FUTURE LOAD SHIFT POTENTIALS OF ELECTRIC VEHICLES IN DIFFERENT CHARGING INFRASTRUCTURE SCENARIOS

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Agenda

- Motivation
- Methodology
- Case study
  - Scenario set-up
  - Results
- Conclusion and outlook

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Motivation and research aim

- Plug in electric vehicles (**PEV**s) as relevant option for decarbonization of transport sector
  - What does the **market penetration** look like?
  - Which types of PEVs and user groups are most likely to diffuse?
  - What is the interaction between **charging infrastructure** and market uptake?

- Increasing share of RES-E generation => rising need for **flexibility** in the electricity system
  - What is the demand response (DR) contribution of PEVs?
  - What happens without DR?
  - How does additional **charging infrastructure** influence the DR potential?

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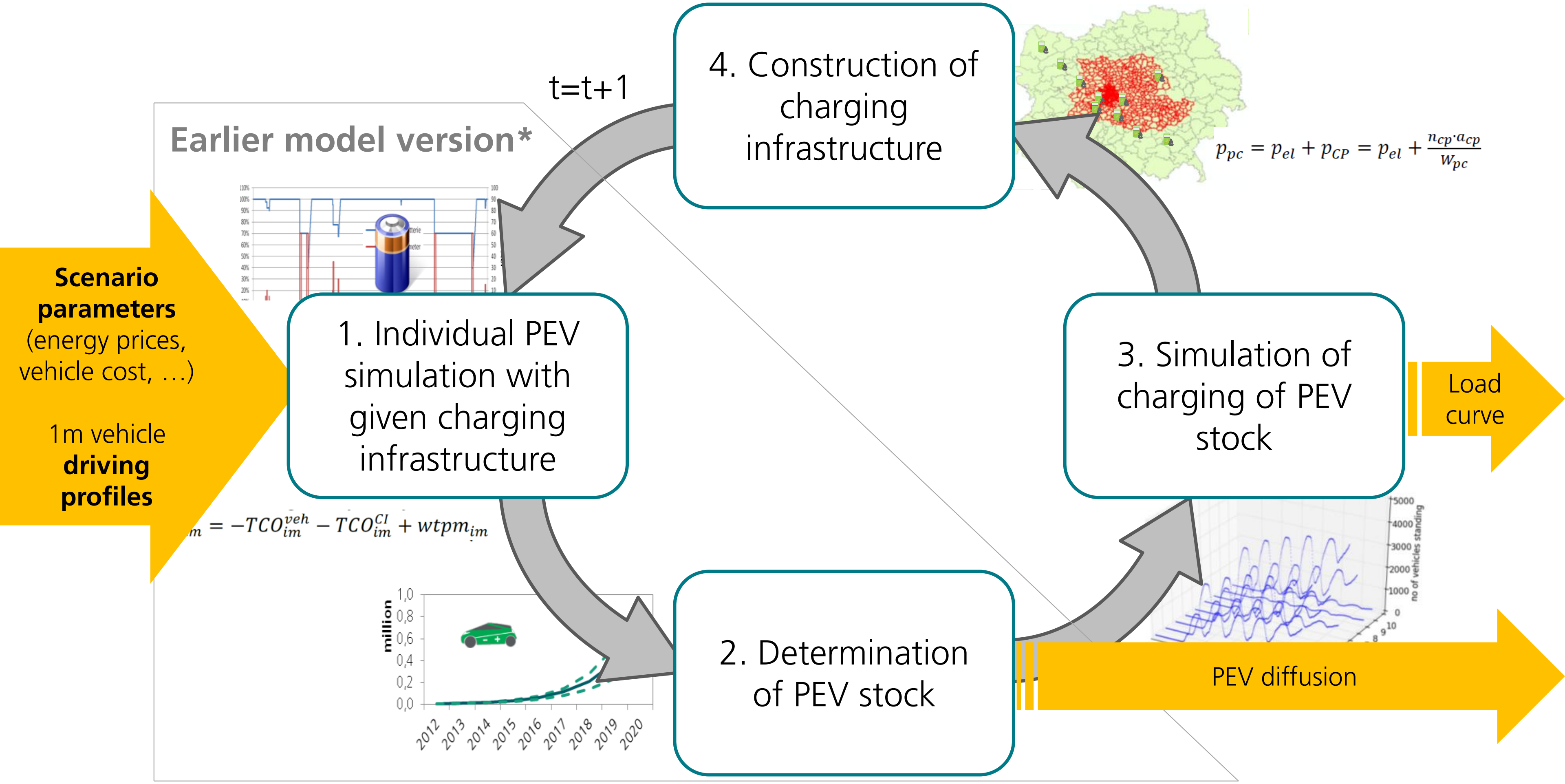
Methodology
The model cluster ALADIN - eLOAD

