Estimating the Value of Distributed Demand Side Management Technologies in Central Western Europe - Assessing Regional Differences in View of Locational Pricing Mechanisms

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Electricity market design in Europe is challenged

- Zonal pricing is the prevalent market design among member states
  - Theory: internal congestion free zones (efficiency criteria)
  - Reality: ~1.2 bn € for redispatch measures since 2017 in Germany [1]

- Efficiency of current market design is challenged by intra-zonal congestions
  - Increasing renewable energy sources in „sweet spots“
  - Delayed power grid expansion

- Modifications of the market design to overcome inefficiencies
  - Market zone reconfiguration
  - Extremely small zones: Nodal Pricing

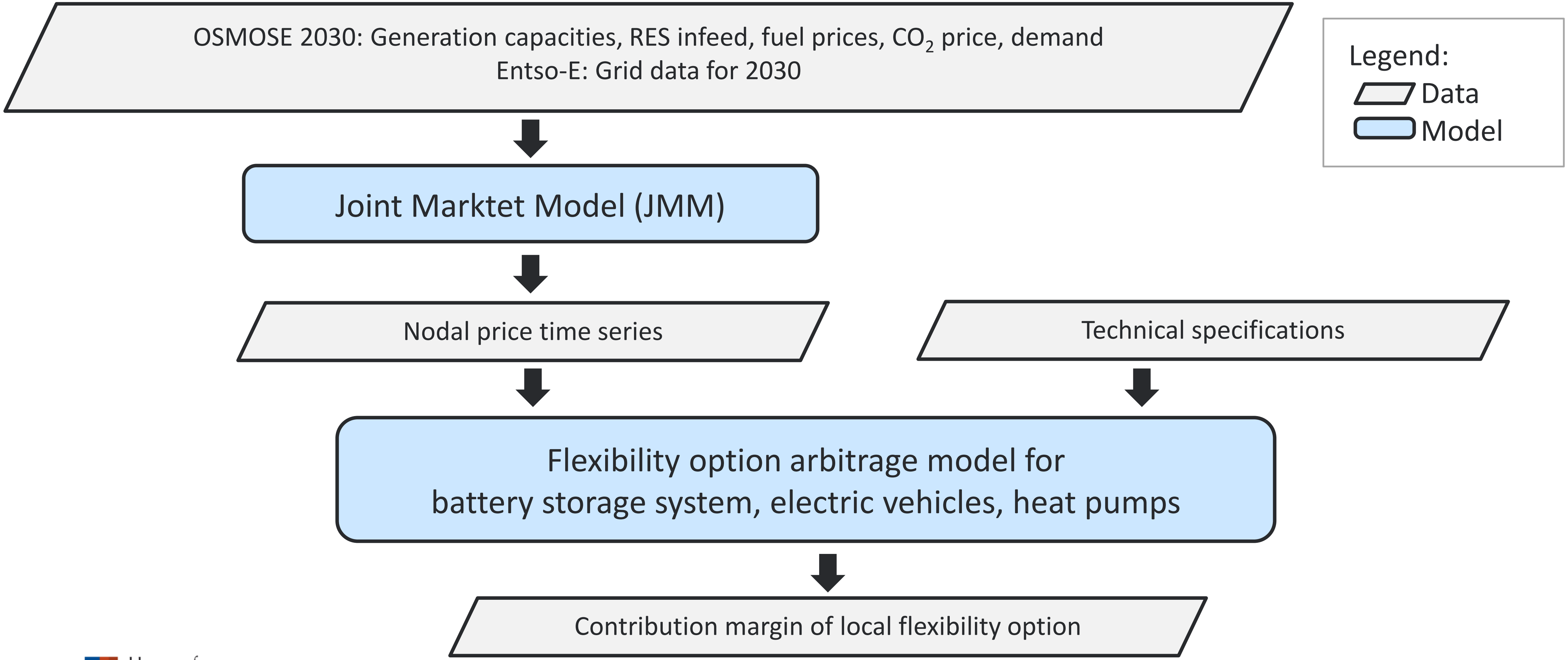
[1] Federal Network Agency Germany, Report “Quarterly Report Network and System Security - Full year 2020”

Research Focus

- Nodal Market Design
  - Each HV node reflects a market zone
  - Scarcity of the grid is part of nodal electricity price → One step clearing mechanism
  - Theory:
    - Efficient market design
    - Nodal price signal as regional investment incentive
  - Nodal market design is already implemented (e.g. US ISOS)

- Research Question
  - To what extent would nodal prices vary in 2030 in CWE?
  - What is the local value of flexibility under nodal market design for different flexibility options?

