Project: VERMEER (FKZ: 03EI1010A)
Supported by:
Federal Ministry for Economic Affairs and Energy
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Day-ahead market coupling in an agent-based electricity market model

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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 heterogenous 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 renumeration schemes

Project VERMEER

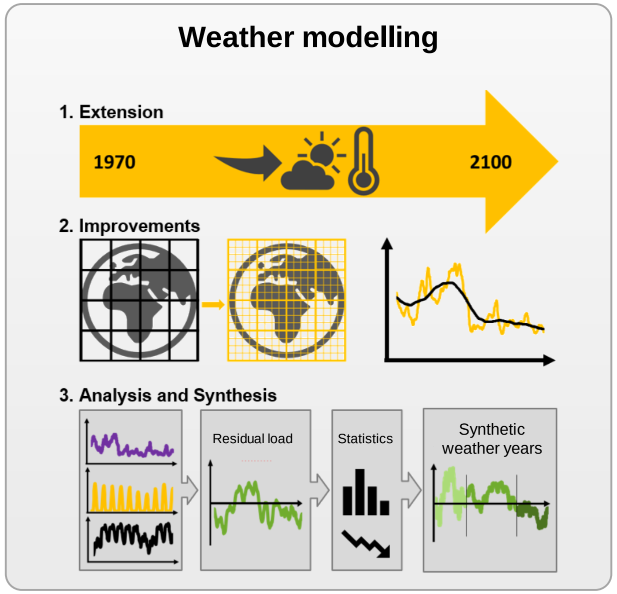
Security of supply in Germany and Central Europe during extreme-weather events

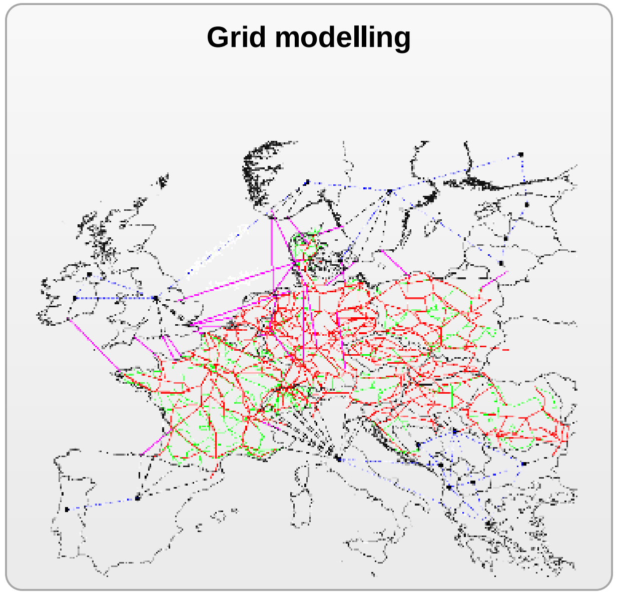
Investigation of flexibility of cross-border electricity trading during extreme-weather events considering dynamic Net Transfer Capacities (NTC)

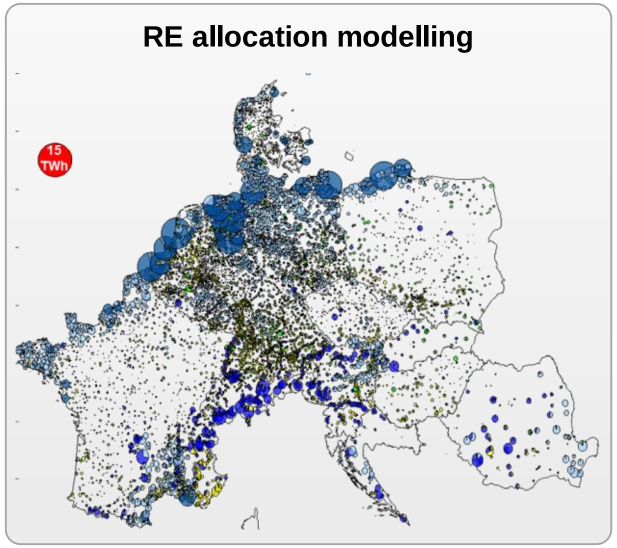
Funded by BMWi (03EI1010A)

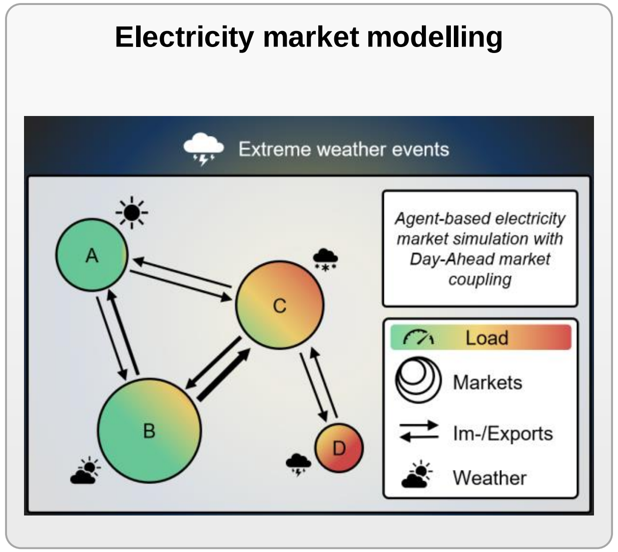
Project partners:

KIT Karlsruhe (https://www.iip.kit.edu)
DLR Stuttgart (https://www.dlr.de/ve)









Nitsch et al. (2021): VERMEER - Versorgungsicherheit in Deutschland und Mitteleuropa während Extremwetter-Ereignissen. Jahrestreffen 2021 des Forschungsnetzwerks Energiesystemanalyse, 18.-20. Mai 2021, https://elib.dlr.de/142348/

AMIRIS

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

Model

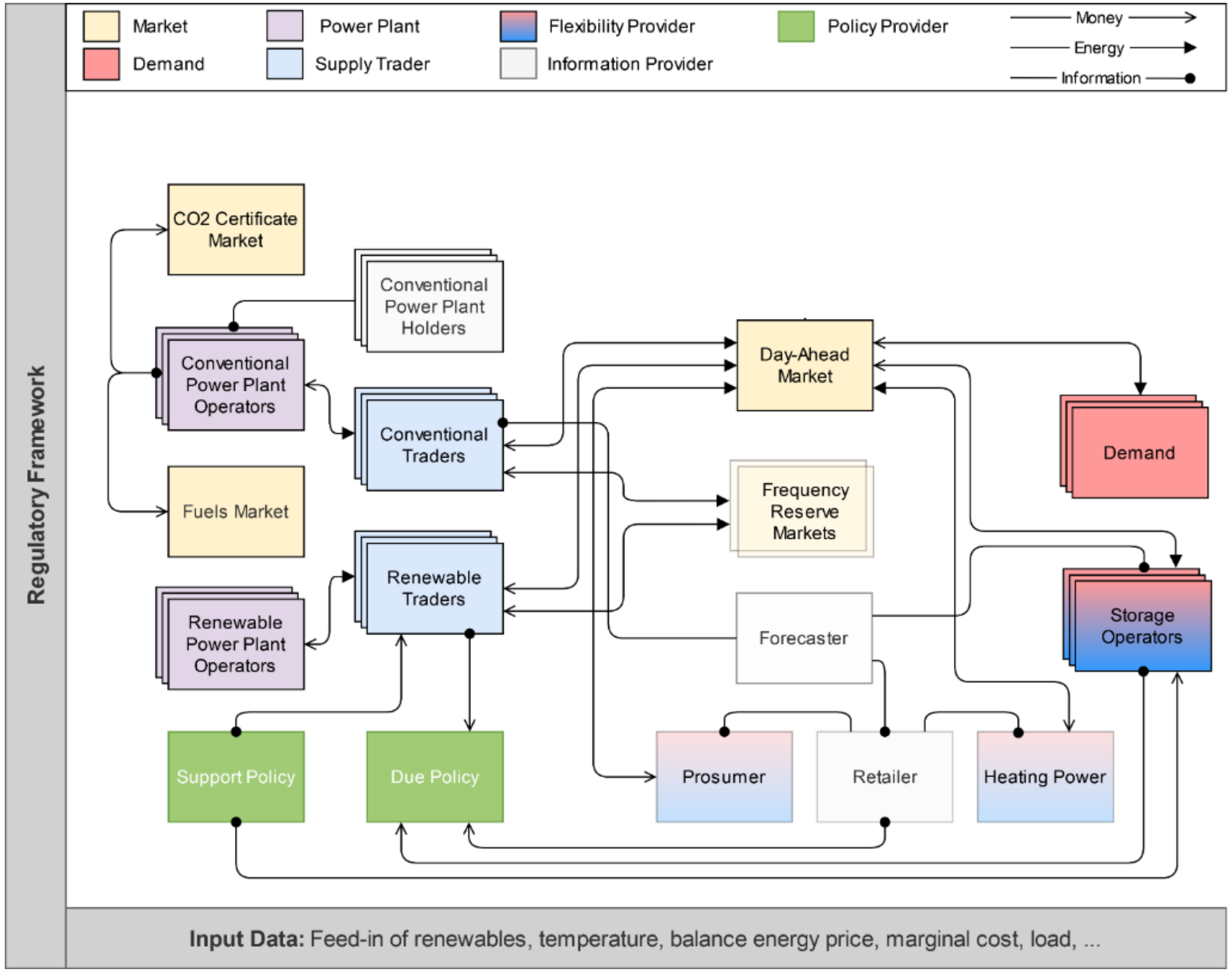
- Electricity market simulation
- To be **Open Source** in Q4/2021

