SPONSORED BY THE
Federal Ministry of Education and Research

FLEXIBLE AND ACCURATE PRICE TIME SERIES FORECASTS FOR THE APPLICATION IN ELECTRICITY MARKET SIMULATIONS

Felix Nitsch[1], Christoph Schimeczek[1]

EnInnov Graz, Austria

February 16th, 2024

Acknowledgements
Valentin Bertsch,
Kristina Nienhaus on behalf of the EnEc Group

DLR

* Felix Nitsch felix.nitsch@dlr.de [1] German Aerospace Center | Institute of Networked Energy Systems | Energy Systems Analysis

Motivation

What Will Electricity Markets Look Like in the Future?

- Well established field of energy systems modelling (ESM) Gilliland, 1975
- Modelling challenges due to growing complexity Pfenninger et al., 2014, Pye et al., 2021

- Agent-based modelling (ABM) – a promising approach
  - incorporating the actors‘ perspective Nitsch et al., 2021
  - representation of heterogenous actors Kraan et al., 2018
  - execution of real-world examples computationally cheap Hansen et al., 2019

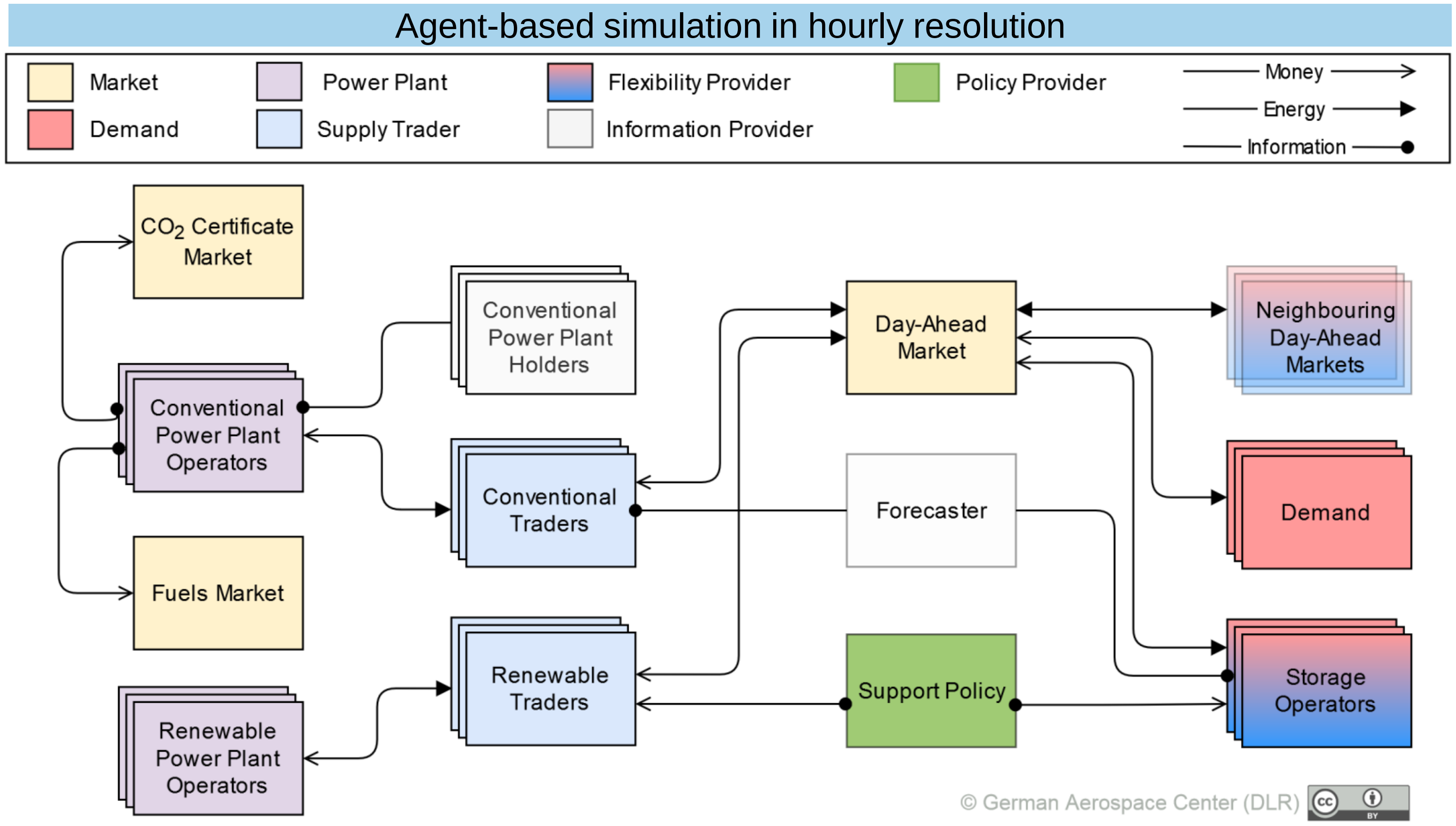
- Applying the ABM AMIRIS[1] to simulate electricity markets
  - integration of renewable energies & flexibility options in electricity systems
  - analysis of market effects caused by policy and remuneration schemes

