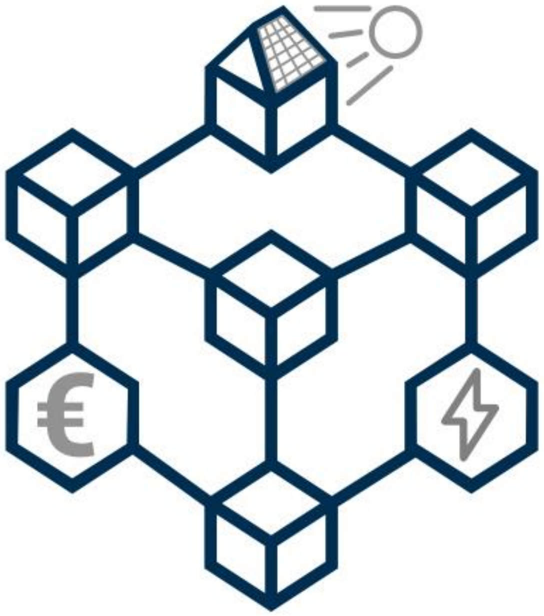
Impact of Grid Fee Structure on Congestions under Dynamic Electricity Prices



Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

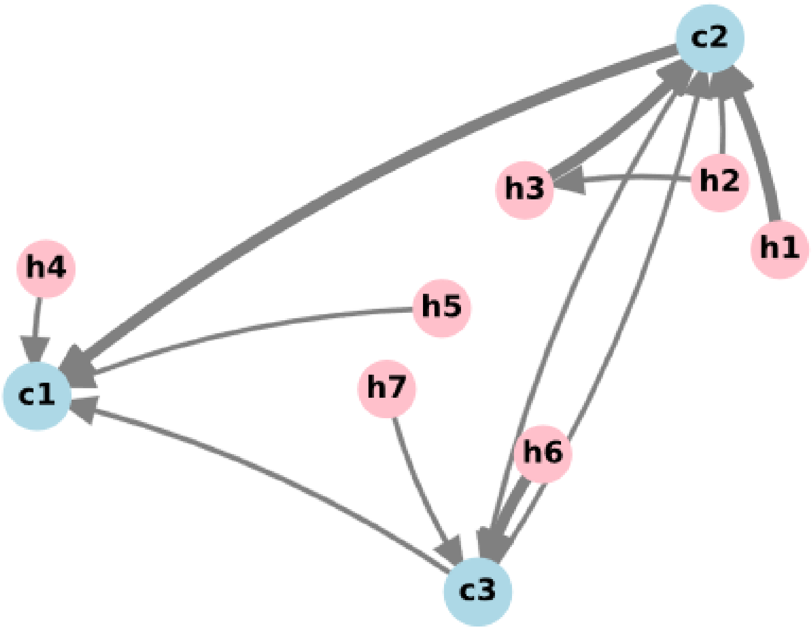
aufgrund eines Beschlusses
des Deutschen Bundestages

Subject of the study

This study in the context of a local electricity market (LEM) aims to better understand the effects of differentiated grid fees:

- according to grid utilization
- according to grid level fairness of causality

- model regional grid topology, consumption, generation and flexibility structure for the years 2021/2023, and 2035
- simulate actor behaviour in LEM using simply [1]
- cases: fixed prices, dynamic prices and dynamic grid fees and regional grid fee reduction (similar to Austria [2])



