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MODELLING BIDDING STRATEGIES OF FLEXIBILITIES UNDER UNCERTAIN PRICE FORECASTS

An agent-based modelling approach

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DLR

Motivation

- 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

Agent-based **M**arket model for the **I**nvestigation of **R**enewable and **I**ntegrated energy **S**ystems

Model

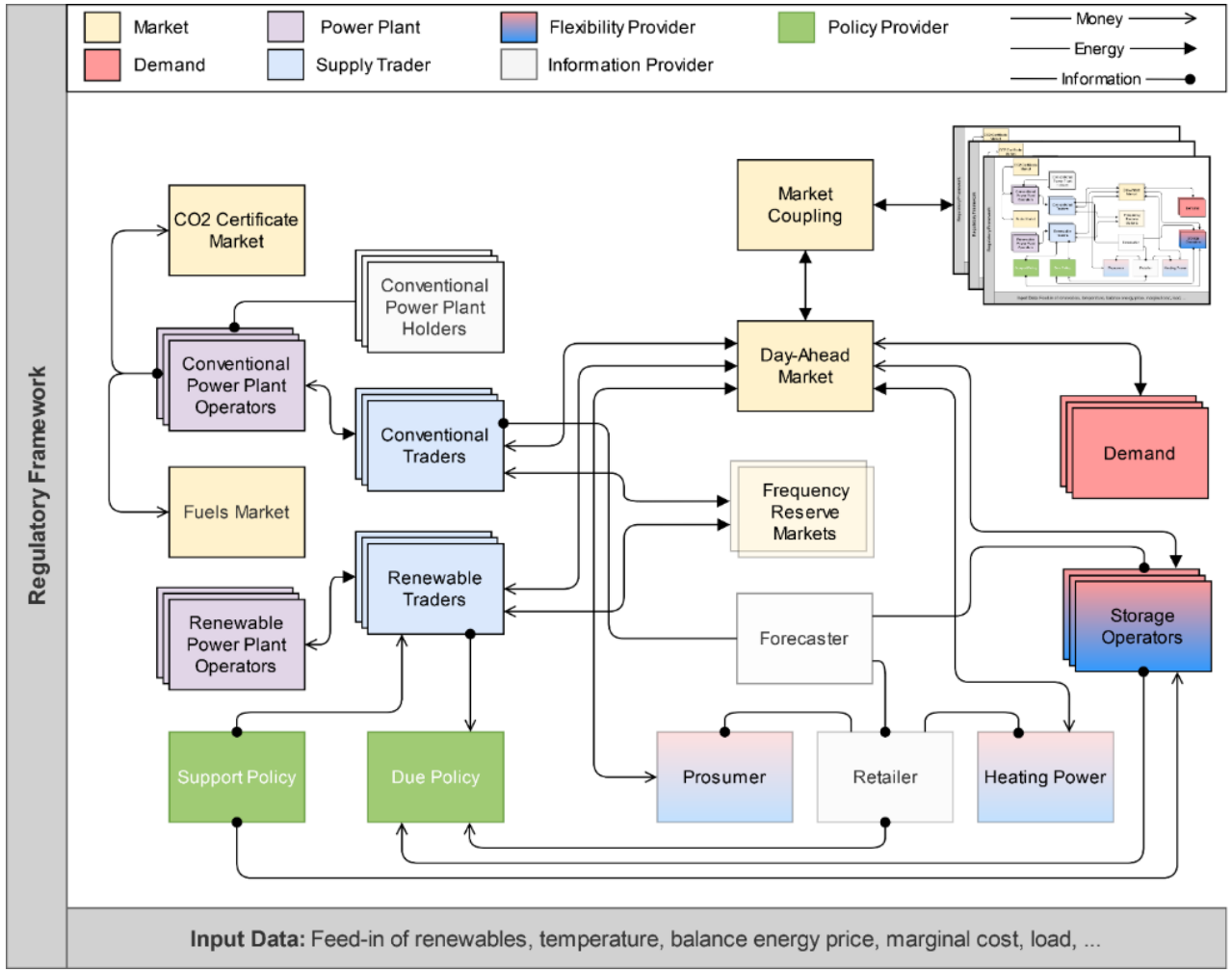
- Electricity market simulation
- Open source (Apache 2)

Agents

- Conventional Plants
- Renewable Plants
- Traders
- Flexibilities
- Markets
- Policy
- Forecasting

Calculates

- Electricity prices
- Plant dispatch
- Market values
- Emissions
- System costs



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

Nitsch F. & Schimeczek C, Institute of Networked Energy Systems, 09/2023

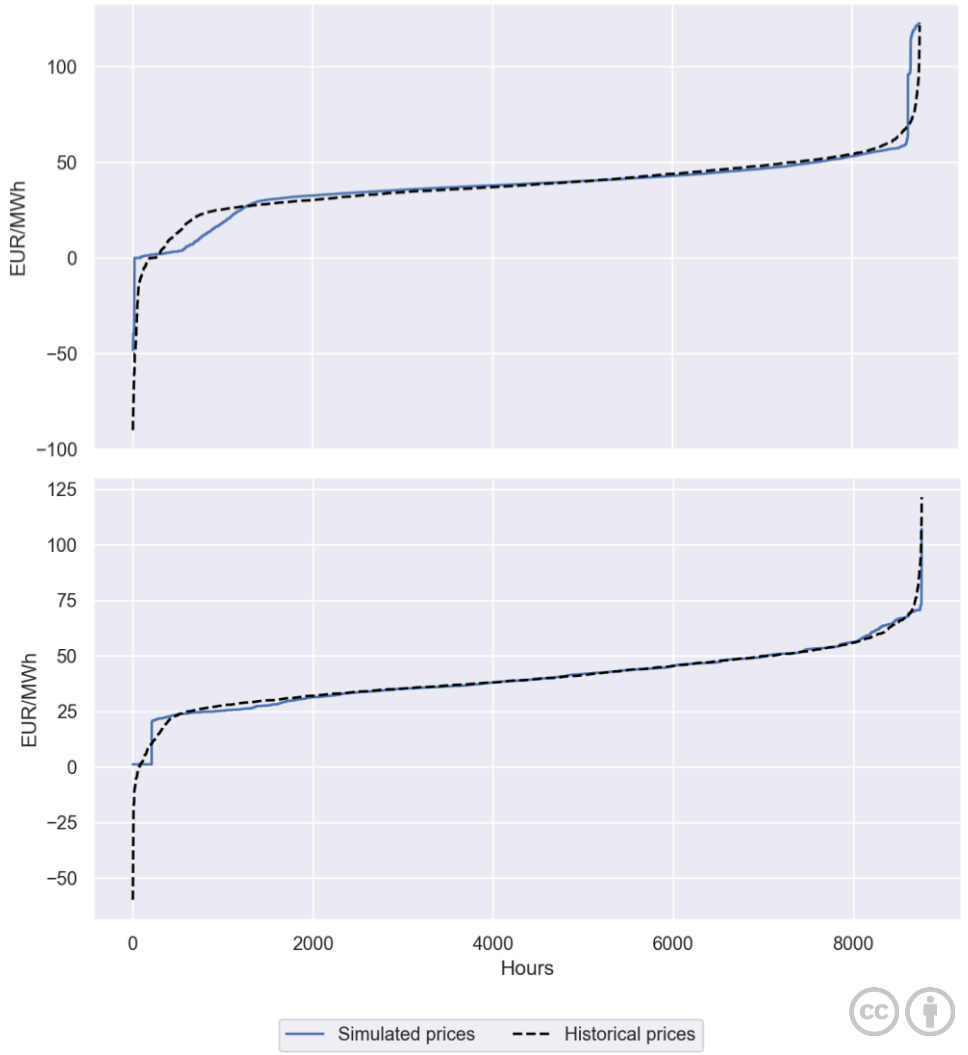
AMIRIS: Parameterization and Validation

Motivation
- Convenient Parameterization
- Reproducibility, Accuracy, Transparency