Agents

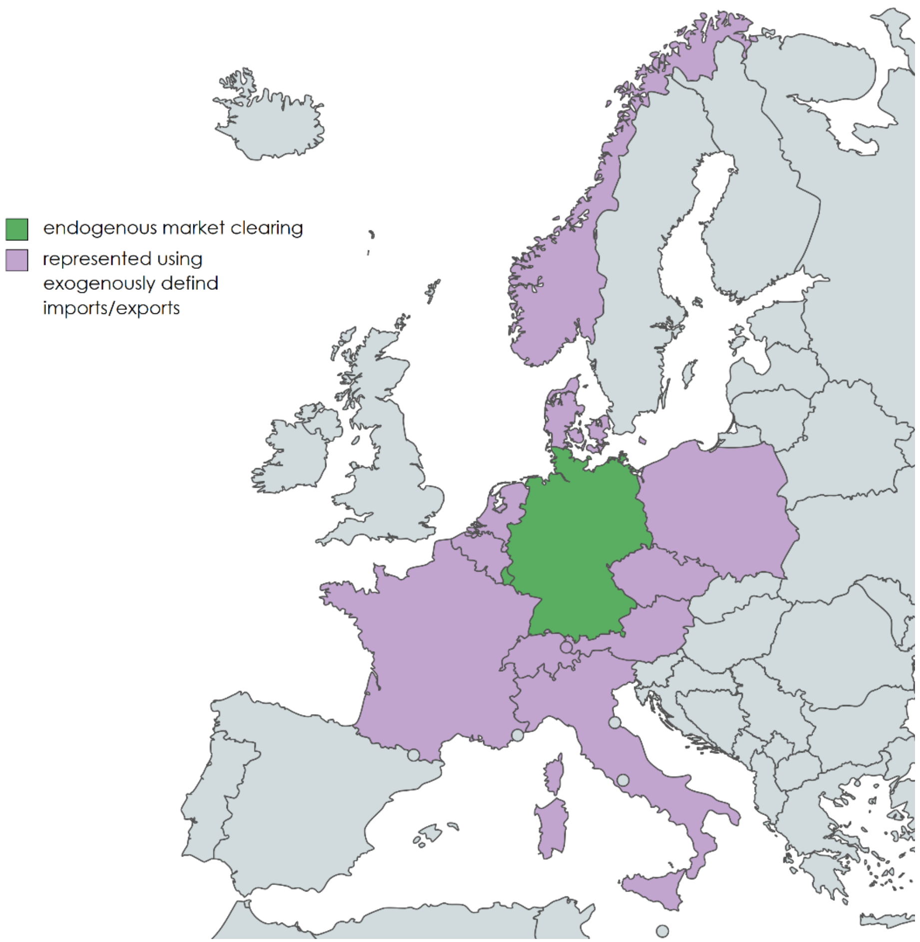
- Conventional Plants
- Renewable Plants
- Traders
- Flexibilities
- Markets
- Policy
- Forecasting

Calculates

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

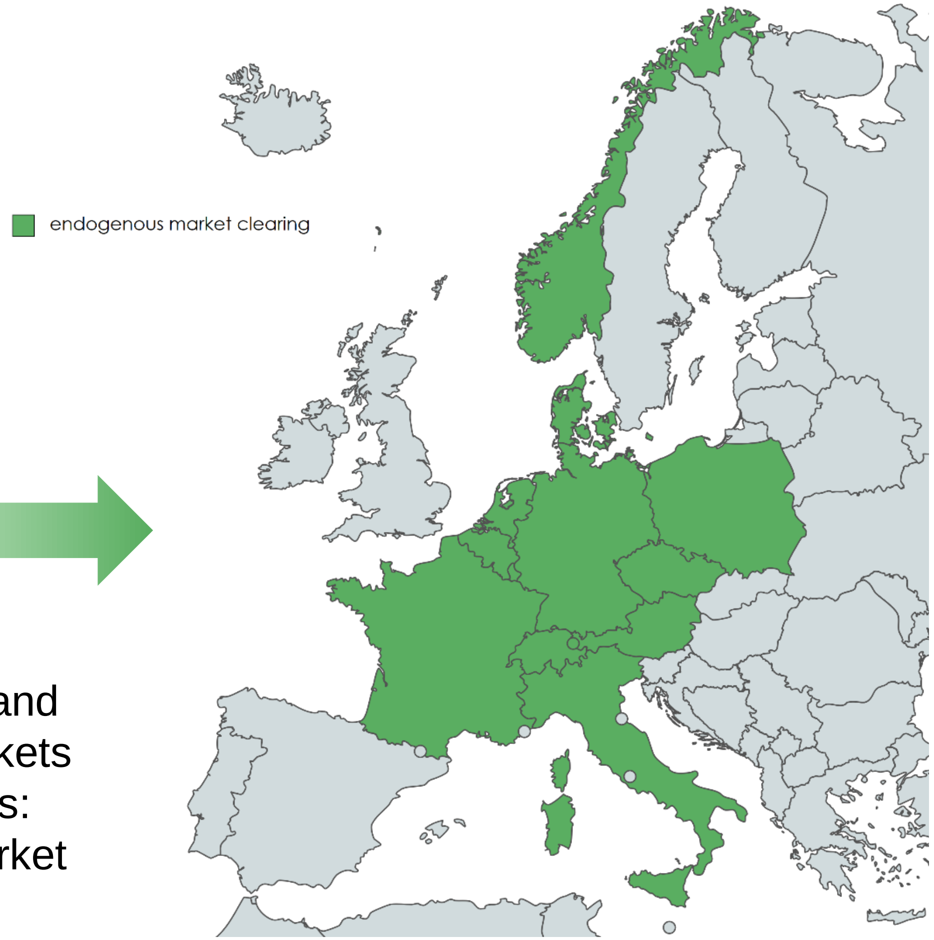


Geographic scope of AMIRIS



Currently:

- German market model
- Imports & exports: predetermined timeseries



Goal:

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

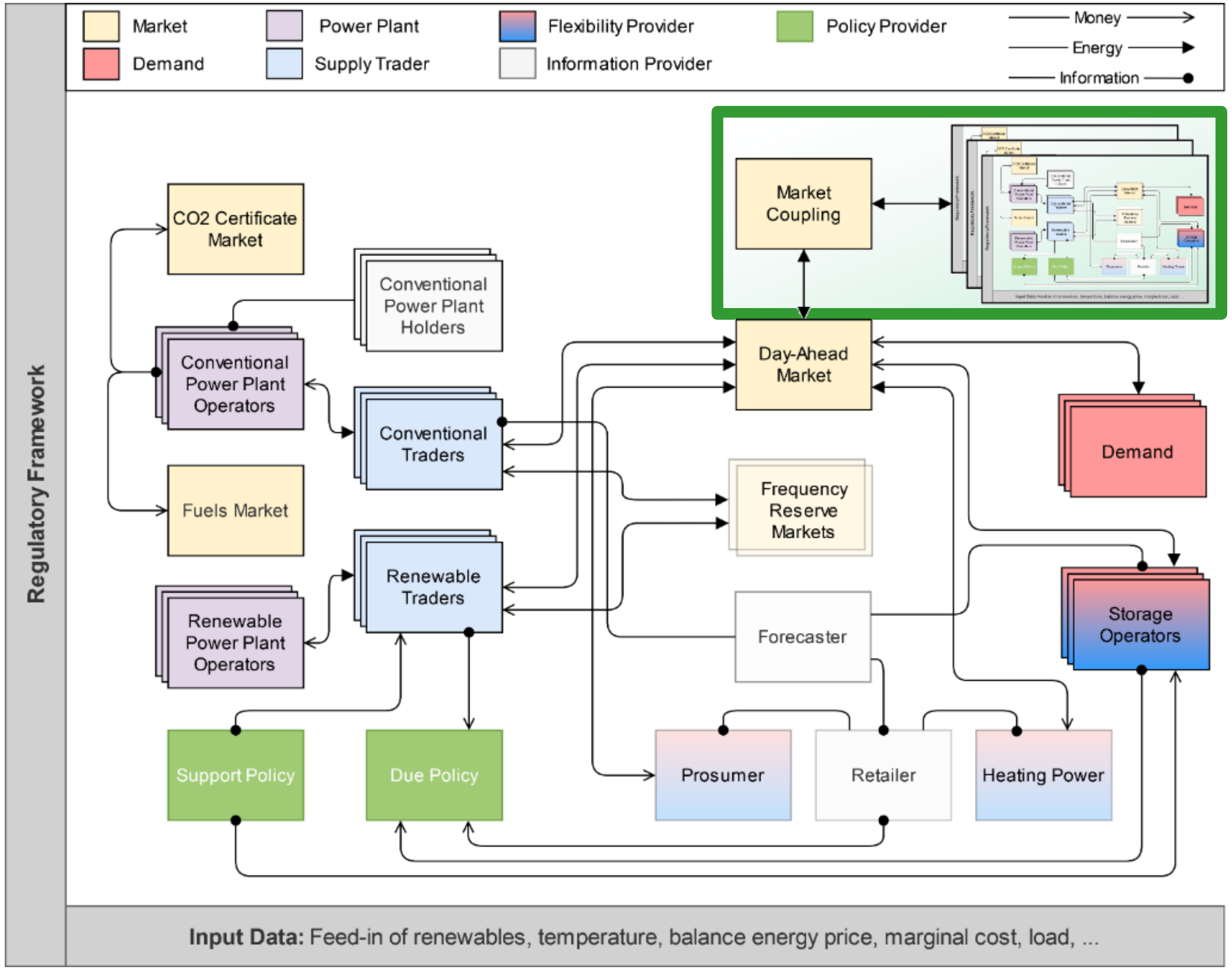
Coupling markets in AMIRIS

Concept

- Introducing a new agent type *MarketCoupling*
- Participating day-ahead markets are connected to the *MarketCoupling* agent

Procedure

1. Day-ahead market agent collects bids & asks of its associated traders
2. Information together with Net Transfer Capacities (NTC) is sent to *MarketCoupling* agent
3. Market coupling is carried out ensuring NTCs are met
4. Updated (coupled) price is sent back to traders via their local day-ahead market agents

