

# Day-ahead market coupling in an agent-based electricity market model

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A large, curved satellite image of the Earth's surface occupies the bottom right portion of the slide. It shows a view of the Arctic region, with white ice and snow covering the landmasses and swirling cloud patterns over the surrounding oceans. The blue of the atmosphere is visible along the horizon curve.

Knowledge for Tomorrow

# Motivation

- Long record of energy system models (ESM) (Gilliland, 1975)
- Growing complexity leading to new challenges to modelers (Pfenninger et al., 2014)
- Challenging to account for highest GHG reduction targets in current ESM (Pye et al., 2021)
- Agent-based modelling (ABM) is a promising approach:
  - incorporating the actors' perspective (e.g. Nitsch et al., 2021)
  - representation of heterogeneous actors (e.g. Kraan et al., 2018)
  - real-world examples relatively cheap in terms of computational cost (e.g. Hansen et al., 2019)
- Therefore, we apply the ABM AMIRIS to simulate electricity markets
- Our main research interest:
  - integration of renewable energies & flexibility options in electricity systems
  - analysis of market effects caused by policy and remuneration schemes



# Project VERMEER

Security of supply in Germany and Central Europe during extreme-weather events

Investigation of flexibility of cross-border electricity trading during extreme-weather events considering dynamic Net Transfer Capacities (NTC)

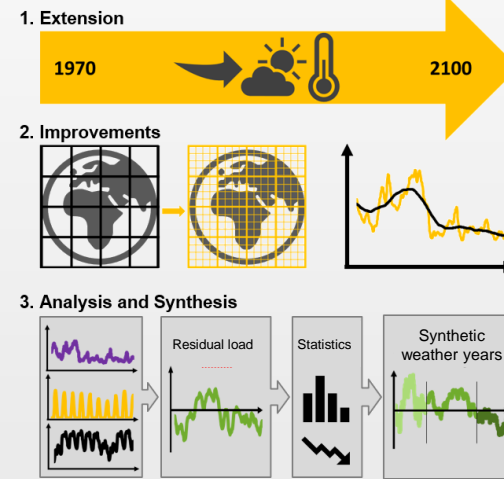
Funded by BMWi (03EI1010A)

Project partners:

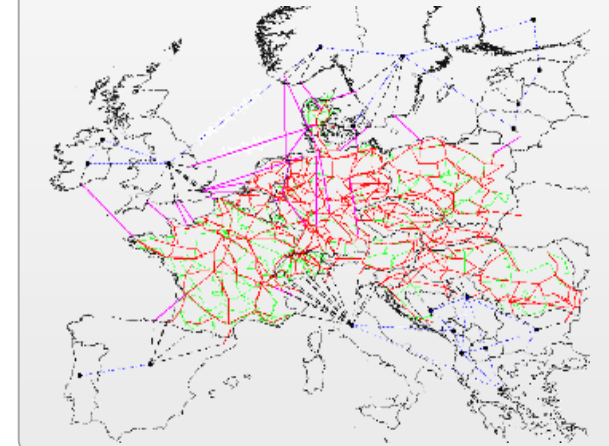
KIT Karlsruhe (<https://www.iip.kit.edu>)

DLR Stuttgart (<https://www.dlr.de/ve>)

