House of Energy, Climate & Finance
Markets, Systems and Decisions

UNIVERSITÄT DUISBURG ESSEN

Offen im Denken

Disentangling the Effects of Metering and Tariff Configurations on Household Flexibility in Energy Systems

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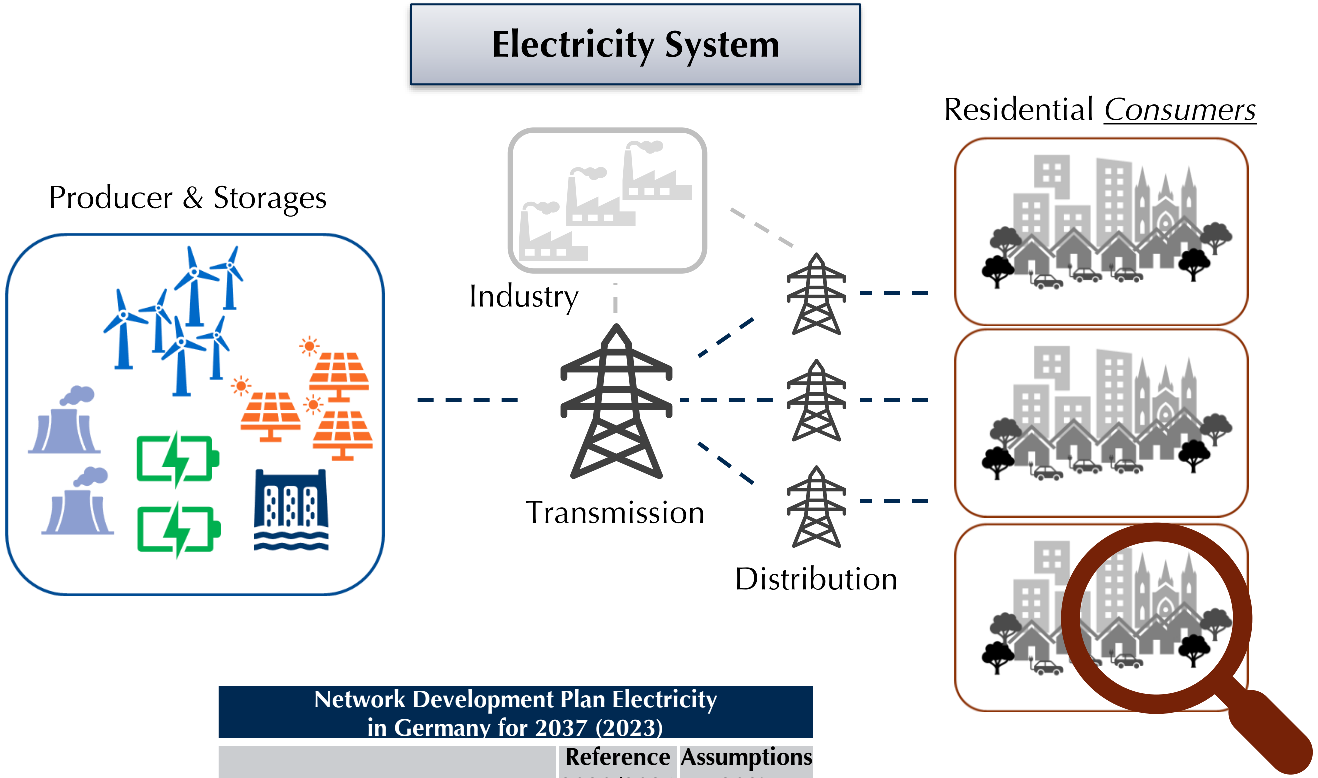
Demand response by residential consumers is of pivotal relevance to meet transformation challenges



Network Development Plan Electricity in Germany for 2037 (2023)		
	Reference 2020/2021	Assumptions 2037
Heat Pumps (HPs) in million	1.2	14.7
Electric Vehicles (EVs) in million	1.2	25.2-31.7
Photovoltaic (PV) & Battery Storage Systems (BSS) in GW	1.3	67.4

