Integration of Electric Transportation

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Agenda

- **Balancing of electrical system with electric transportation**
  - **Charging**
  - **Discharging**
  - **Electric Road Systems (ERS)**

- EVs in the distribution grid
  - Current limitations
  - Voltage limitations

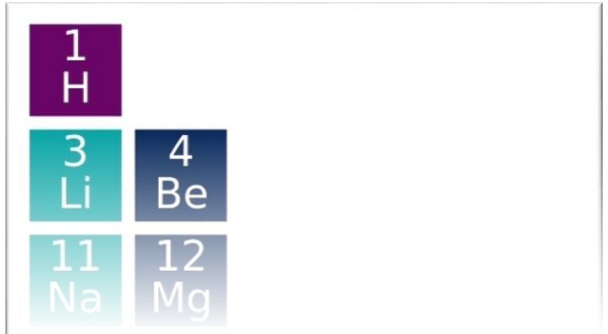
Balancing

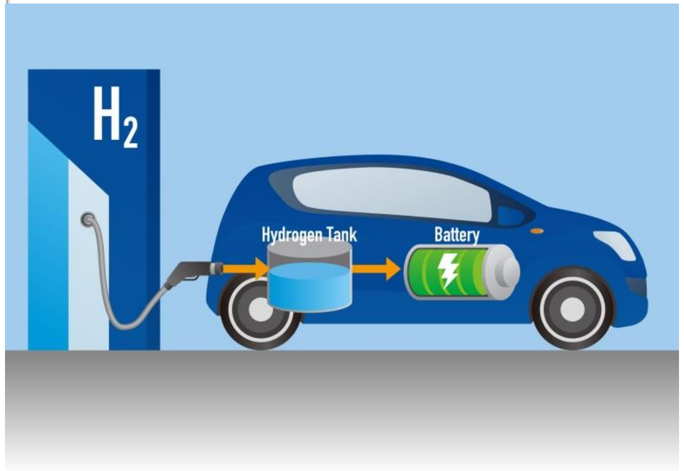
Flexibility

Electric road system (ERS)

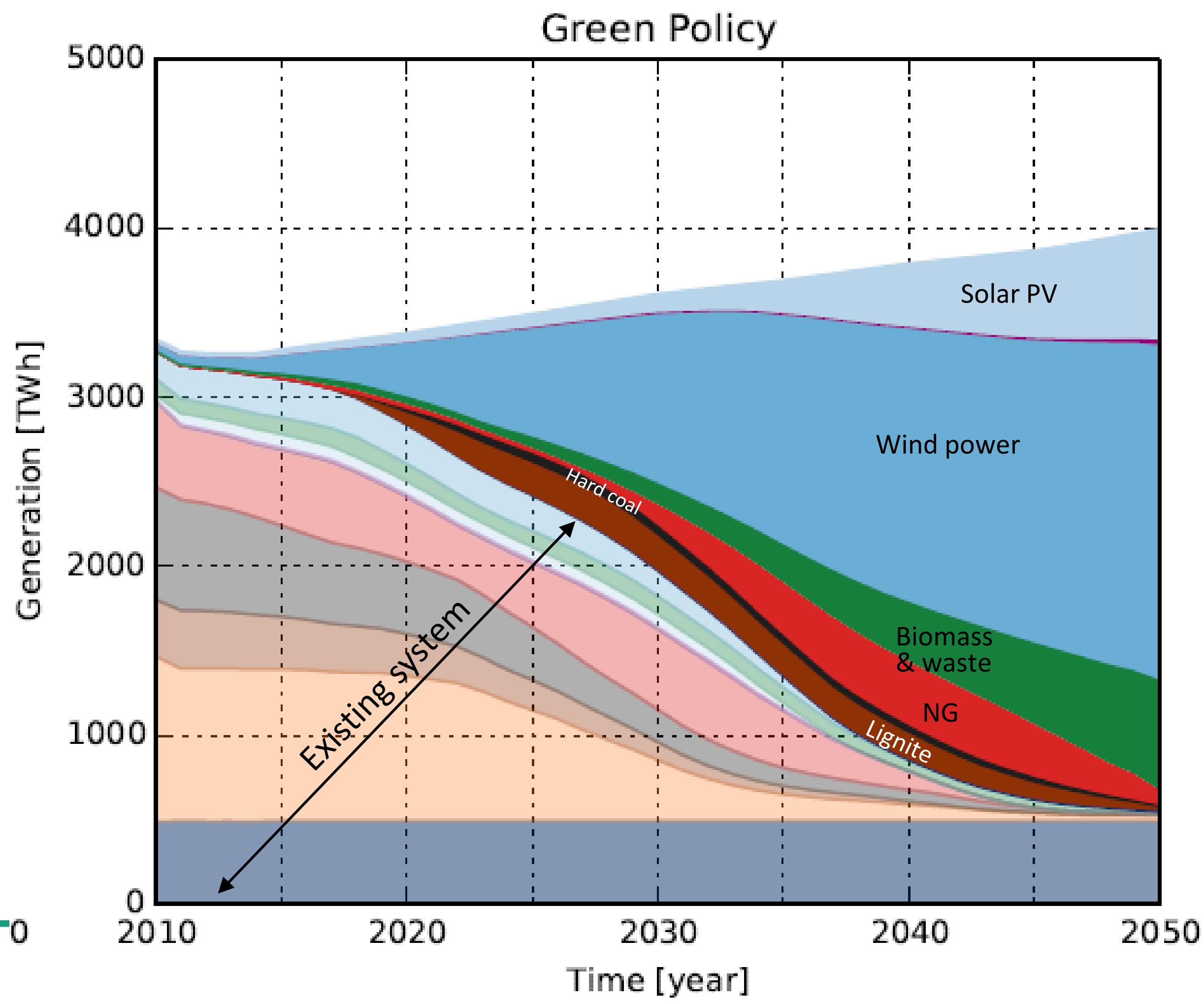
Static charging / discharging (V2G)

Electrofuels





Europe (EU-27+NO+CH): Generation up to 2050
Green Policy scenario



Odenberger et al. (forthcoming)

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Balancing - Models

- To investigate how an electrification of the transport sector could impact the Swedish and German electricity system with respect to energy and power

- Application of two different electricity systems models - developed at Chalmers and Fraunhofer IEE
  - Models developed entirely independently from each other

- Initial work carried out within the CollERS project – an ERS project supported by