ALADIN

eLOAD

ALADIN: modeling the stock evolution of PEVs and charging points



*As published in (Plötz et al. 2014, Gnann et al. 2015)

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Methodology
The model cluster ALADIN - eLOAD

ALADIN

eLOAD

Methodology

- **Bottom-up PEV market diffusion simulation** (PEV registrations) based on more than one million vehicle driving profiles
- **Agent-based simulation model for PEV charging** at public charging points (PEV stock)
- **Differentiation of user groups** (private, commercial fleet car)

Results

- Market **diffusion** of **plug-in electric vehicles**
- Resulting **load curve** for different market diffusion scenarios and uncontrolled charging
- **Differentiation of charging locations** (domestic, commercial, work, public)

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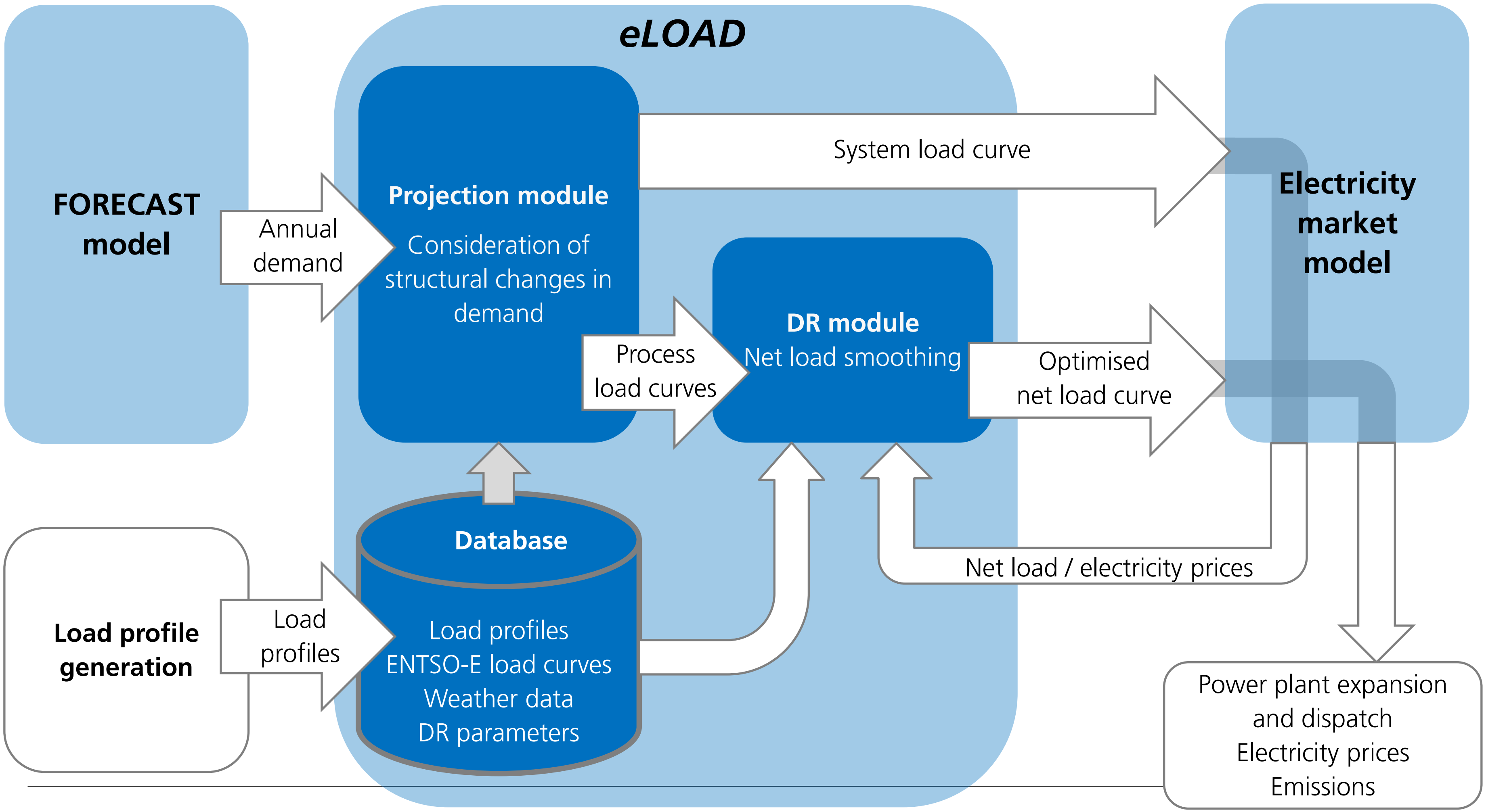
eLOAD: assessing changes in the system load curve and the impact of DR