[1] https://github.com/BESTenergytrade/simply

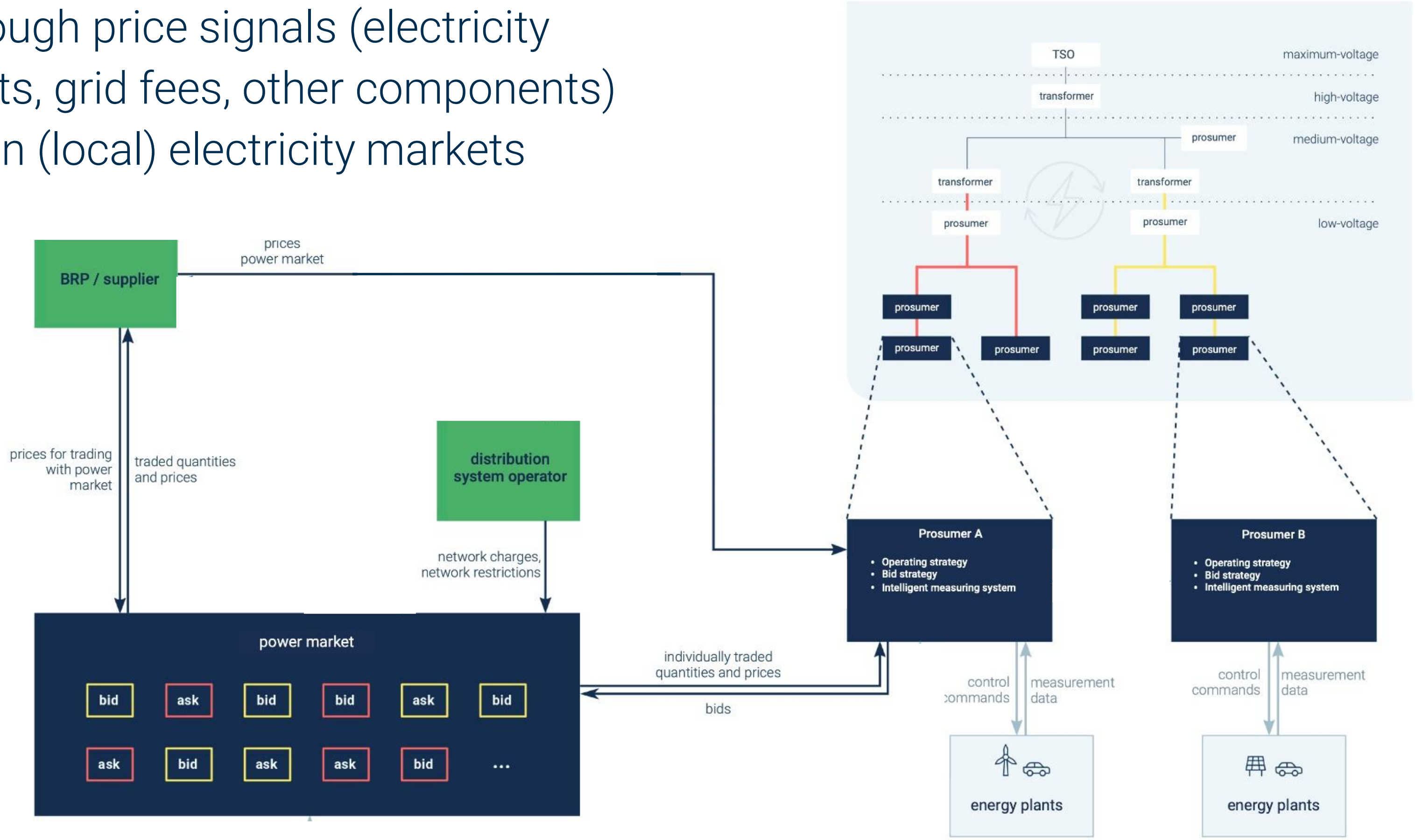
What do we do

Table 1: We compare the maximum power at a local substation for 5 scenarios

2021/2023	2035_noChange	2035_dynPrice	2035_AU	2035_dynFee
• Status quo	• Ramp up of PV, storage and sector coupling • Same regulation and fixed tariffs as 2021/2023	• Dynamic electricity prices • Fixed grid fees	• Dynamic electricity prices • Grid fees according to usage of grid levels	• Dynamic electricity prices • Grid fees according to inferred transformer load

What is simulated with simply?

- Load shifting through price signals (electricity procurement costs, grid fees, other components)
- Price formation on (local) electricity markets

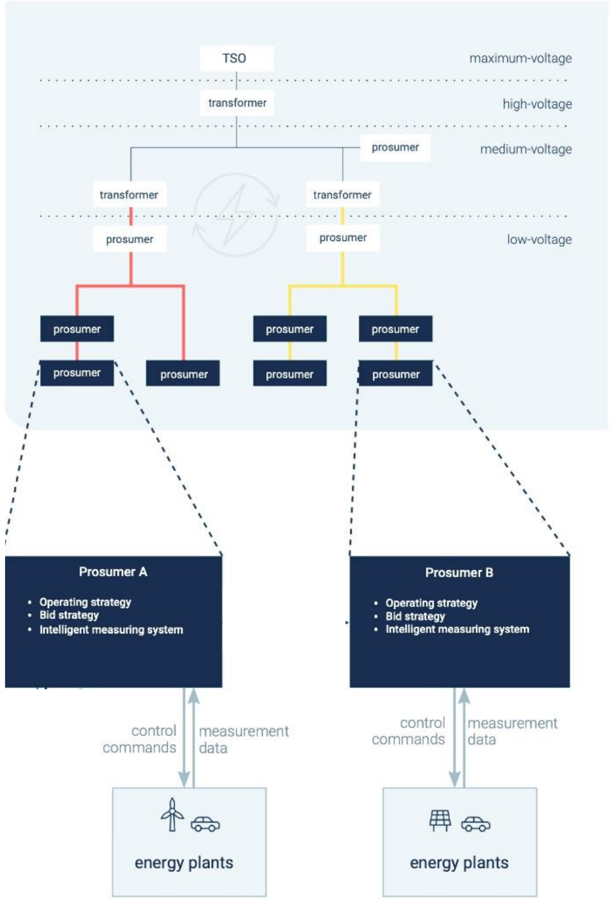


What is modelled - Actors

Actors/Prosumers are agents that participate on the market..

They are characterized by:

- Fixed time series:
  - Demand (e.g. household load/heat pump)
  - Generation (e.g. PV/wind)
- Flexibility:
  - Battery (start SOC, capacity, C-rate)
  - Electric Vehicle (driving profile, start SOC, C-rate)
- Strategy (single bid, no update)
  - Output: (Trading volume, Price)
- Grid location

