



# Backtesting the open source electricity market model AMIRIS by simulating the Austrian day-ahead market

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# Motivation for agent-based modelling

## Background

- Transformation of electricity system
  - Rising shares of renewable energies
  - Growing demand for flexibility
- Electricity systems are complex systems
  - Interdependencies of players
  - Emergence and non-linearity

## Aim

- Understanding market interactions of renewable energies and flexibility options, and their accompanying market effects

## Method

- Agent-based modelling of electricity markets using AMIRIS
  - Modelling the German (and European) electricity markets
  - Agents decision rules can be of various model types (optimization, simulation, etc.)





# Simulating electricity markets with AMIRIS

## The model

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

## Development

- 10+ years at German Aerospace Center
- 5-10 developers
- Open source since 2021
- German market, expanded in recent projects

## Strengths

- Individual decision-making
- Many paradigms
- Explicit policy modelling
- Simulating energy system not in equilibrium
- Explorative and evolutionary nature





# Main agent types in AMIRIS

## Input

- RE feed-in
- Load
- Power plant park
- Efficiencies
- Plant availabilities
- Fuel & CO<sub>2</sub> costs

## Output

- Electricity prices
- Power plant dispatch
- Storage dispatch
- Market values
- Emissions
- System costs

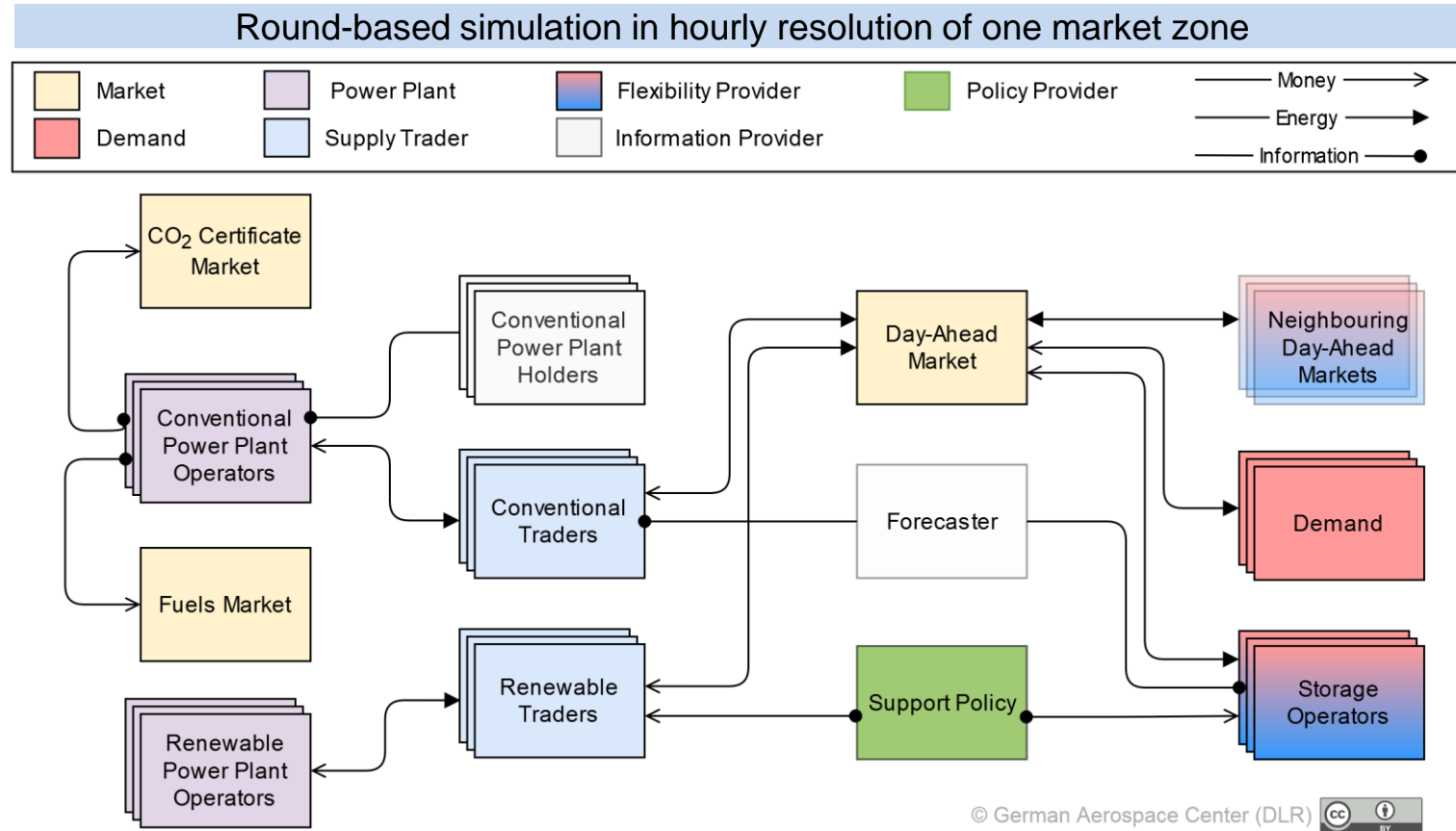


Figure 1: AMIRIS architecture





# AMIRIS parameterization for Austria

## Idea

- Proof-of concept for originally German electricity market model
- Starting point for further analysis

## Methodology

- Collecting open data\*
- Parameterization of agents

## Outcome

- Fully open model parameterization for Austria in year 2019
- Backtesting against historical prices
- Published under CC-BY-4.0 license

<https://gitlab.com/dlr-ve/esy/amiris/examples>

\* Sources: [SMARD Strommarktdaten](#), [E-CONTROL](#), [APG](#), [EEX](#), [Destatis](#)

Table 1: AMIRIS input data

	Parameter	Value	Unit
<b>Demand</b>	Electric load	time series	MWh/h
<b>Imports/Exports</b>	Electric load	time series	MWh/h
<b>Emission allowances</b>	CO <sub>2</sub>	time series	EUR/t
<b>Fuel prices</b>	Gas	time series	EUR/MWh <sub>th</sub>
	Coal	5	EUR/MWh <sub>th</sub>
	Oil	40	EUR/MWh <sub>th</sub>
<b>Capacities</b>	Coal	264	MW
	Gas Turbine	1,208	MW
	Gas CC	3,260	MW
	Biomass	500	MW
	Oil	178	MW
	Pumped Hydro Storage	3,400	MW
<b>Feed-in</b>	Hydro Reservoir	time series	MWh/h
	Run-of-river	time series	MWh/h
	Waste	time series	MWh/h
	PV	time series	MWh/h
	Wind	time series	MWh/h
<b>Specific emissions</b>	Gas	0.201	tCO <sub>2</sub> /MWh <sub>th</sub>
	Coal	0.354	tCO <sub>2</sub> /MWh <sub>th</sub>
	Oil	0.264	tCO <sub>2</sub> /MWh <sub>th</sub>
<b>Availabilities</b>	Gas	97	%
	Coal	98	%
	Oil	93	%
<b>Minimum and maximum efficiencies</b>	Gas	30 – 60	%
	Coal	40	%
	Oil	35	%