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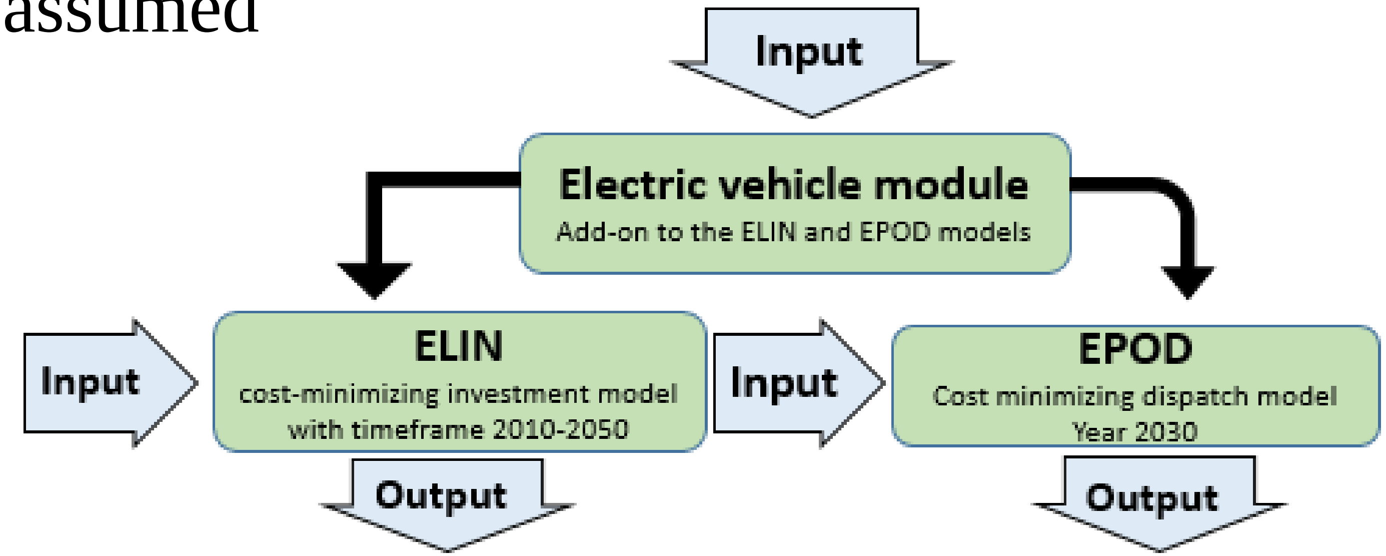
SWEDISH TRANSPORT ADMINISTRATION

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

Balancing
Chalmers' ELIN/EPOD models

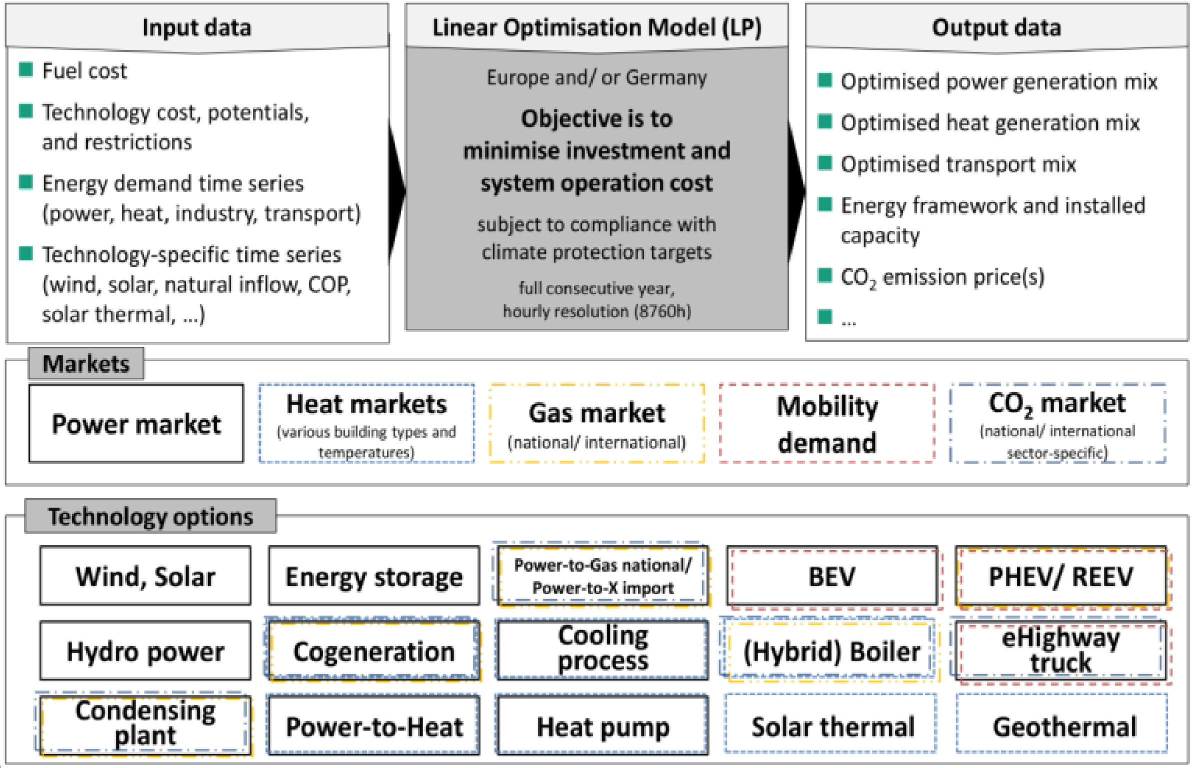
- Electric vehicles: 20% share of total fleet by 2030 and 60% by Year 2050 in all European countries
- A cap on CO_2 corresponding to 99% emission reduction by 2050 relative 1990 emissions *for the electricity sector* is assumed