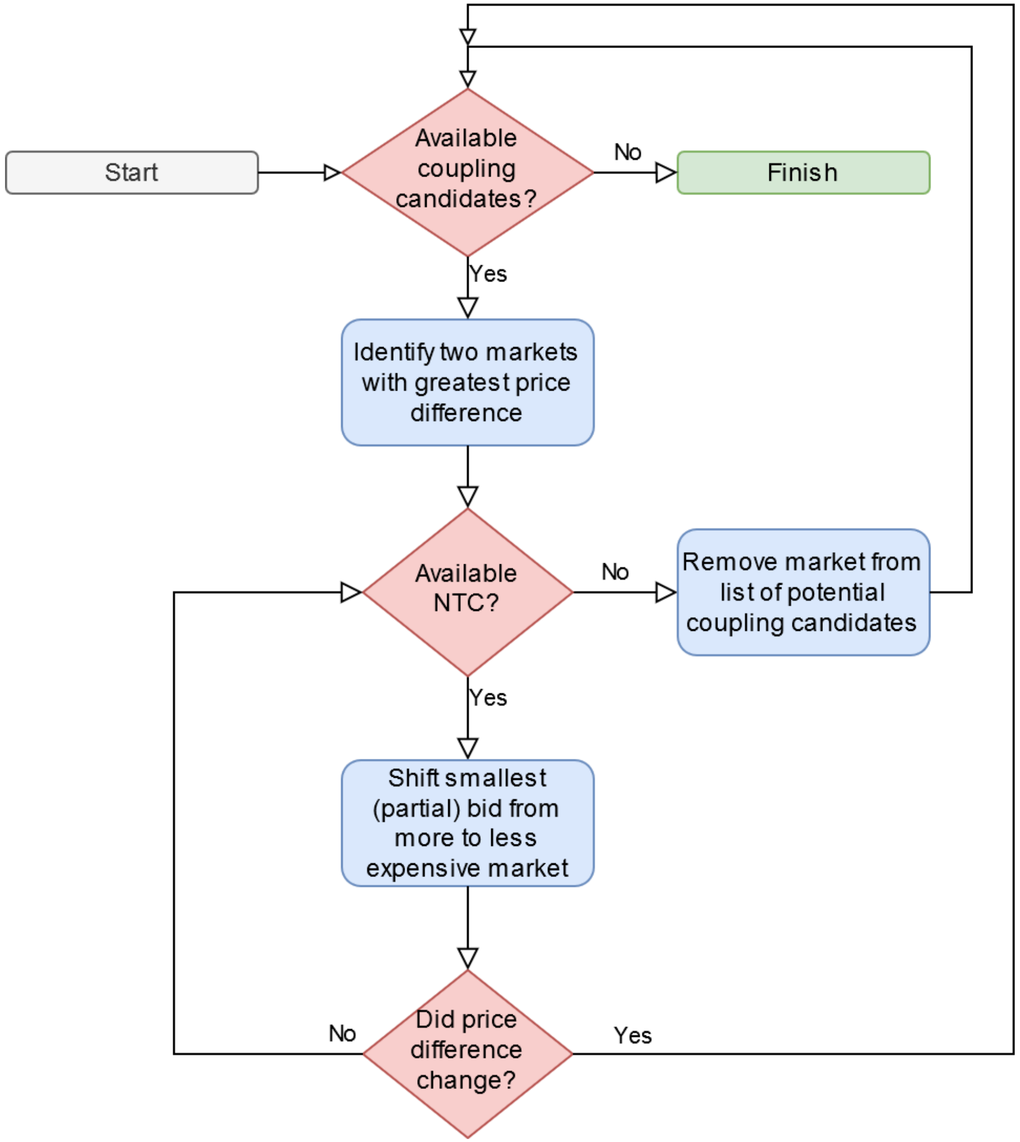


Detailed description of market coupling

- 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

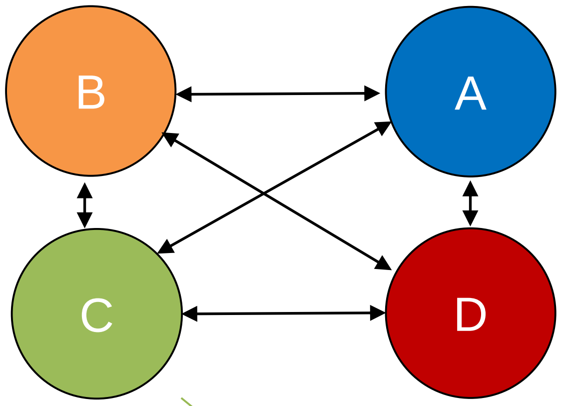