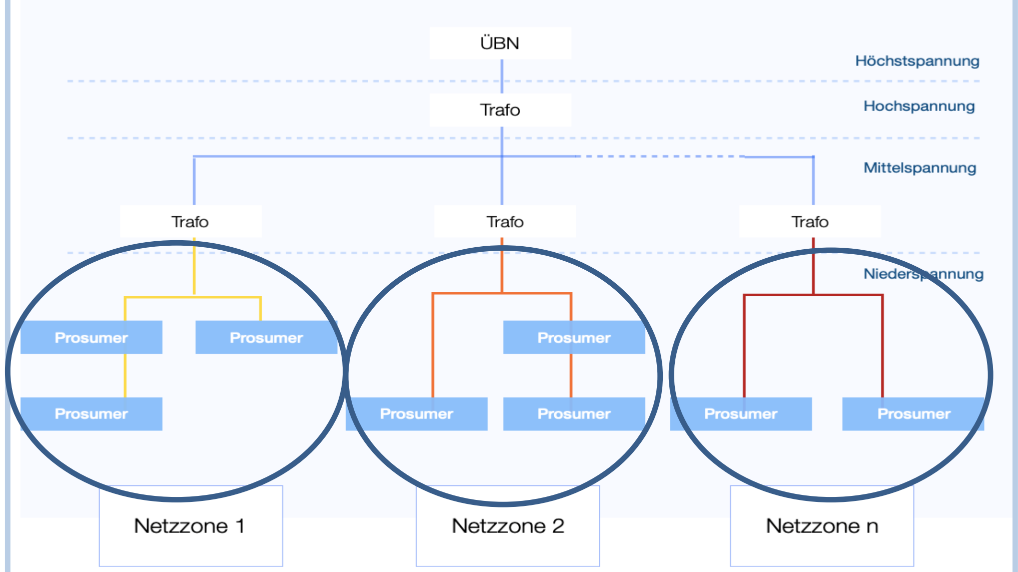


How is it modelled – power grid and grid fees

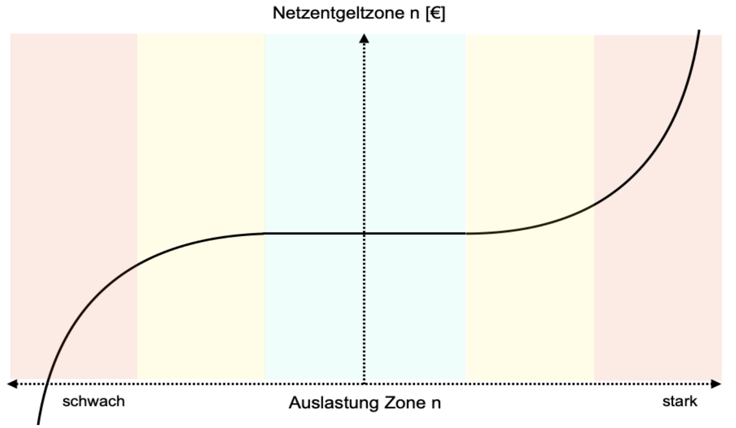
- The power grid is represented as a graph.
- Actors are assigned to nodes
  → actor nodes are clustered to local grid areas
- Grid fees between the grid areas are assigned using a matrix

GRID AREA	N_1	N_2	N_n
N_1	NE_{min}	$NE_{1\to2}$	$NE_{1\to n}$
N_2	$NE_{2\to1}$	NE_{min}	$NE_{2\to n}$
N_n	$NE_{n\to1}$	$NE_{n\to2}$	NE_{min}

The matrix is made up of the combinations of grid areas.



Grid areas are defined on the basis of the distribution grid topology to be represented



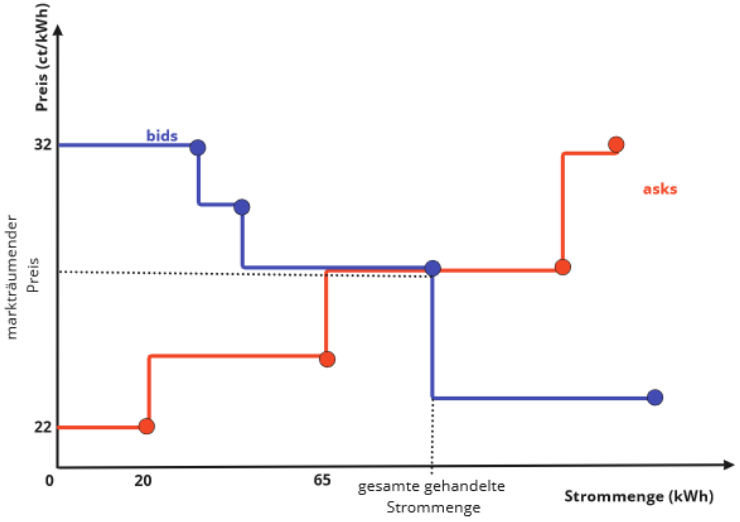
Prices can be adjusted independently for each entry in the matrix

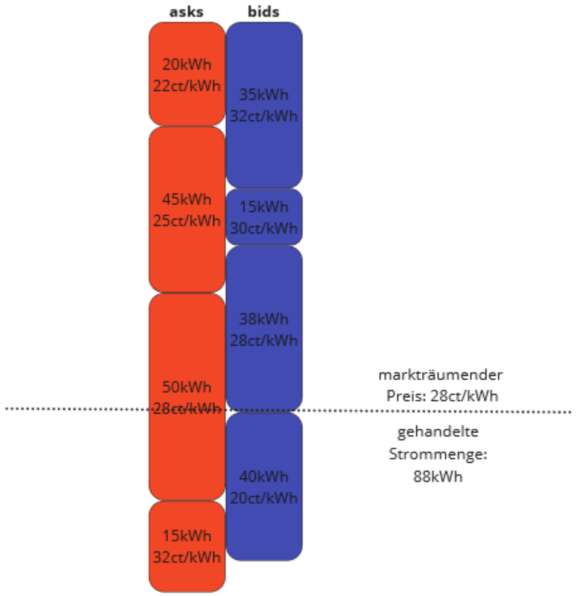
What is modelled - trading

Prosumers and aggregator/market maker meet on a trading platform. The market maker buys and sells an unlimited amount of electrical energy at fixed prices. These prices are known to the prosumer agents and are taken into account in their strategies.