Model Chain Setup



Results - Joint Market Model

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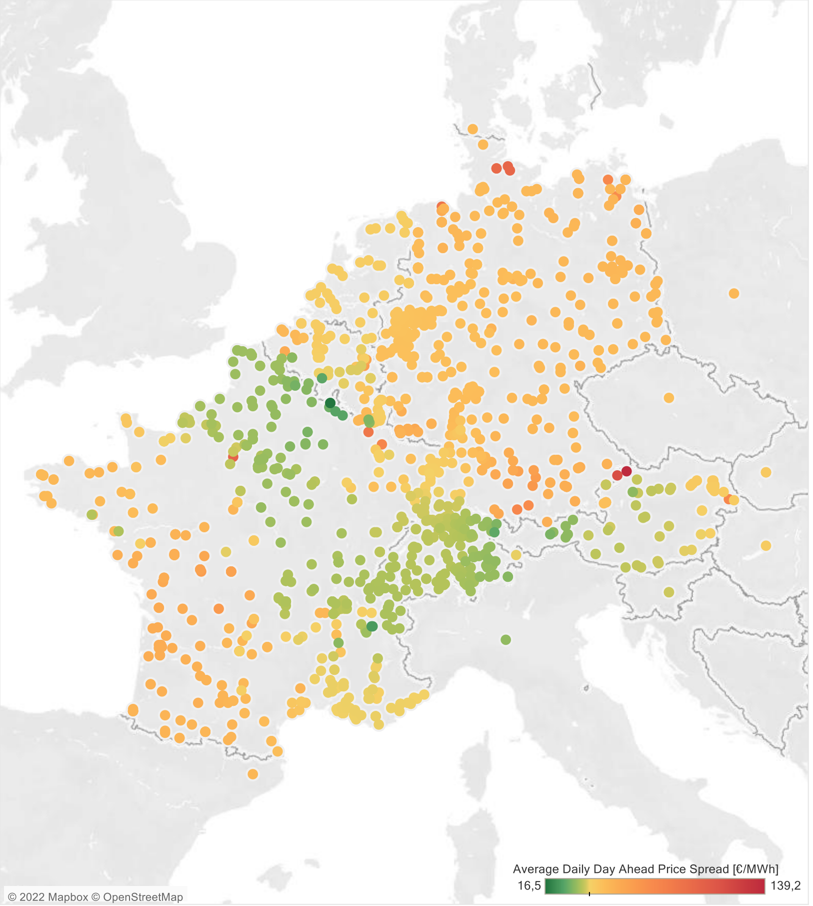
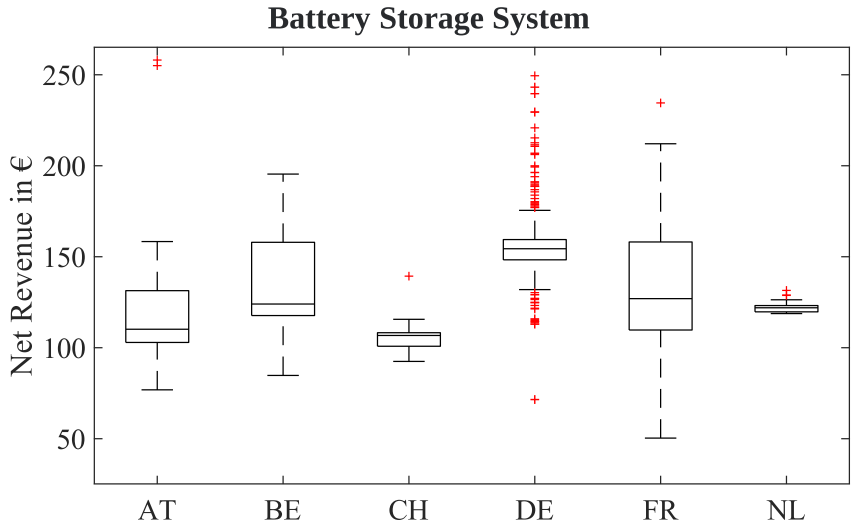
Price Patterns for CWE