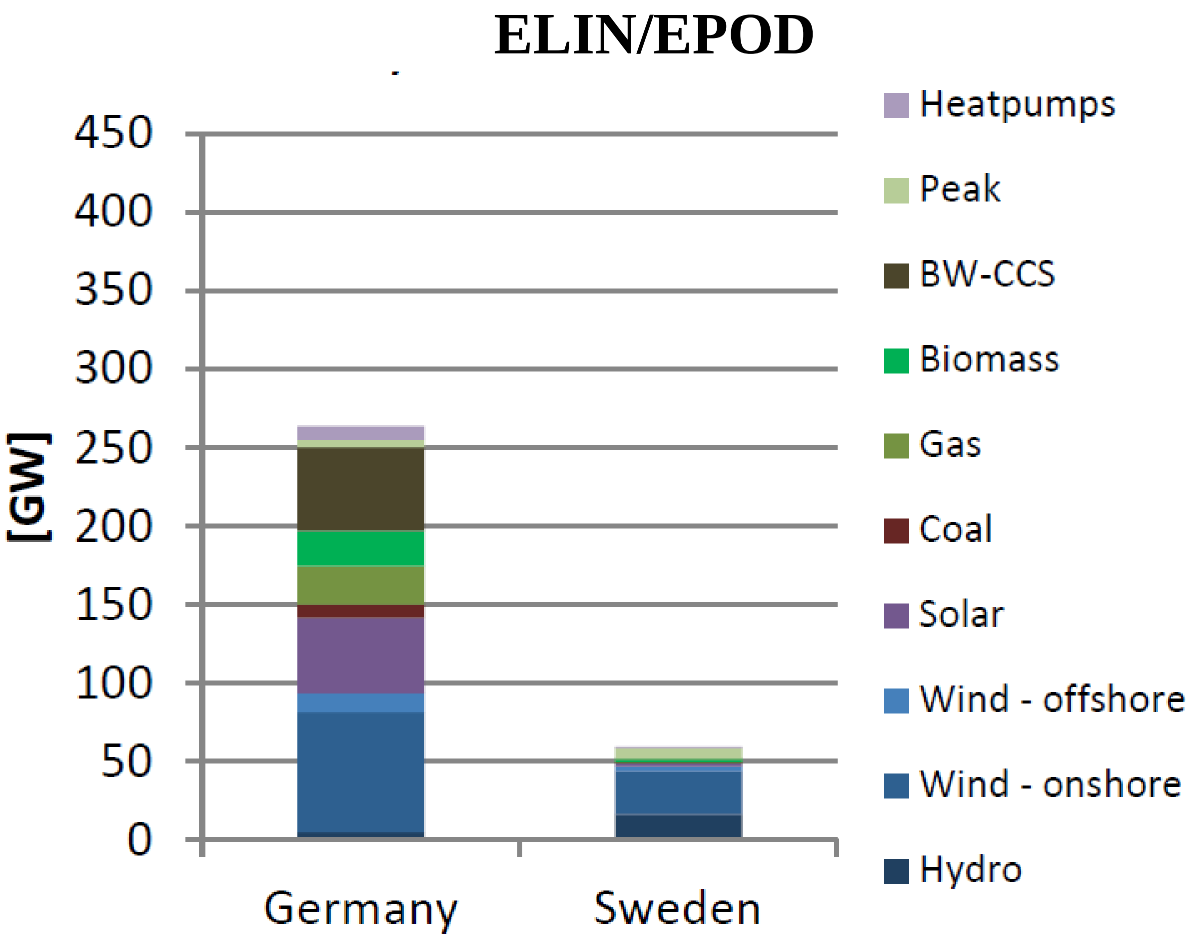
Balancing

Fraunhofer IEE's SCOPE model

- A cap on CO_2 corresponding to 95% emission reduction by 2050 relative 1990 emissions for the *electricity sector and transportation* is assumed

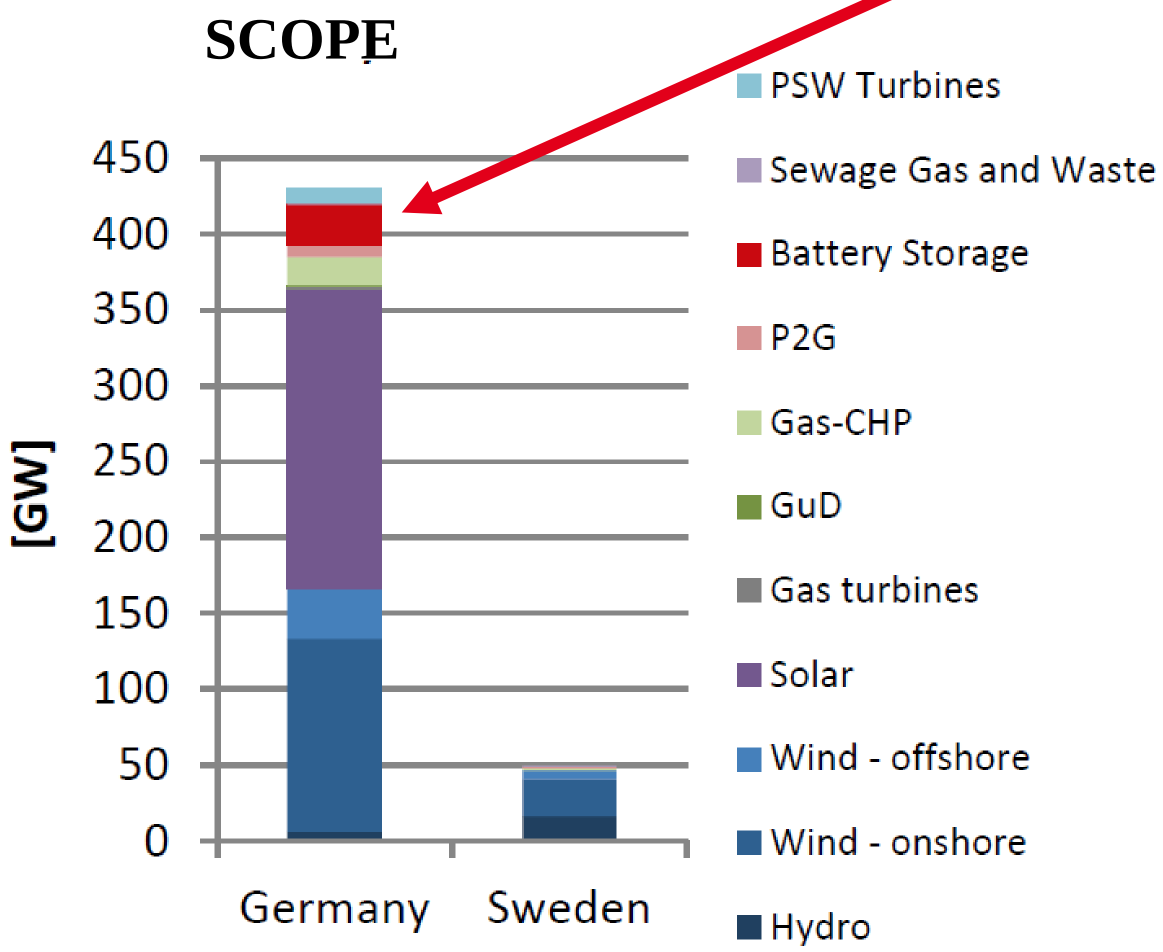


Installed capacity 2050
optimized charging (no discharging)



Incl. CCS in Germany
Biomass used to offset CCS emissions

Stationary storage



CCS not considered in Germany

Higher full load hours for CCS plants than for VG
⇒ less total capacity in the ELIN model for Germany

