The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION.
Barcelona, Spain
17th-20th November 2013

Interdependencies of Home Energy Storage Between Electric Vehicle and Stationary Battery

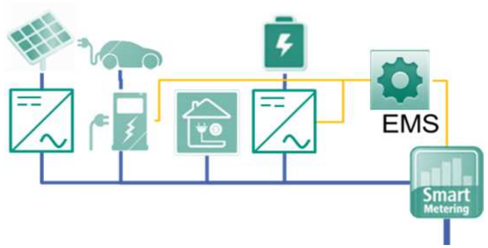
Thomas Kaschub, Patrick Jochem, Wolf Fichtner
Karlsruhe Institute of Technology (KIT), Chair of Energy Economics

Organized by Fira Barcelona, avele
Hosted by AVERE
In collaboration with Ajuntament de Barcelona, EVAAP, EDTA
Supported by European Commission

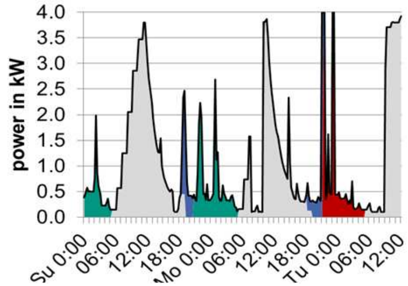
Agenda

- Introduction and Motivation

- Modelling Overview and Assumptions



- Results



- Conclusion

Introduction and Motivation

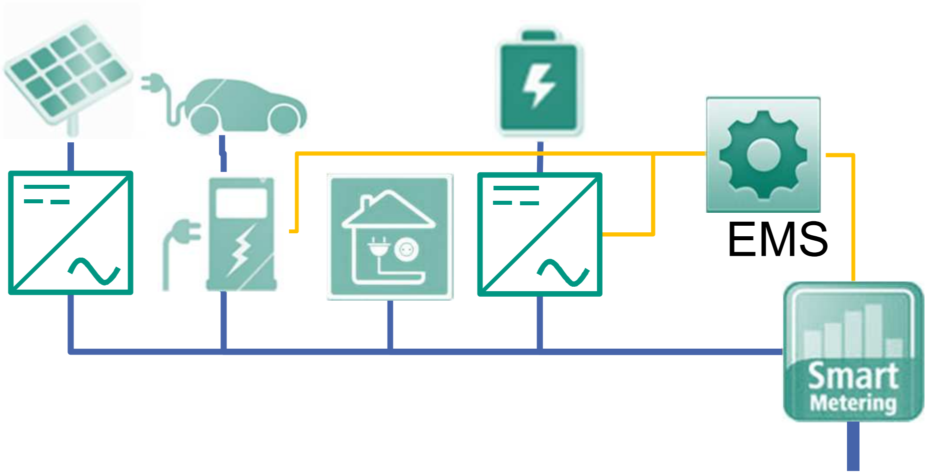
- photovoltaic on rooftops
  - mass market with more than 1 Mio. installations in Germany
- self-consumption prior to grid feed-in

- Stationary battery storage
  - increase of self-consumption
  - economy of investment?

- electric vehicles with high load shift potential at home or for power grid
  - mobility need is most important
  - charging capacity is volatile
- Vehicle to Home (V2H)
  - bi-directional charging is possible
  - degradation and efficiency losses of battery

use of decentralized battery storage at home
might be on the way to mass market and application

Overview Model: Operation and Profitability of Battery Storage (BS) and EV in Single Households



- Electric Vehicle (EV) integration
  - EVno no EV considered
  - EVstart charging starts instantly
  - EVopt controlled charging
  - EV2H controlled charging and feed-back to home

Assumptions for Optimization

- 20 years considered from 2016
- BS Investment 600 €/kWh
  - 7000 cycles
  - η=94%, self discharge 2%/M
  - 1% for maintenance
  - charging power limit function
- electr. price: 25,1ct/kWh (`11) + 3%/a
- PV investment: 950 €/kWp
  - feed-in tariff: 3 ct/kWh (no EEG)
- EV investment not considered
  - primary use is mobility
- 50 exemplary households and mobility behaviors

Target Function of the Developed Model for Storage Optimization and NPV Calculation

$$\max \boldsymbol{NPV} = -Inv^{BS}\boldsymbol{Cap}^{BS}\left(1+\frac{\boldsymbol{LT}^{\boldsymbol{BS,red}}}{LT^{BS}}\right)\frac{1}{Deg^{BS}} - Inv^{PV}$$

