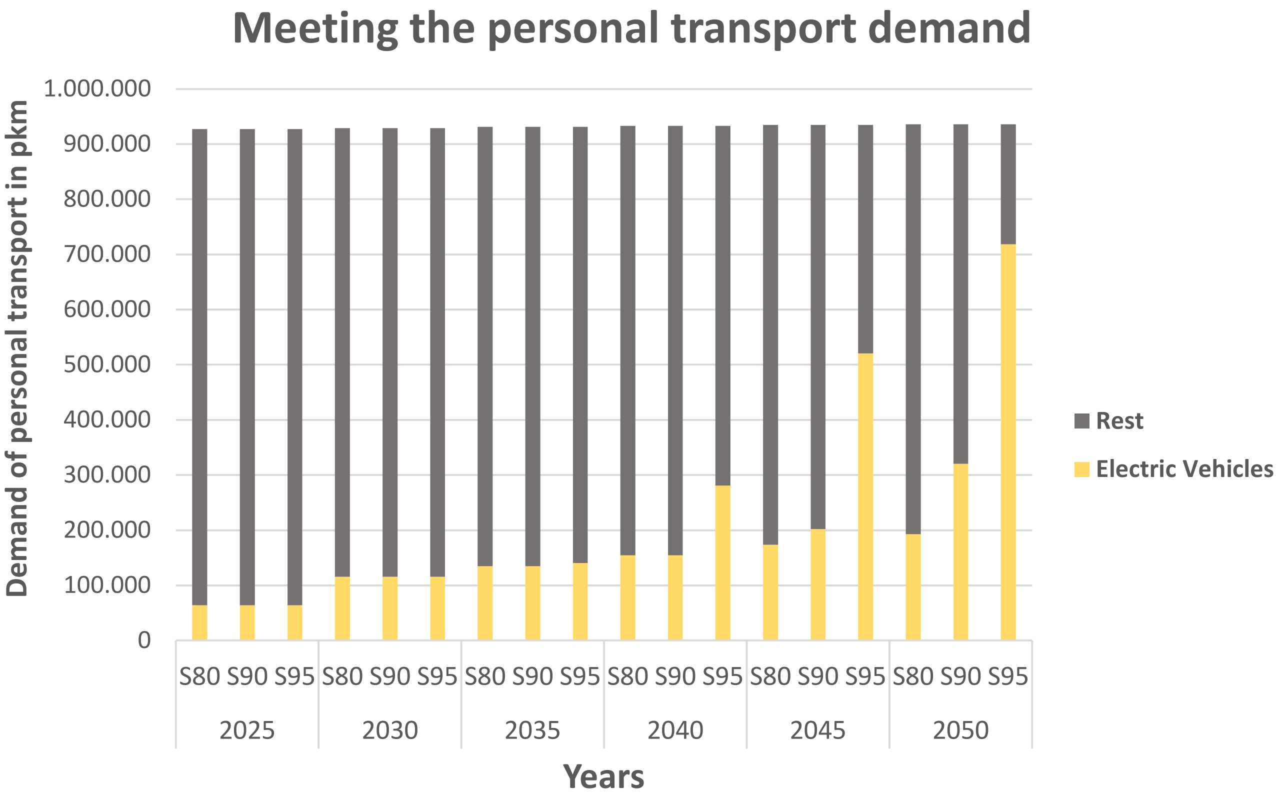
Freight Traffic



- **13.3 GW** additional load in S90
- **18 GW** additional load in S95
- load directly dependent on driving behaviour