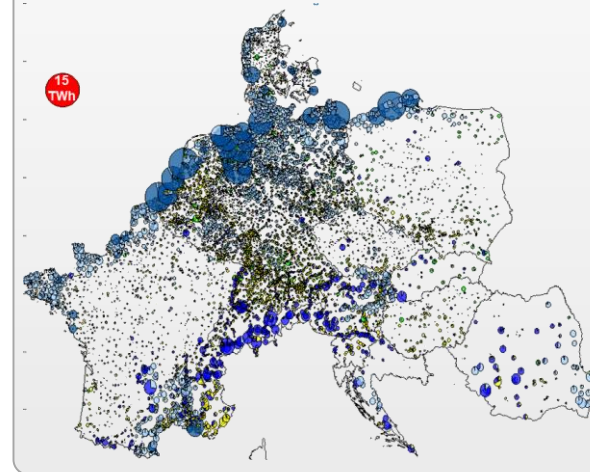
## Weather modelling



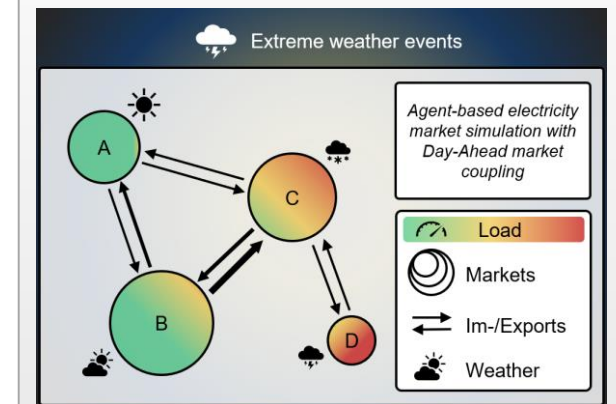
## Grid modelling



## RE allocation modelling



## Electricity market modelling



# AMIRIS

## Agent-based Market model for the Investigation of Renewable and Integrated energy Systems

### Model

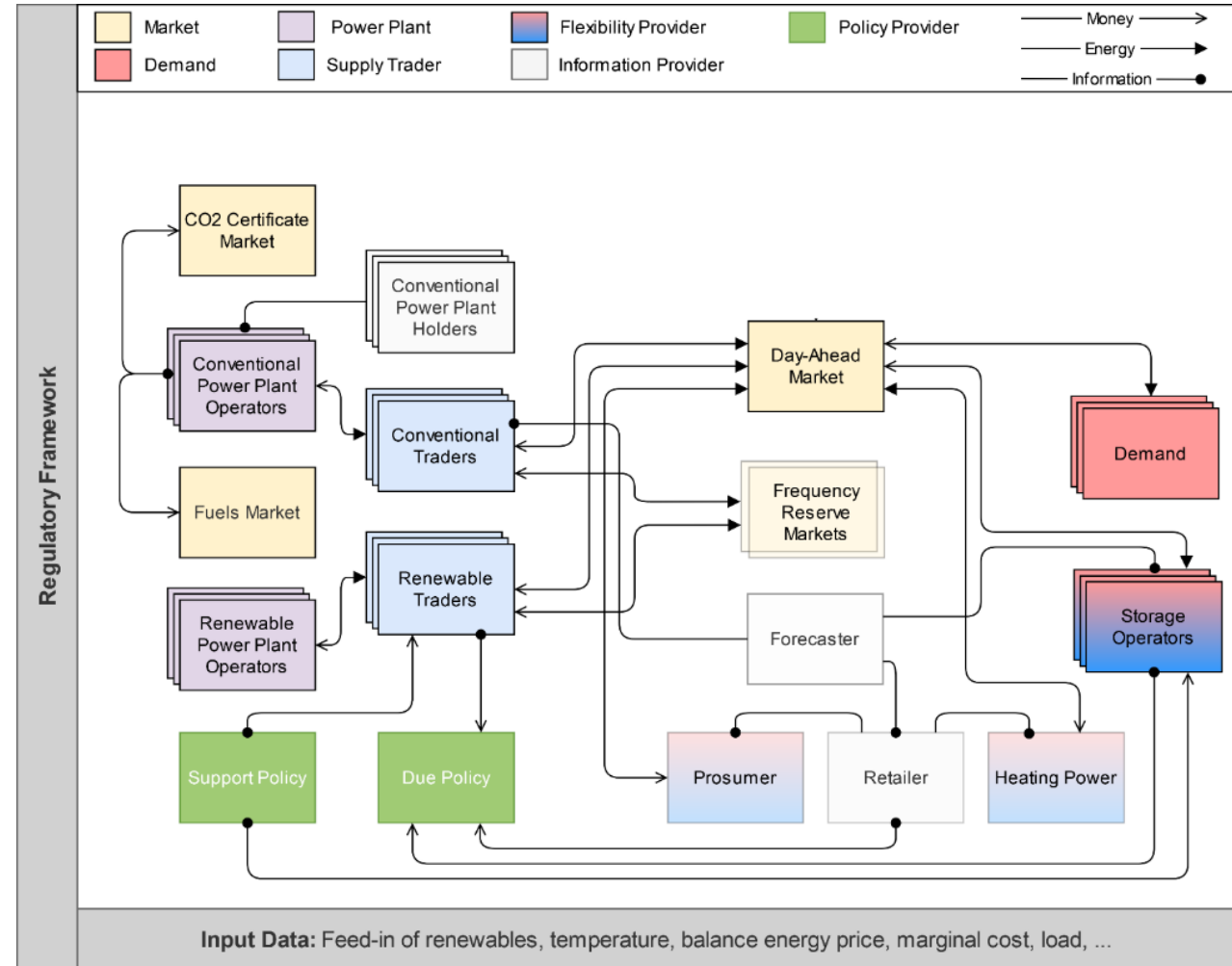
- Electricity market simulation
- To be **Open Source** in Q4/2021