Trading on the platform can be done in the following ways:

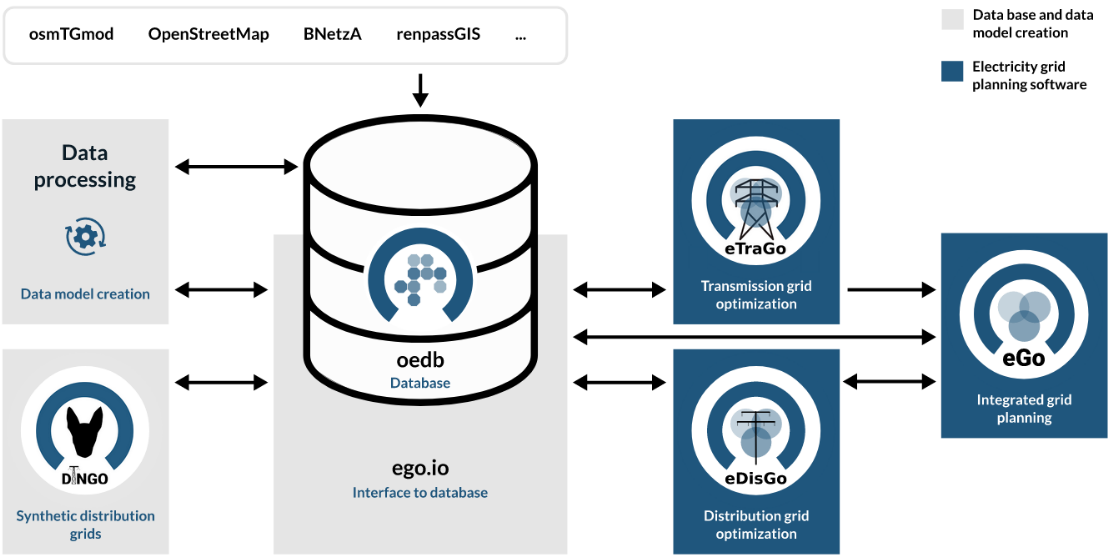
- Fixed electricity price
- Dynamic electricity price/ grid fees
- Market matching
    - Pay as bid
    - Merit order
    - Cluster-based Merit order
- Optimization with regard to
    - Trading volume
    - Minimization of grid fees





Scenarios and data sources

- Scenarios are composed of:
  - Prosumer agents
    - Distribution of assets to agents [a]
    - Strategy definition
  - Distribution of agents in the network [a]
  - Representation of the power grid [a]
  - Market maker electricity prices
  - Grid fees



[a] Data partially derived from projects and tools carried out or developed at RLI mainly the eGon – Project [3]

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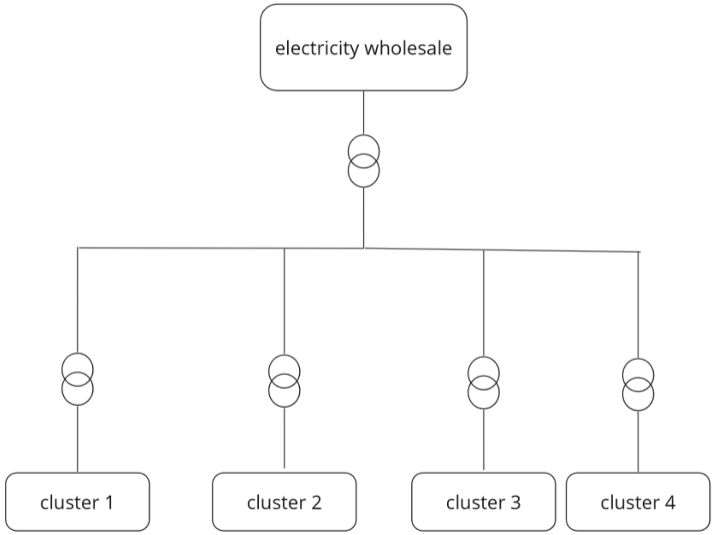
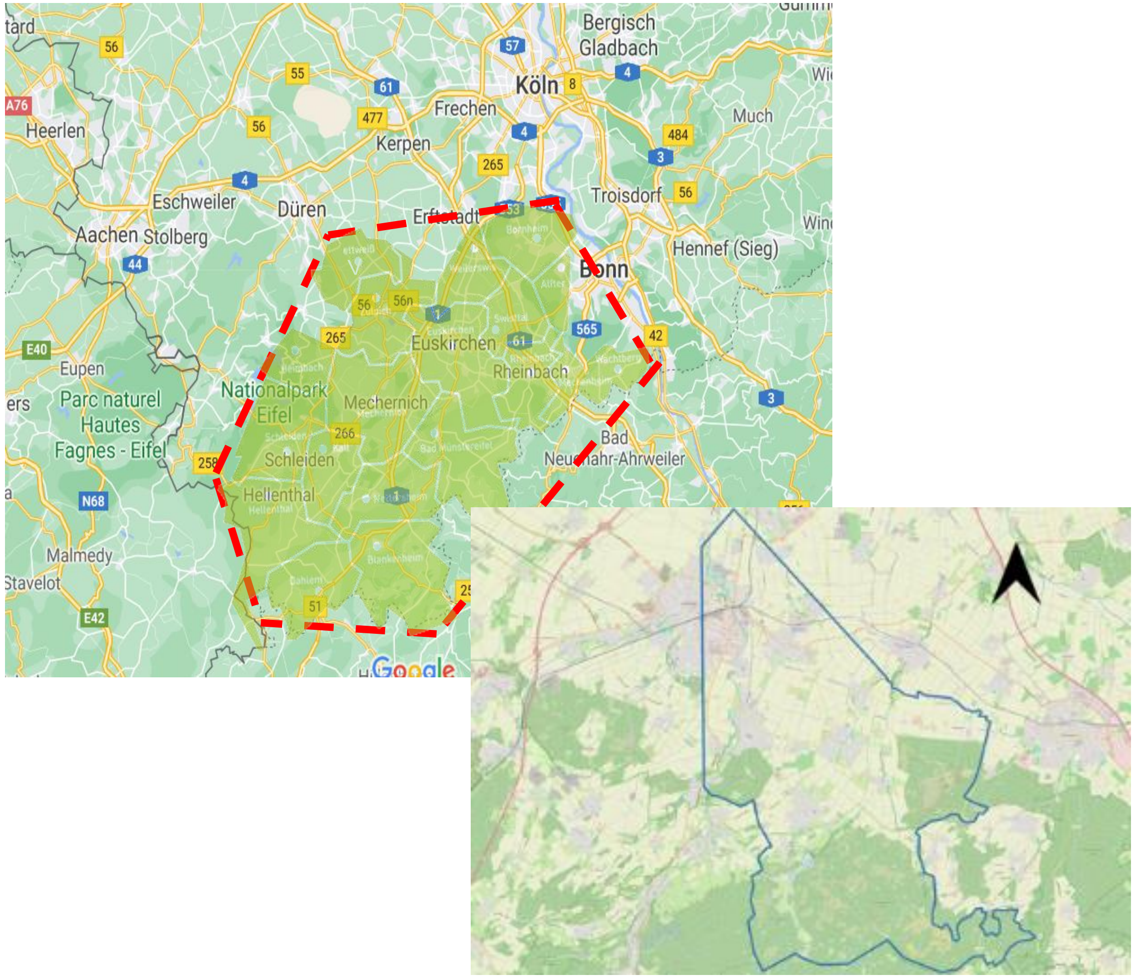
Mapping grid topology