[1] https://dlr-ve.gitlab.io/esy/amiris/home/

AMIRIS
Open Agent-based Electricity Market Model

Input
- RE feed-in
- Load
- Power plant park
- Efficiencies
- Plant availabilities
- Fuel & CO_2 costs

Output
- Electricity prices
- Power plant dispatch
- Storage dispatch
- Market values
- Emissions
- Dispatch system costs



AMIRIS model architecture

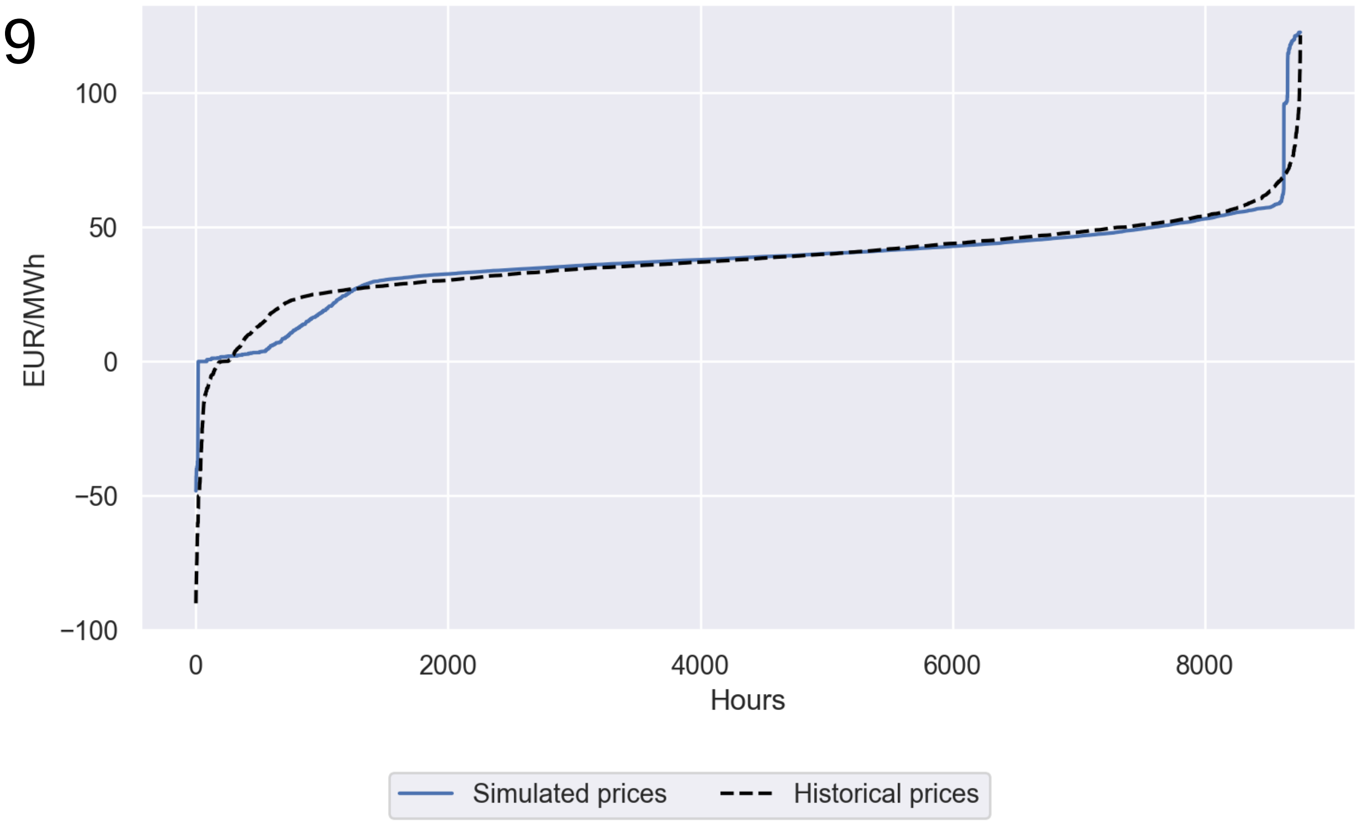
Published **open source** under Apache 2 license
See also https://dlr-ve.gitlab.io/esy/amiris/home/