Invest-ments

$$+\sum_{a}\Big(\Big[-\sum_{t}\left(\boldsymbol{P}_{\boldsymbol{t}}^{\boldsymbol{grid}}\,DT\,p_{a}^{grid}\right)$$

$$-Co^{BS,maint.}\boldsymbol{Cap}^{BS}\left(1+\frac{\boldsymbol{LT}^{\boldsymbol{BS,red}}}{LT^{BS}}\right)\frac{1}{Deg^{BS}}$$

$$-\sum_{t,EV}\left(\boldsymbol{P}_{\boldsymbol{t,EV}}^{\boldsymbol{EV2H}}\,DT\,p^{deg}\right)$$

$$+\sum_{t}\left(\boldsymbol{P}_{\boldsymbol{t}}^{\boldsymbol{PV,feed-in}}\,p_{a}^{PV}\right)\Big]/(1+i)^{a}\Big)$$

contri-bution margins, real

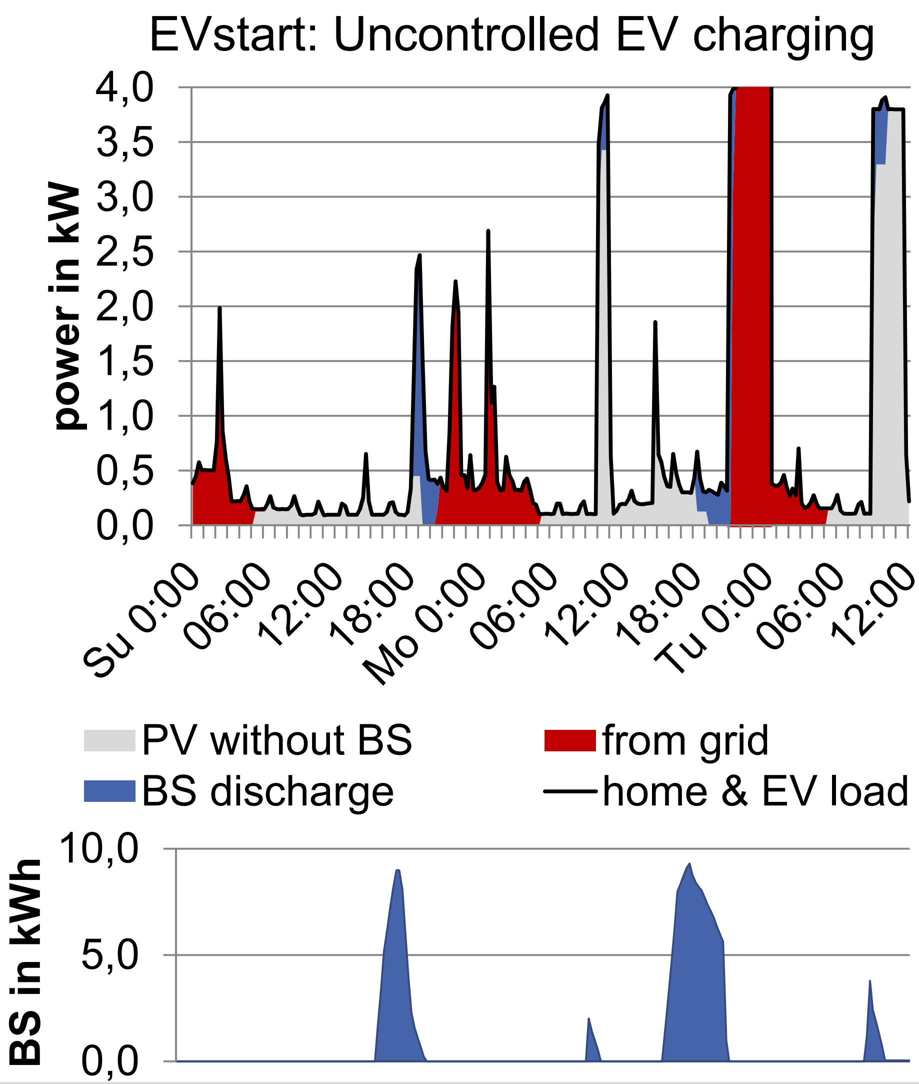
- NPV of PV-BS-system is maximized
- Mixed integer linear programming (binary variable for charging restriction)
- further functions for restrictions and e.g. power balance