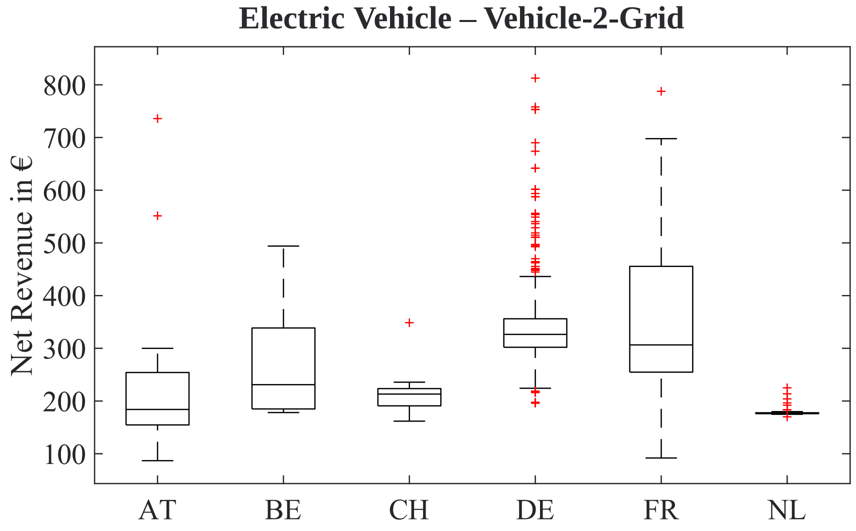


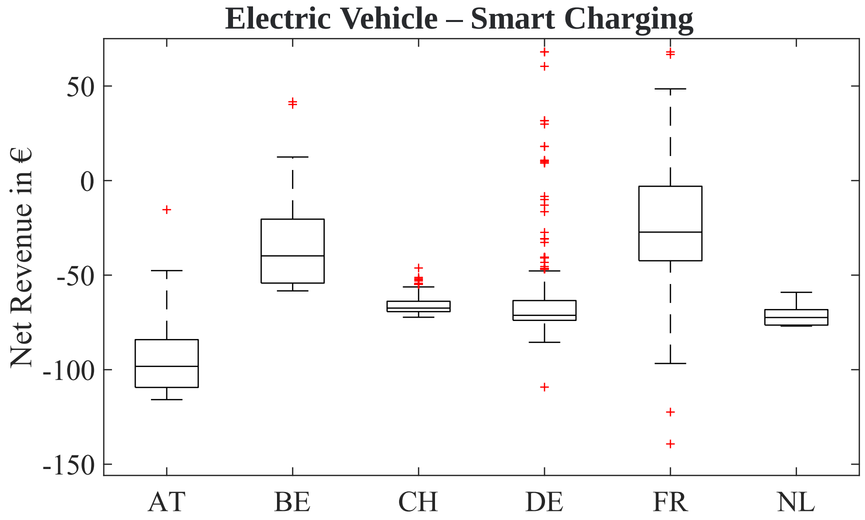
Average Day Ahead Price [€/MWh]