Schimeczek et al. (2023a). 10.21105/joss.05041
Schimeczek et al. (2023b). 10.21105/joss.05087
Nitsch et al. (2023a). 10.21105/joss.04958

Case study
Varying Storage Specifications

- Base scenario:
  German Day-Ahead Market 2019
- Open parameterization,
  see AMIRIS Examples
- Variation of Storage
  - Power
  - Capacity (resp. E2P ratio)
  - Storage strategy
    - Minimize system costs
    - Maximize profits

What's the performance of different storage systems?



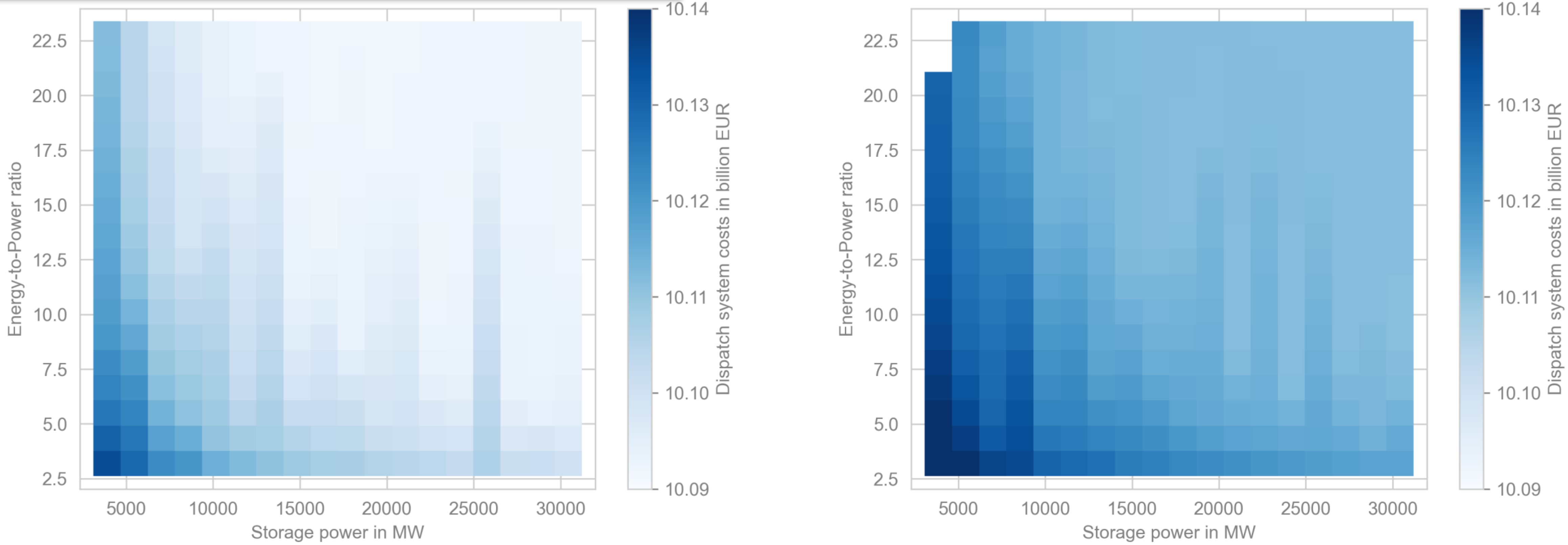
Comparison of simulated and historical prices