- Study is part of BEST project [4] done with the local energy supplier e-regio
- Simulations are based on part of their grid
  - medium-voltage grid with 4 low-voltage grids
  - 20 % of residential grid connections randomly sampled → 97 households





[4] https://best-strommarkt.de/

Distribution of assets to actors


```
{
    "comment": "",
    "prosumerType": "residential",
    "prosumerName": "building_2277617",
    "gridLocation": "N01",
    "strategy": 2,
    "pricing_strategy": {
        "name": "linear",
        "param": [
            0.1
        ]
    },
    "devices": [
        {
            "deviceType": "load",
            "deviceID": "Load_mvgd_32866_lvgd_1009200004_9_residential.csv"
        },
        {
            "deviceType": "solar",
            "deviceID": "Generator_mvgd_32866_lvgd_1009200004_pv_rooftop_401.csv"
        },
        {
            "deviceType": "battery",
            "capacityKwh": 5.9,
            "initialSOC": 0.5
        },
        {
            "deviceType": "ev",
            "deviceID": "ev_0001.csv"
        }
    ]
},
```


- Time series for devices from eGon-data for 2021 and 2035 [5]
- heat pump load is included in fixed “load”

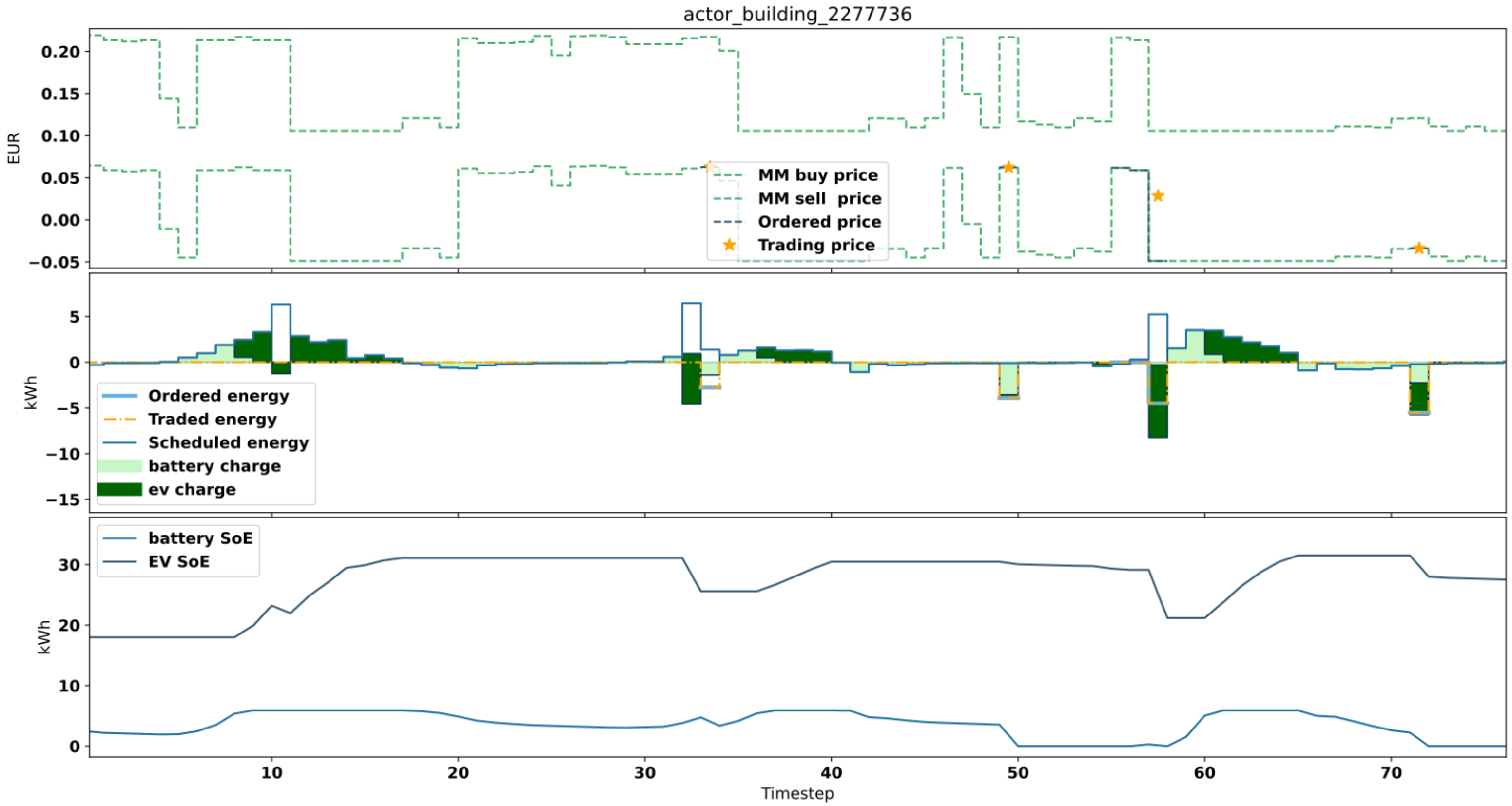
Scenarios

Table 2: Scenario description, defining assets and price components.