### Agents

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

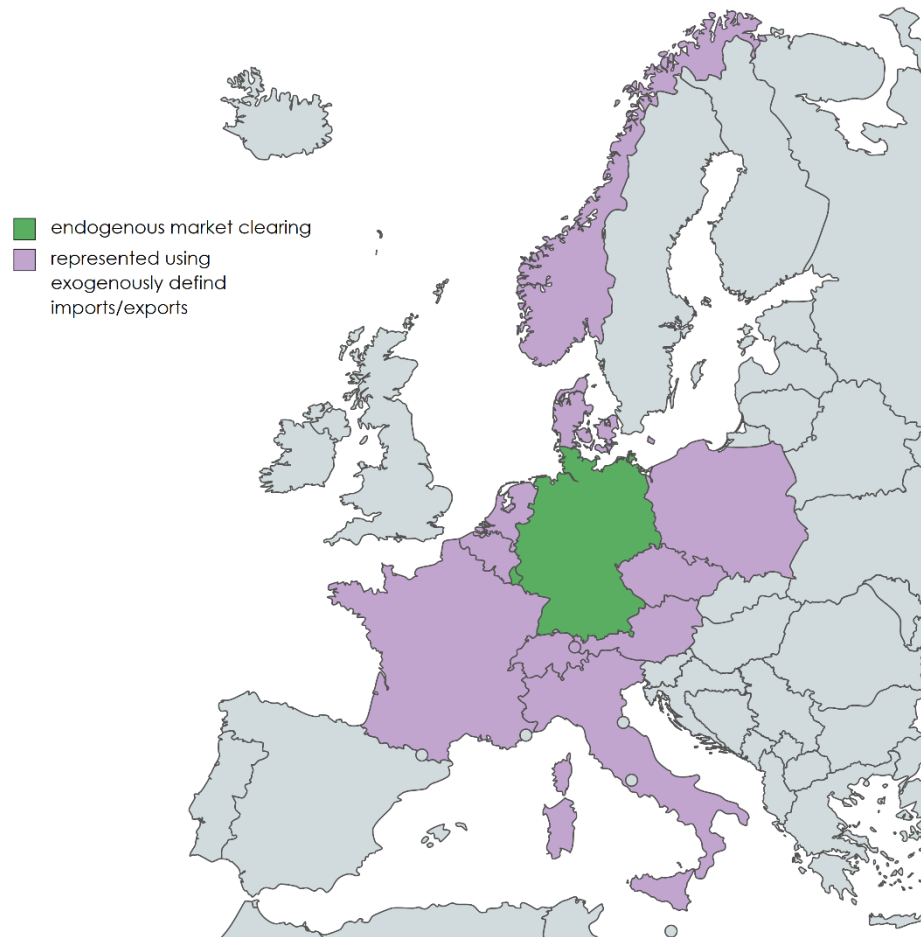
### Calculates

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





# Geographic scope of AMIRIS



## Currently:

- German market model