Methodology
- Collecting Open Data*
- Parameterization of Agents
- Fitting Day-Ahead Prices

Outcome
- Configurations for Germany & Austria
- Validation Against Historical Prices
- Published under CC-BY-4.0 License
  https://gitlab.com/dlr-ve/esy/amiris/examples

* Sources: SMARD, E-Control, APG, EEX, Destatis



Price duration curves for Germany in 2019 (top) and Austria in 2019 (bottom)

Nitsch F. & Schimeczek C, Institute of Networked Energy Systems, 09/2023

Nitsch et al. (2021a). 10.1016/j.apenergy.2021.117267
Nitsch et al. (2021b). 10.5281/zenodo.5726738

Agent Types in AMIRIS

AMIRIS Agents

Types

Markets
- Determine prices

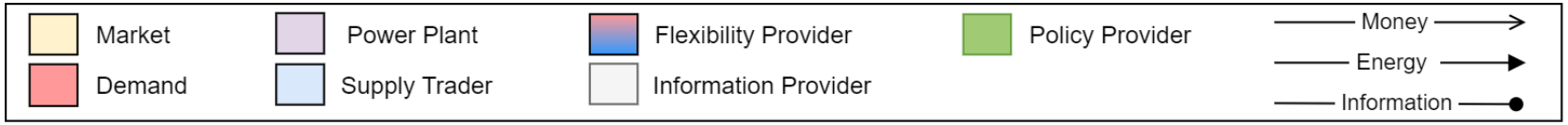
Plant operators
- Control power plants

Traders
- Fulfil marketing strategies

Flexibility providers
- Optimise dispatch

Information provider
- Create forecasts

Policy
- Provide support



AMIRIS Agents

Conventionals

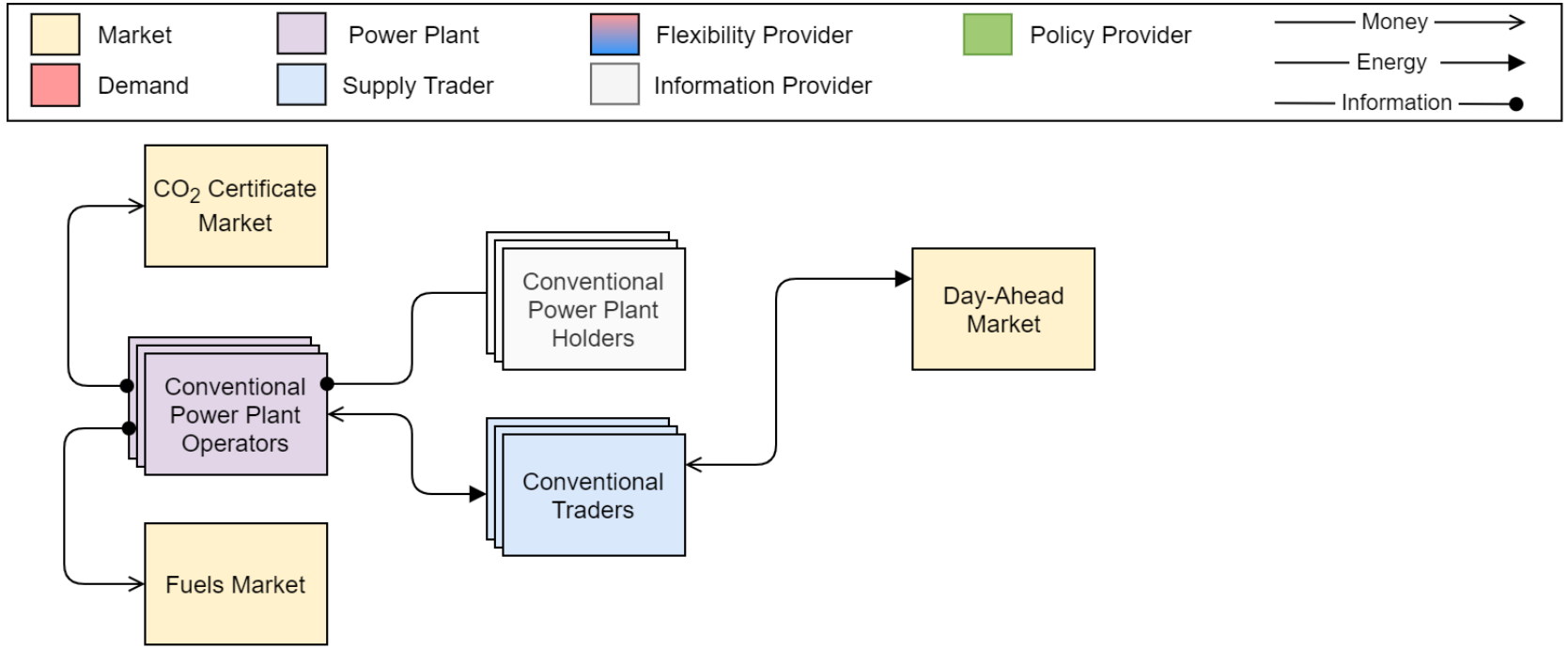
Power Plant Holder
- Set up plant portfolio