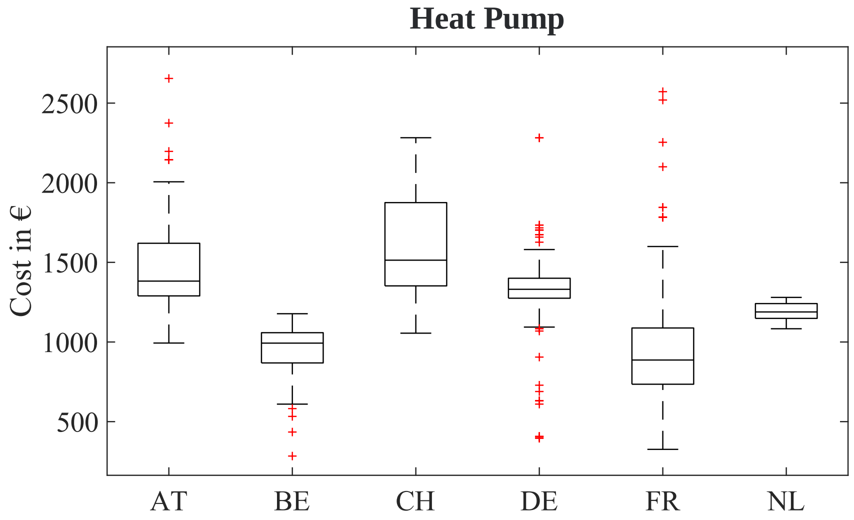
Results – Arbitrage Model

Boxplots of Flexibility Options









Conclusion

- Nodal prices in 2030 reflect today‘s market zones
  - Main driver: scarcity of international transmission capacities
  - Zones differ in internal level of congestion
- Regional differences in the value of flexibility are observable: (1) between and (2) within countries
  - The use of flexibilities should be particularly encouraged in regions with high flexibility values
- Technical characteristics reward flexibility options differently in the regions of scope
  - Specific incentives for the locational choice of flexibility investment are advisable

Thank you
for your attention!

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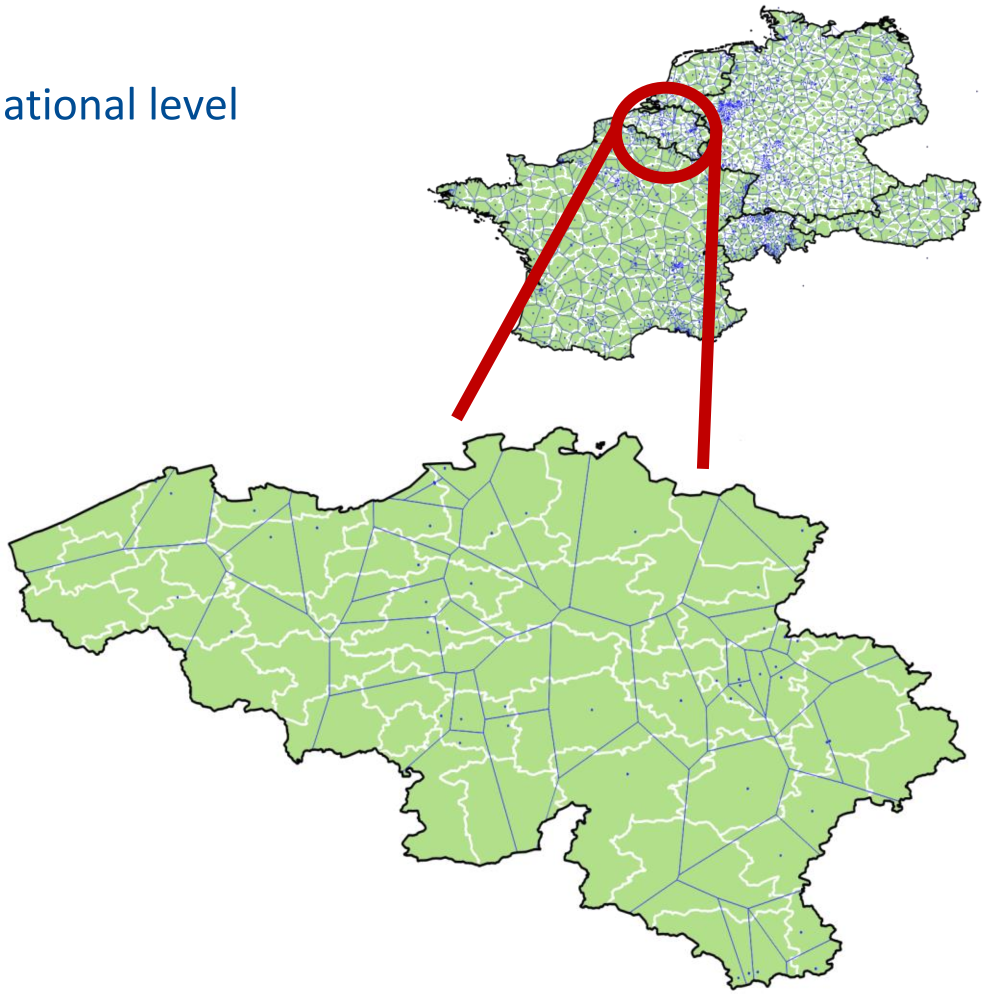
Methodology