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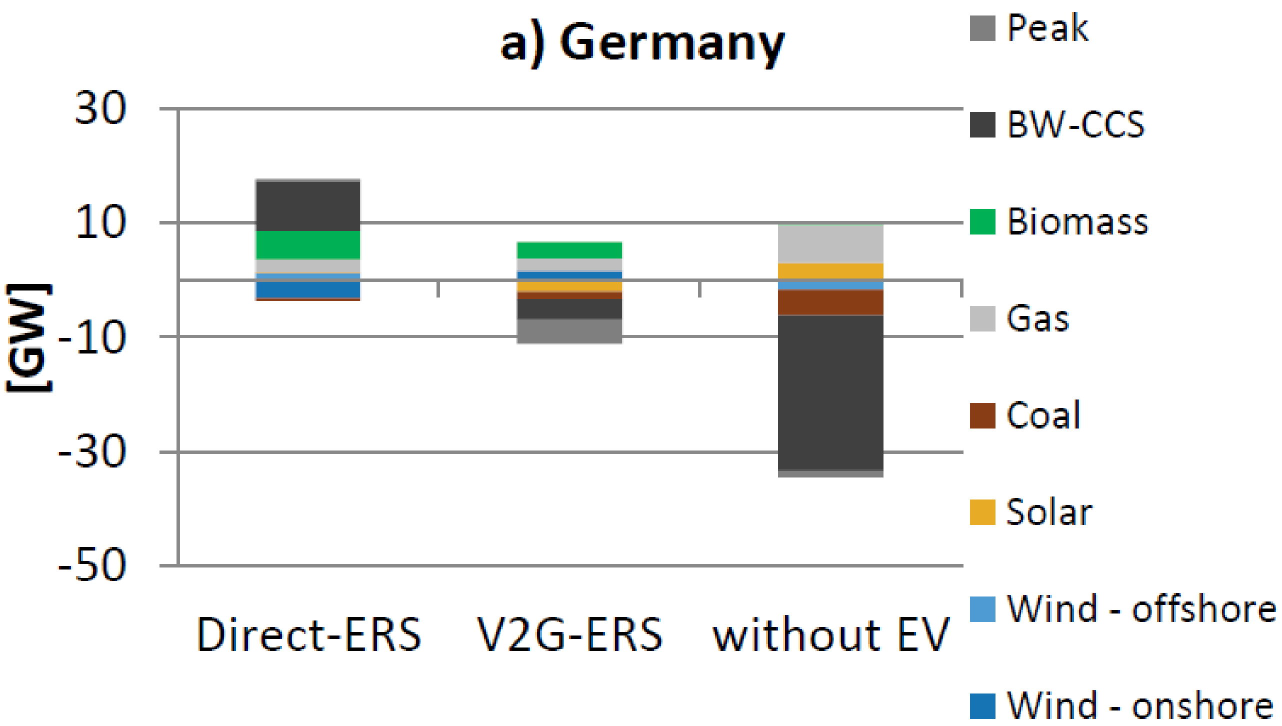
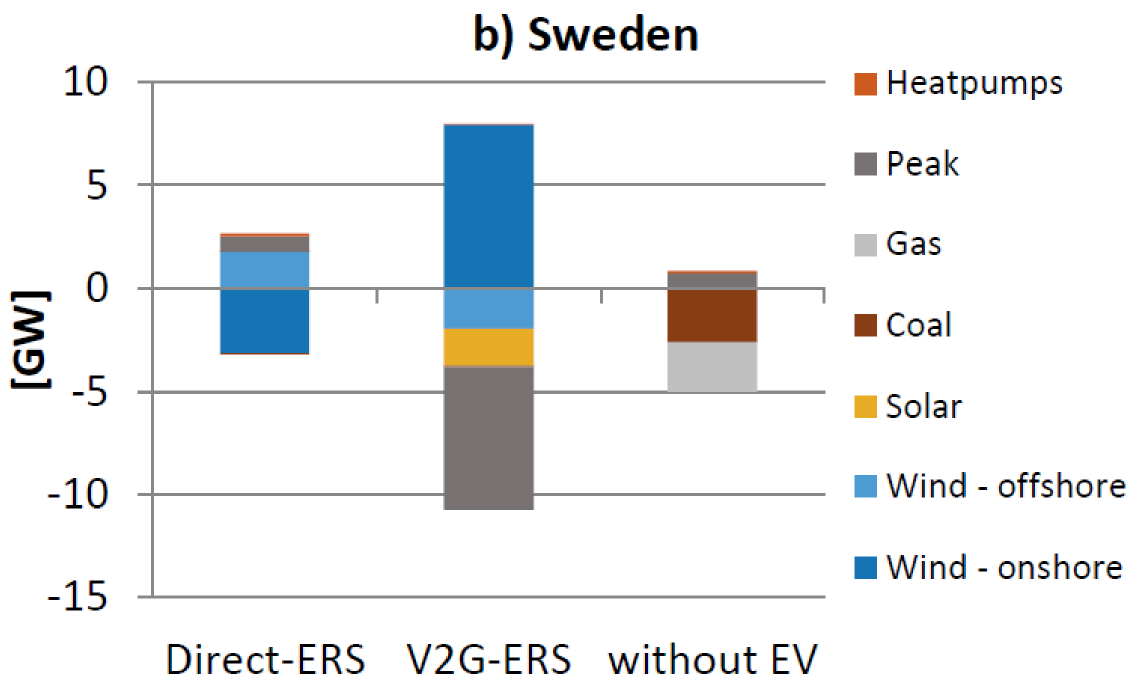
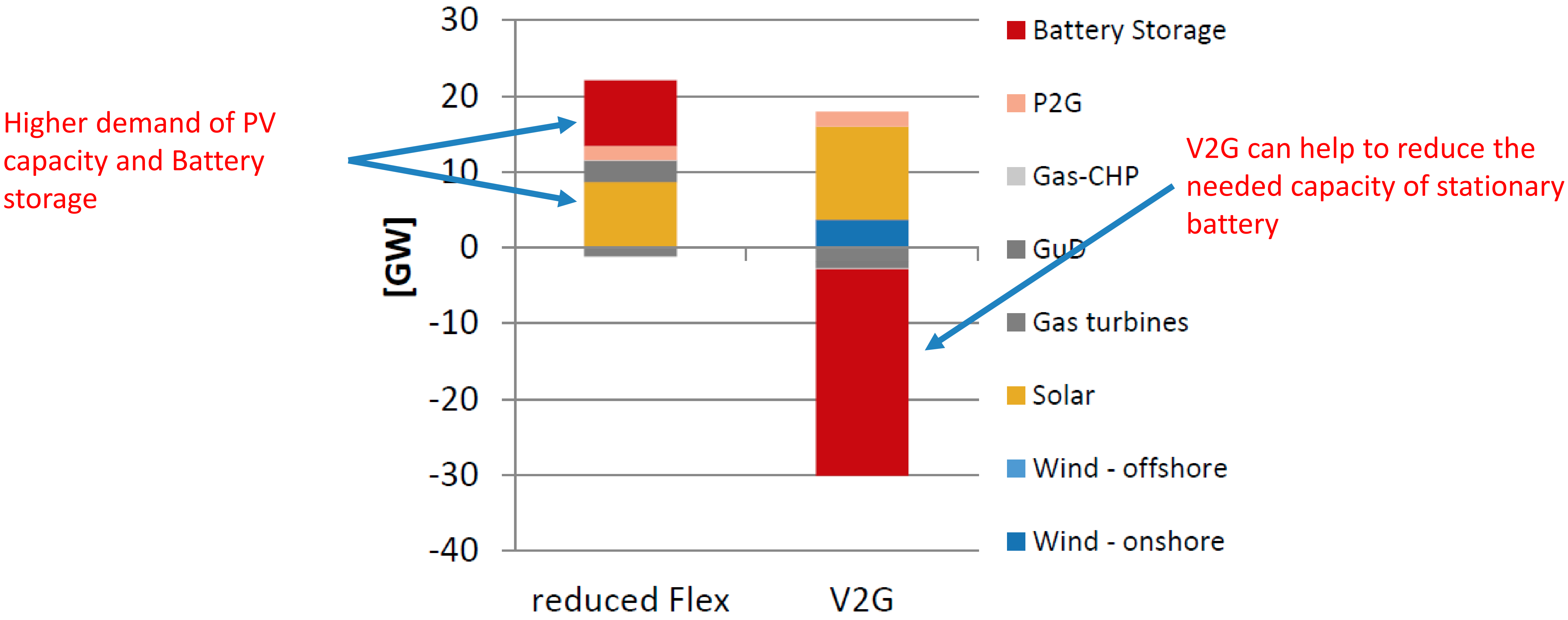
Difference between investments in the *optimized charging* case vs *direct charging*, *optimized charging+V2G* and *without EV* ELIN model