eLOAD energy LOad curve ADjustment tool

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Methodology
The model cluster ALADIN - eLOAD

ALADIN → PEV stock and demand / Charging profiles → **eLOAD**

ALADIN

Methodology

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eLOAD

Methodology

- Long-term simulation of **changes in hourly system load** curve (8760h) using load profiles
- Mixed-integer **cost optimisation** from consumer perspective for different **DR programs** (e.g. RTP) to determine **optimal load schedule**
- For PEVs: explicit modeling of **storage** constraints and availability of **charging point**

Results

- Evolution of system load curve and **peak** load
- Cost-optimal load profile and **DR potential** of individual end-uses
- Impact on **net load, curtailment**, power plant expansion and dispatch

Case study
Scenario set-up

Germany, until 2030

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PEV market penetration modeling

- Driving profiles for the region of Stuttgart for private and commercial vehicles [1]
- Differentiation of charging infrastructure availability:

Scenario	Domestic/ commercial	Work	Public
S1	3.7 kW	-	-
S2	3.7 kW	3.7 kW	-
S3	3.7 kW	3.7 kW	3.7 kW

eLOAD

DR modeling

- **Scenario framework**: Leitstudie [2]
  - RES share: 35%/50% (2020/2030)
  - Total electricity demand: -9% /-15% vs. 2010 (523 TWh)
- **DR setting**
  - Modeling of private and fleet PEVs
  - Net load as basis for optimisation
  - No monetary parameters considered
  - No other DR option considered

[1] (Hautzinger et al. 2013, Fraunhofer ISI 2015); [2] (Fraunhofer ISI 2015)