Nodalizing National Input Timeseries

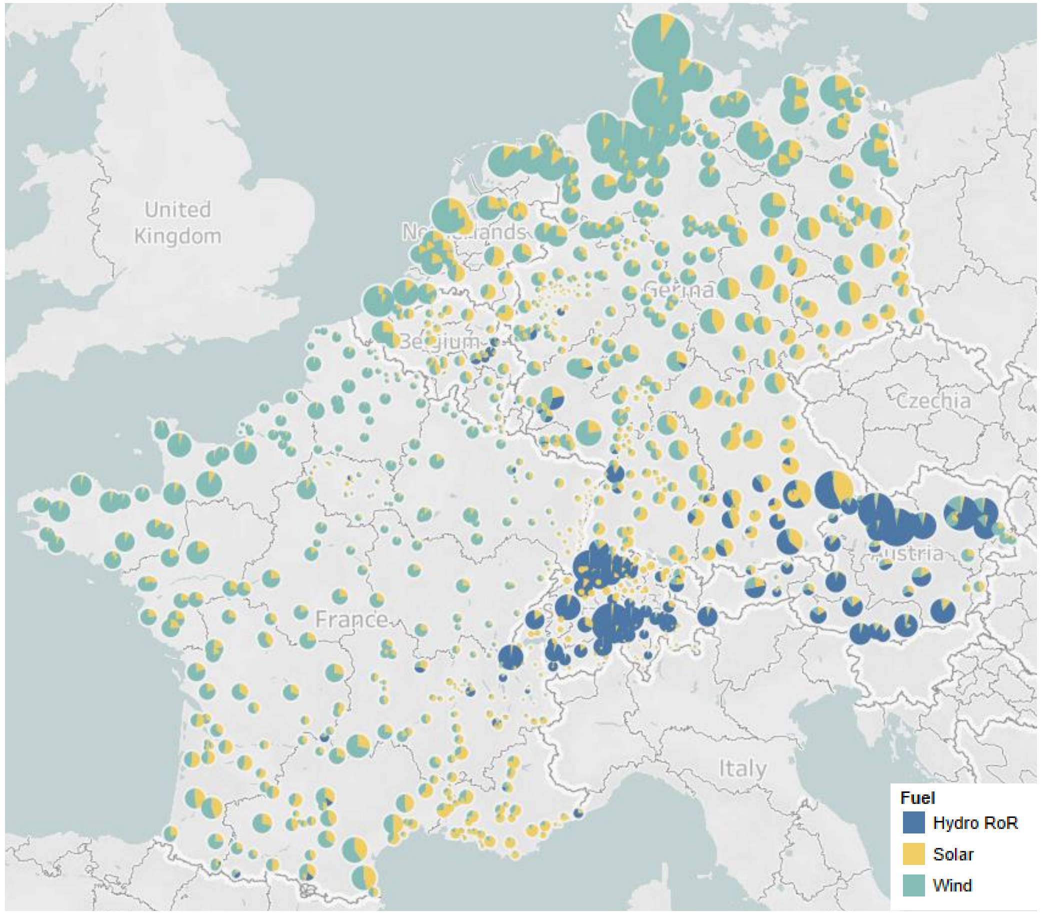
- RES infeed on NUTS3-level
  - Comparison of existing RES capacities and target level on national level
  - Open space analysis
  - Discrete choice model to build up missing capacities
  - Applying a weather year (MW → MWh)

- Voronoi regions around HV nodes
  - Covered area assigned towards the respective center node
  - Proportional distribution of split NUTS regions