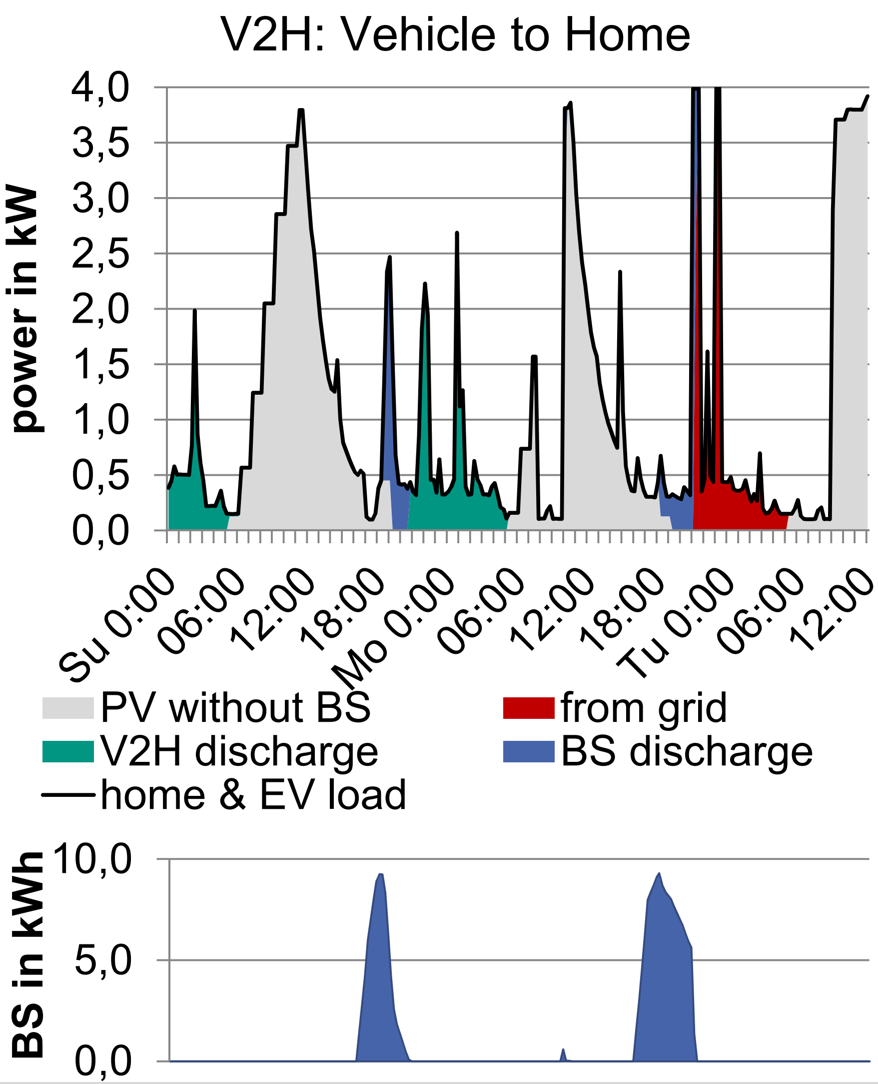
legend

variables are in bold face

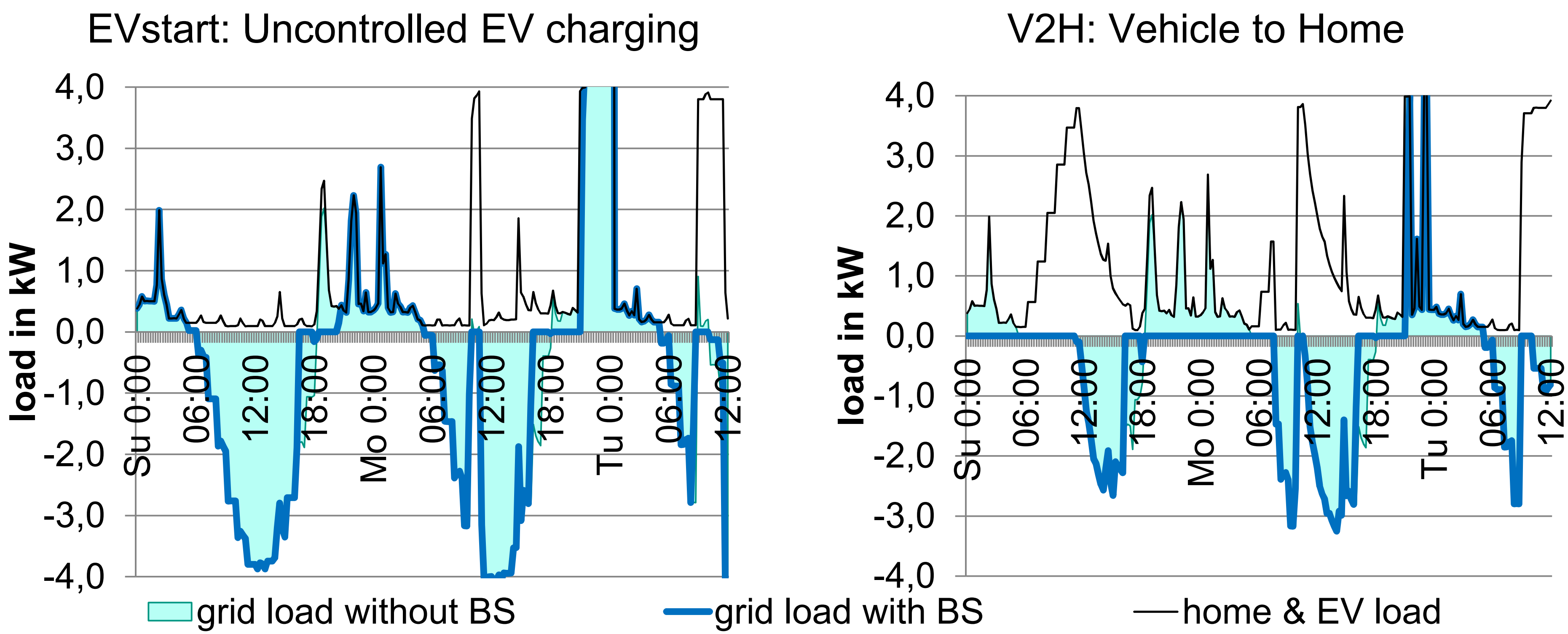
- a annum / year
- t time slice (4x8760)
- EV Electric Vehicle
- NPV Net Present Value
- Inv investment
- LT lifetime
- DT duration time slice
- Cap installed capacity
- Deg degeneration
- Co costs
- P power
- p price in €/kWh