Nienhaus et al. (2022). 10.5281/zenodo.7789050

Case Study Results: Dispatch Systems Costs in Bill. EUR

Minimize System Costs vs. Maximize Profits

Minimize System Costs strategy achieves reduction of dispatch system cost

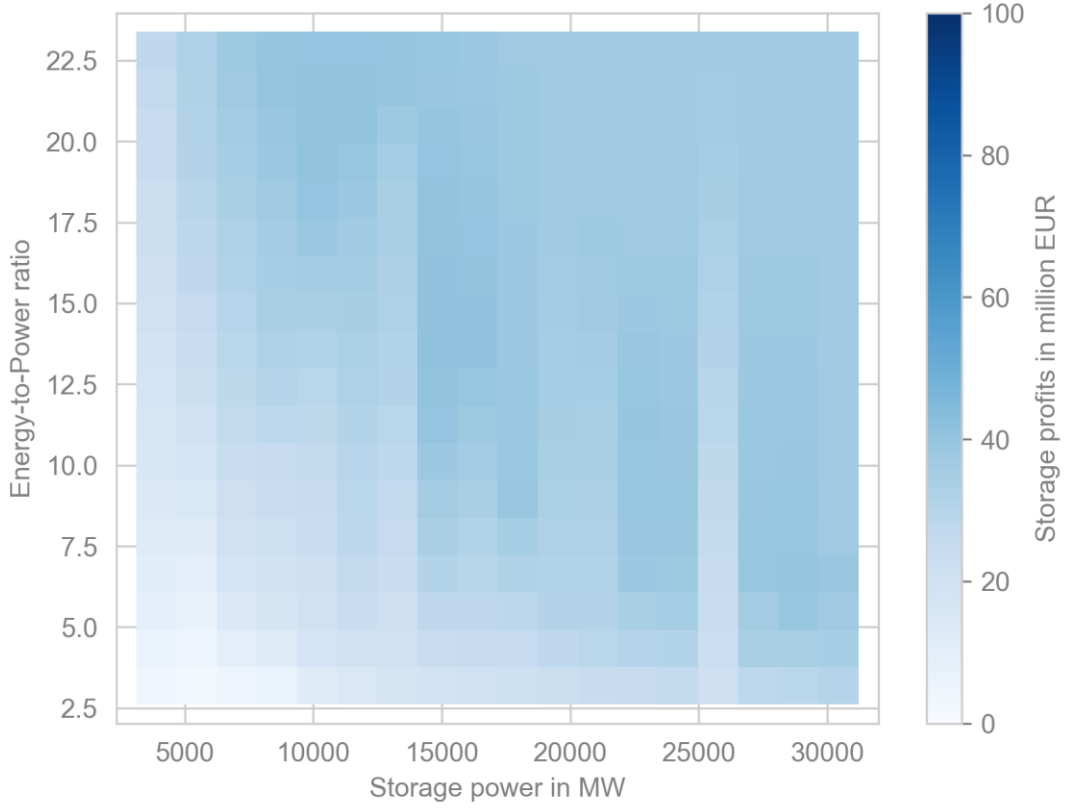


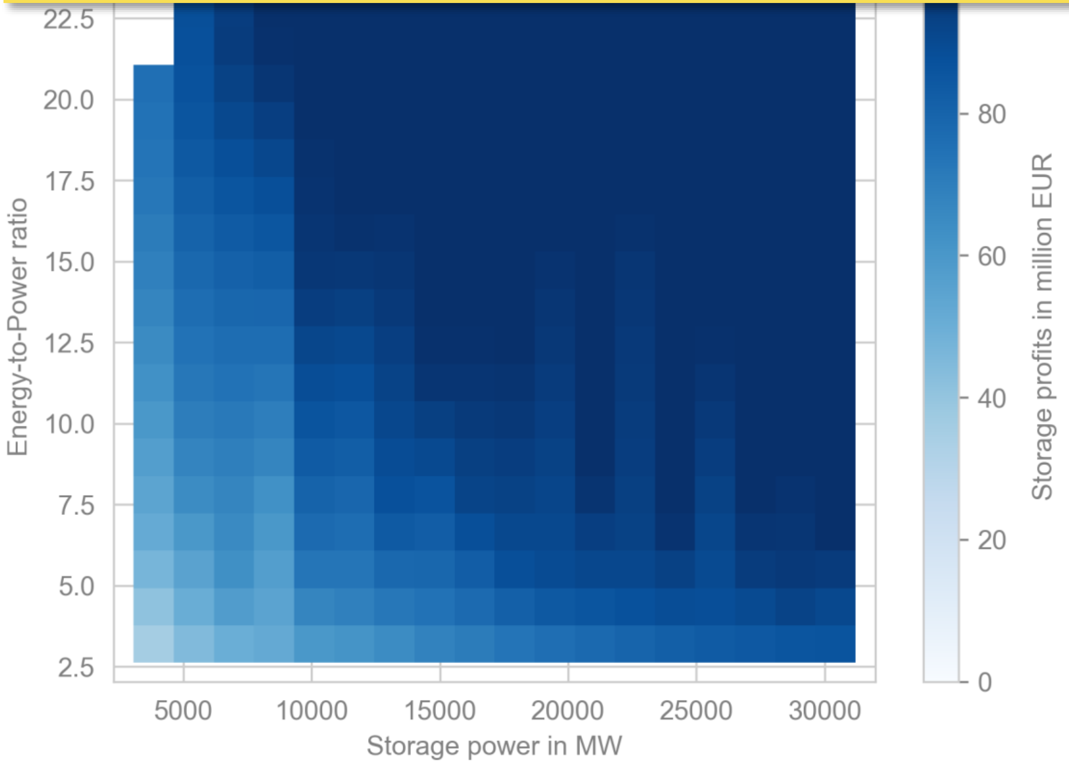
System costs from dispatching power plants in 300 scenarios with different Power and E2P combinations under minimize system costs strategy (left) and maximize profits strategy (right)