V2G help reducing need for peak power capacity

Difference between investments in the *optimized charging* case vs *reduced flexibility, optimized charging+V2G*
SCOPE model



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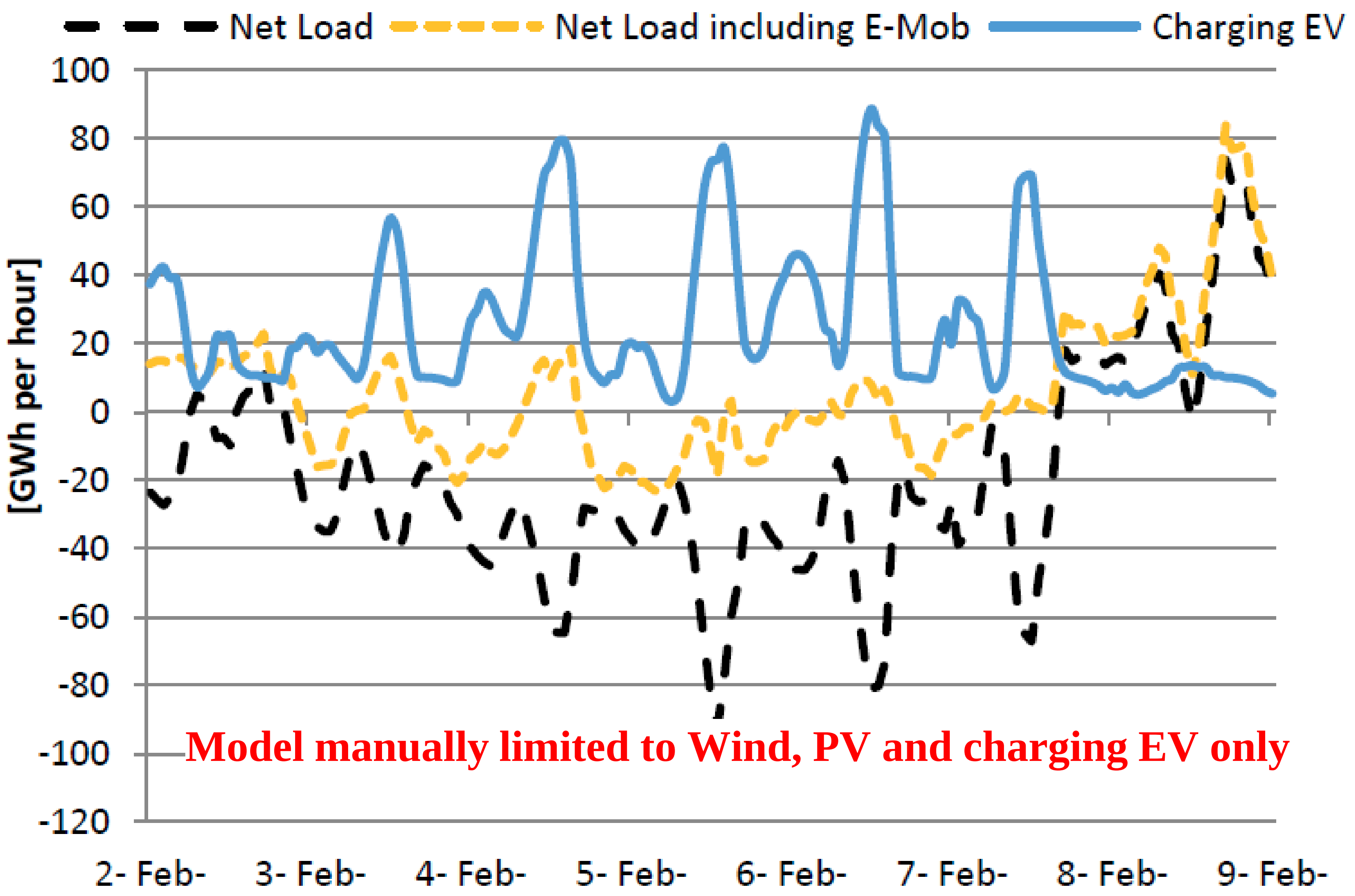
Net load - load minus wind and solar generation
One week in February in Germany (SCOPE model)