- Imports & exports: predetermined timeseries



## Goal:

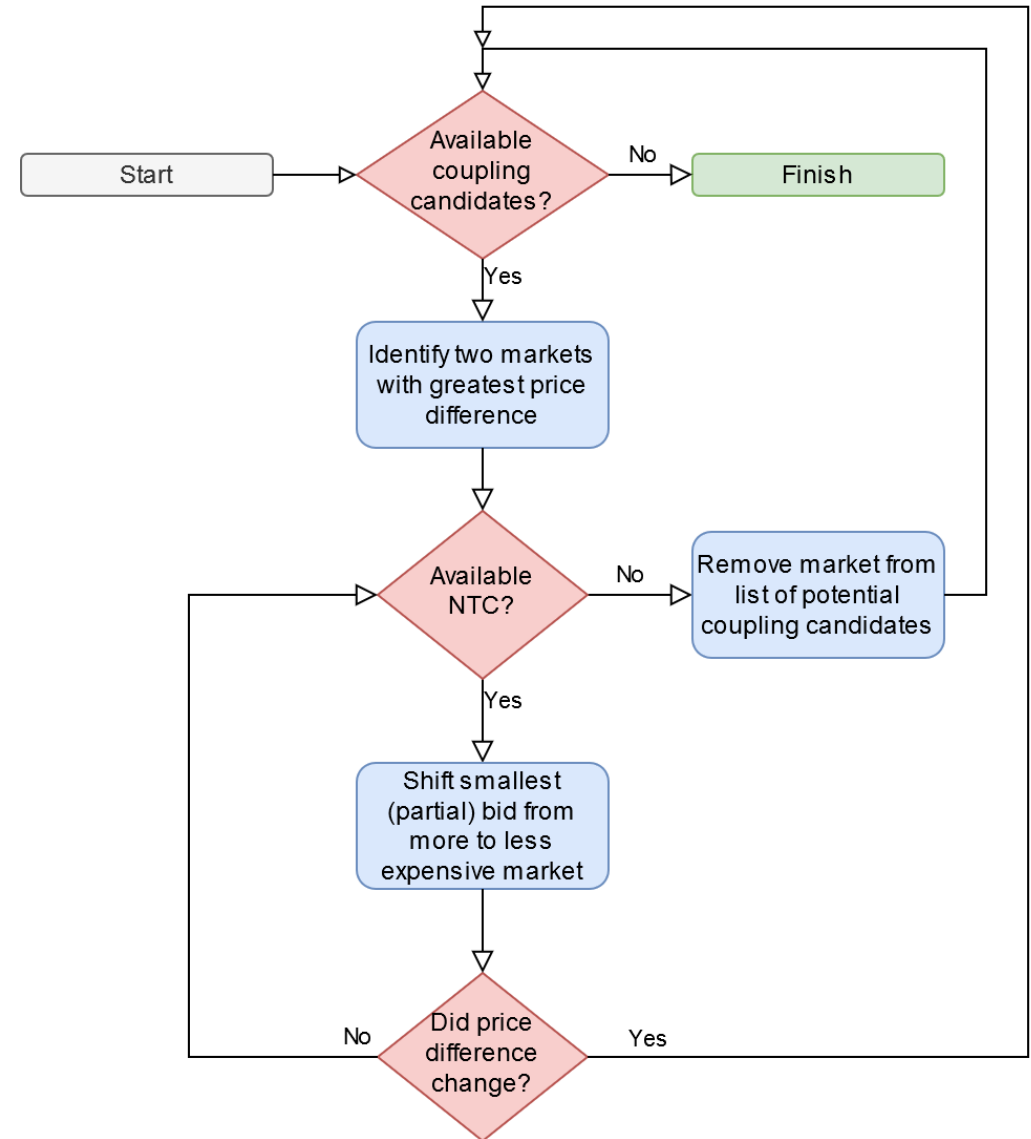
- Modell German and neighboring markets
- Imports & exports: Modelled via market coupling