Power Plant Operator
- Dispatch power plants
- Calculate marginal cost

CO_2 Market
- Define certificate prices

Fuels Market
- Define fuel prices

Trader
- Assign bid markups



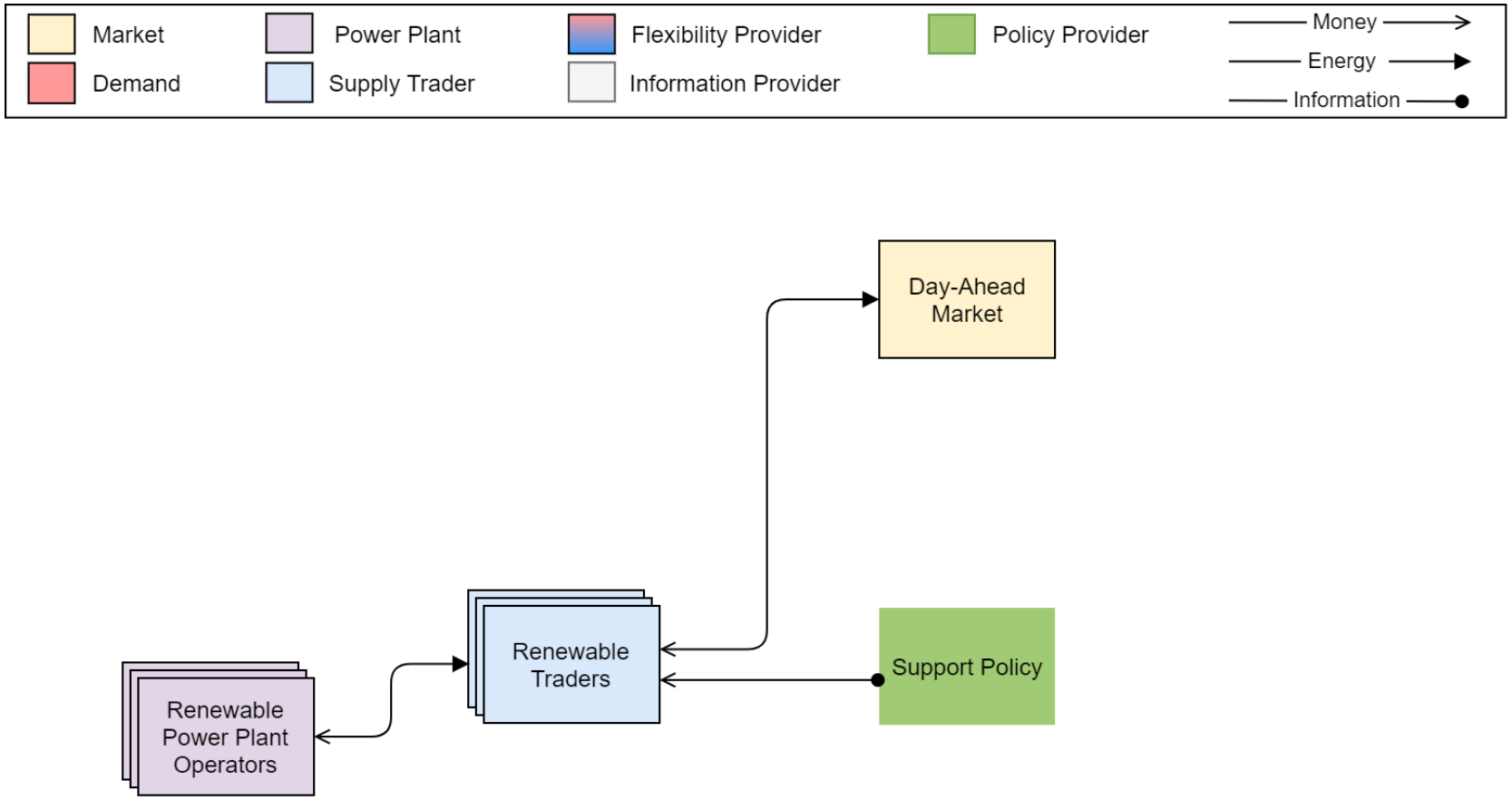
AMIRIS Agents

Renewables

Power Plant Operator
- Calculate marginal cost
- Dispatch power plants

Renewable Trader
- Create bid
- Request support

Support Policy
- Calculate support tariffs
- Provide support funding



AMIRIS Agents

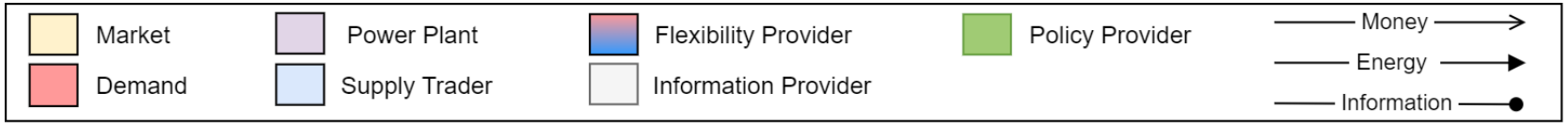
Demand

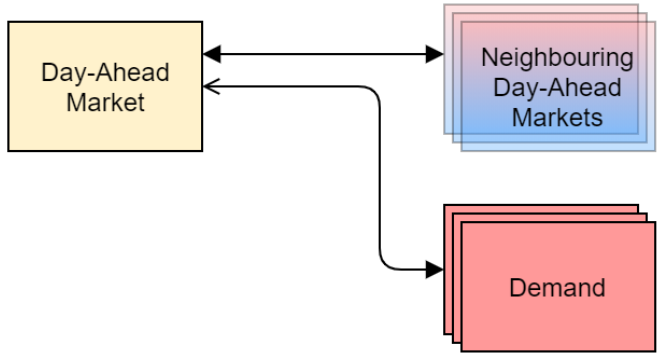
Demand

- Provide static demand bids
- Load shedding

Neighbouring markets

- Can be integrated using MarketCoupling
- Alternatively: emulated with Demand / Supply timeseries