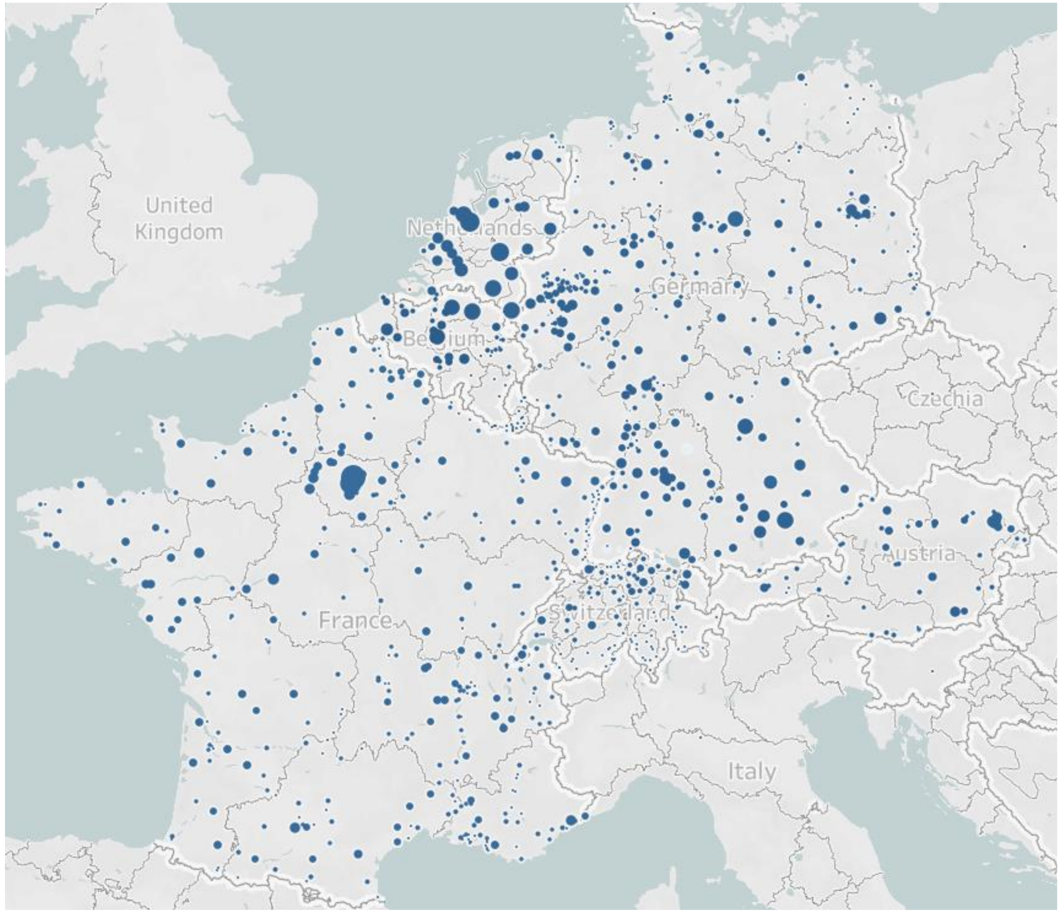


Methodology

Nodal RES Infeed and Demand



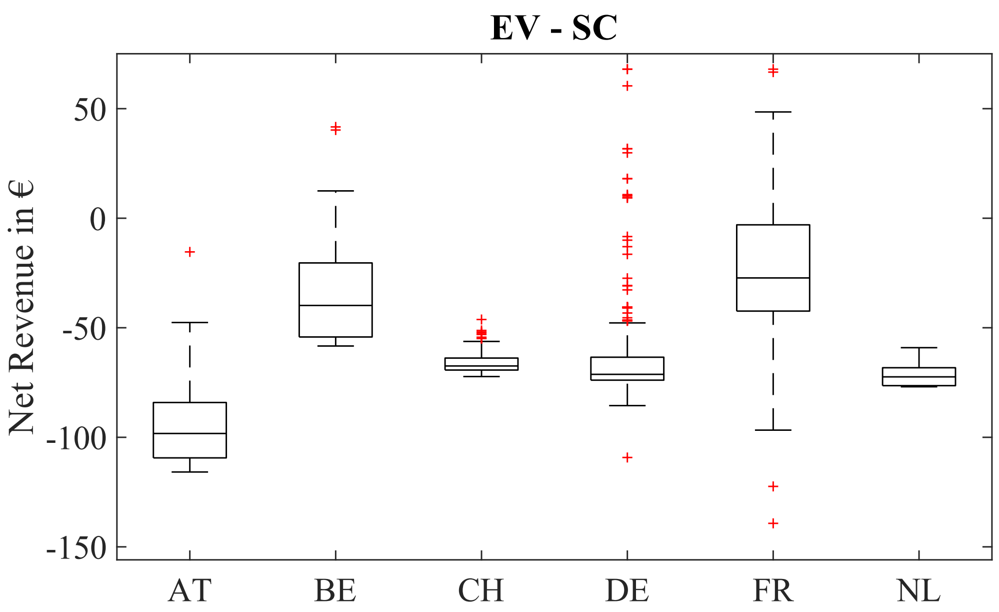
Nodal Distribution of RES

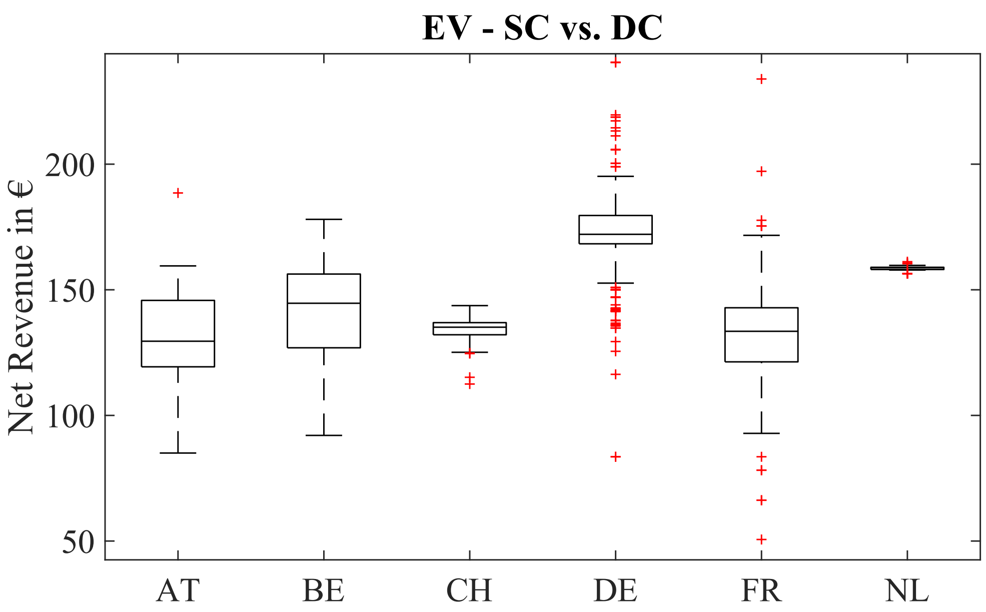


Nodal Distribution of Electricity Demand

Electric Vehicle Comparison

Price Effect





- Relative value in FR is low → low prices
- Relative value in AT is lower compared to DE,NL → similar prices with lower volatility

→Reference price niveau has to be considered
→High volatility makes exploitation more valuable

Regional Storage Arbitrage Model

$$\text{maximize} \sum_{t \in \mathcal{T}} \pi_t \cdot (P_t^{OUT} - P_t^{IN})$$

- Maximize Margin through Interaction

Subject to

$$E_{t+1}^{SOC} = E_t^{SOC} + \tau \cdot (\eta^{IN} P_t^{IN} - 1/\eta^{OUT} \cdot P_t^{OUT} - P_t^{DRIVE}) \qquad \forall\, t \in \mathcal{T} \backslash \{t_{end}\}$$

- Intertemporal Filling Level Update

$$0 \leq E_t^{SOC} \leq \overline{E^{SOC}} \qquad \forall\, t \in \mathcal{T}$$