# Detailed description of market coupling

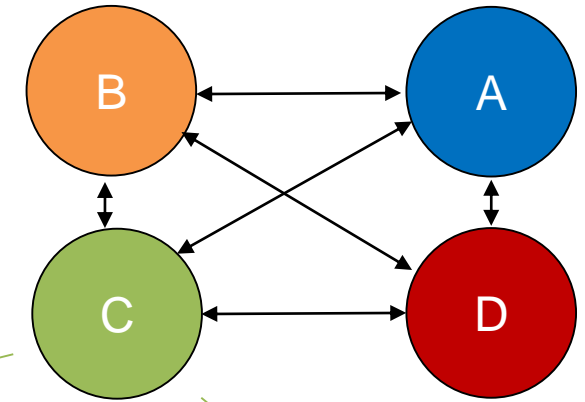
- Identify potential candidates consisting of two markets
- Finding best candidates for coupling
- Decreasing price difference by smallest possible shift of demand from one market to other
- Re-evaluation of best candidates for coupling
  
- Termination when price differences cannot be minimized anymore, e.g.:
  - a) price differences are zero, or
  - b) all NTC are used
  
- Solution considered as global optimum



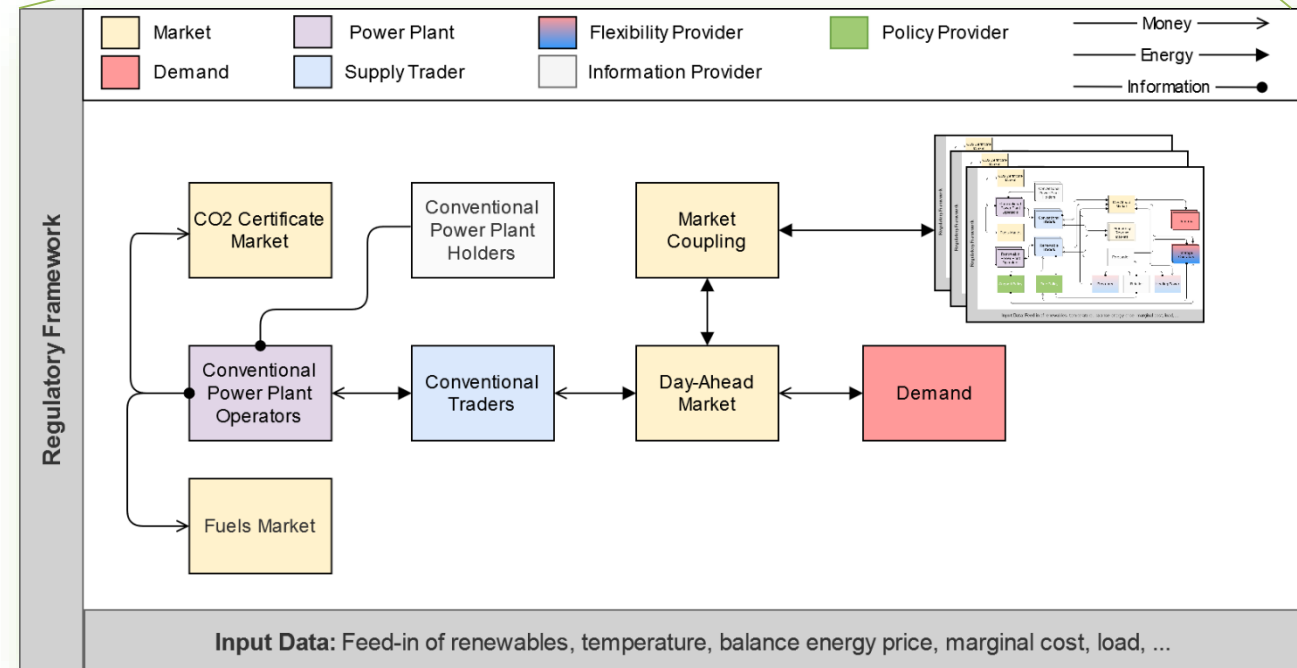
## Case study

- Demonstration of implementation using 3 and 4 markets
- Different levels of NTCs (up to unlimited capacity)
- Investigation of:
  - electricity prices
  - awarded power
- Weekly plots of hourly resolution