	2021/2023	2035_noChange	2035_dynPrice	2035_AU	2035_dynFee
LOAD/PV	eGon household [a]	eGon household [a]			
Battery	1kWh per 1kWp	1kWh per 1kWp			
EV	None	43% [b]			
Heat Pump	None	eGon household [a]			
Electricity Price	24,28 ct/kWh [c] 8,2 ct/kWh [d]	24,28 ct/kWh [c] 8,2 ct/kWh [d]	dynamic [e]		
Grid Fee	7,73 ct/kWh [f]	7,73 ct/kWh [f]	7,73 ct/kWh [f]	cluster/region [g]	dynamic [h]

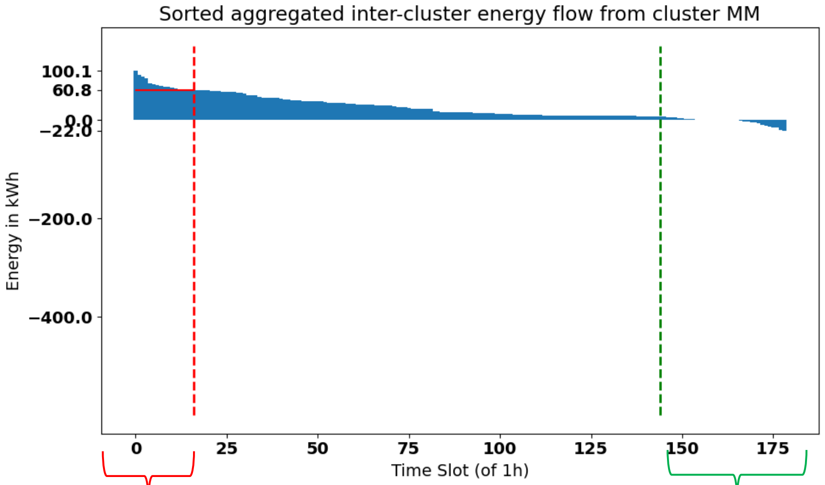
[a] assets asigned to households according to eGon-data [5]
[b] EV with a driving profile according to eGon-data [5] assigned to 43% of households
[c] BDEW average in 2023 [6]
[d] feed in tariff for PV power plants with a nominal power less or equal to 10 kWp (2024) [7]
[e] dynamic prices derived from [8]
[f] net commodity charge for SLP customers at Westnetz GmbH (2023)[9]
[g] within cluster 3.324 ct/kWh, from other regional clusters 5.566 ct/kWh, from market maker 7.73 ct/kWh
[h] explained in results section on slide 16

Results – Actor Example



Actor:
- Optimizes self-consumption
- Buys at guaranteed lowest price within horizon
- Sells excess energy at guaranteed highest prices within horizon

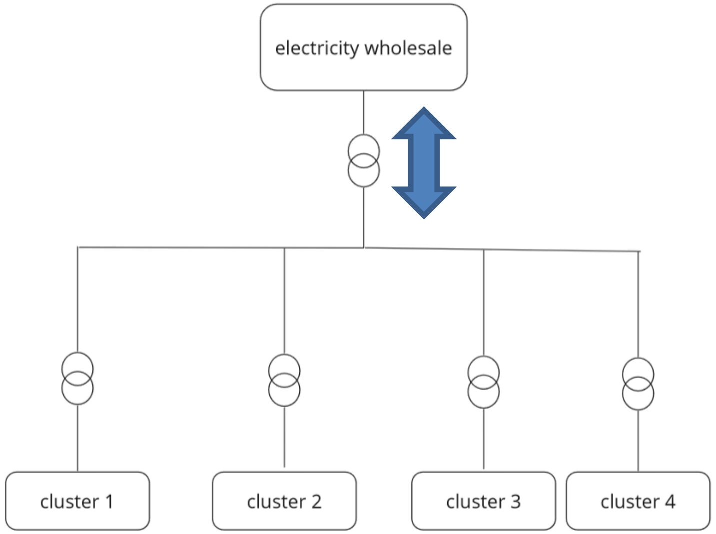
Results – Transformer Load from Selected Households