# Results: price-duration curve

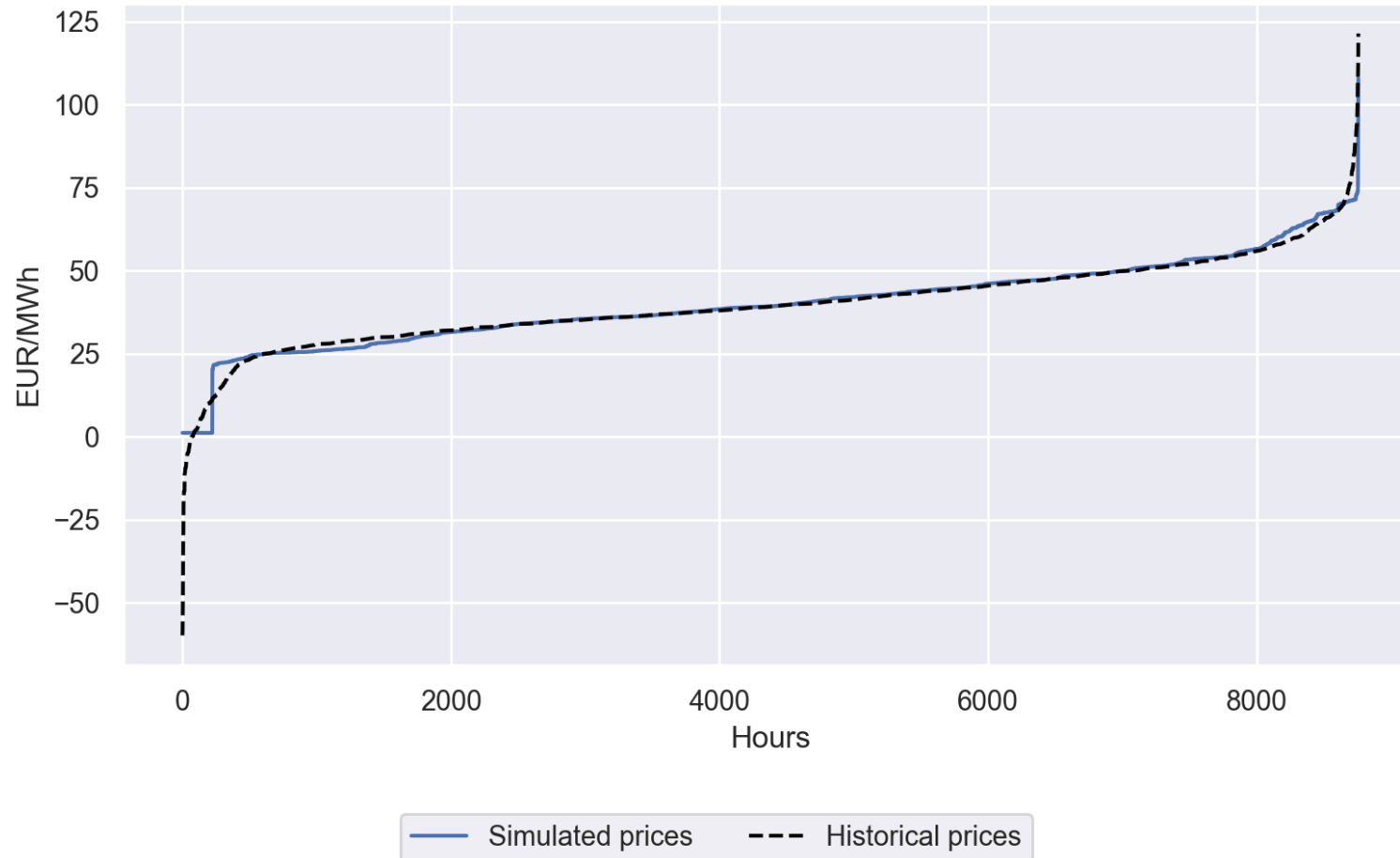


Figure 2: Price duration curve comparing simulated and historical day-ahead prices for the Austrian day-ahead market 2019

Table 2: Comparison of price time series in EUR/MWh

	Simulated	Historical
<b>Mean</b>	40.20	40.06
<b>Std. Deviation</b>	12.88	13.09
<b>Minimum</b>	1.20	-59.78
<b>25%</b>	32.21	32.92
<b>50%</b>	39.34	39.21
<b>75%</b>	48.51	47.98
<b>Maximum</b>	107.89	121.46