Example of four fully connected markets

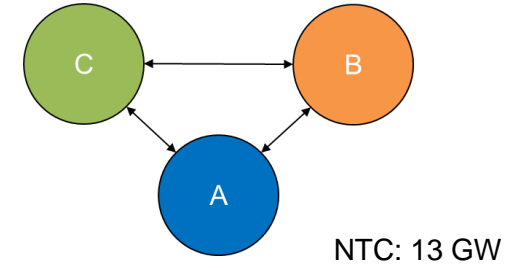
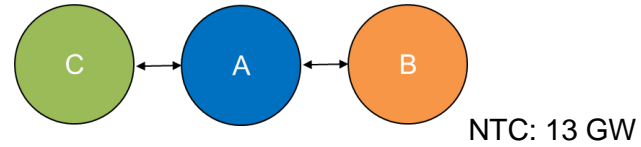
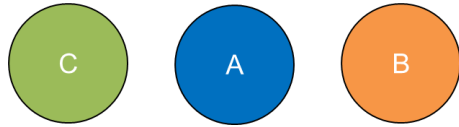


AMIRIS simulation with reduced number of agents

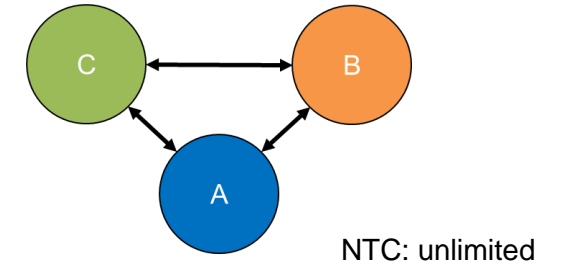
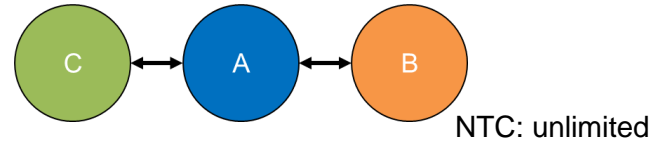
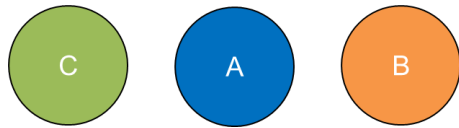




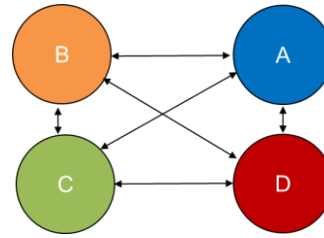
## Results: Case study of three markets



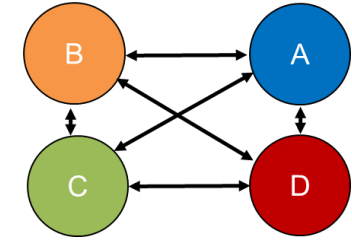
## Results: Case study of three markets – unlimited NTC



## Results: Case study of four markets

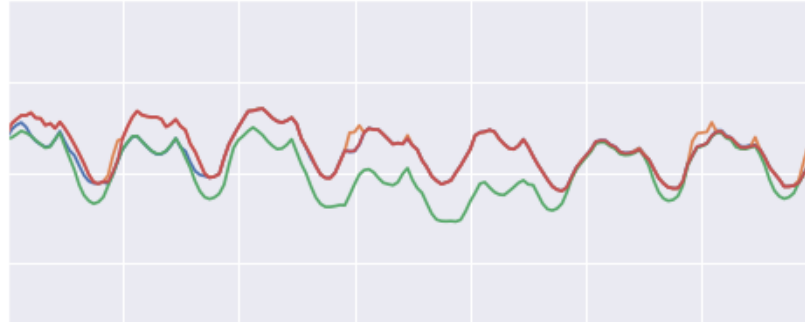
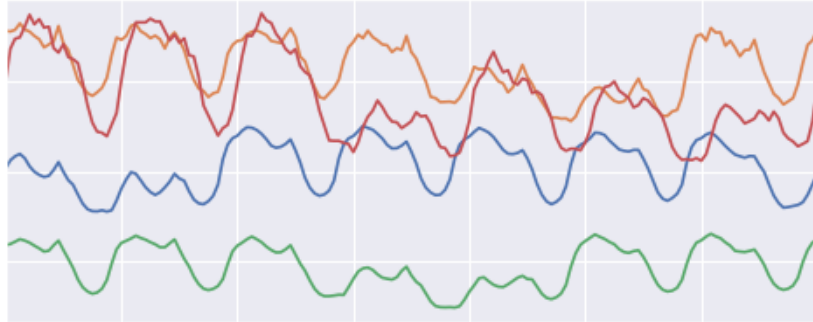