- Upper and lower Storage bound

$$E_1^{SOC} = E_{8760}^{SOC}$$

- Initial Charging State = End Charging State

$$BIN_t^{IN} + BIN_t^{OUT} \leq 1 \qquad \forall\, t \in \mathcal{T}$$

- Only Charge or Discharge

$$0 \leq P_t^{IN} \leq BIN_t^{IN} \cdot \overline{P^{IN}} \qquad \forall\, t \in \mathcal{T}$$

- Maximum Charging Rate

$$0 \leq P_t^{OUT} \leq BIN_t^{OUT} \cdot \overline{P^{OUT}} \qquad \forall\, t \in \mathcal{T}$$

- Maximun Discharging Rate

Variables used:

E_t^{SOC} …	Storage state of charge filling level
P_t^{IN} …	Storage charging power
P_t^{OUT} …	Storage discharging power
BIN_t^{IN} ….	Binary state: Charging
BIN_t^{OUT} …	Binary state: Discharging

Parameters used:

η^{IN} …	Charging efficiency
η^{OUT} …	Discharging efficiency
τ …	Time step size
$\overline{P^{IN}}$ …	Max. charge power
$\overline{P^{OUT}}$ …	Max. discharge power

Sets used:

$t \in \mathcal{T}$ …	time step in timestep horizon