- i interest rate
- BS battery storage
- PV photovoltaic
- maint. maintenance
- red reduced
- EV2H feed-back to home

Power load of an exemplary home with EV (in springtime) divided into power sources





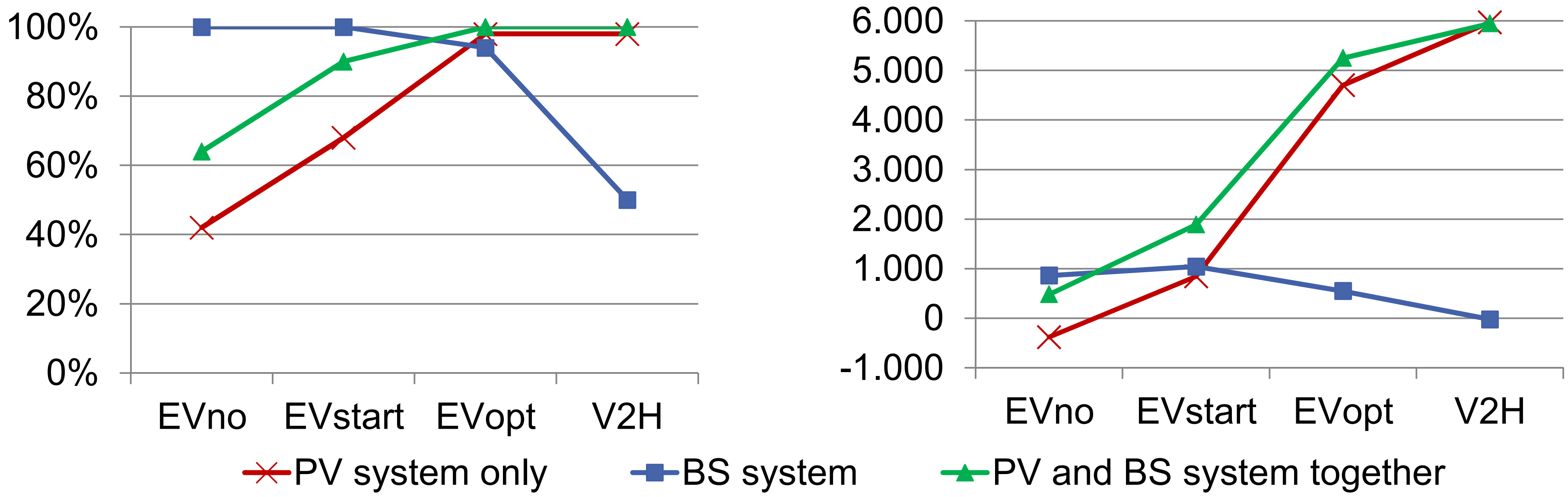
Grid load for an exemplary home with EV
Comparison without and with stationary battery