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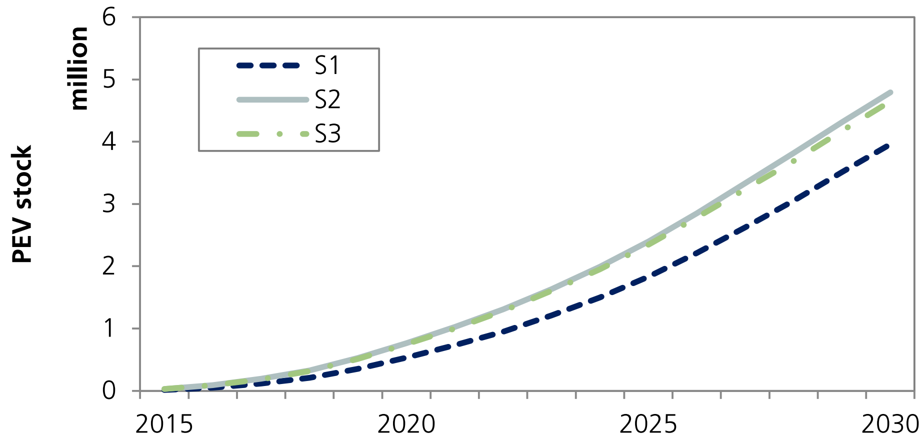
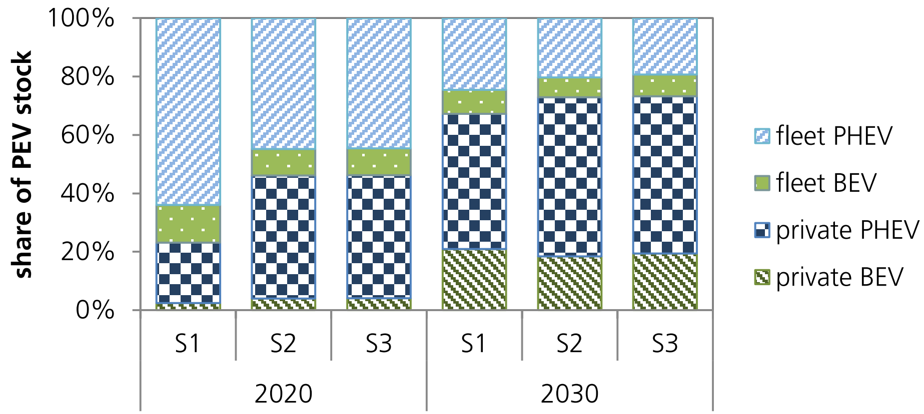
Case study
Results - PEV market penetration

- Substantial PEV market penetration possible with only **domestic/ commercial** charging infrastructure
- Charging **@work** (S2) increases market shares and PEV stock
- **Public** slow charging has no impact



- **User groups**
  - **2020**: PEV stock dominated by commercial fleet users
  - **2030**: larger shares for private PEVs 2030 (former fleet vehicles)
- **PEV types**
  - **PHEVs** dominate in 2020 and 2030



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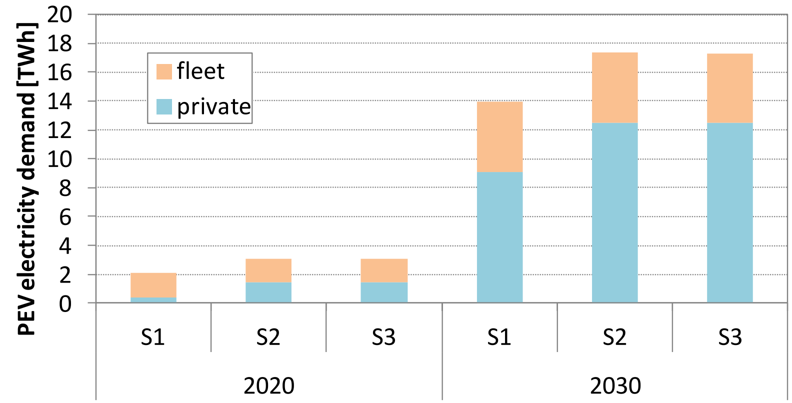
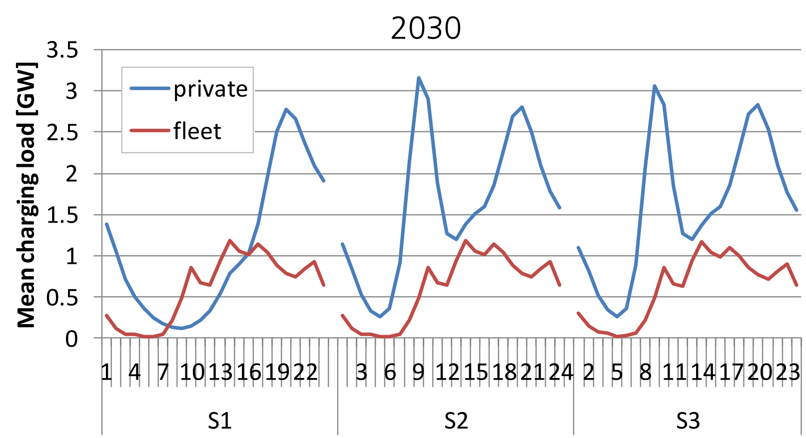
Case study
Results – Electricity demand