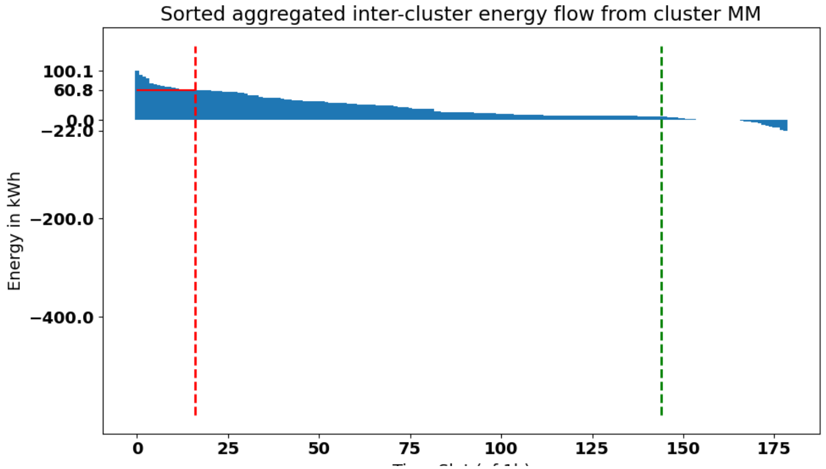
10% of time with highest value

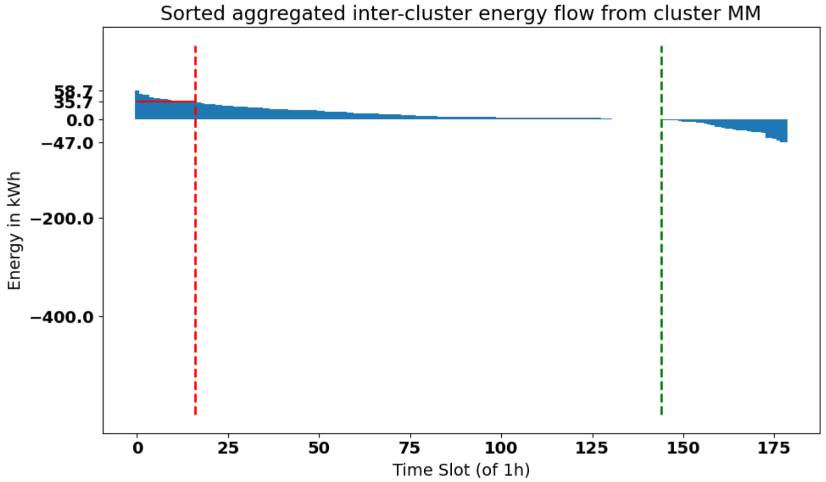
20% of time with lowest value

- Following results compare the aggregated energy flow from all clusters of the region from or to the LEM market maker



Results for Fixed Price: 2021 vs. 2035





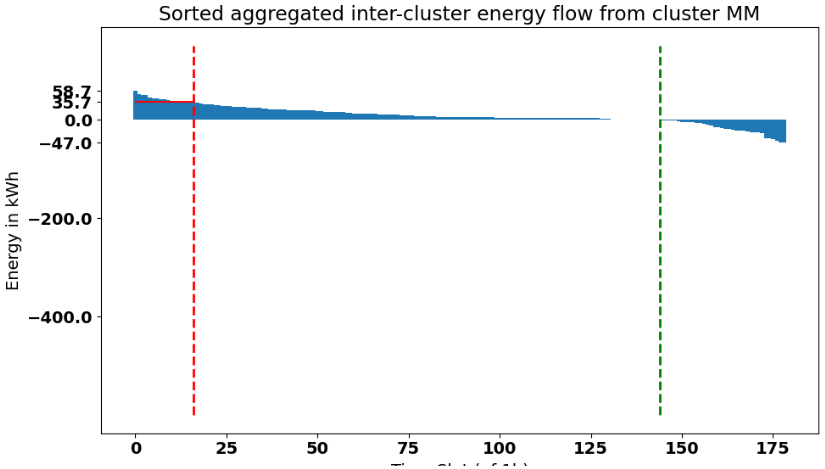
2021/2023

- Self-consumption optimized
- Energy is traded in the moment when it is needed

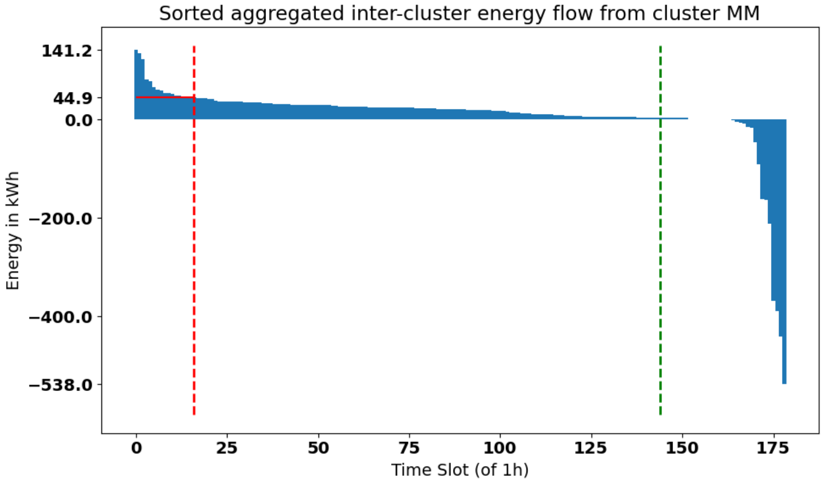
2035_noChange

- More generation and demand
- More flexibility (EVs)
  → Higher self consumption
  → Higher volume of excess generation

Results for 2035: Fixed vs Dynamic Prices



2035_noChange



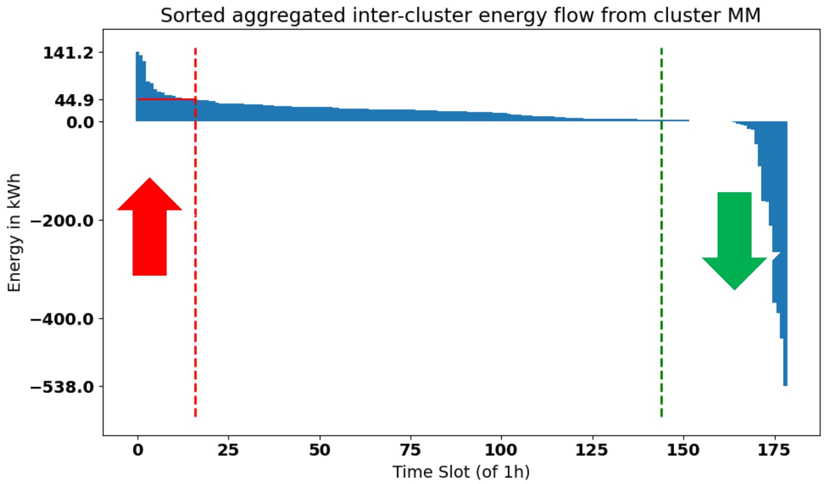
2035_dynPrice

- Actors optimize buys for guaranteed high prices and sells for guaranteed low prices
- Synchronization of loads or feed-in
  → Introduces potential grid congestions