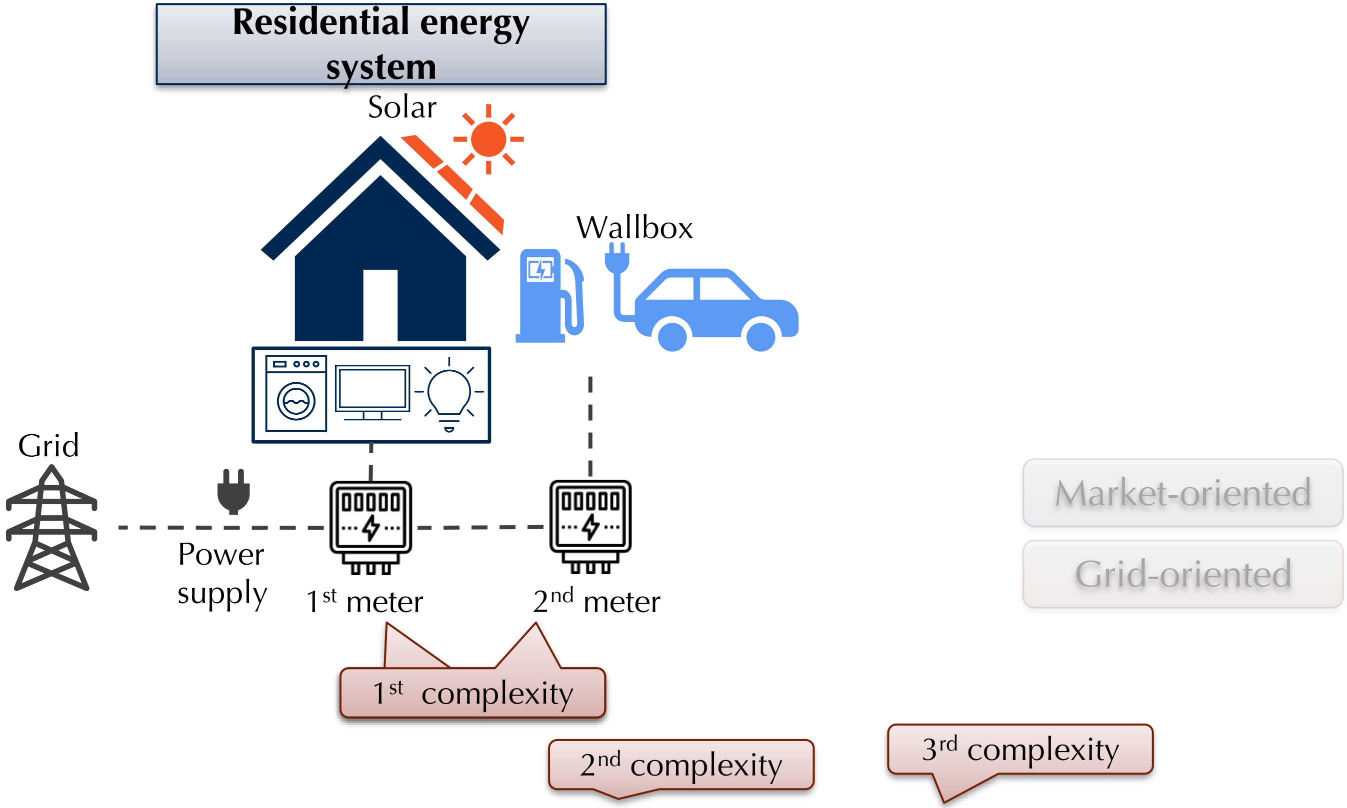
- Challenges from overall energy system perspective:
  - Decarbonization (cross-sectoral)
  - Grid / system resilience
  - Integration/Coupling of renewables
    - (price-driven) **Demand response**