# Results: November 2019

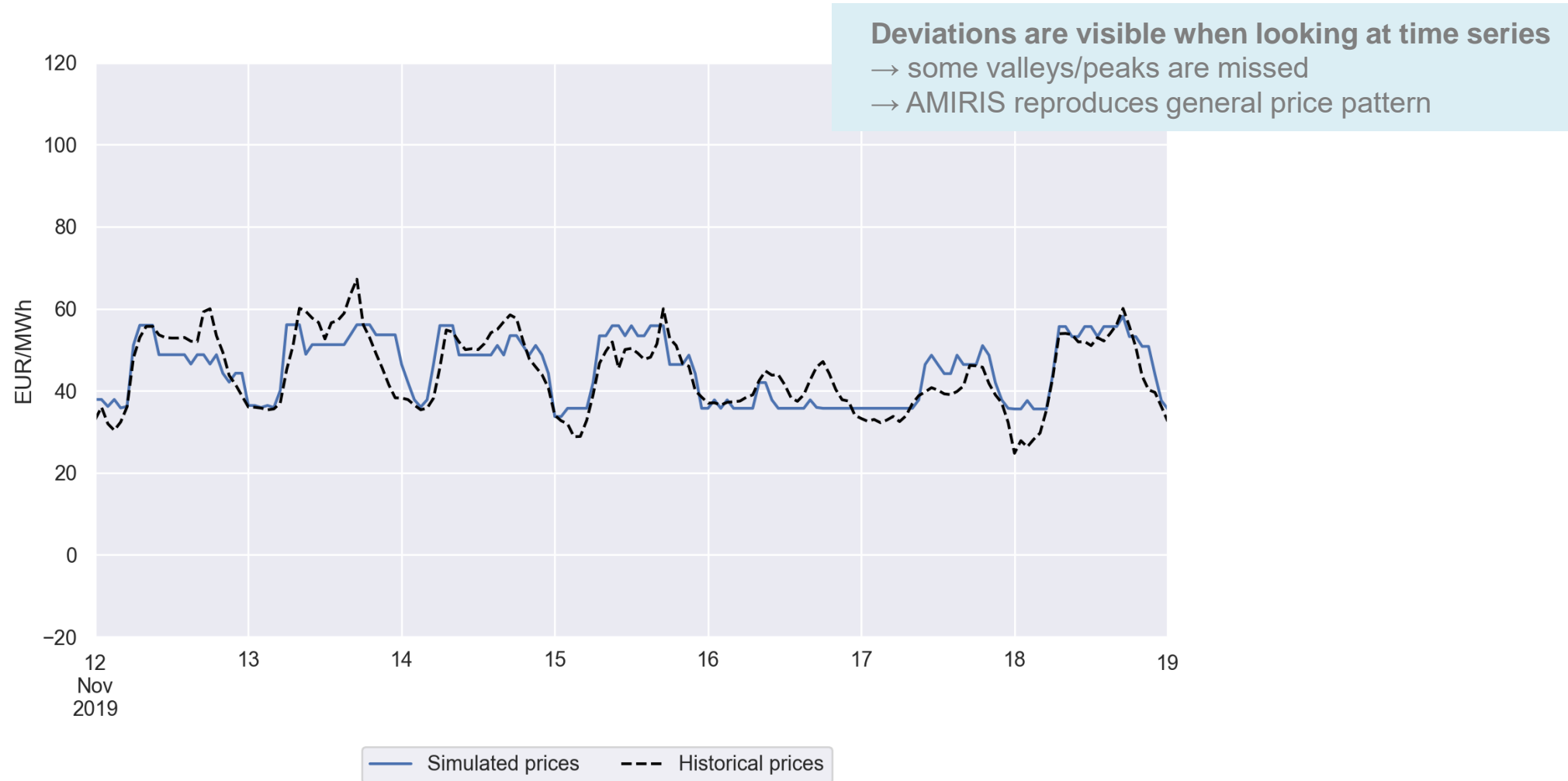


Figure 3: Simulated and historical day-ahead prices for the Austrian day-ahead market in November 2019