AMIRIS Agents

Flexibilities

Forecaster

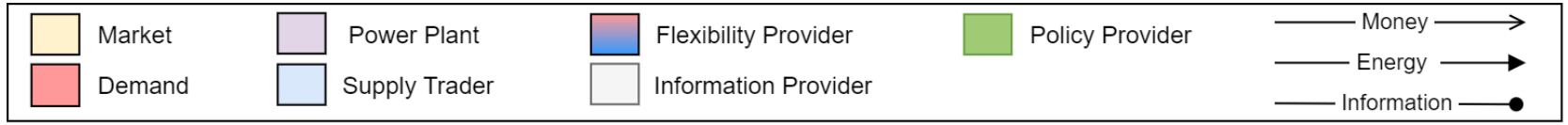
- Calculate forecasted merit order

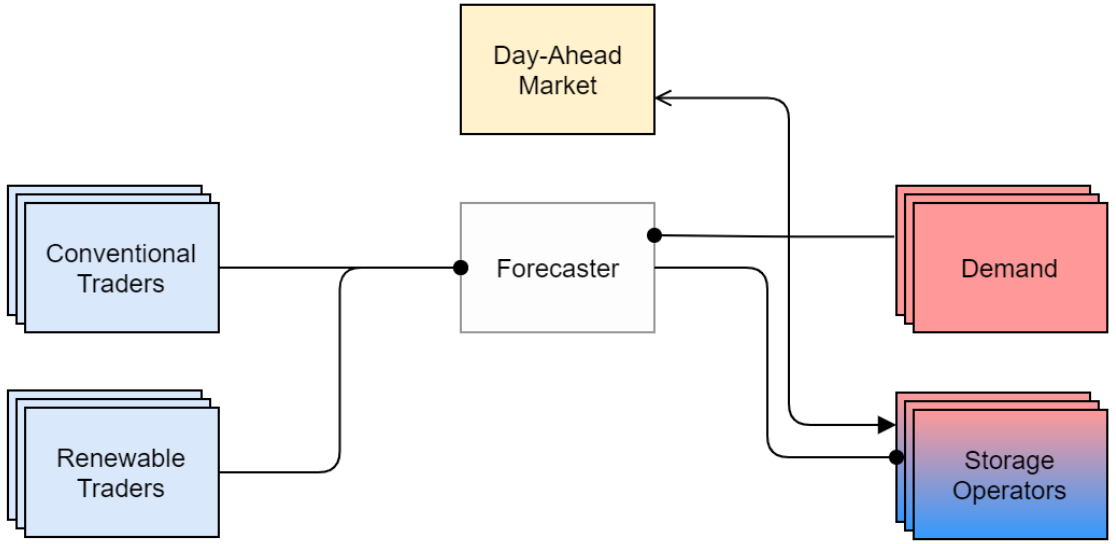
Storage Operator

- Evaluate forecasts
- Optimise dispatch
- Consider own impact on prices

Other Traders

- Assumed “inflexible”
- Provide forecasted bids





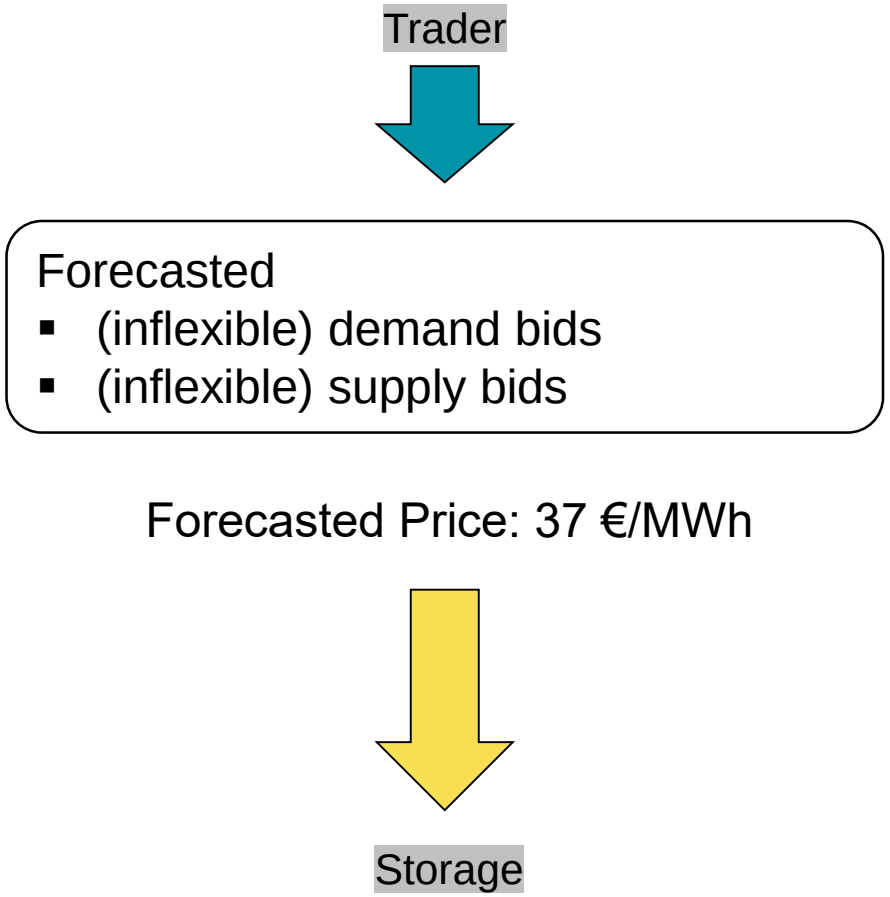
Current Approach of Simulating Flexibility

Flexibilities

Forecaster

Actions

1) *Get (inflexible) forecasted bids*
2) *Clear forecasted market*
3) *Send forecasted clearing data*



Flexibilities

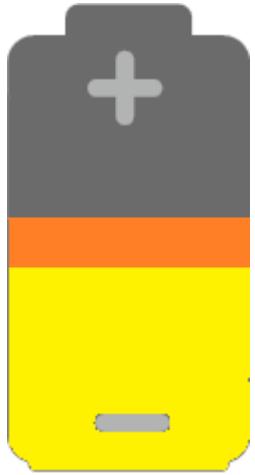
Storage operator

Actions

1) *Get forecast clearing data*
2) *Optimize bidding*
3) *Send bids to Exchange*
4) *Receive awards*
5) *Operate storage device*

Forecaster

Forecast:
37 €/MWh



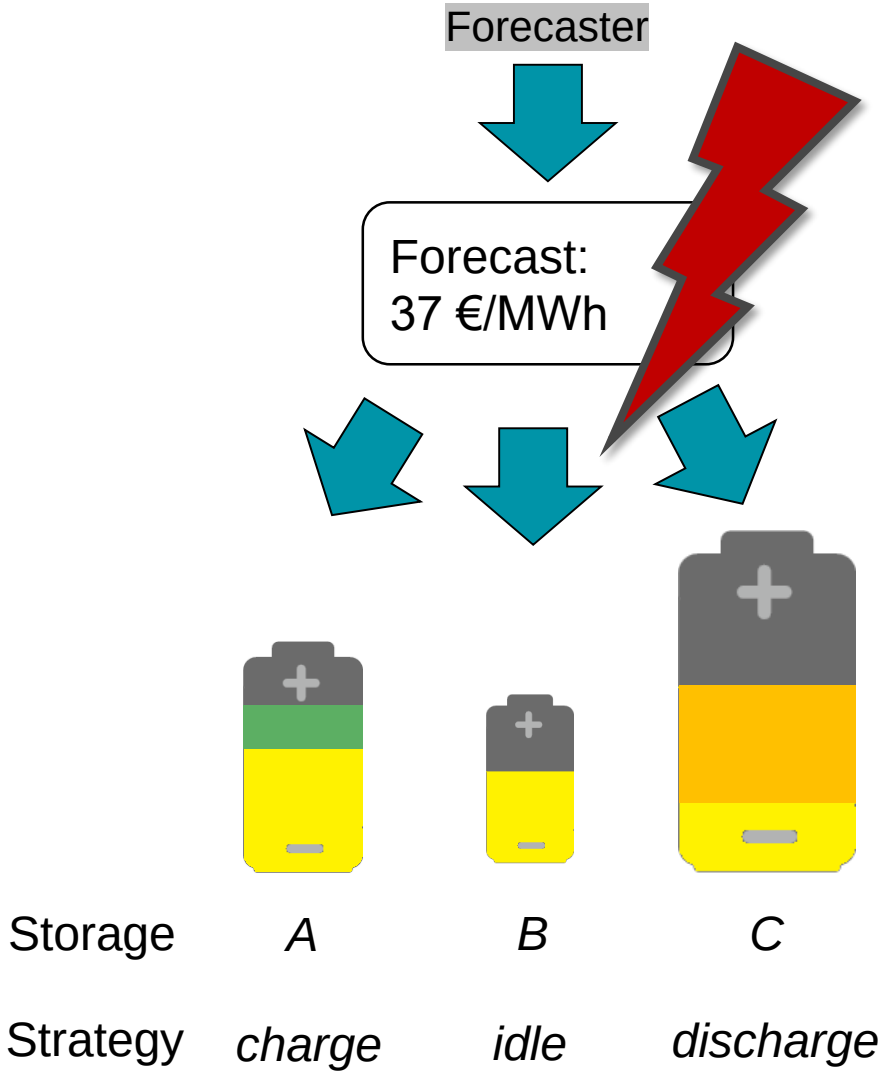
MW	€/MWh
500	11

Exchange

Discharge
500 MWh

Exchange

Current Limitation in AMIRIS
Simultaneous Modelling of Multiple Flexibility Options



Bids *A* – *C*

MW	€/MWh
500	11

Exchange

Multiple flexibility-option agents mutually distort their forecasts due to their competitive actions

→ Significant impacts on the accuracy of the price forecast

Idea I – Robust Strategies

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Heuristic Strategy: Price Median

Idea

- 24h Price median M,
- Losses ➔ Security margin S
- Bid price $b_{\mathrm{d/c}} = M \pm S$
- Power ~ Polynomial $f_i(p_i)$