➢ As energy systems continue to transform, small-scale flexibility resources are becoming increasingly important

Market-oriented	Grid-oriented
Renewables integration **Peak-demand reduction** …	**Grid stability** **Avoidance of congestion**

➢ Key lever for efficient implementation: Configuration of **meters** and **tariffs**

Residential consumer face several decision-making hurdles for an efficient (system-oriented) configuration of meters and tariffs



$\textit{Electricity Tariff} = \textit{Basic Charge} + \textit{Energy charge} + \textit{Grid charge} + \textit{other components}$

- Static price [€/kWh]
- Time-variant price [$€_t$/kWh$_t$]
- Dynamic price [$€_t$/kWh$_t$]

- Module 1 lump sum [€ p.a.]
- Module 2 consumption-dependent fee [€/kWh]
- Module 3 time-variant fee [$€_t$/kWh$_t$]

- Disentangling the influence of electricity meter and tariff configurations on the provision of flexibility to the overall energy system
- The focus is on three complexities:
  1. Number of meters*
     (Simplified 1 meter = 1 tariff)
  2. Pricing module
  3. Grid charge module
     – 1: Taking into account household-specific characteristics, what is the optimal configuration?

       2: Taking into account household-specific tariff configurations, what interaction effects can be observed between the wholesale market and households?

* Simplified assumption: one meter = one tariff

Literature review reveals a gap on wholesale market interaction, consideration of uncertainty and future technological options (meter)

Storyline & Research

	Objective	Scope
Stute & Klobasa (2024)	Interplay between **dynamic tariffs and different grid charge** designs	Households & Grid
Spiller et al. (2023)	Effect of tariffs on household **adoption of small-scale flexibilities**	Households
Vom Scheidt et al. (2019)	Potential **individual economic consequences** of tariff selection	Households
Andruszkiewicz et al. (2021)	**Effectiveness of ToU tariffs**, used as price-based demand response programs	Households
Pallonetto et al. (2016)	Effectiveness of demand response (**All-electric**) strategies using ToU tariffs	Household & Utility perspective
Schreck et al. (2022)	Effect of **grid tariff design on demand and feed-in peaks** and the resulting financial effects	Households vs. Local Energy Markets
Pinel et al. (2019)	Relationship between **grid tariffs and investment**	Neighborhoods & Grids

- Relevant literature <u>analyzes</u>
  - Interplay of tariff components
  - Incentives for investments
  - Financial consequences
  - Interaction with distribution system operators

➢ But lacks interactions with markets

- Relevant literature <u>considers</u>
  - Various combinations of tariff components
  - Different levels of electrification of residential consumers

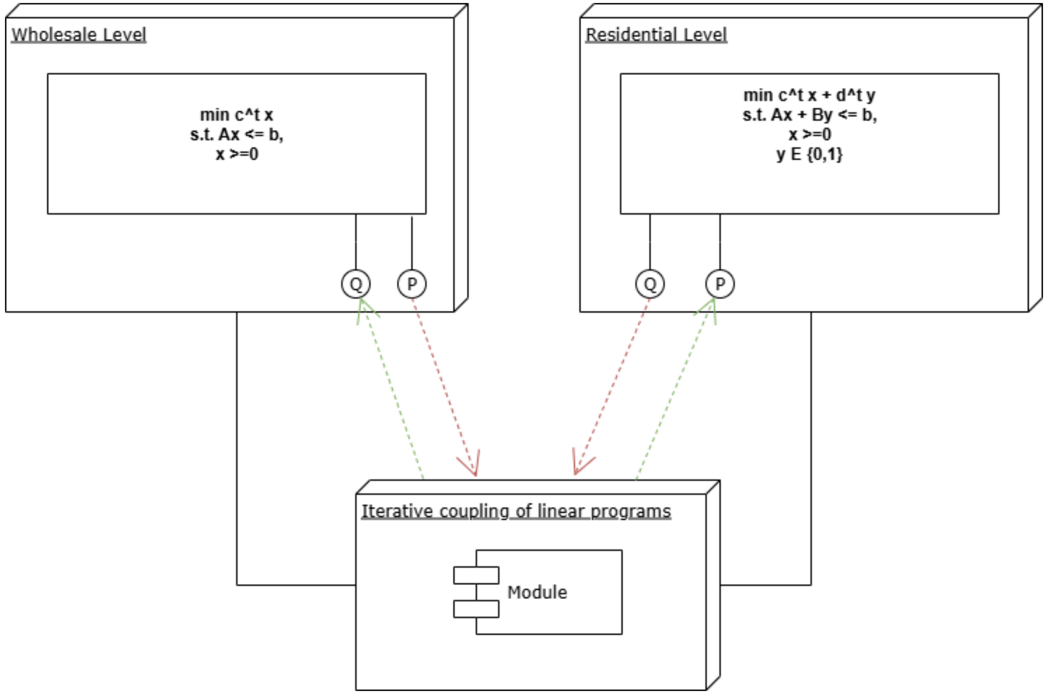
➢ But predominantly relies on static data inputs