NTC: 13 GW

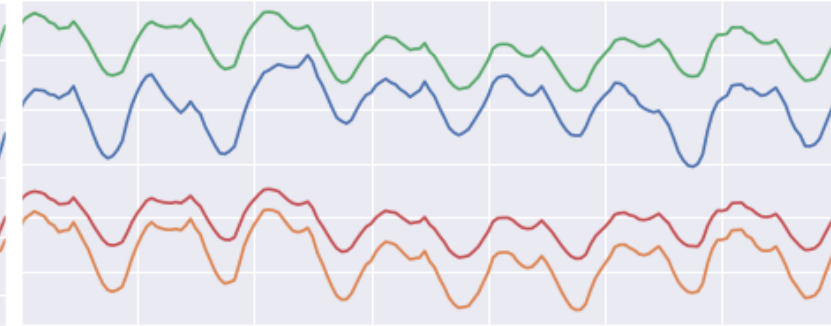
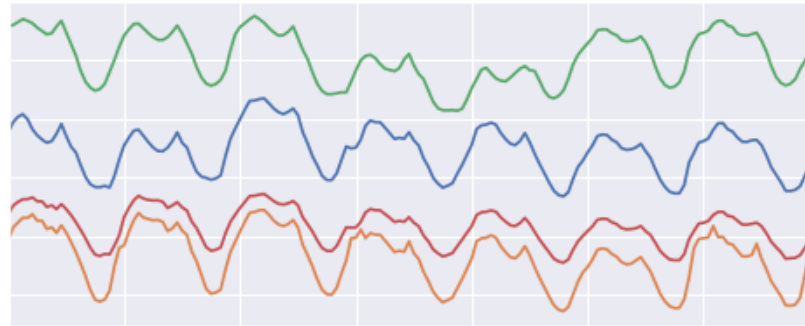
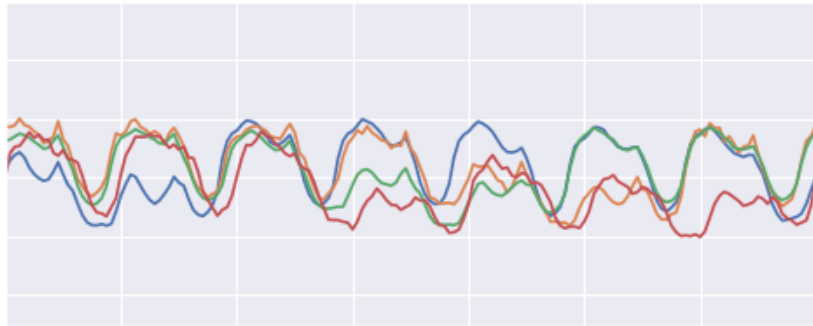