Example

$M = 45.09$ €/MWh

$S = 2.44$ €/MWh

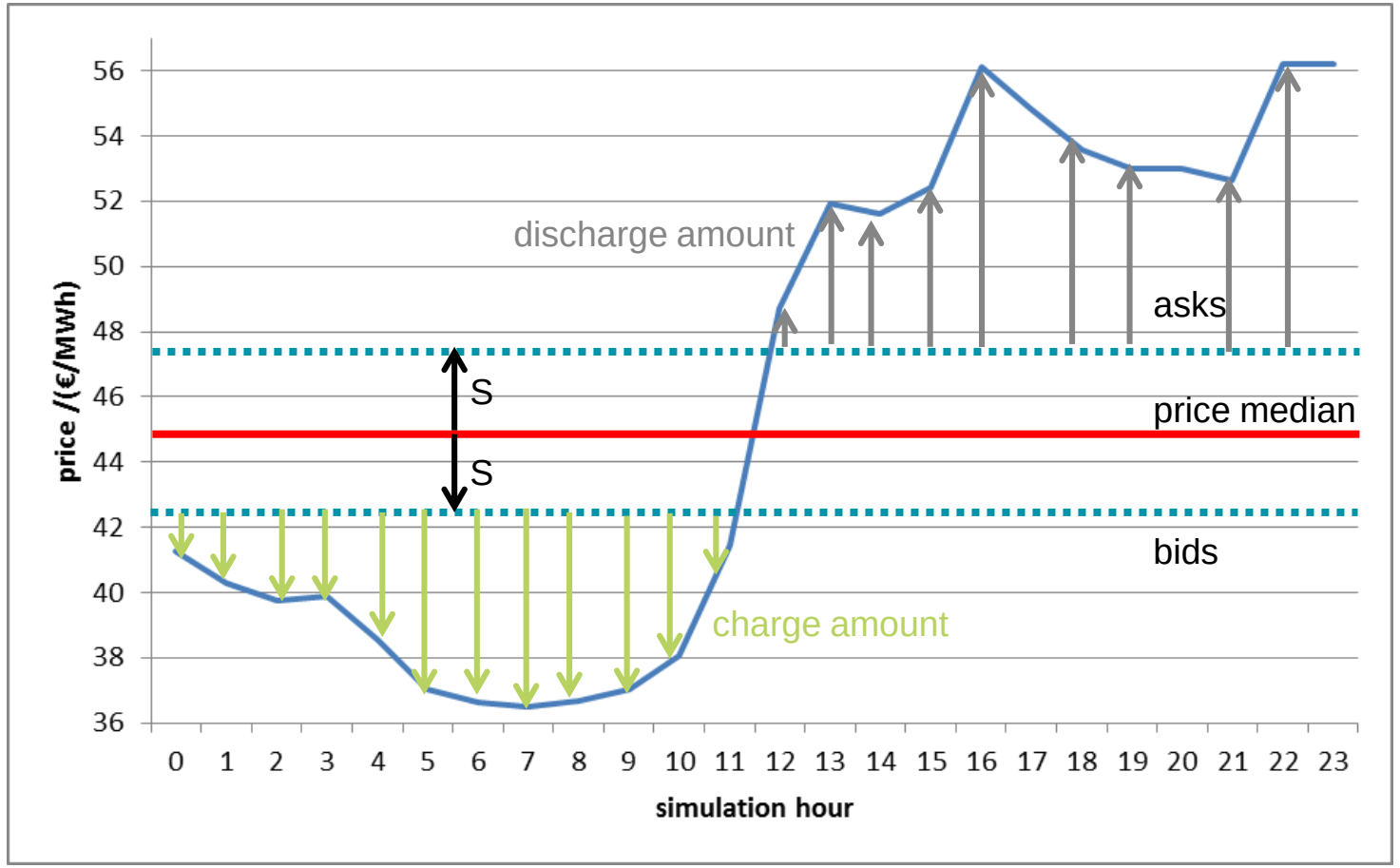
$f_i(p_i) \sim (p_i - (M \pm S))$

Benefits

- Multiple storages compete
- Fast to calculate

Drawbacks

- Less profitable
- Merit-Order shape not considered

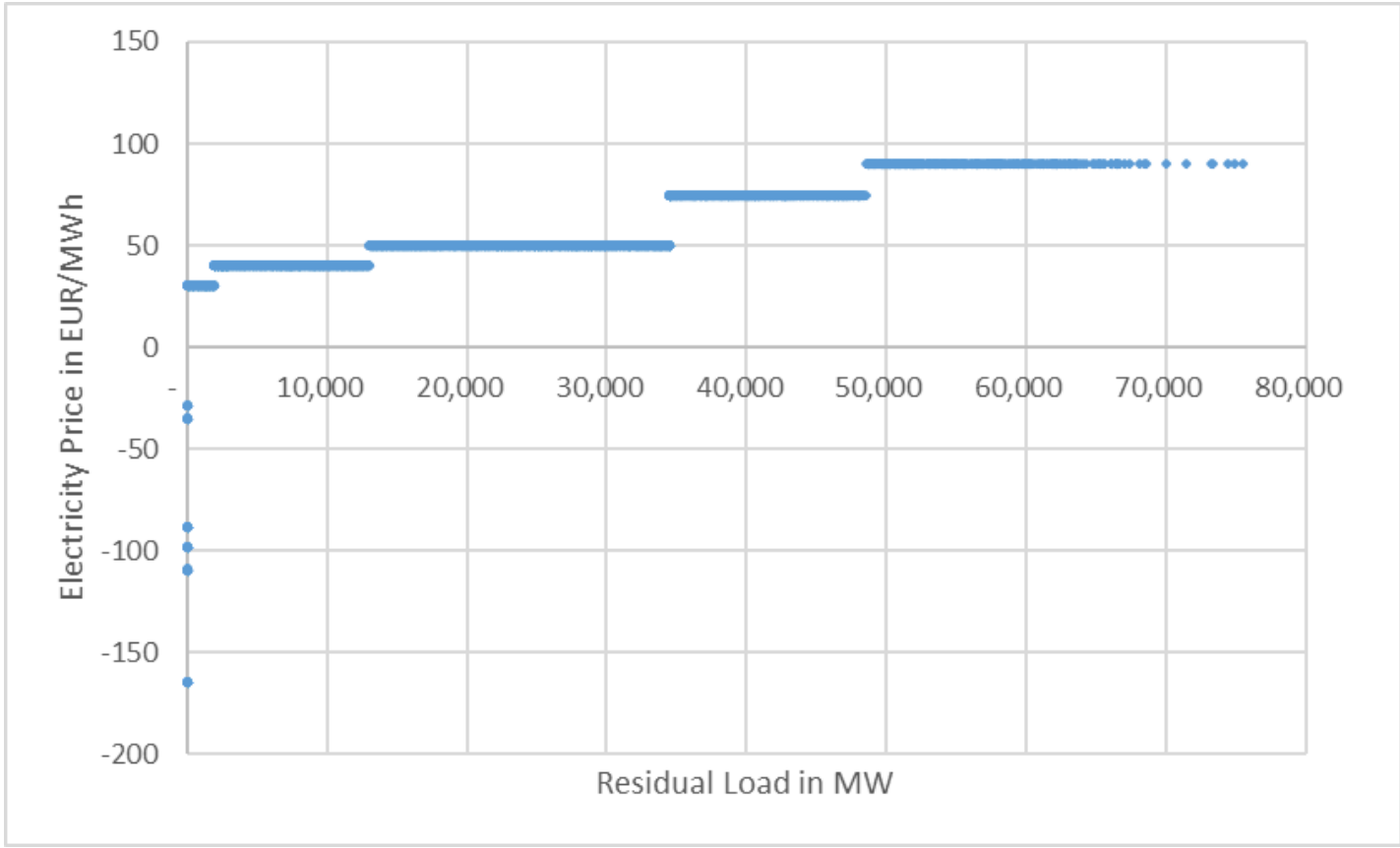


Flexibility Dispatch: Estimate Price Changes

Idea
- Use Merit Order representation
- Estimate flexibility dispatch
- → Estimate price changes

Merit Order Representation
- Piece-wise linear interpolation
- Residual load estimate without flexibilities