- Relevant literature does not consider
  - differentiation of small-scale flexibilities in the tariff selection decision

➢ Individual tariff heterogeneity

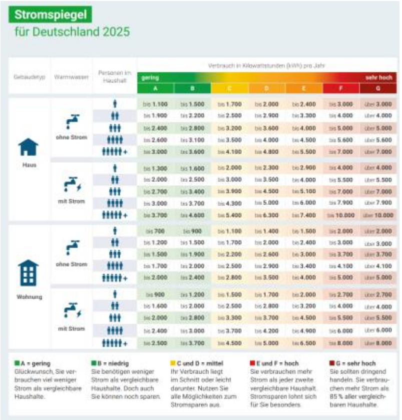
Iterative Optimization of Wholesale level and household level leads to equilibria

Method & Data



- Configuration Meter/Tariff (optimized)
  - …
- (Smart) Charging (optimized)
  - …
- Common restrictions at Wholesale and Residential Level

- Data
  - So far stylized Data
  - Next Steps incorporate granular residential characteristics
    - Eg. EFH-1P-….



Optimal Choice of Meter and Tariff Configuration

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- Restrictions for Meter & Tariff Configuration

1. $griddemand^{base}(h,r,i,t) \leq bigM\ (h,r) * x(h,r,i)$
2. $griddemand^{EV}(h,r,i,t) \leq bigM\ (h,r) * y(h,r,i)$
3. $\sum_i x(h,r,i) = 1$
4. $\sum_i y(h,r,i) = 1$

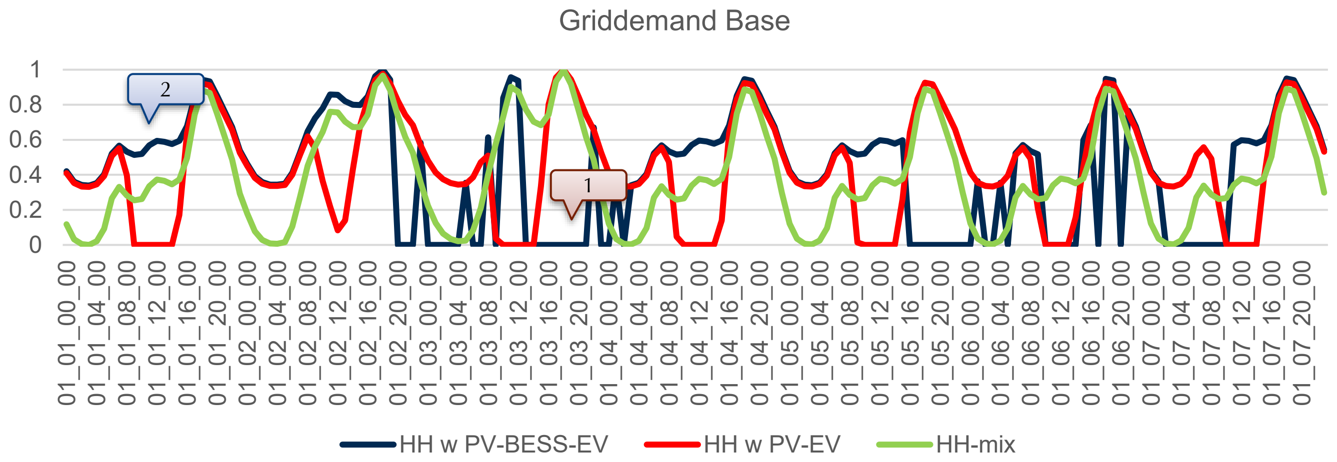
(1.–4.) For one meter, only one tariff can be chosen