Case Study Results: Total Storage Profits in Million EUR

Minimize System Costs vs. Maximize Profits

Maximize Profits Strategy significantly outperforms other strategy in terms of profits



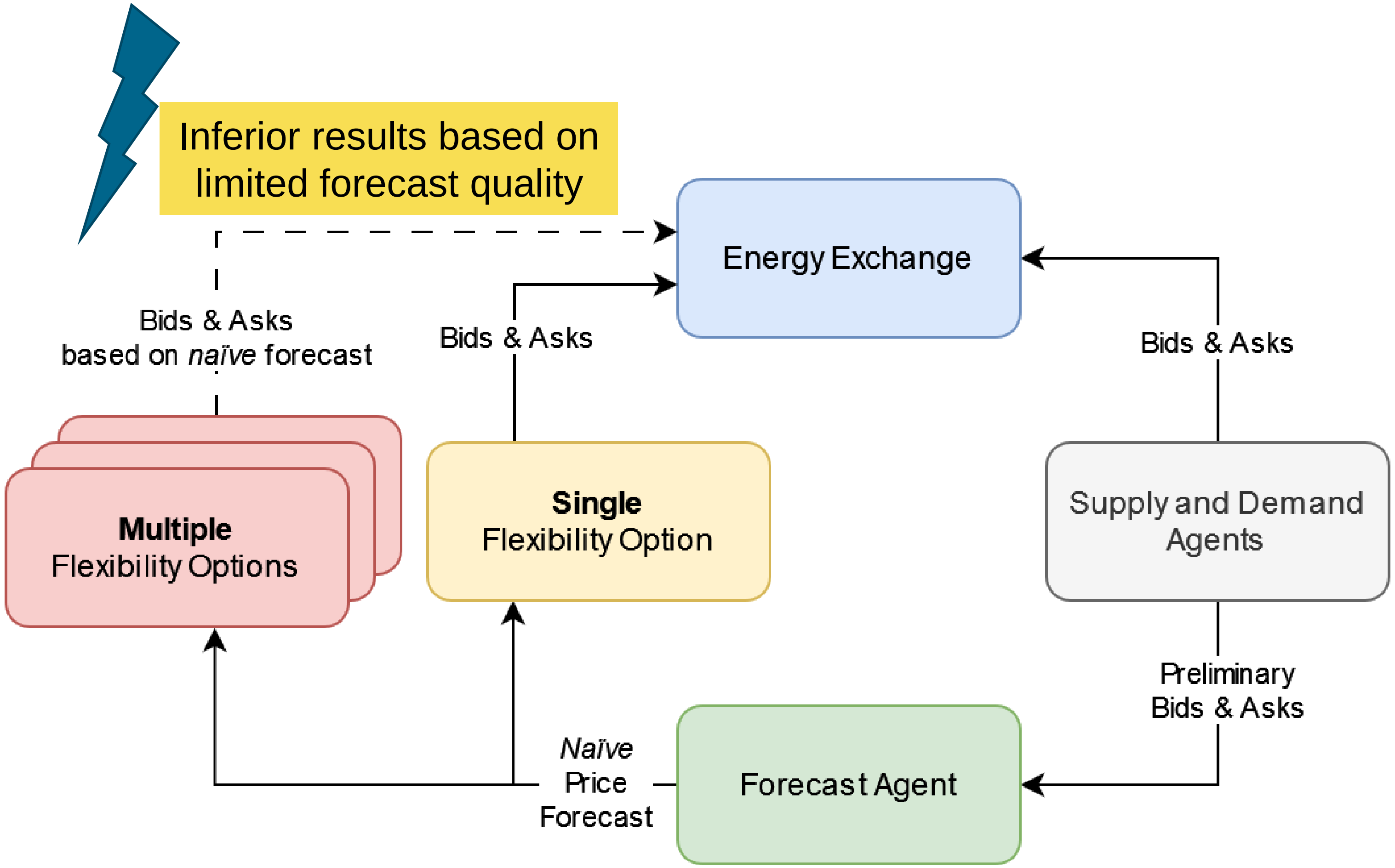


Total profits in 300 scenarios with different Power and E2P combinations under minimize system costs strategy (left) and maximize profits strategy (right)