Price Change Estimation
- Own dispatch plans: known
- Other flexibilities = own dispatch * correlation factor
- Own + other dispatch → price change



Performance Comparison

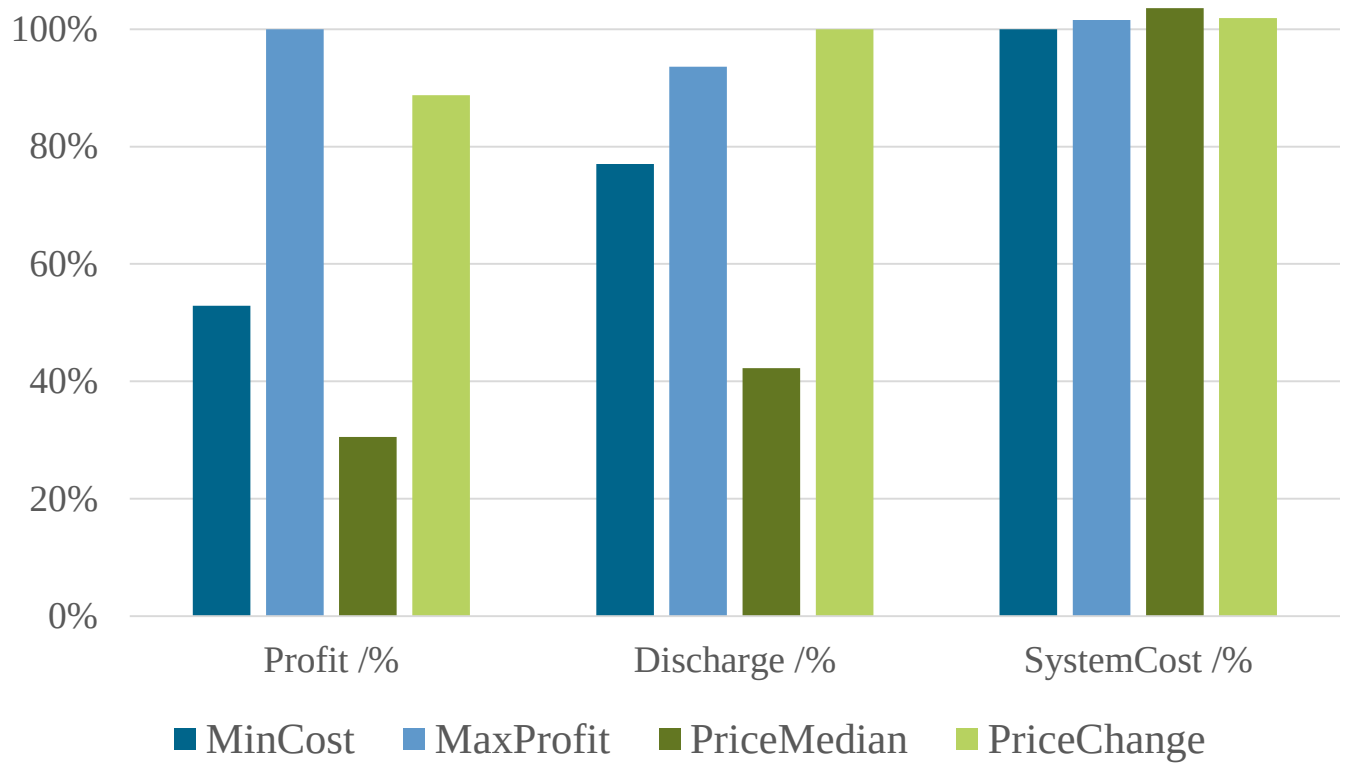
Strategies: 1 Storage, perfect knowledge
MinCost: Minimize system cost
MaxProfit: Maximise own profits

Strategies: Multiple Storages
PriceMedian: Heuristic Strategy
PriceChange: Estimation Strategy

→ PriceChange shows excellent performance even with multiple storages, **if** all storages have same E2P (correlation factors are simple)

Price Change Strategy Drawbacks
- How to deal with different E2P?
- Iterate and find correlation factors?

→ Improving forecasts instead?



Idea II – Improved Forecasts

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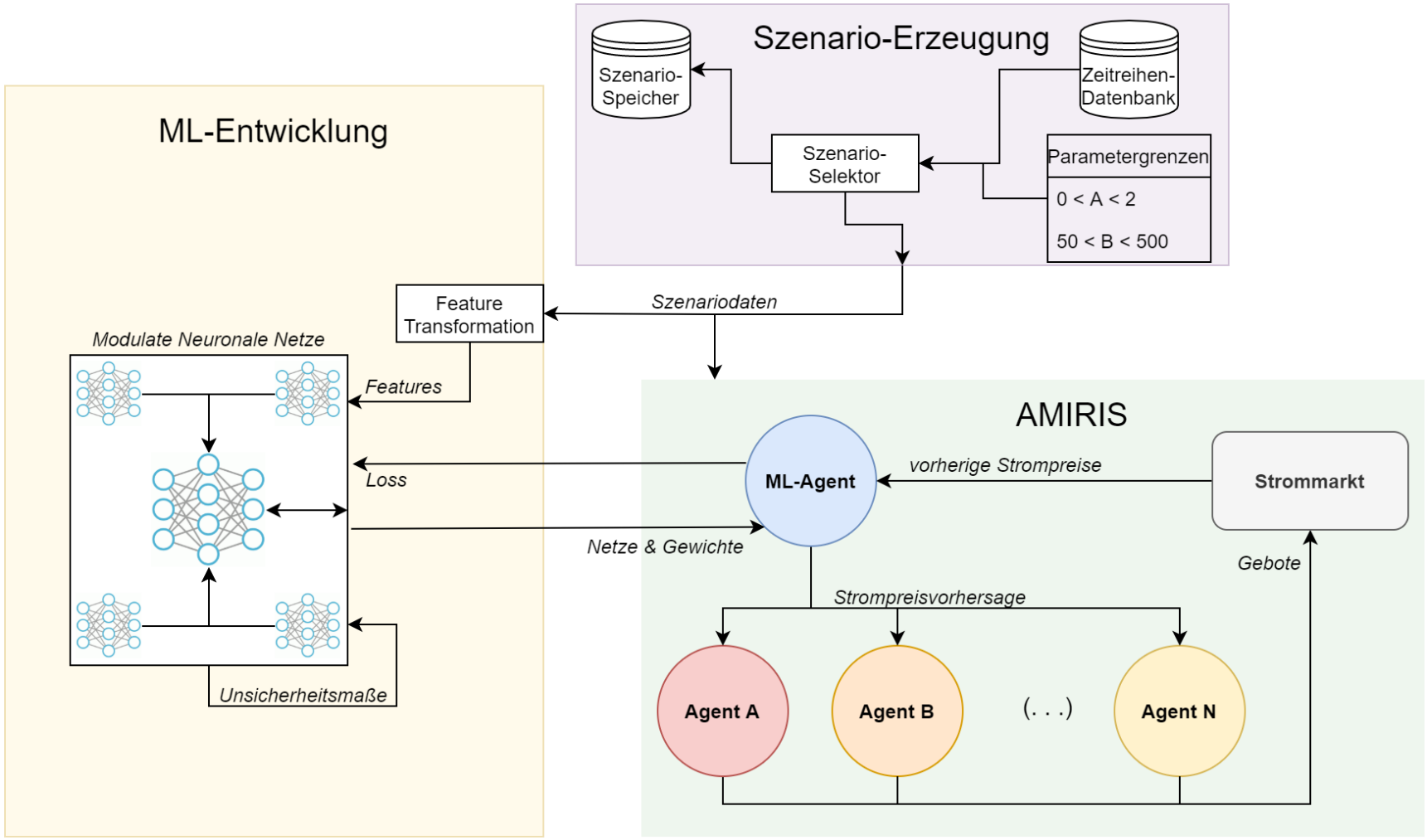
FEAT Project
Setup