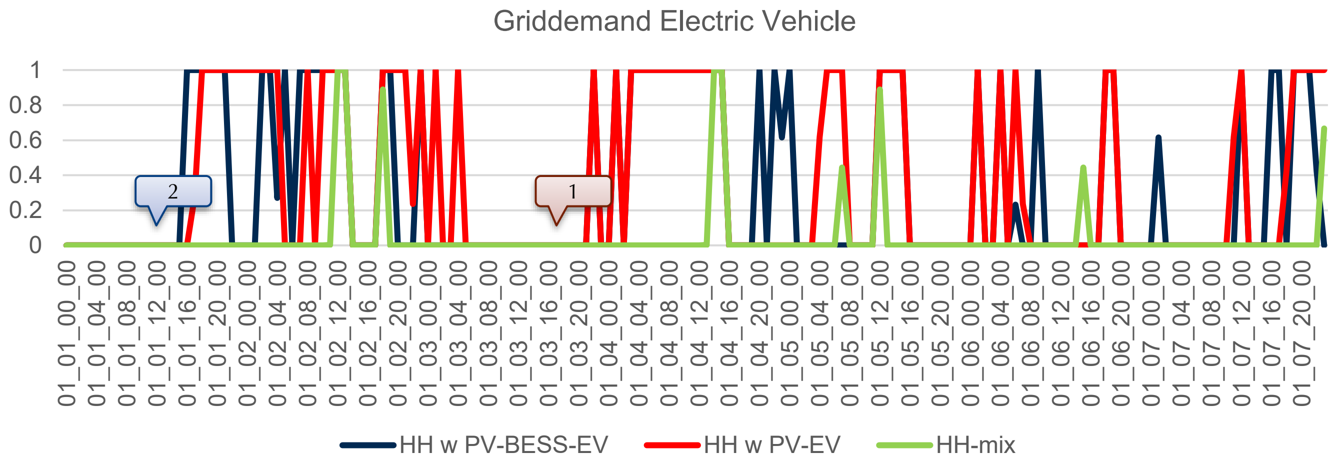
5. $x1(h,r,i) - y1(h,r,i) \leq z\_meter(h,r)$
6. $y1(h,r,i) - x1(h,r,i) \leq z\_meter(h,r)$

(5.–6.) In case of same tariff choice
for Baseload and EV-load, only one meter is installed

Preliminary Results

	HH-mix	HH w PV-EV	HH w PV-BESS-EV
Meter	2	2	1
Tariff (Base / EV)	Static / dynamic	Static / dynamic	dynamic





Discussion

- Model extension:
  - Detailed representation of agents
    - Using Long-term Modelling
  - Bidirectional charging
    - V2H, V2G
  - Scenario setting and data
    - E.g. Load profiles

- Optimized vs exogenous Configuration

1. Taking into account household-specific characteristics, what is the optimal configuration?

2. Taking into account household-specific tariff configurations, what interaction effects can be observed between the wholesale market and households?

Thank you for your attention!

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