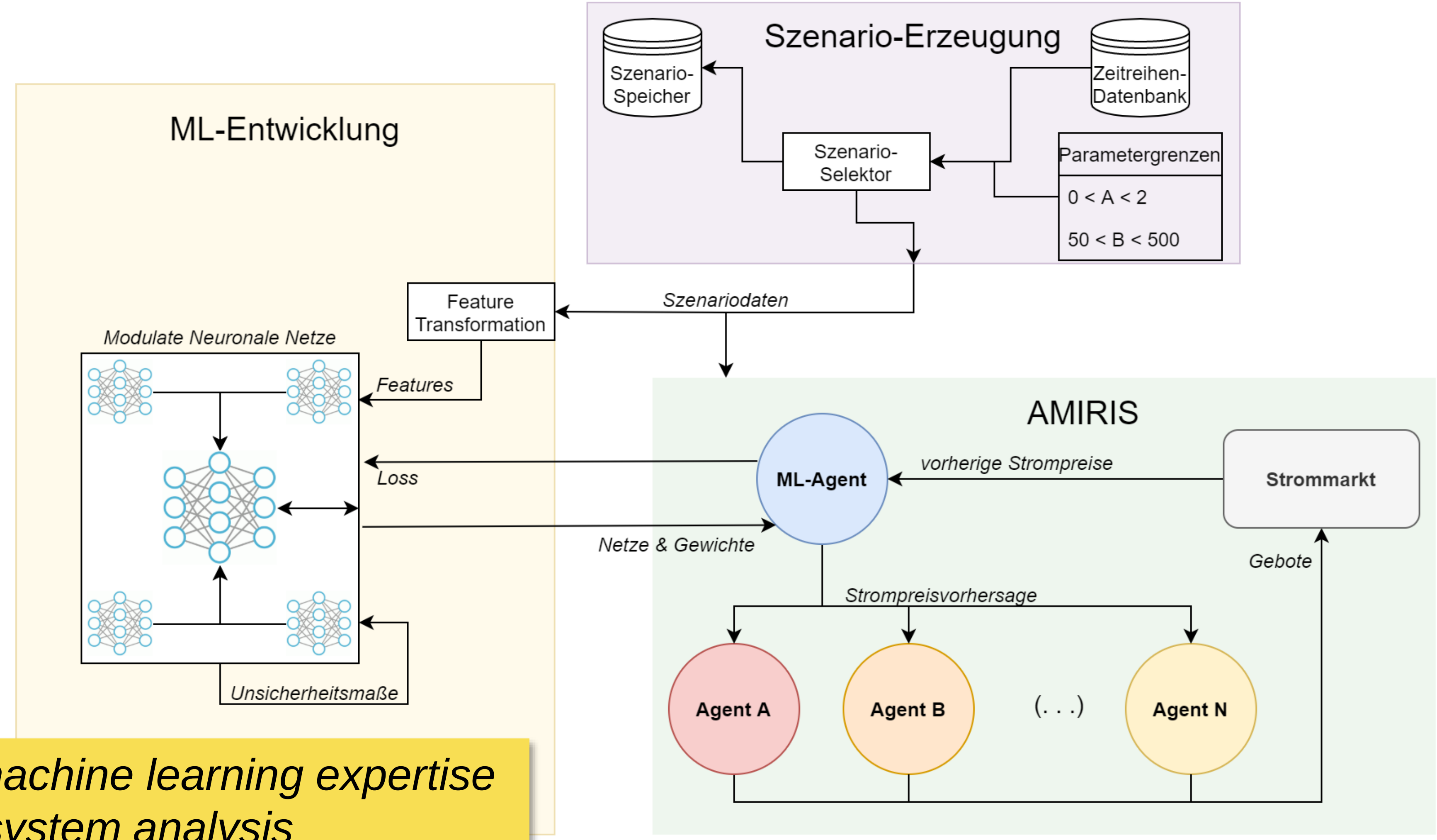
What's missing? – Consideration of market competition amongst storage operators