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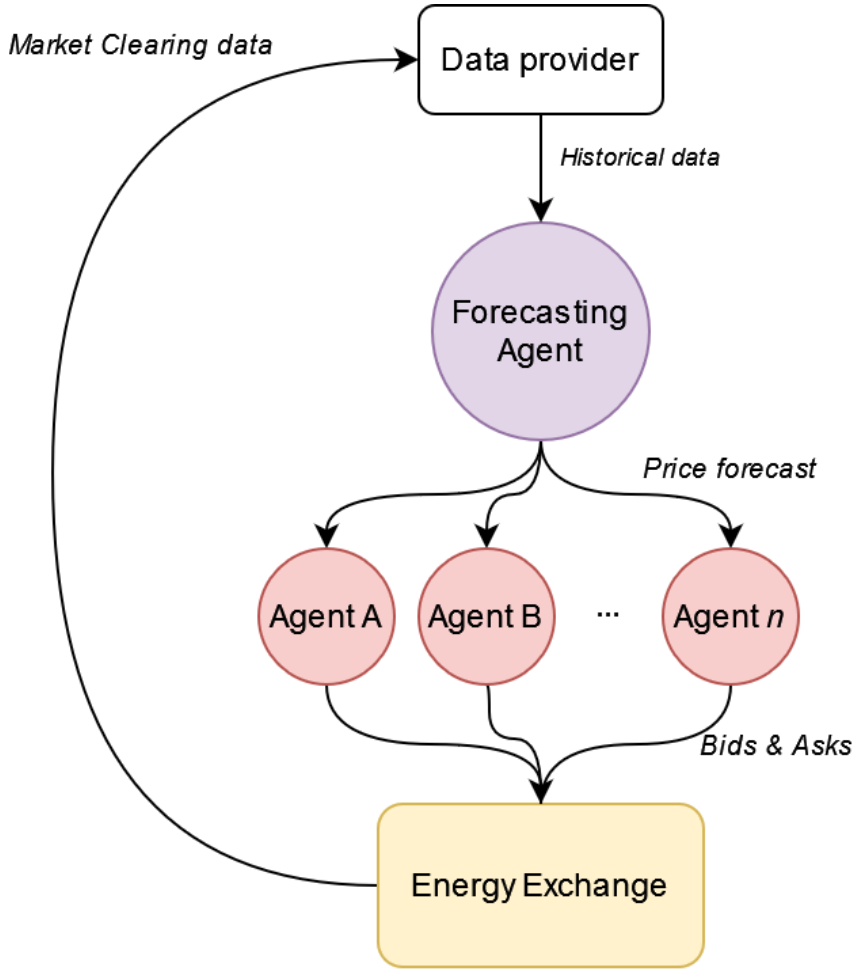
Concept of Improved Forecasting Agent
Providing Enhanced Price Forecasts

Aim

- Central forecast agent
- Price forecasts for >=24h
- Feeds schedule optimization of agents

Available Inputs

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



Concept of new Forecasting Agent in AMIRIS

Nitsch et al.(2023d). Time Series Forecasting in Energy System Models. To be published soon.

Preliminary Results

Tab.: Mean Absolute Percentage Error (MAPE) for four test scenarios with rising flexibility capacities

Scenario / Method	Scenario I *No Flex*	Scenario II *Little Flex*	Scenario III *Mid Flex*	Scenario IV *High Flex*
Naïve t_1	21.89	18.34	15.93	15.20
Naïve t_{24}	20.20	17.77	14.78	13.93
Exponential Smoothing	19.00	15.79	13.50	12.87
Linear Regression	24.89	21.80	17.79	16.87
Light GBM Model	23.29	21.00	17.68	16.36
Random Forest	23.26	20.79	17.35	16.21
NBeats	16.85	14.71	12.68	12.07
TFT	9.69	9.19	7.54	7.68
TFT w/ future covariates	7.35	8.13	7.68	6.74

Preliminary Results Machine Learning
NBeats Architecture

Exemplary predictions

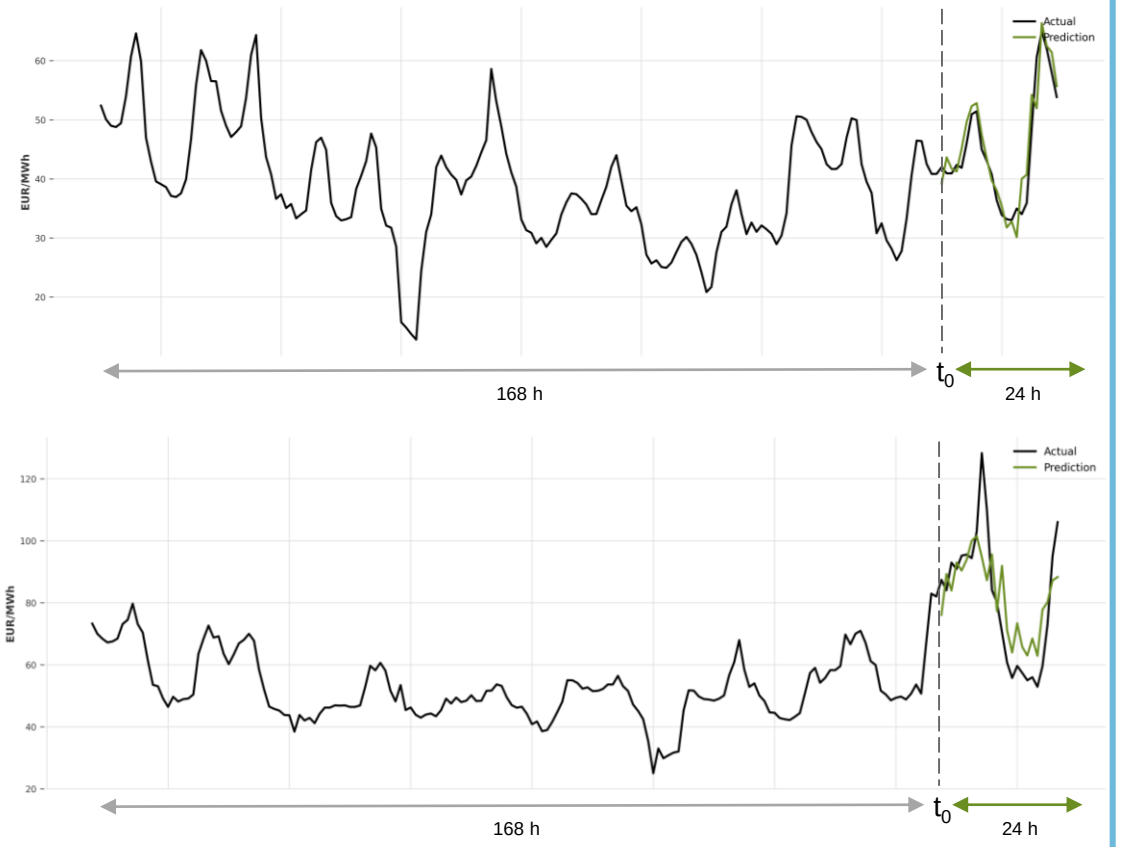
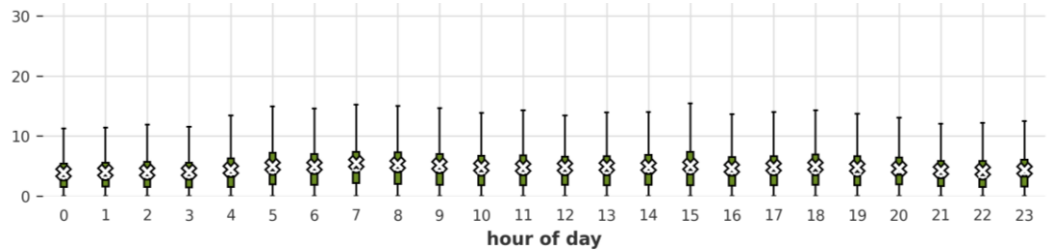