# Results: January 2019

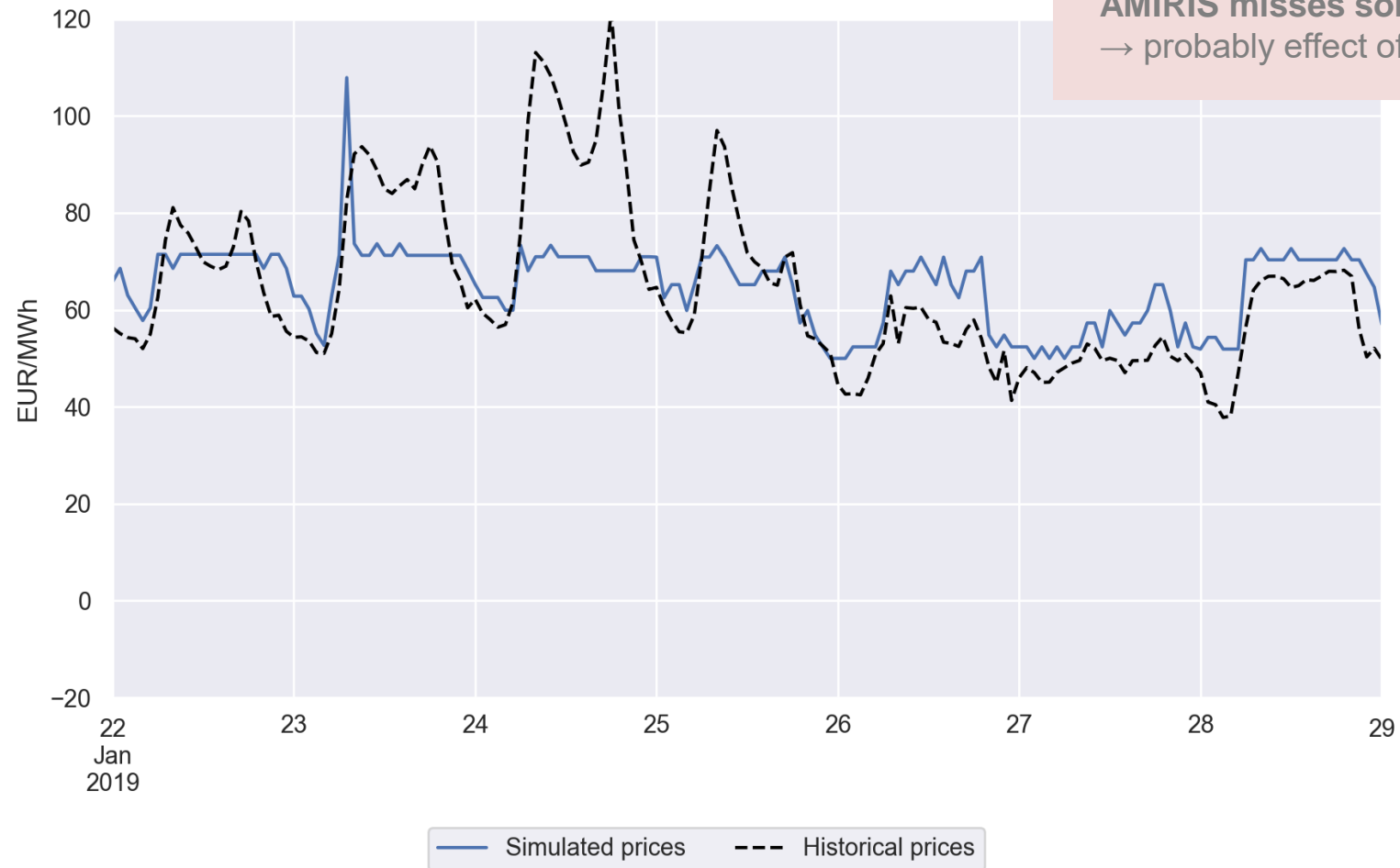


Figure 4: Simulated and historical day-ahead prices for the Austrian day-ahead market in January 2019



# Results: April 2019



Figure 5: Simulated and historical day-ahead prices for the Austrian day-ahead market in April 2019