Price Forecasting in AMIRIS

Limitations of Current Approach



FEAT Project
Flexible, Explainable, and Accurate Price Forecasts



Combining machine learning expertise with energy system analysis

SPONSORED BY THE Federal Ministry of Education and Research

Concept of Improved Forecasting Agent
Providing Enhanced Price Forecasts

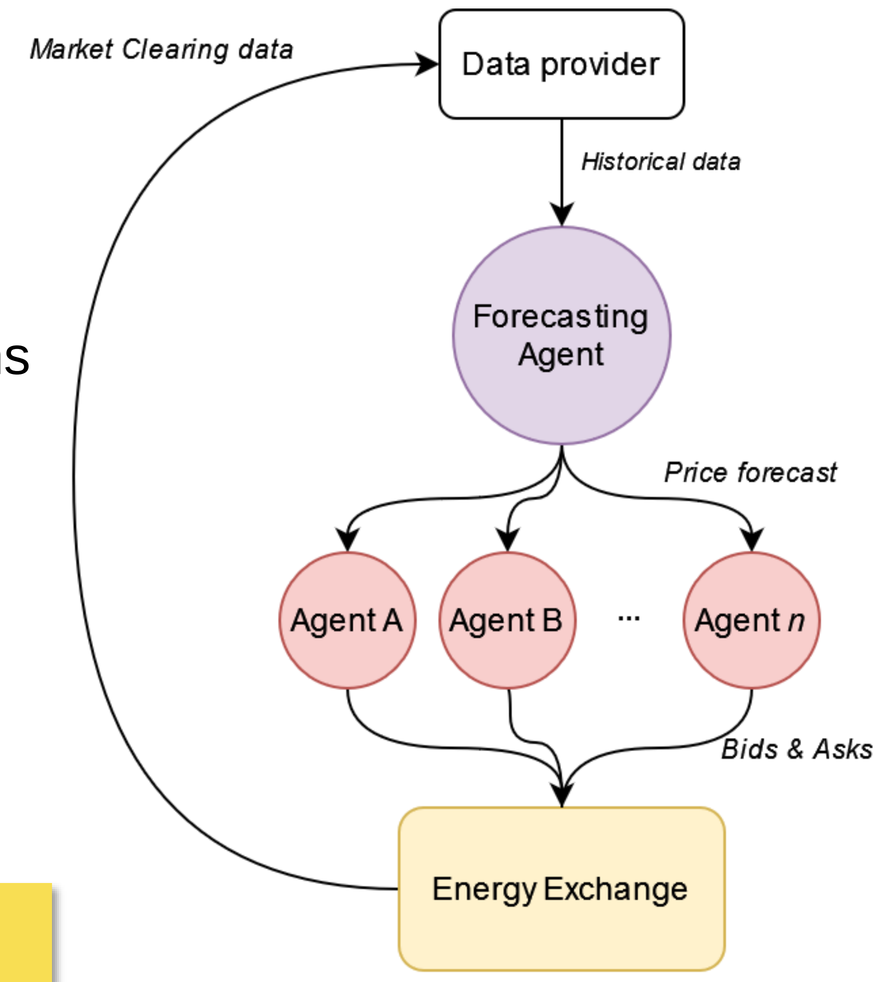
Aim

- Central forecast agent
- Price time series forecast of >=24h
- Input for schedule optimization of agents
- Enabling forecasts on future energy systems

Available Data

- Previous electricity prices
- Previous residual load
- Future forecasted (residual) load
- Future forecasted RE generation

Forecasting agent should consider impacts of bidding agents



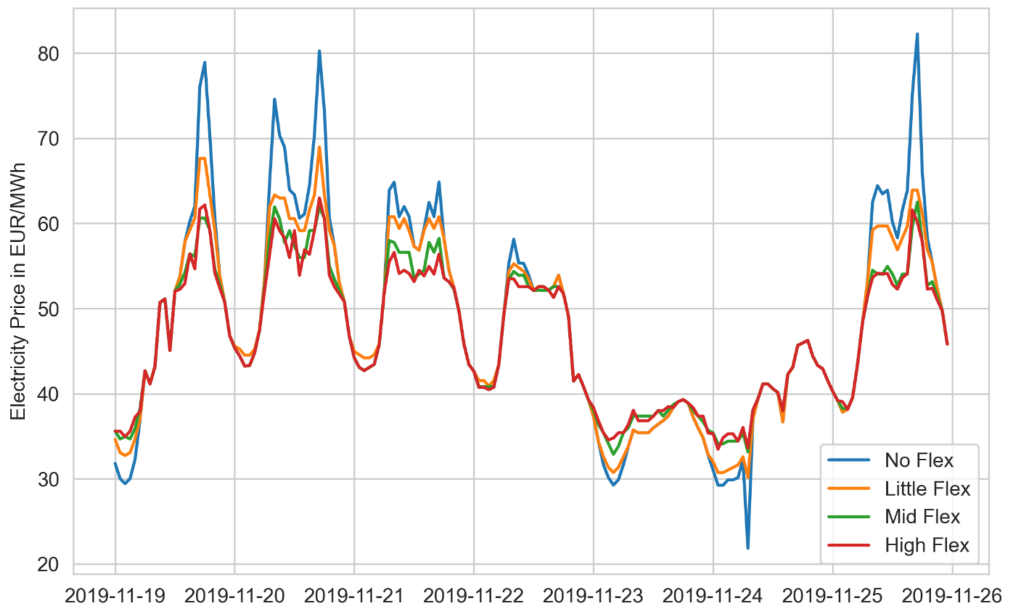
Concept of new Forecasting Agent in AMIRIS