Controlled charging of EV can help to smooth the generation of wind and solar PV



Agenda

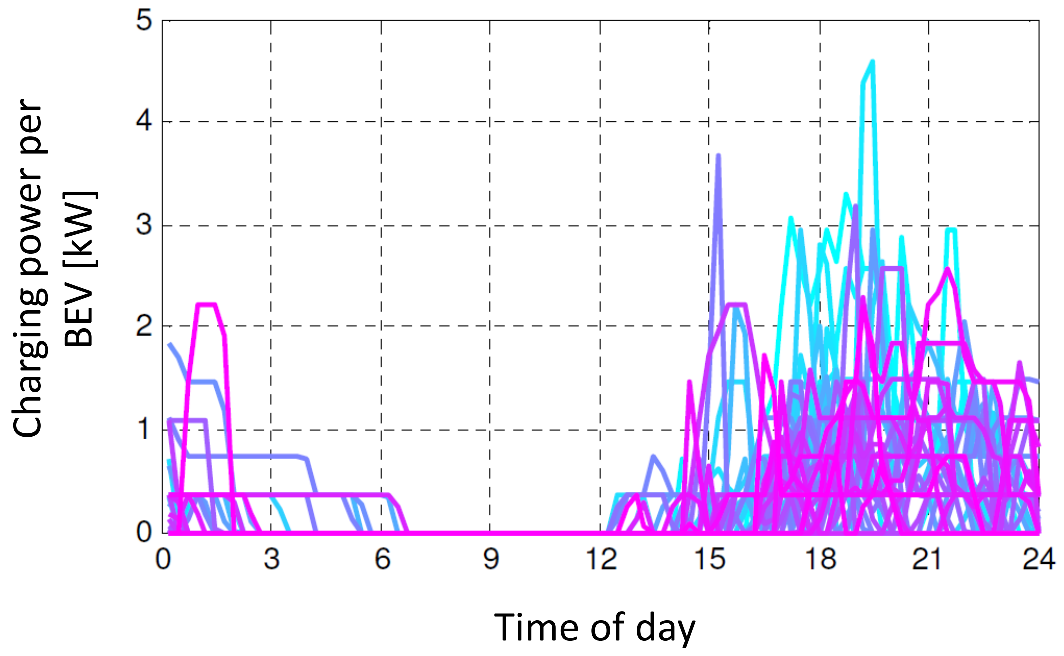
- Balancing of electrical system with electric transportation
  - Charging
  - Discharging
  - Electric Road Systems (ERS)

- **EVs in the distribution grid**
  - **Current limitations**
  - **Voltage limitations**

EVs in the distribution grid

- In the absence of market induced effects it is very unlikely that all BEVs in a grid **charge at the same time** with their rated power

Charging profiles of 10 BEVs *



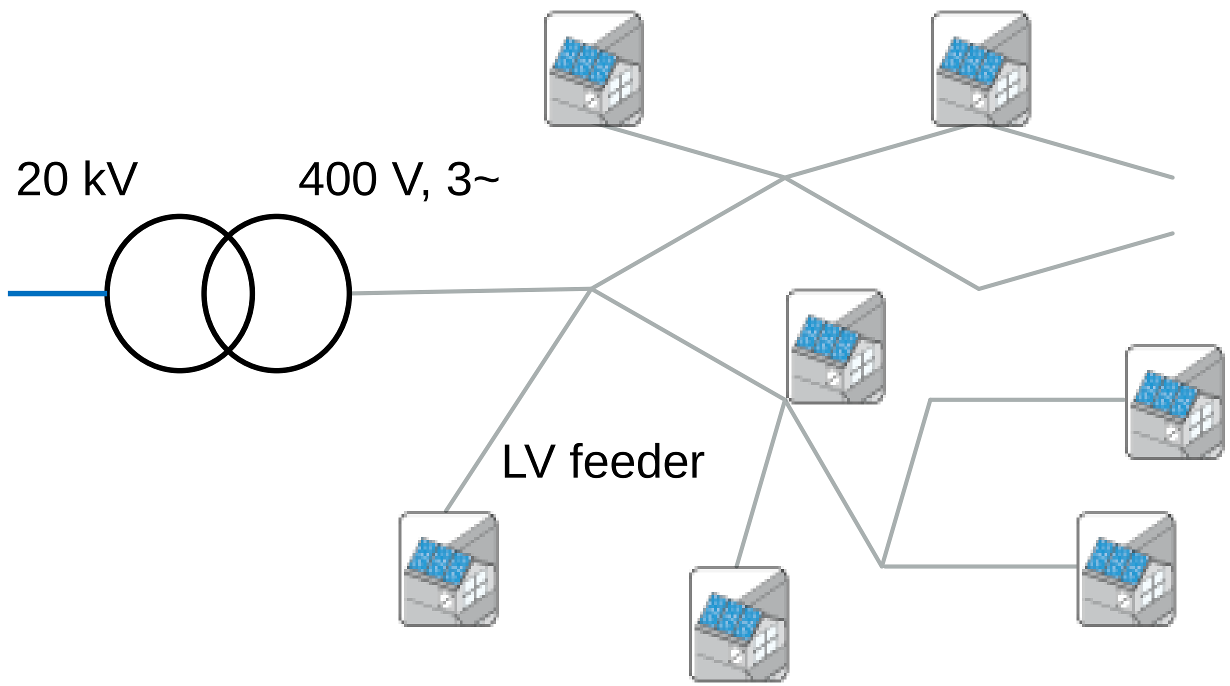
- Common method: usage of **simultaneity factors** in order to **scale down** power consumption per BEV according to the number of simultaneously charging vehicles

- Suitability for small numbers (<500) of vehicles is **questionable**

* reprinted [translated] from: A. Probst, Auswirkungen von Elektromobilität auf Energieversorgungsnetze analysiert auf Basis probabilistischer Netzplanung

The German distribution grid

- **Typical transformer:**
  - **3 phase**
  - **20kV / 400V**
  - **400 or 630 kVA**
- **50 -100 houses connected to one transformer**
- **Each house 3~, 400V phase to phase, 230V phase to ground**
- **LV lines are cables, typical a few hundred yards, sometimes up to a few miles**



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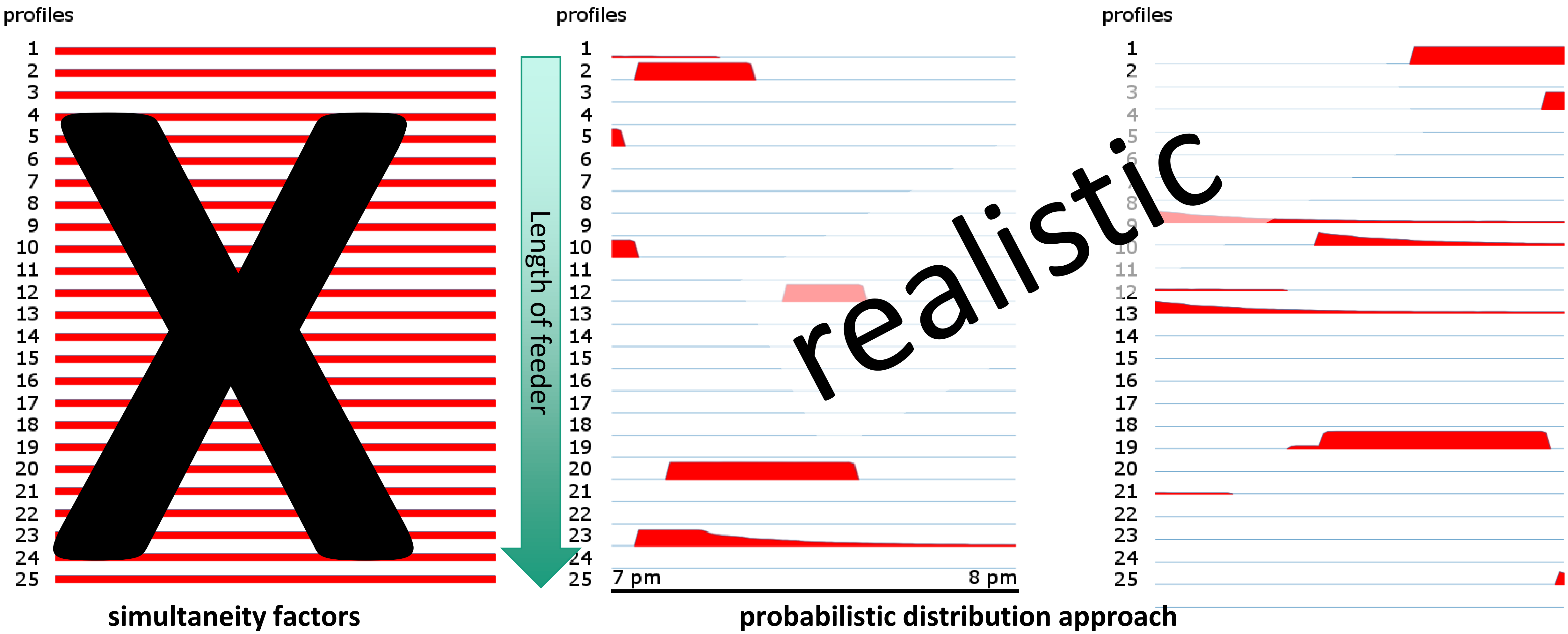
EVs in the distribution grid