Additional electricity demand

- **Private**
  - @work raises 2030 demand by 3.5 TWh
- **Fleet PEVs** same demand in all scenarios
- **Total:** +2-3 TWh (2020) = +0.6%
  - +14-17 TWh (2030) = +3-4%



Uncontrolled charging

- Charging **@home**:
  - Private PEVs in evening hours: +3 GW
  - Fleet PEVs charge during the day => less impact on system load peaks
- Charging **@work**: additional morning peak
- Public charging has no impact

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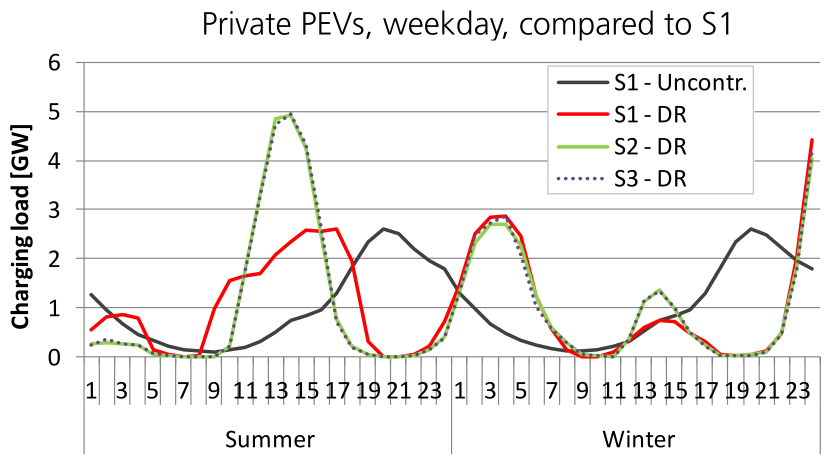
Results for 2030

Case study
Results – Flexibility potentials

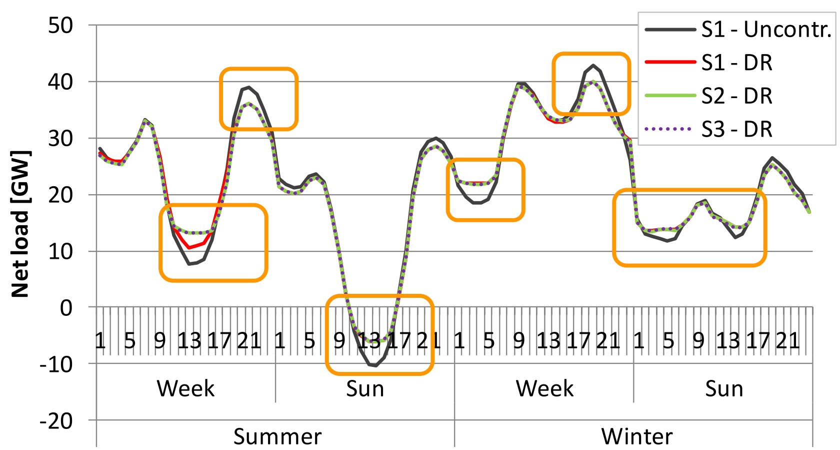
Impact on charging profile

- Shiftable load of smart charging **@home**:
  - In midday hours limited to 3 GW for private PEVs
- **@work/public**: +5 GW for private PEVs; no impact on comm. PEVs



Impact on peak load and curtailment

- Smart charging **@home:**
  - Max. net load: -2.4GW / -3.6%
  - Curtailment: -1.6 TWh / -26%
- **+ @work:** Curtailment: -1.8 TWh / -30%; but no further peak load reduction
- **+ @public:** No additional impact



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Conclusion and outlook

- **PEV market uptake** already **takes place** with charging infrastructure **at home**
- PEV stock is dominated by **PHEV**s (80% in 2020 and 70% in 2030 in all scenarios)
  - However, reduced DR potential due to smaller batteries and lower electricity demand
- **Commercial fleet vehicles** have significant shares but low impact on system peak load
- **Smart charging** facilitates the **integration** of **private** PEVs in the system

- **Charging** infrastructure **at work facilitates** PEV market penetration and increases flexibility potential
- **Public charging** infrastructure has **no additional benefit** on PEV diffusion AND load shifting potential.
- **Smart charging** smoothens the net load but may imply **new** system load **peaks locally** that may additionally challenge the grid.