- Solution considered as global optimum



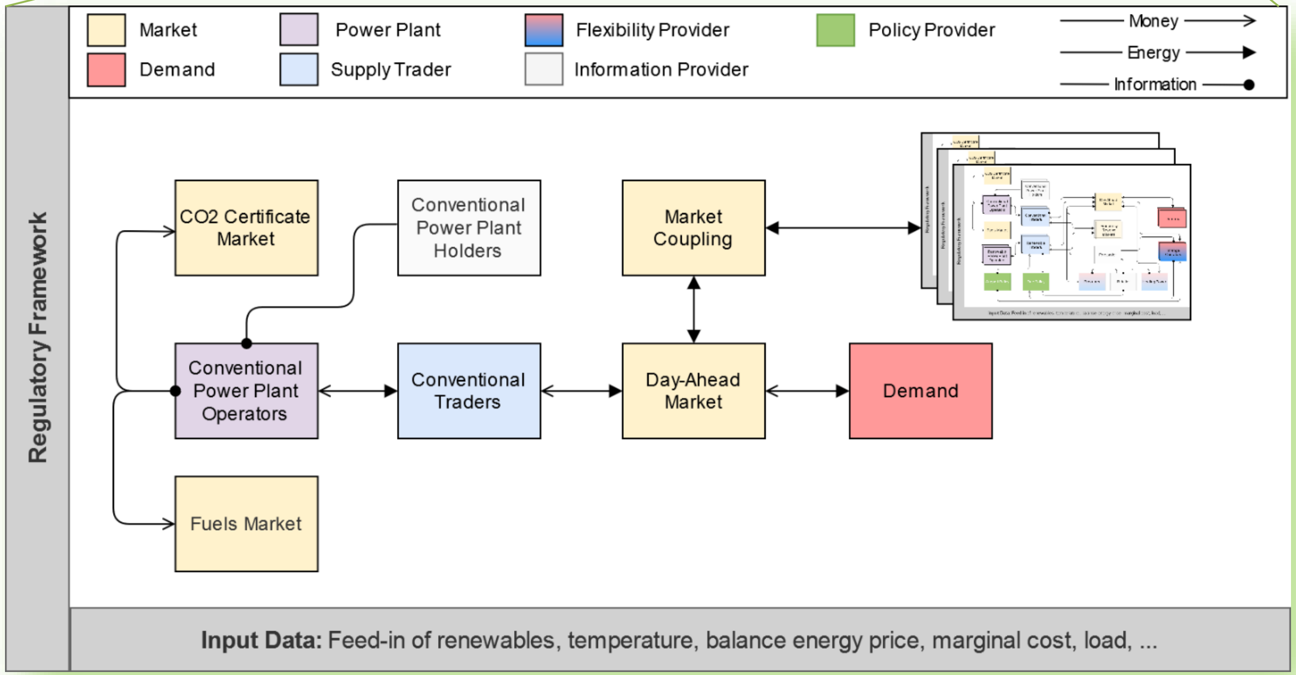
Case study

- 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