Fig.: Timeseries of historical prices (black) and forecasted prices (green)

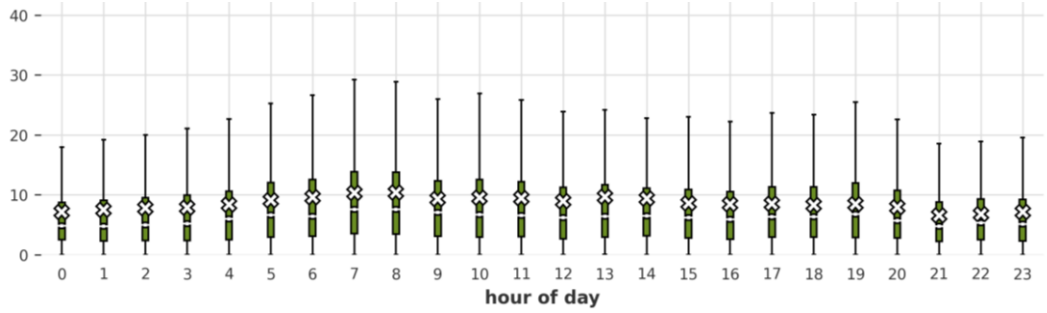
Performance overview

Fig.: Mean Absolute Error (MAE) in €/MWh for each hour in year

Validation 2018



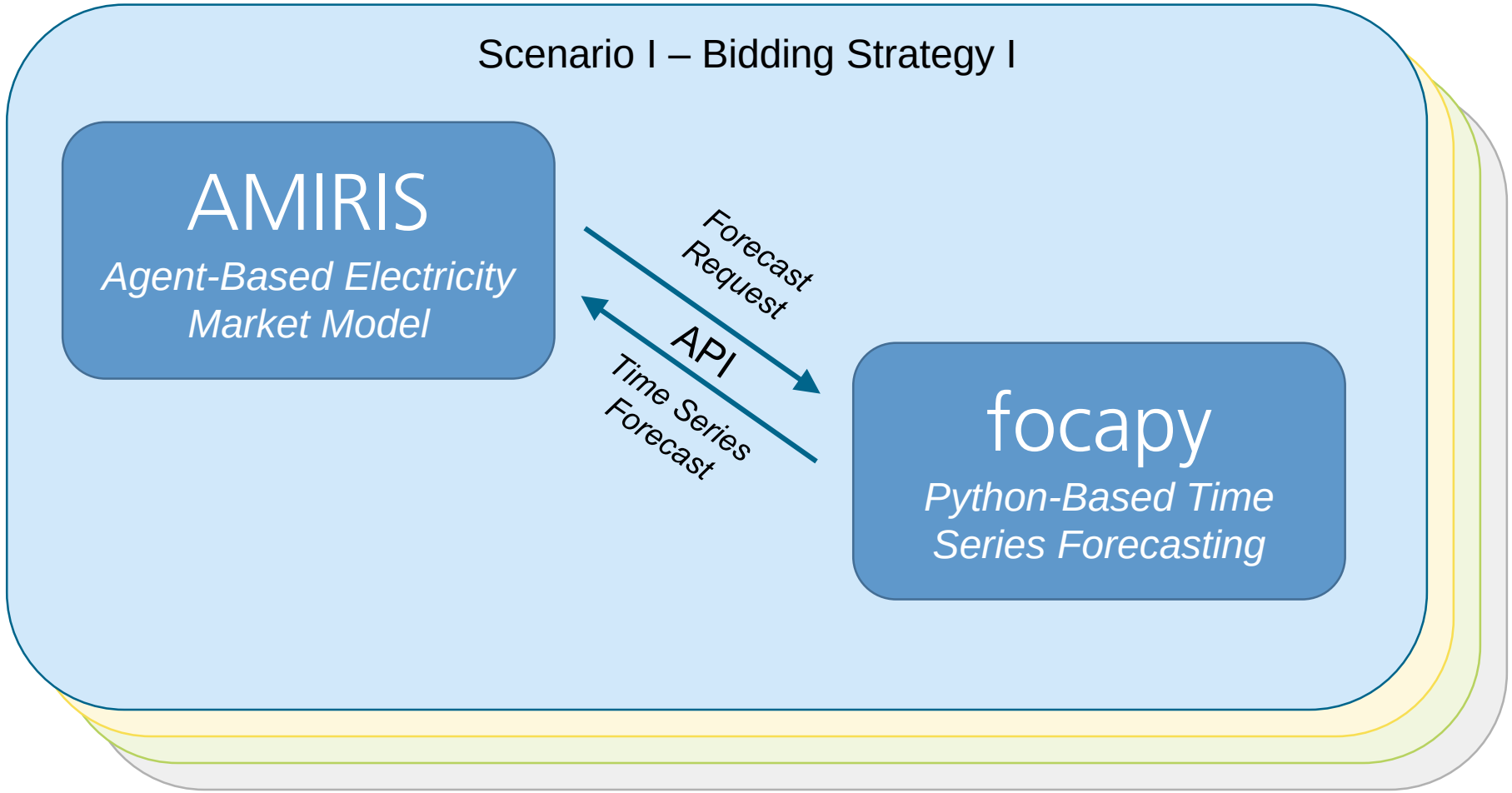
Test 2019



Nitsch F. & Schimeczek C, Institute of Networked Energy Systems, 09/2023

Nitsch et al.(2023d). Time Series Forecasting in Energy System Models. To be published soon.

Planned Concept of Modelling Competition
Finding Robust Strategies



Nitsch (2023e). focapy – Time Series Forecasting Framework. [Available soon].
Schimeczek (2023c). AMIRIS URL Model Service. AMIRIS v2.0.0 [Available soon].

Discussion

- How is *PriceChange* strategy impacted by different storage technologies?
- How are AMIRIS model results impacted by forecast performance?
- How to retrieve and use information of uncertainty?
- How general are these models?
- How to train in future scenarios?

Conclusions

- Investigation of electricity markets using agent-based model AMIRIS
- Limitation to simulate market competition of flexibility options
- Option I: New strategy *PriceChange* which estimates price impacts by flexibility options
- Option II: Enhanced price forecasting by applying ML approaches
- Results: Proof-of-concept of both options, yet extensive testing outstanding

Outlook

- Integrate ML-based forecasting in AMIRIS
- Assess performance of improved forecasts
- Model market competition among flexibility options

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Imprint

Title:	Modelling bidding strategies of flexibilities under uncertain price forecasts
Date:	06.09.2023
Author:	Felix Nitsch
Institute:	Institute of Networked Energy Systems
Credits:	DLR (CC BY-NC-ND 3.0), if not stated otherwise.

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