Results

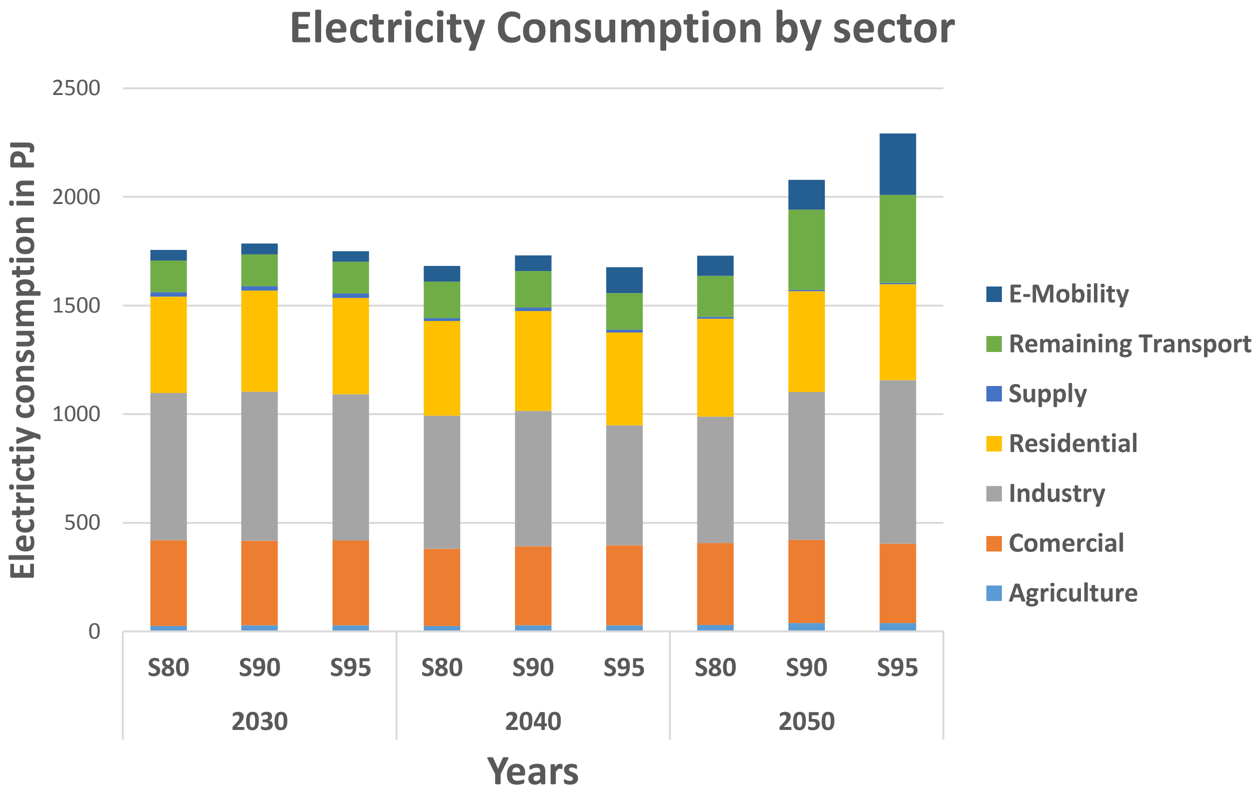
E-Mobility



- no difference between the scenarios until 2035
- contribution of electric vehicles varies between **21%** (scenario S80) and **75%** (S95) in 2050
- **choice of the long-term** target has a **major impact** on the utilization of electric vehicles

Results

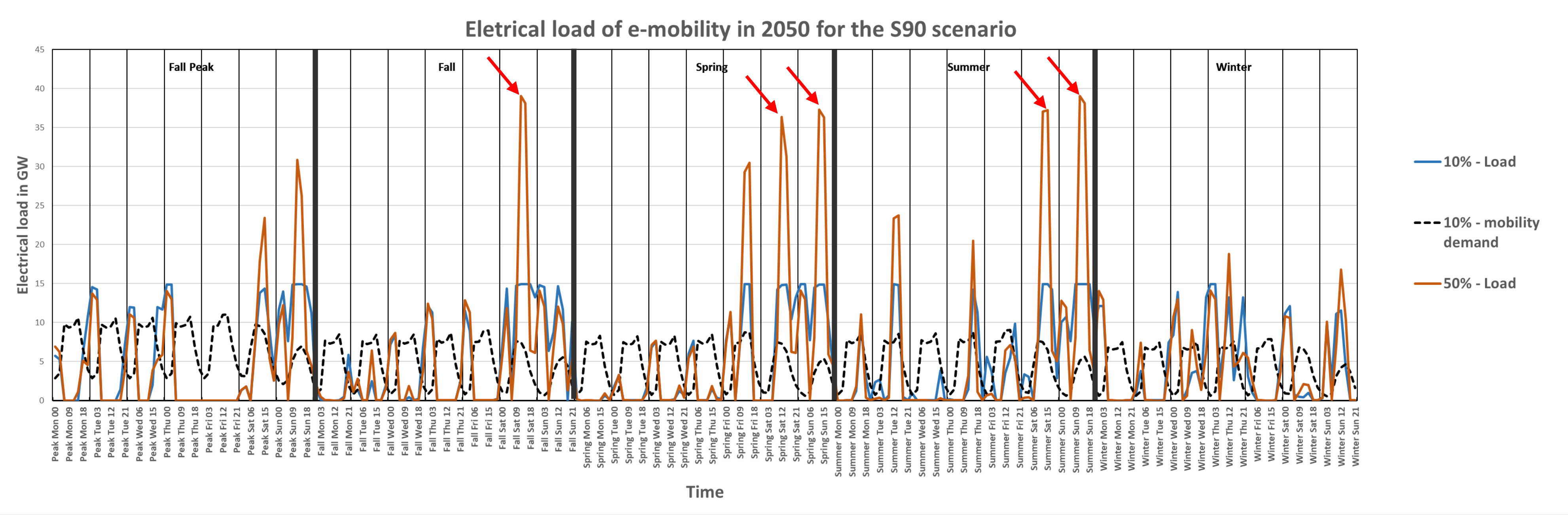
E-Mobility



- higher electricity consumption in 2050 due to electrification of all sectors
- in the S95 scenario e-mobility accounts for **10%** of the total power consumption in 2050 **(280 PJ)**
- S95: 190 PJ more by e-mobility compared to S80