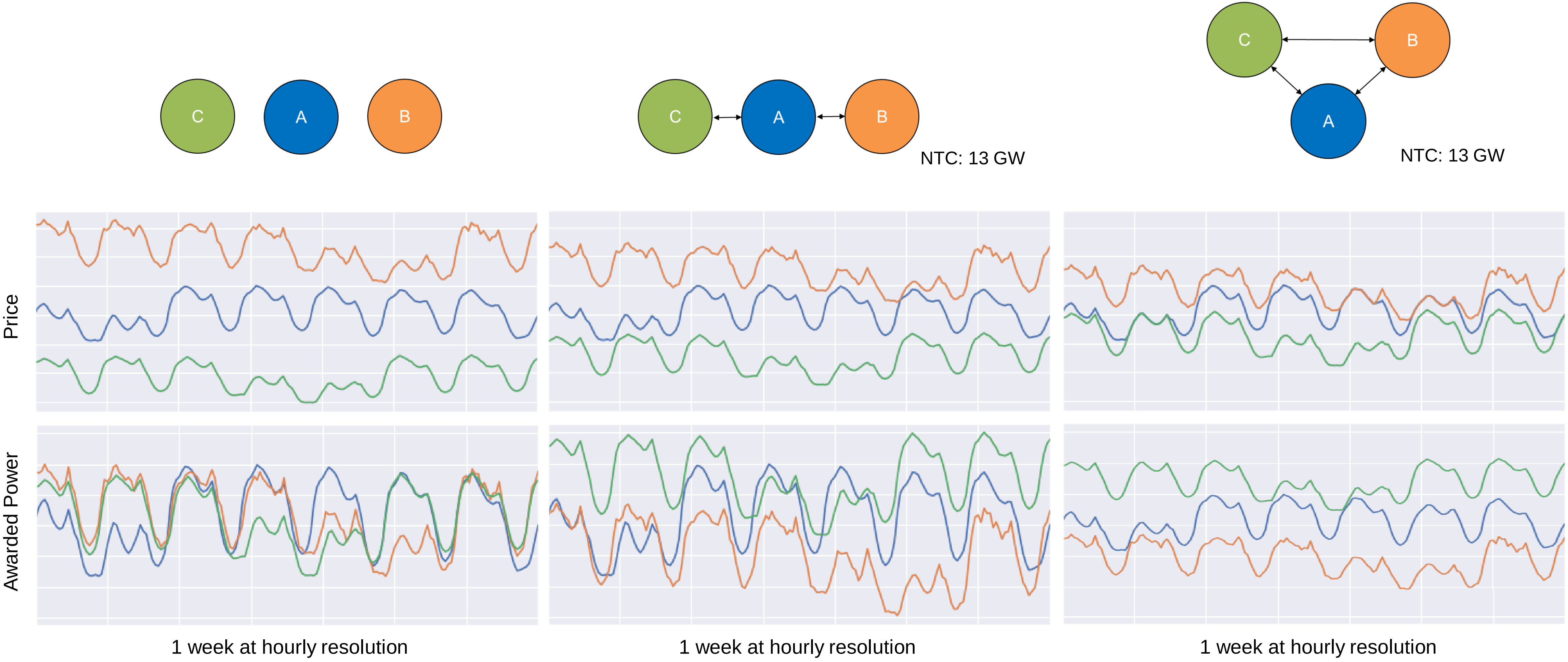
Example of four fully connected markets



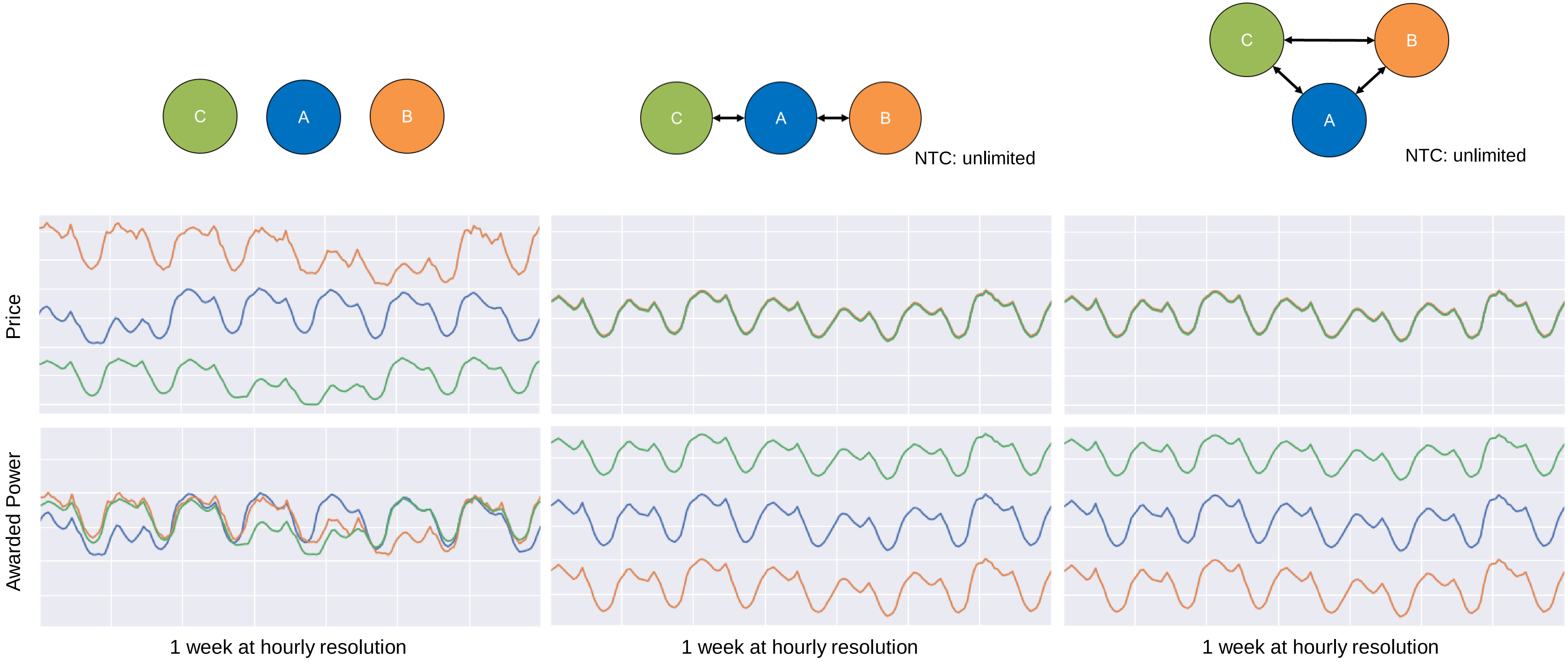
AMIRIS simulation with reduced number of agents