Forecasting Performance – Case: Flexibility Share Variation

Overview and Price Impacts

Mean Absolute Error (MAPE) for four test scenarios with rising flexibility capacities

Metric \ Scenario	I *No Flex*	II *Little Flex*	III *Mid Flex*	IV *High Flex*
Naïve t_1	9.29	7.78	6.76	6.45
Naïve t_{24}	8.57	7.54	6.27	5.91
Exponential Smoothing	8.06	6.70	5.73	5.46
N-BEATS	7.15	6.24	5.38	5.12
TFT	4.11	3.90	3.20	3.26
TFT w/ future covariates	3.12	3.45	3.26	2.86



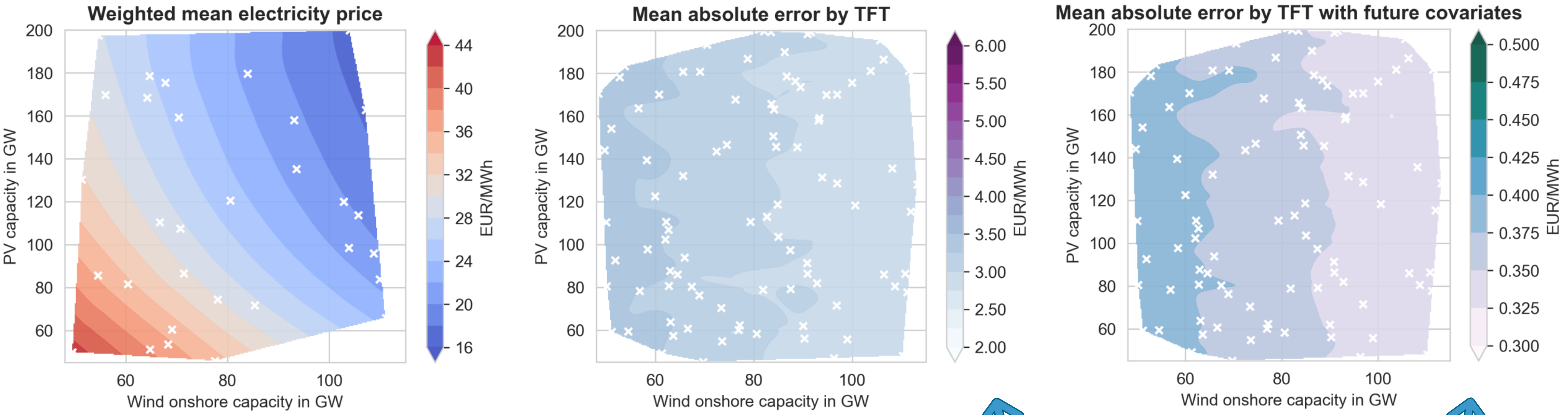
Price dampening impact of different flexibility capacities in the four scenarios on electricity prices over a one-week period in November 2019.

Machine learning methods perform best

Forecasting Performance – Case: Renewable Expansion

Price Forecasting Applying Temporal Fusion Transformer

Train | **Test I** | **Test II**



Forecasting performance in scenarios of varying renewable energy expansion

Be aware of different scaling

Superior performance of model with future covariates

Note: Scenarios are considered as parameter variations and shall not be interpreted as definitive and complete future electricity systems

Discussion
Limitations and Strengths

- Missing analysis of impact by different weather years
- Initial training computationally intensive

- Training and testing beyond historical data
- Powerful approach capable to model future price dynamics
- Results on error metrics allow integrating in electricity market simulations

Conclusion

- Motivation: Modelling market competition among flexibility options
- Aim: Precise time series forecasts in energy system models
- Method: Comparison of methods (naïve, regression, machine learning)
- Results: ML outperforms benchmarks even in future electricity market scenarios

Outlook

- Fine-tuning and further testing of models
- Integration of NN in AMIRIS enabling endogenous & comprehensive forecasts
- Investigation on competition among flexibility options
- Further analysis in FEAT project, see https://www.mlsustainableenergy.com/

Imprint

SPONSORED BY THE
Federal Ministry of Education and Research

DLR

Topic:	Flexible and accurate price time series forecasts for the application in electricity market simulations
Date:	15.02.2024
Author:	Felix Nitsch, Christoph Schimeczek
Institute:	Institute of Networked Energy Systems
Credits:	DLR (CC BY-NC-ND 3.0)