- Grid load is not necessarily reduced by integrating an EV into home or installing an stationary battery system → grid optimum is not optimum of single homes
- Incentives are necessary to reduce grid load
  - Demand Response and Dynamic Pricing are promising possibilities that we evaluate in our research projects

Results in Overview (1)
Net Present Values

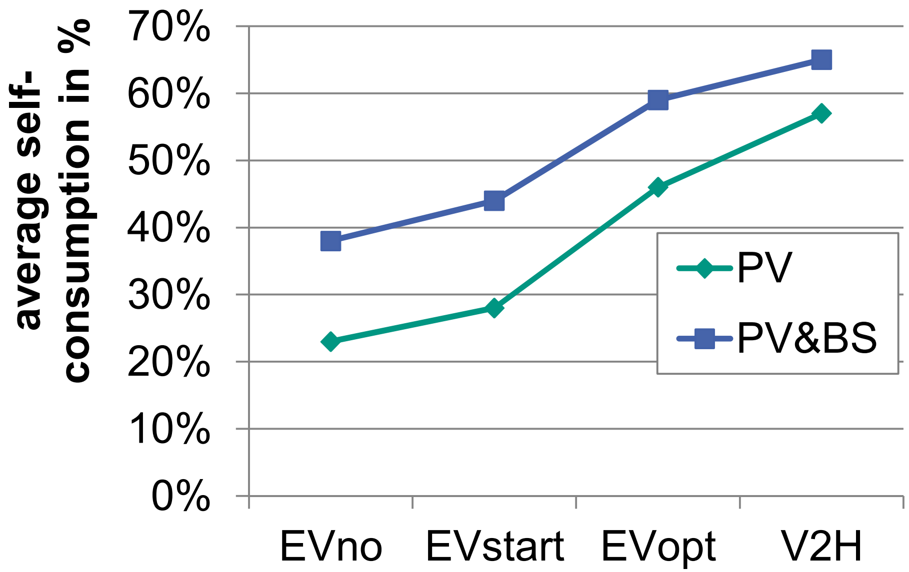
- Share of analyzed homes with positive NPV
- Average NPV in EUR



- Integration of EV into Home is most important for positive NPV of PV system
- Battery Storage (BS) is reasonable with uncontrolled charging or without EV
  - nevertheless not all systems have positive NPV; depending on HH load curve

Results in Overview (1)
Self-consumption of PV electricity

Karlsruhe Institute of Technology



- BS increase average self -consumption between
  8 % (V2H) and 16 % (EVstart)
  - BS is due to profitability small dimensioned (1-5 kW capacity)
- Integration of EV increases self-consumption with
  - EVopt (controlled charging) 18 %
  - V2H (withfeed-back to home) 29 %

Conclusion

Karlsruhe Institute of Technology

- In few years an investment in a rooftop PV system might be economic (in Germany) without subsidies like German EEG
  - Dependent on further price reductions for PV systems and price increase of households electricity
- The integration of an EV into the home energy management system by controlled charging or additionally discharging to home (V2H) increases self-consumption and NPV of PV system
- Additional stationary battery system (BS) increases self-consumption further
- Positive NPV for BS is likely, when EV is not integrated into home
  - Price reductions for BS are assumed as well as high performance (calendar and cycle lifetime) as promised by manufactures
- Grid load reduction is not presumable without incentives

- Further work on identifying important characteristics of mobility behaviors and household loads profiles to specify evaluation results

Karlsruhe Institute of Technology

Thank you for your attention! Questions?

Thomas Kaschub

kaschub@kit.edu | Tel.: +49 721 608-44559

Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

Teil der Initiative „IKT für Elektromobilität 2“; Förderkennzeichen: 01ME12013

INSTITUTE FOR INDUSTRIAL PRODUCTION (IIP), Department of Economics and Management
Chair of Energy Economics (Prof. Fichtner)