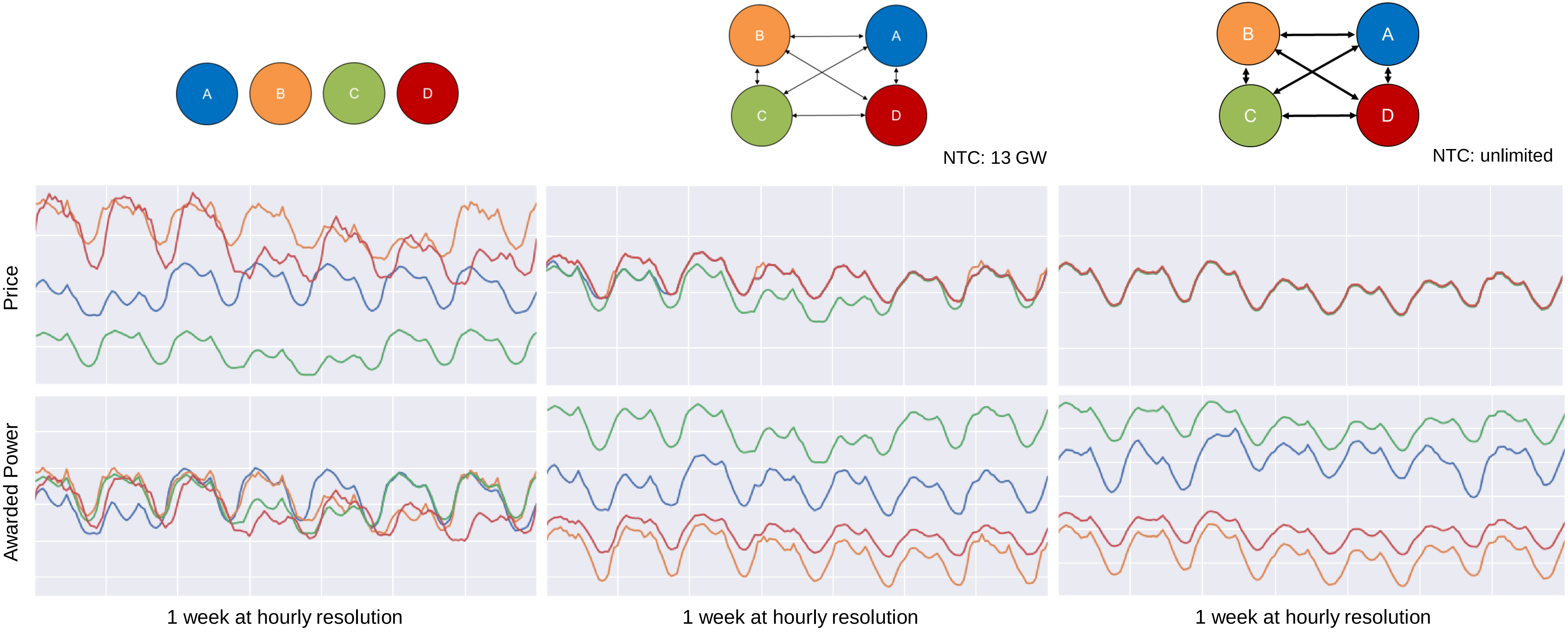
Results: Case study of three markets



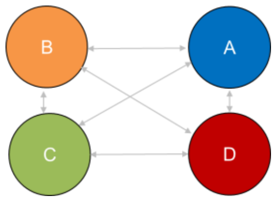
Results: Case study of three markets – unlimited NTC

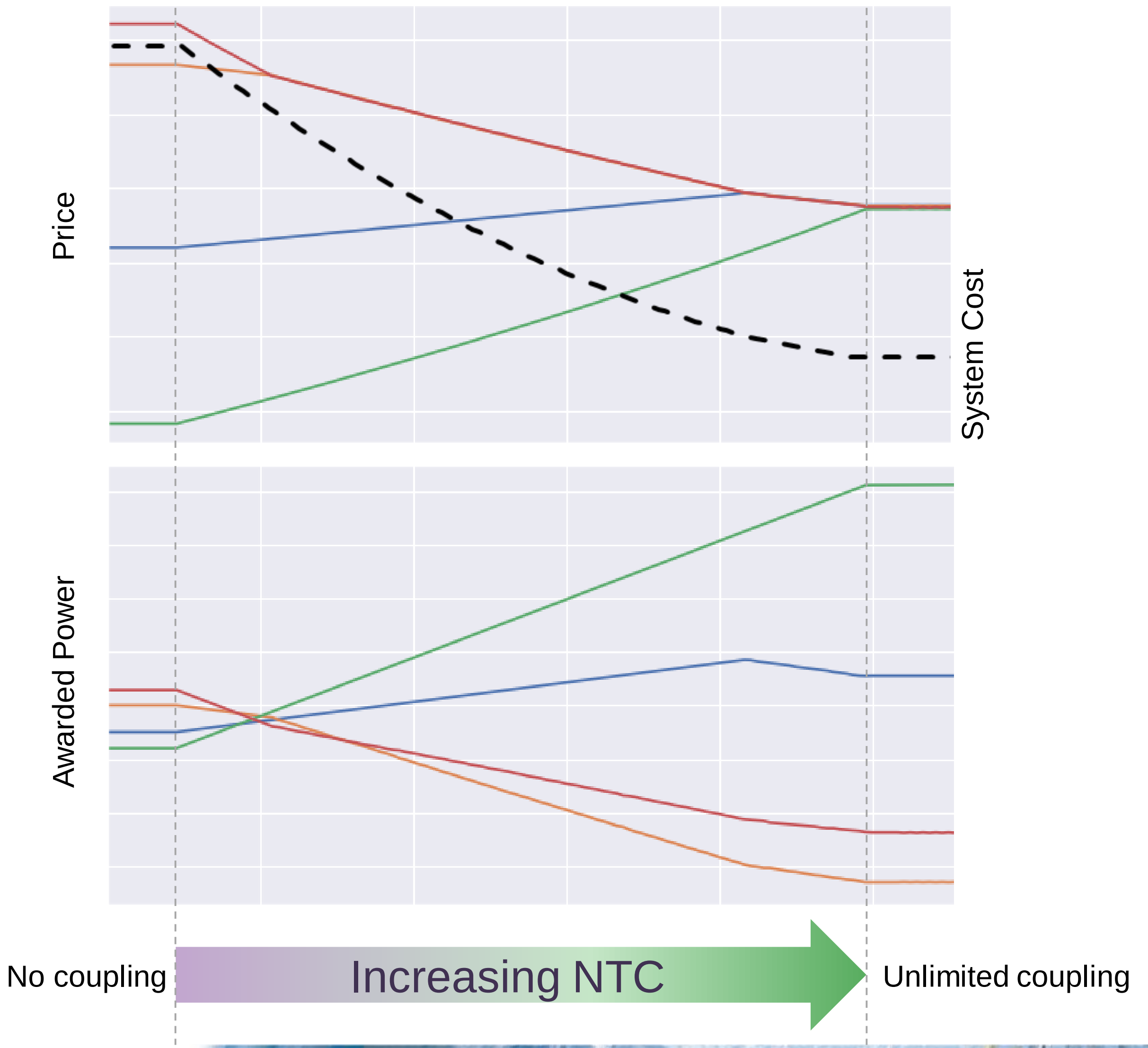


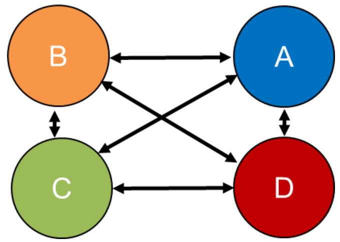
Results: Case study of four markets



Results: From zero to unlimited NTC







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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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