BEV Charging Profiles



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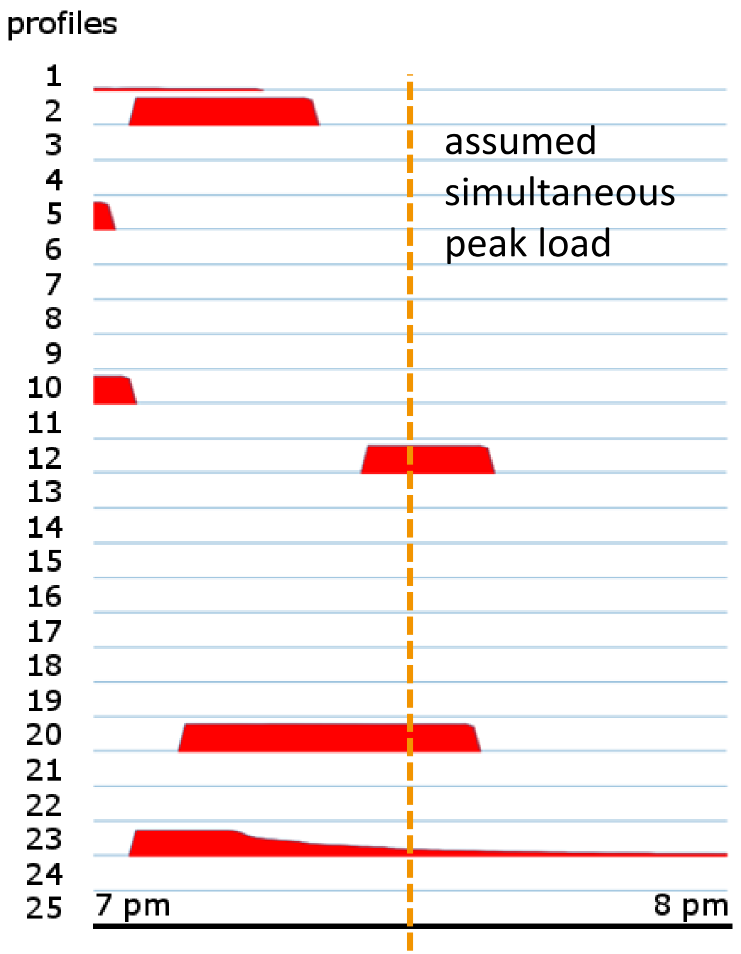
EVs in the distribution grid

BEV Charging Profiles



Simulated BEV charging profiles with consideration of:

- Usage behaviour of BEV owners (time of day, time spans, travelled distance, …)
- Technical specifications of common BEV models (battery capacity, energy consumption per km, …)
- BEV market shares
- Charging behaviour of lithium-ion batteries (charging speed dependence on state of charge)

→ **10.000 BEV charging profiles generated, 25 taken randomly**

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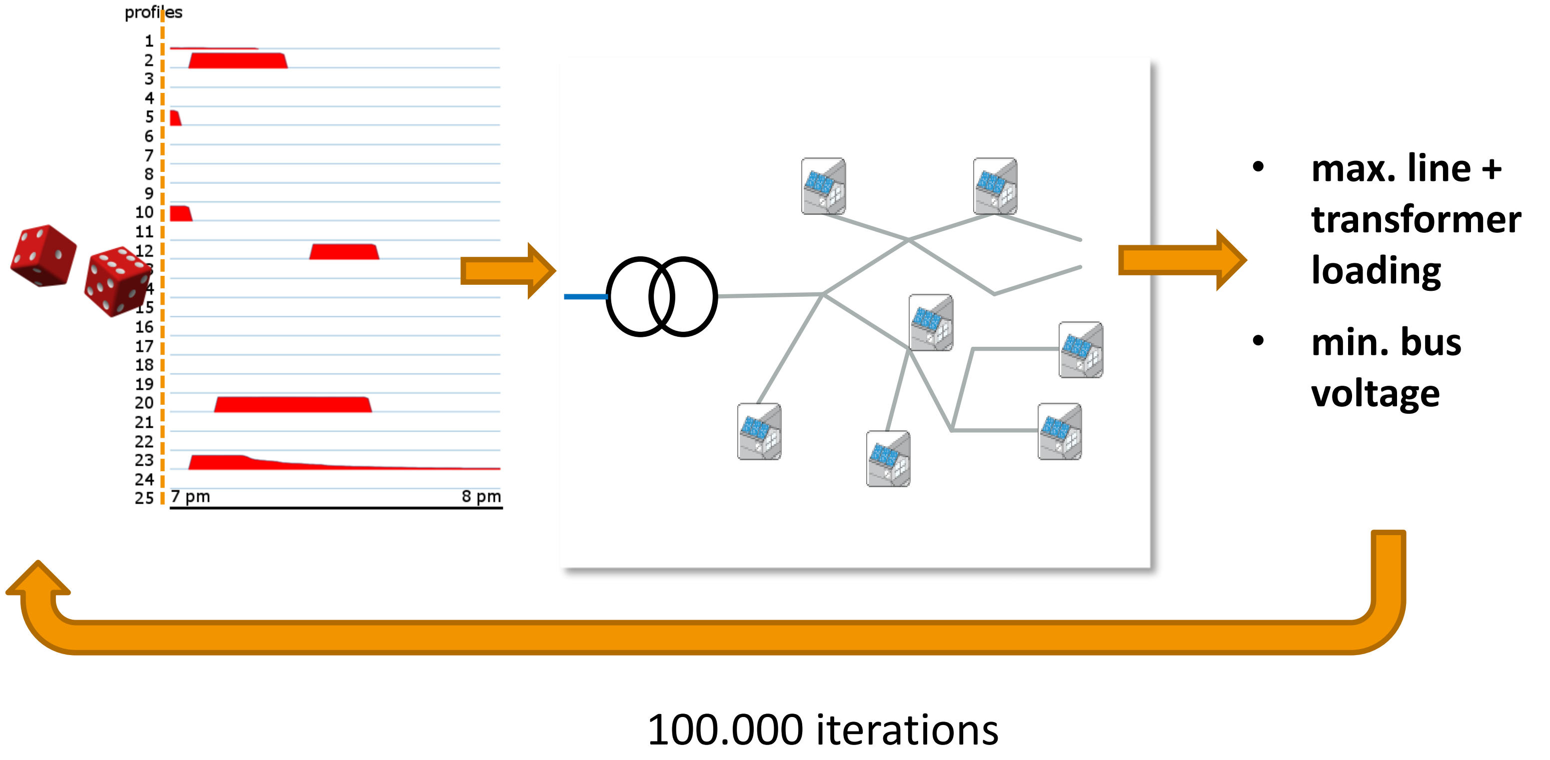
EVs in the distribution grid

