# Why modelling of energy storage direly needs deep reinforcement learning and agent-based modelling?

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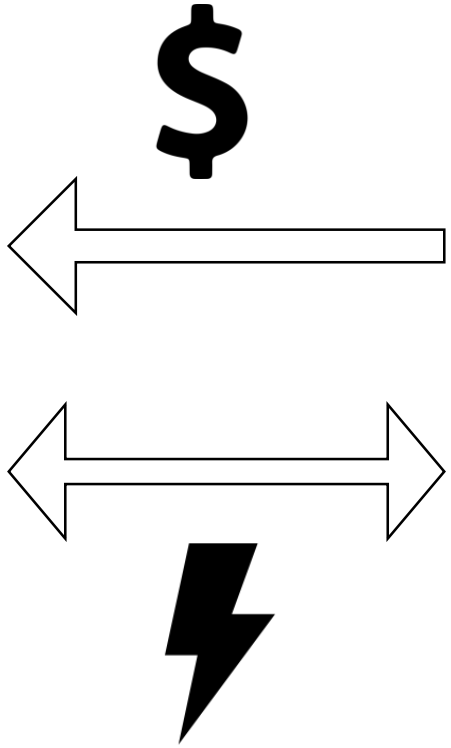
# What do we want to understand?



# What do we want to understand?

# How to simulate electricity markets?

## Energy System Models State-of-the-art

- Standard Approach: Optimization Models
  - --- Most common
  - --- Social planner / Price taker approach
  - --- Least cost minimization or similar
  - --- Sophisticated complexity and model depth
  - --- Usually solely determined by techno-economic specifications

- Alternative: Agent-Based Models
  - --- Less common
  - --- Typically built on decision rules
  - --- Aggregated aggent types
  - --- Behavioral and model simplifications
  - --- Often requires modeller to predefine behavior

# How to simulate electricity markets?

## Energy System models

### Austria

- ATLANTIS (TU Graz)
- MEDEA (BOKU Wien)
- HIREPS (TU Wien)
- Green-X (Tu Wien)
- No ABMs to the best of my knowledge

### Germany

- Some ABMs
- Power-Ace (Karlsruhe Institute of Technology)
- AMIRIS (Deutsches Zentrum für Luft- und Raumfahrt)
- Mozubi (TU Braunschweig / IZES)
- More classical models …

Caveat:

Perfect Competition

or

Units bid their marginal costs

# Validity and Problems of the „Perfect Competition“ Assumption

**Thermal Generation**

- Marginal costs are determined by **fuel costs & efficiency**
- Opportunity costs are negligible

- Rarely Pivotal, if slow-ramping
- Market Power less relevant

Hence:

Perfect competition assumptions well-justified,

Bidding behavior doesn’t need to be represented in the model

**Storage**

- Marginal costs are determined by **opportunity cost**
- Cost to run are negligible

- Frequently pivotal
- Market Power matters

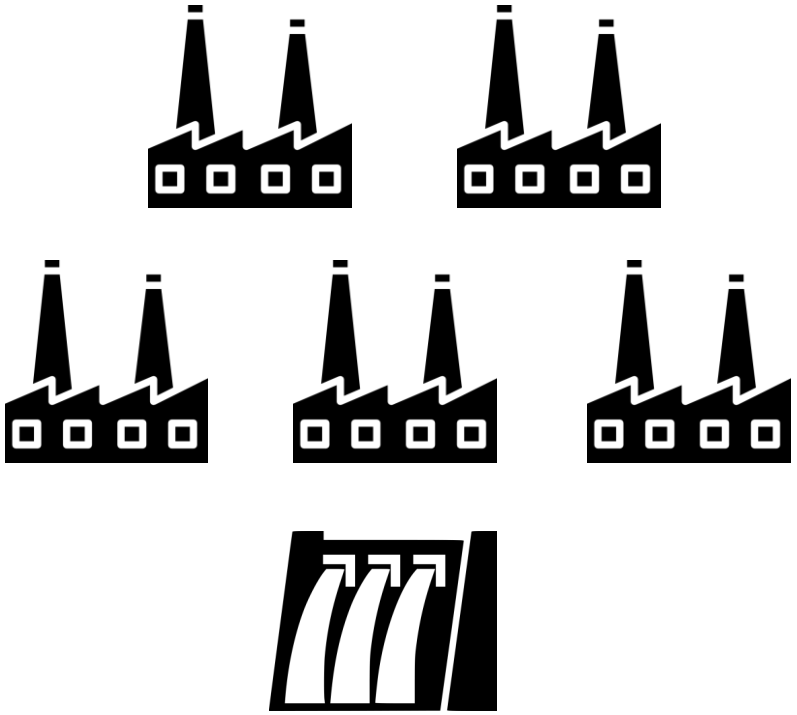
Hence:

Perfect competition assumptions not well-justified,

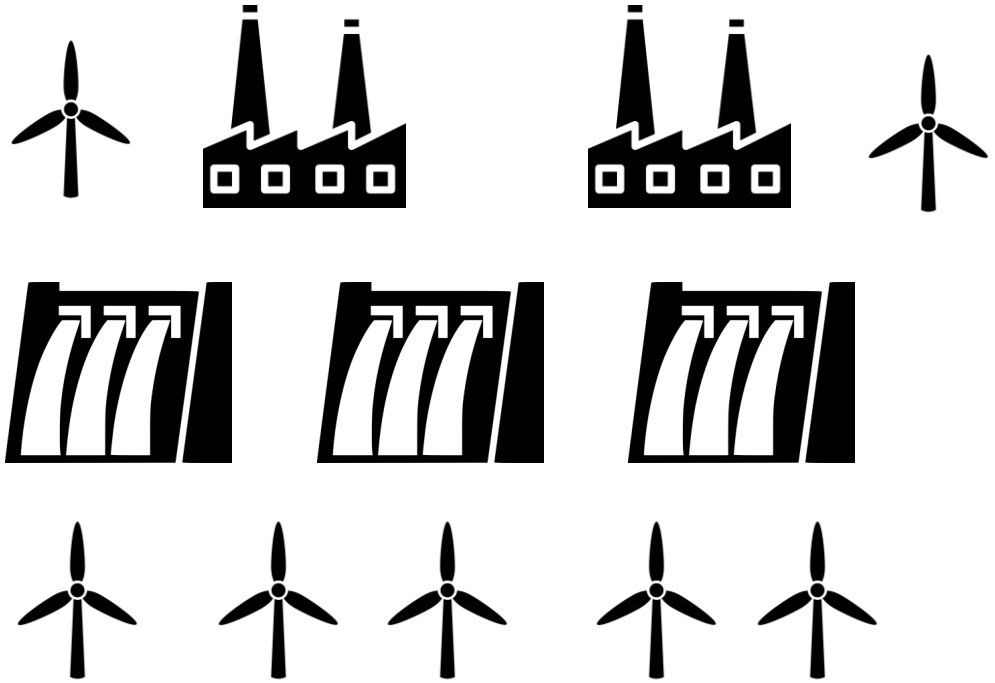
Bidding behavior matters

# Future Development of the „Perfect Competition“ Assumption

**Classical Power System**



**Power System Based on Intermittent Sources**



# Why ABMs?
# Why reinforcement learning?

# Reinforcement Learning complements ABMs

## Improvements upon ABMs

RL is self-learning from a reward mechanism (i.e. electricity market auction)

- ABMs well suited to model scenarios of (imperfect) competition
- RL does not require predefined behaviors
- RL explores the market environment
- RL does not require input data on past bidding behavior or other private info
- RL relies on detailed models of the market clearing process and on units technical characteristics, both are usually public
- RL feasible due to new neuronal network techniques

„Computational Performance of Deep Reinforcement Learning to find Nash Equilibria “