NTC: unlimited

Price



Awarded Power



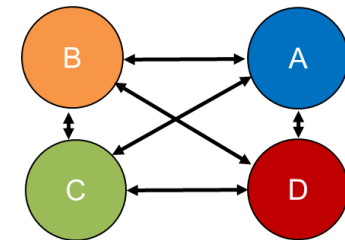
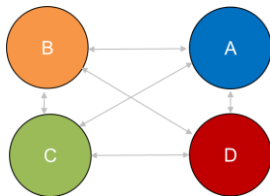
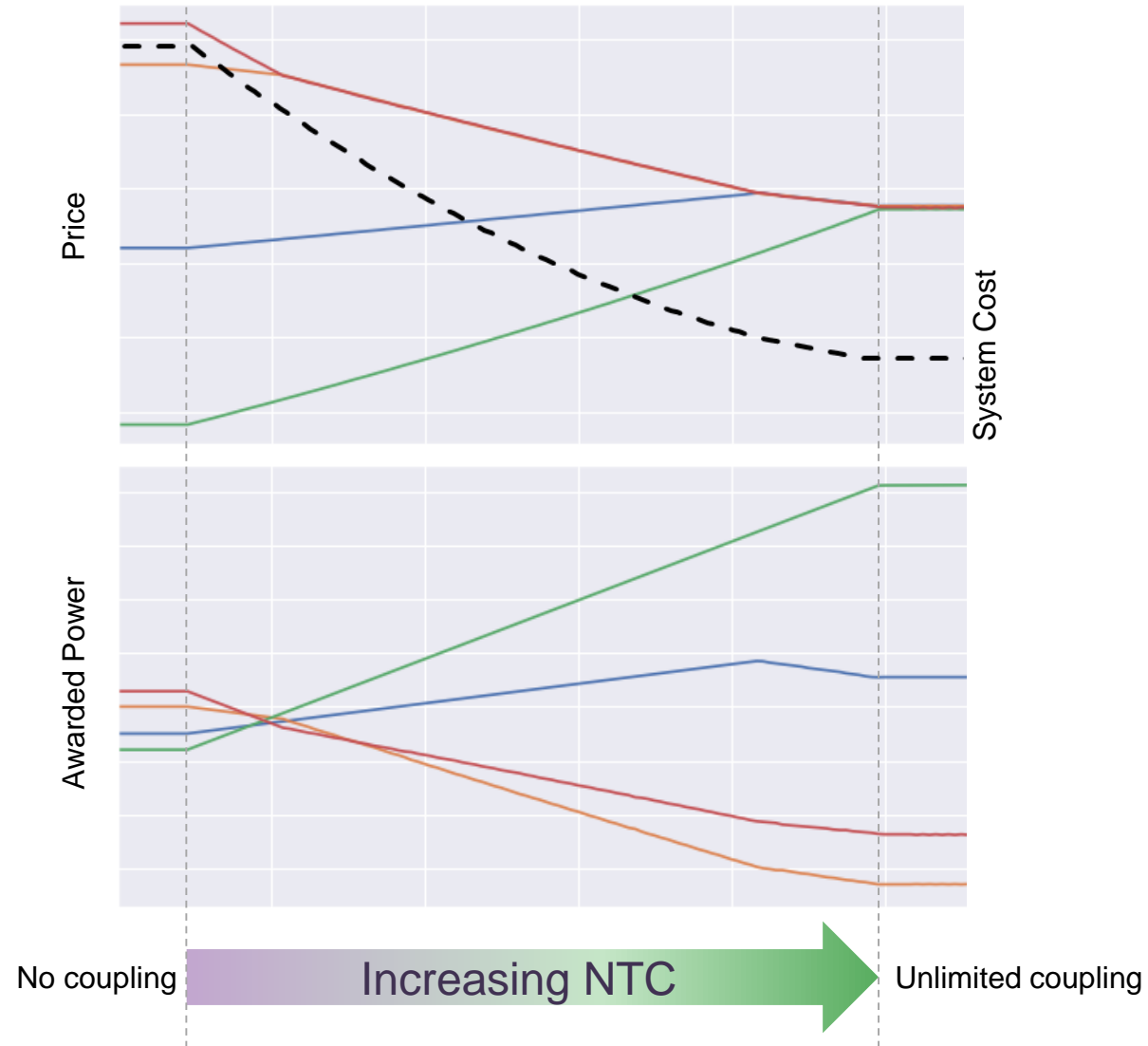
1 week at hourly resolution

1 week at hourly resolution

1 week at hourly resolution



# Results: From zero to unlimited NTC





# Conclusion

- Investigation of electricity markets using AMIRIS
- Introduction of *MarketCoupling* agent in AMIRIS allowing to extend geographic scope
- Implementation of Java based, incremental, and dynamic solving algorithm minimizing price differences
- Accounting for hourly Net Transfer Capacities as constraints to optimization
- Case study shows promising results, finding global optimum reliably

# Discussion & Outlook

- Heuristic-based algorithm
- Consideration of domain specific properties (e.g. price steps due to merit order, minimum shift size)
- Full-scale deployment in real-world electricity market scenarios
- Further performance improvements of algorithm



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