Dynamic Grid Fees

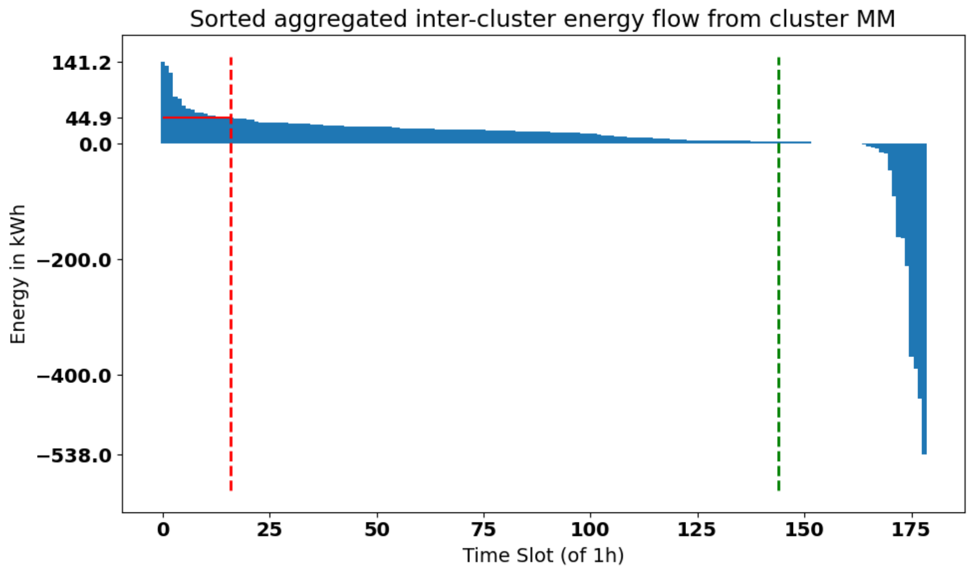
We derive dynamic grid fees from results of 2035_dynPrice scenario for

- hours with 10% highest loads on transformer
  - raise grid fee by 25%
- hours with 20% lowest loads/highest feed-in on transformer
  - Reduce grid fee by 25 %



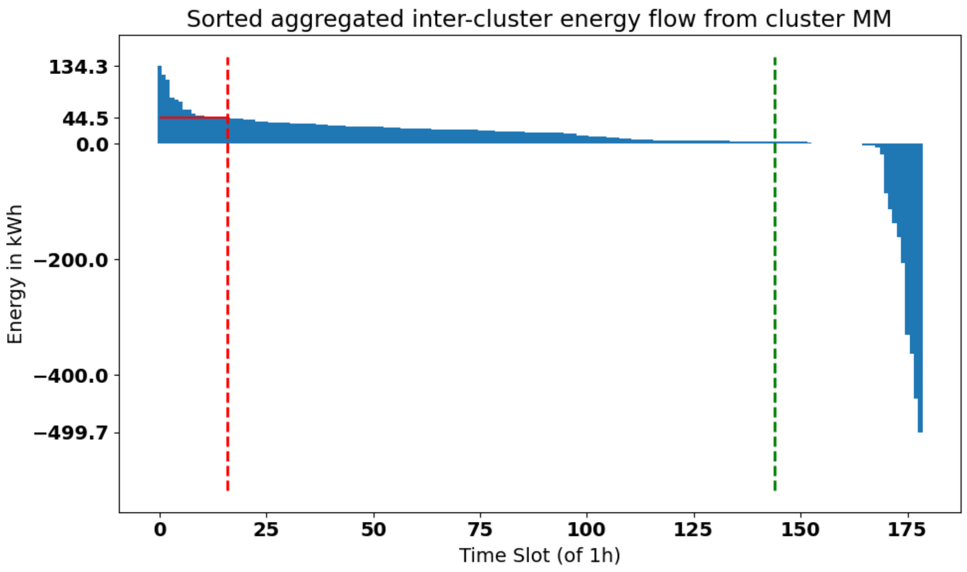
Results for 2035 Differentiated Grid Fees: temporal vs locational

2035_AU



- No effect on peak values
- Local grid fees potential for higher profits are ineffective in selected actor strategy

2035_dynFee



- Slight reduction of peak values
- Peak mostly shifted to the time slot with next lowest price:

dynPrice: [36, 133, 157, 12, 60, 128, 109, …]

dynFee: [37, 134, 158, 106, 59, 13, 110, …]

Conclusion and Discussion

A module was presented that allows the analysis of grid fee policies regarding the utilization of network resources.

Dynamic back-up prices that are guaranteed, introduce **synchronization** of load or feed-in.

Adapting the grid fee based on location or time alone is **unable to reduce congestion**
→ Local / regional grid fee reduction can only be exploited as additional profit, if agent's strategy bids with non-guaranteed prices

The consistent depiction of a future scenario is a major challenge

Further development of the model
- Enable nodal pricing concept
- Further actor strategies (local trading, RL)
- Combine local grid fee concept with dynamic fees
- Actor flexibility modeling (e.g. heat pump)

Thank you for your attention!

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Your ideas?

… Partnerships

… Reseach cooperations

… Joint project proposals

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

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[7] Jens Burkhardt, 2024. Einspeisevergütung 2024: Tabelle & Neuerungen. Echtsolar. URL https://echtsolar.de/einspeiseverguetung/ (last visit March 15, 2024).

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