## Results: April 2019 with profit-maximizing storage strategy\*

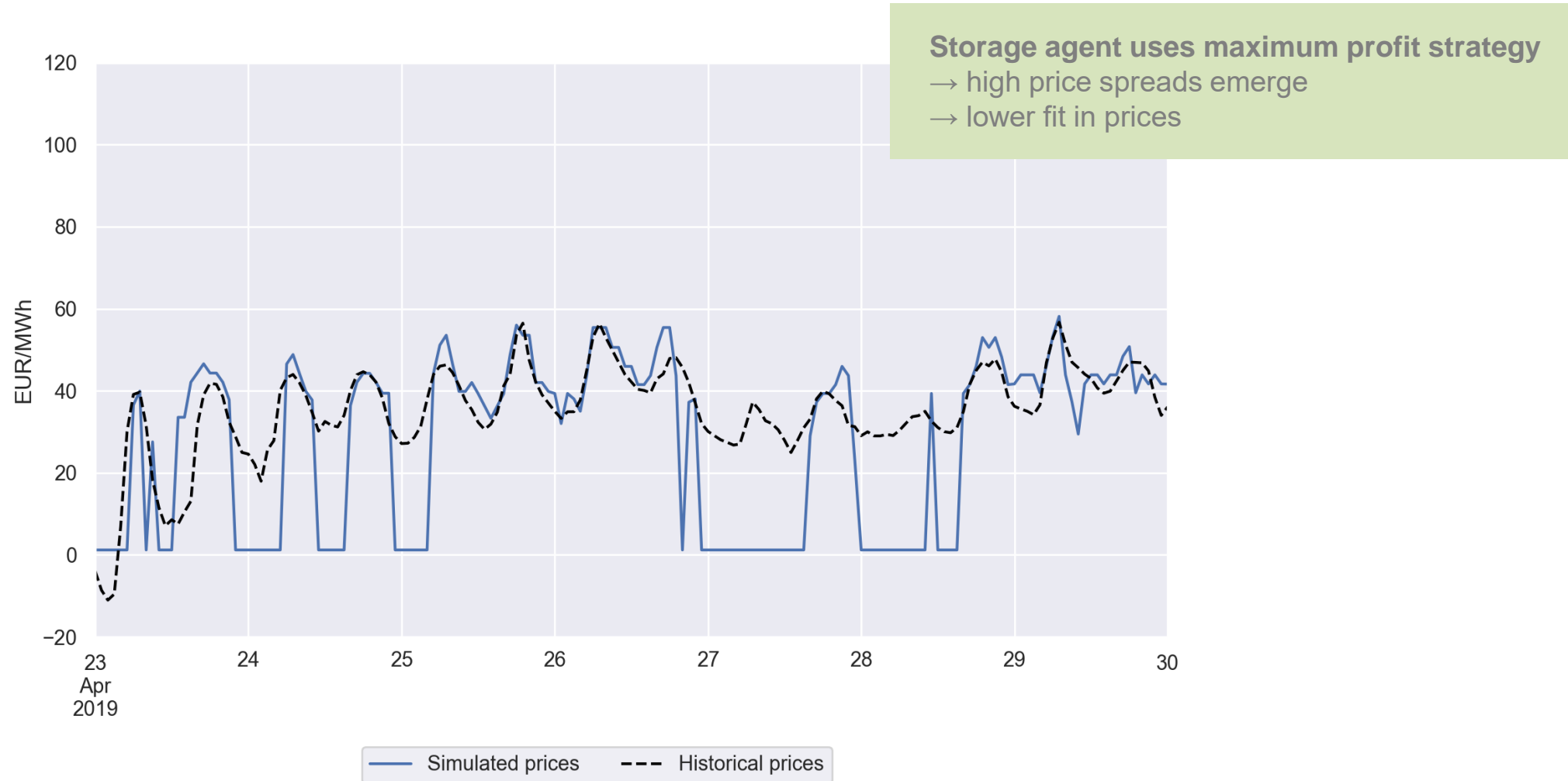


Figure 6: Simulated and historical day-ahead prices for the Austrian day-ahead market in April 2019 with profit-maximising storage agent





# Conclusion

Parameterization of the open source model AMIRIS and publication of model configuration

Simulation and comparison of price time series with Austrian day-ahead prices in 2019

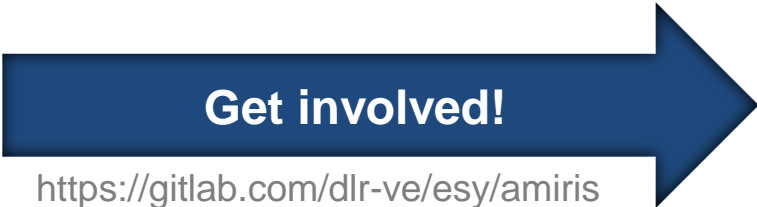
Results show a decent position for further research

# Outlook

Applying AMIRIS in various research projects, e.g.:

- Assessment of different EE remuneration schemes
- Modelling competition among flexibility options
- Investigating effects of market coupling
- Analyzing emergence phenomena due to prosumers

Building an active open source community!



<https://gitlab.com/dlr-ve/esy/amiris>





# Appendix



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# Link collection

- AMIRIS source code <https://gitlab.com/dlr-ve/esy/amiris/amiris>
- AMIRIS examples <https://gitlab.com/dlr-ve/esy/amiris/examples>
- AMIRIS website <https://dlr-ve.gitlab.io/esy/amiris/home>
- AMIRIS wiki <https://gitlab.com/dlr-ve/esy/amiris/amiris/-/wikis/home>
- AMIRIS openmod Forum <https://forum.openmod.org/tag/amiris>
  
- FAME framework <https://gitlab.com/fame-framework>