https://arxiv.org/pdf/2104.12895.pdf

https://github.com/ckrk/bidding_learning

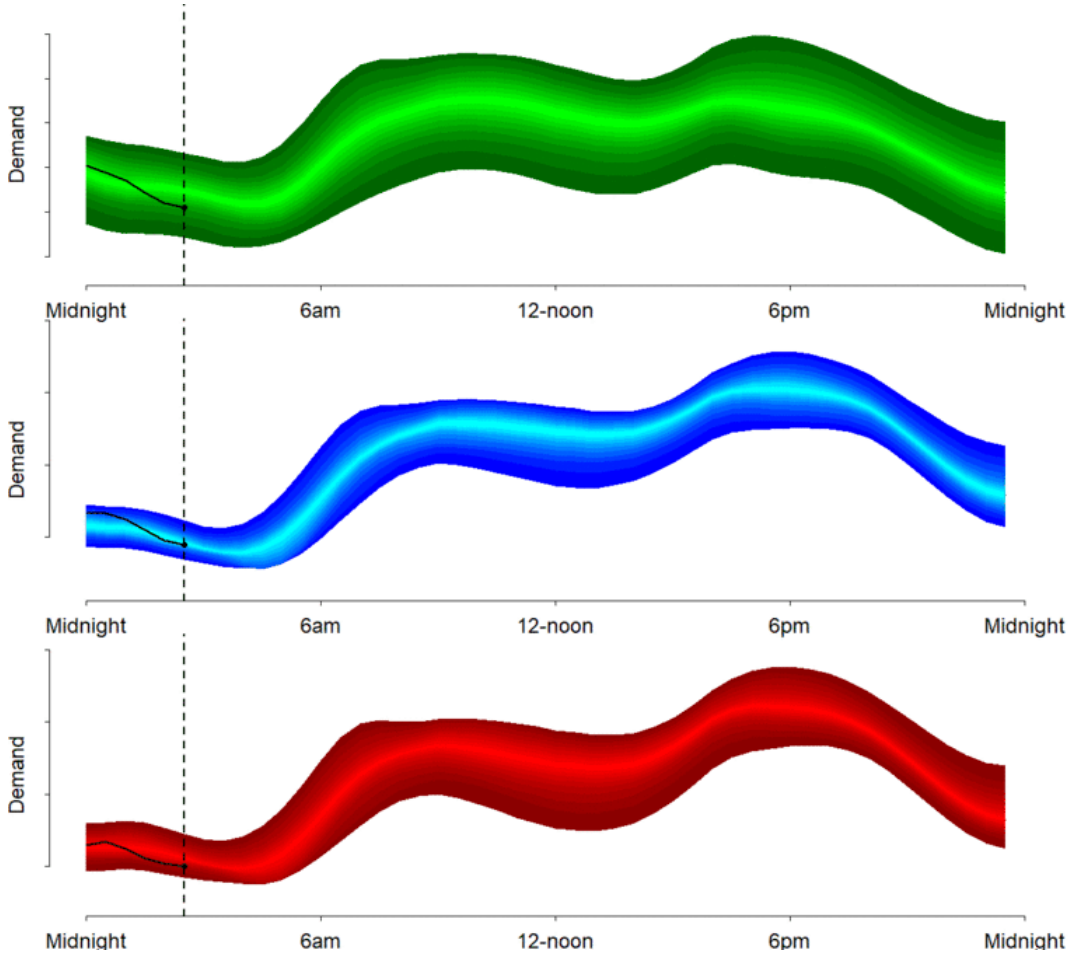
# What have we done?

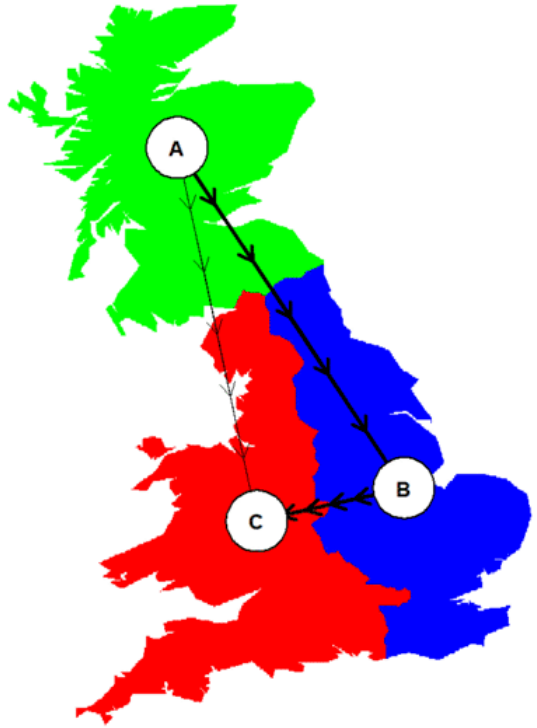
- (i) Study Thermal Generator Duopoly in Electricity Market Auctions
- (ii) Deep Reinforcement Learning allows fully continous State-Action Spaces
- (iii) Analytically derive equilibrium in this situation
- (iv) Show that with correct parametrization the algorithm converges to equilibria with up to 99%
- (v) Top 3 in the “Pathways to Netzero“ AI-Competition

- Furthermore: Open Source Repo & Sensitivity Analysis

# AI Competitions

AI for the Energy Sector: www.rangl.org



Please Get in Touch
We are looking for:

- Real Life Data
- Modelling your Reservoir
- Benchmarking against other RL & Optimizations
-Join our AI-Team for next years rangL competition
- …

# Thank You

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