Results

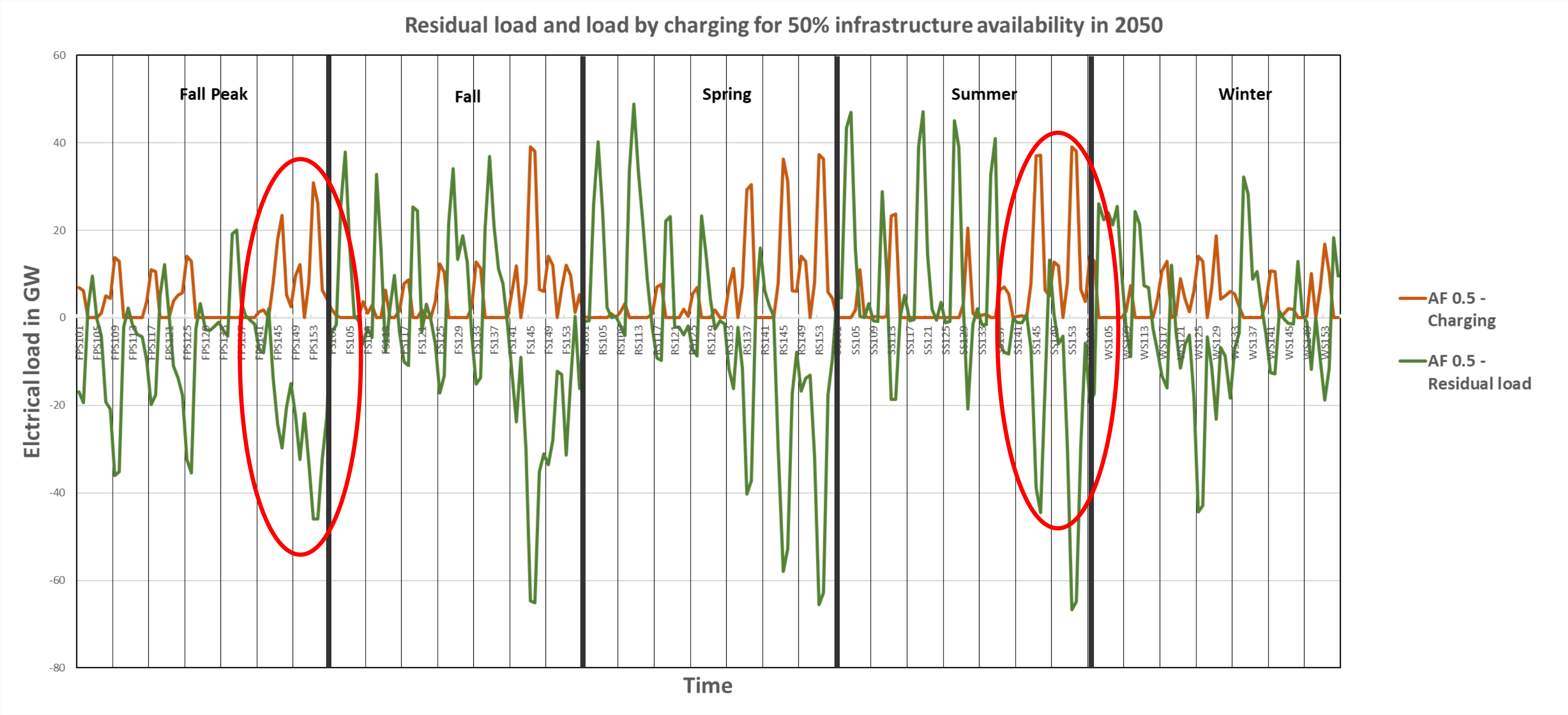
E-Mobility – electrical load caused by charging



huge peaks for 50% availability

Results

E-Mobility – residual load and load by charging



Conclusion

Conclusion

- contribution of the Trolley Truck **heavily dependent** on the choice of emission reduction targets with **no usage** at all in the S80 scenario
- maximal **electrical load of trolley trucks is 18 GW**, likely to vary significantly between different regions
- **significant influence of detailed modelling of infrastructures** on the results of Trolley Truck analyses
- **GHG emission reduction targets with major impact on the utilisation of e-mobility** (varying between 21% and 75%)
- the load caused by charging electric vehicles can be regulated by limiting the simultaneousness of the charging infrastructure
- by not limiting the simultaneousness e-mobility can serve as a **very useful flexibility option**, causing large **additional loads of around 40 GW** however

References

[1] BMWi, “Die Energie der Zukunft - Vierter Monitoring-Bericht zur Energiewende,” Bundesministerium für Wirtschaft und Energie (BMWi), Tech. Rep., 2015.

[2] Bundesministerium für Wirtschaft und Energie, “Energieeffizienz in Zahlen,” Tech. Rep., 2017.

[3] M. Wietschel et al., “Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw,” Fraunhofer ISI, Tech. Rep., 2017.

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Thank you!

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