Probabilistic Distribution Approach



Worst-case scenario of 100.000 iterations:

1) randomly chosen charging profile for every charging point in the grid (positions of charging points are fixed)
2) Power flow calculation with *pandapower**
3) Analyses of transformer loading, line loading and voltages
4) 99.99%-percentile → 10 worst cases are eliminated

* http://www.pandapower.org/

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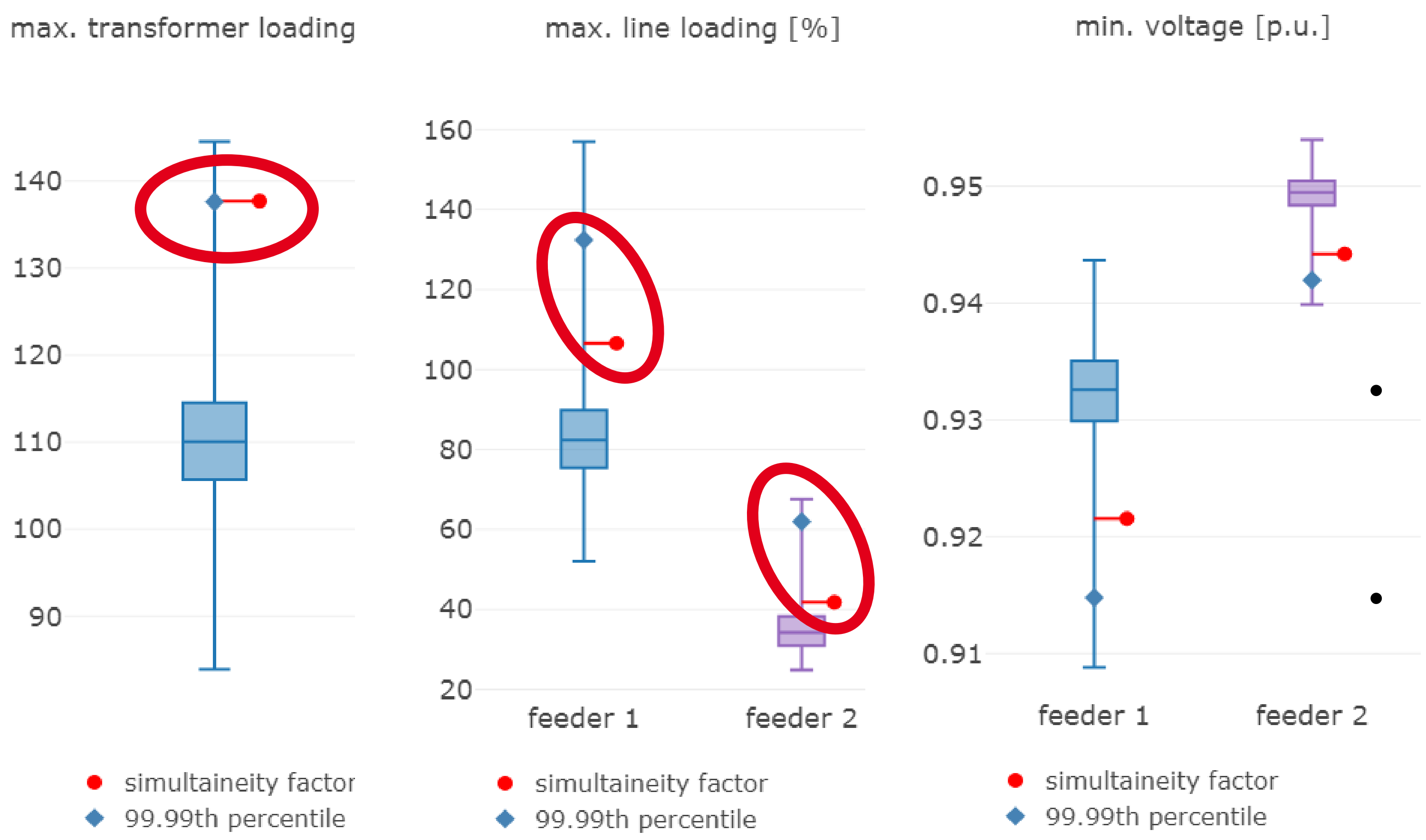
EVs in the distribution grid

Probabilistic Distribution Approach vs. Simultaneity Factors

LV grid - min. voltages and max. loadings in 100.000 BEV distributions



- Max. transformer loading: Simultaneity factor value matches the 99.99th percentile value
- Simultaneity factor approach underestimates min. bus voltages / max. line loadings in all feeders compared to 99.99th percentile

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Conclusions

- Charging and discharging strategies for passenger EVs are **heavily influenced by VG and the load curve** from other sectors
  - Confirmed from two modelling frameworks; the ELIN-EPOD and SCOPE
- Non-flexible ERS could be balanced by **discharging EV batteries**
- A major part of the **static charging** occurs during **night time** to **avoid correlation with the net load**
- The usage of **simultaneity factors** leads to an **underestimation** of power demand, violations and grid integration cost caused by small numbers of BEVs (e.g. in LV feeders)
- **Simultaneity factors** seem to be **well suited** for application in **MV grids** or for assessing MV/LV transformer loading
- **Autonomous driving** might
  - shift more of the **ERS load to night** time
  - change **residential** charging profiles

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