- Consider impact of smart PEV charging on **power market and prices**
- Compare **flexibility potential** of PEVs with other flexiblity options

Thank you for your kind attention!

References

BCG (2013): Trendstudie 2030+ Kompetenzinitiative Energie des BDI. Studie der Boston Consulting Group im Auftrag des Bundesverbandes der Deutschen Industrie (BDI) BCG: München

Boßmann, T. (2015). The contribution of electricity consumers to peak shaving and the integration of renewable energy sources by means of demand response. Dissertation, KIT Karlsruhe.

Fraunhofer ISI. REM2030 Driving Profiles Database V2014-07. Fraunhofer Institute of Systems and Innovation Research ISI, Karlsruhe, July 2014.

Fraunhofer ISI, Consentec, Ifeu, R2b, EEG TU Wien, and TEP Energy (2015). Langfristszenarien und Strategien für den Ausbau der Erneuerbaren Energien in Deutschland unter besonderer Berücksichtigung der nachhaltigen Entwicklung sowie regionaler Aspekte - Leitstudie. Under publication.

Gnann, T. (2015). Market diffusion of plug-in electric vehicles and their charging infrastructure. Dissertation, KIT Karlsruhe.

Gnann, T.; Plötz, P.; Kühn, A.; Wietschel, M.: Modelling Market Diffusion of Electric Vehicles with Real World Driving Data – German market and Policy options. Transportation Research Part A, Vol. 77, July 2015, pp. 95-112

Hautzinger, H., Kagerbauer, M., Mallig, N., Pfeiffer, M., Zumkeller, D. Mikromodellierung für die Region Stuttgart - Schlussbericht - INOVAPLAN GmbH, Institute for Transport Studies at the Karlsruhe Institute of Technology (KIT), Institut für angewandte Verkehrs- und Tourismusforschung e.V., Karlsruhe, Heilbronn, 2013

International Energy Agency (IEA). World Energy Outlook 2012, 2012.

Leipziger Institut für Energie GmbH (2012): Entwicklung der Preise für Strom und Erdgas in Baden-Württemberg bis 2020, Endbericht, Leipzig

McKinsey (2012): Die Energiewende in Deutschland – Anspruch, Wirklichkeit und Perspektiven. McKinsey & Company

MOP. Mobilitätspanel Deutschland 1994-2010. Technical report, Project conducted by the Institute for Transport Studies at the Karlsruhe Institute of Technology (KIT). Available at: www.clearingstelle-verkehr.de, 2010.

Pfahl, S.. Alternative Antriebskonzepte: Stand der Technik und Perspektiven–Die Sicht der Automobilindustrie. In Alternative Antriebskonzepte bei sich wandelnden Mobilitätsstilen: Tagungsbeiträge vom 08. und 09. März 2012 am KIT, Karlsruhe, KIT Scientific Publishing, pages 81–108., Eds. Jochem, P. and Poganietz, W.-R. and Grunwald, A. and Fichtner, W., 2013.

Plötz, P., Gnann, T., and Wietschel, M. Modelling market diffusion of electric vehicles with real world driving data – part i: Model structure and validation. Ecological Economics, 107(0):411 – 421, 2014.

Schlesinger, M., Lindenberger, D., und Lutz, C. (2011): Energieszenarien 2011, Basel/Köln/Osnabrück, Prognos AG, Energiewirtschaftliches Institut an der Universität zu Köln (EWI), Gesellschaft für wirtschaftliche Strukturforschung (GWS)