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ENERGY SYSTEMS ANALYSIS CONSIDERING CROSS-BORDER ELECTRICITY TRADING

Coupling day-ahead markets in an agent-based electricity market model

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DLR

Motivation

- Energy systems modelling well established research field Gilliland (1975)
- Modelling challenges due to growing complexity Pfenninger et al. (2014), Pye et al. (2021)

- Agent-based modelling (ABM) – a promising approach
  - incorporating actors‘ perspectives Nitsch et al. (2021)
  - representing heterogenous actors Kraan et al. (2018)
  - modelling real-world examples computationally cheap Hansen et al. (2019)

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

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

Security of supply during extreme-weather events

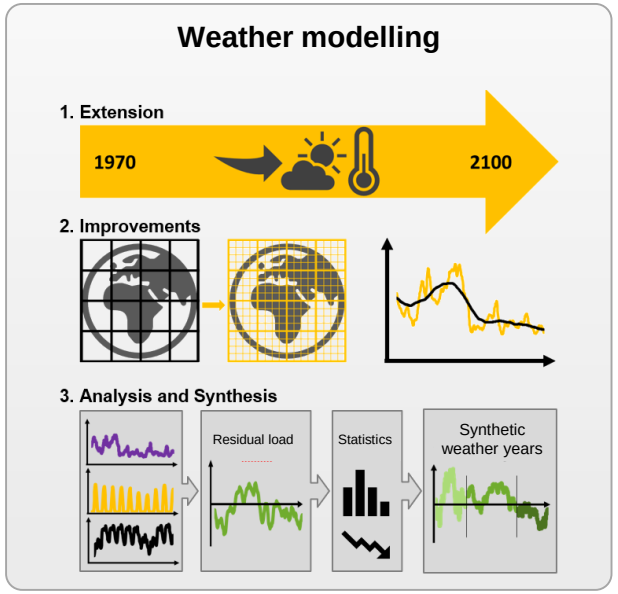
VERMEER Project

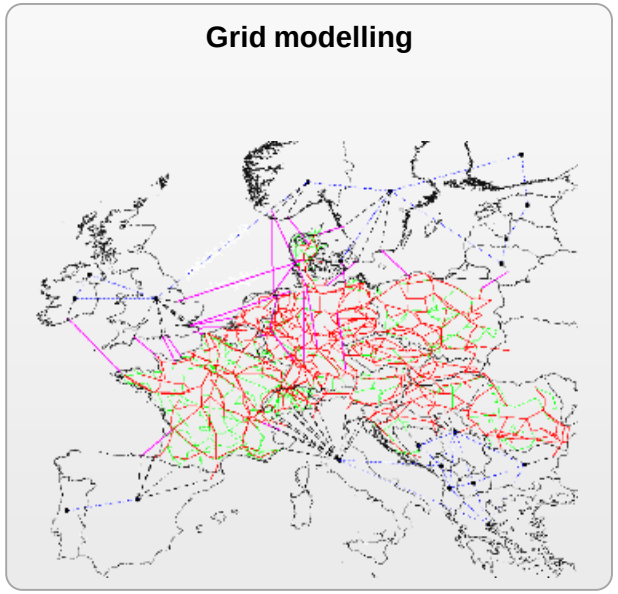
Impact of cross-border electricity trading during extreme-weather events considering dynamic Net Transfer Capacities (NTC) on security of supply

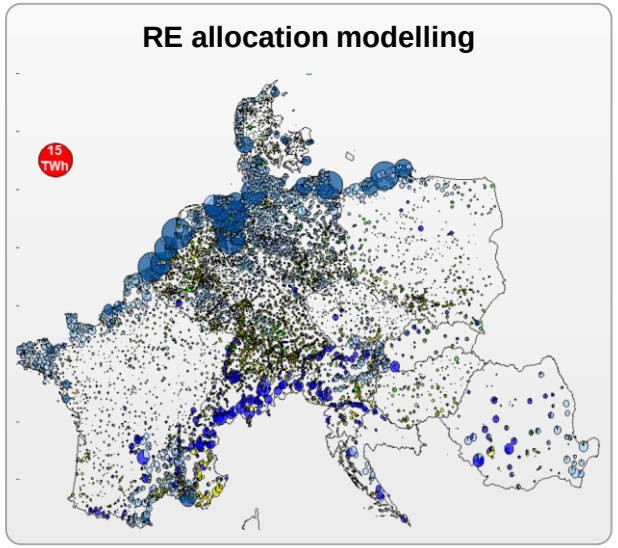
Funded by BMWK (FKZ: 03EI1010A)

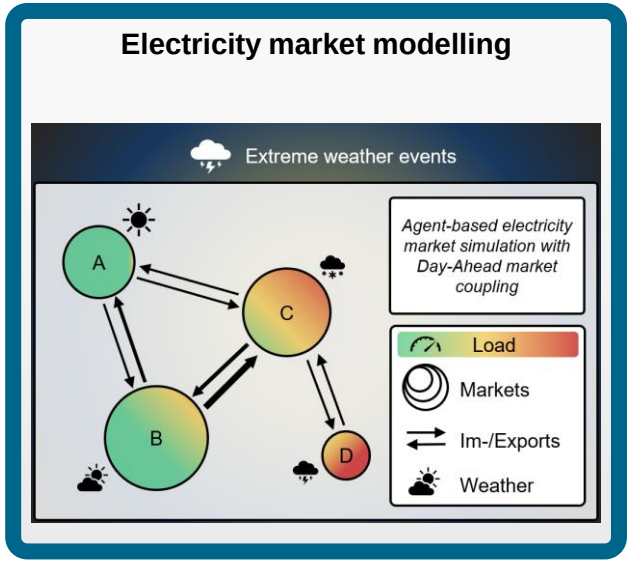
Project partners:

- KIT Institute for Industrial Production (IIP), Karlsruhe https://www.iip.kit.edu
- DLR Institute for Networked Energy Systems, Stuttgart https://www.dlr.de/ve









Nitsch F. & El Ghazi AA., Institute of Networked Energy Systems, 08/2023

AMIRIS

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

Model

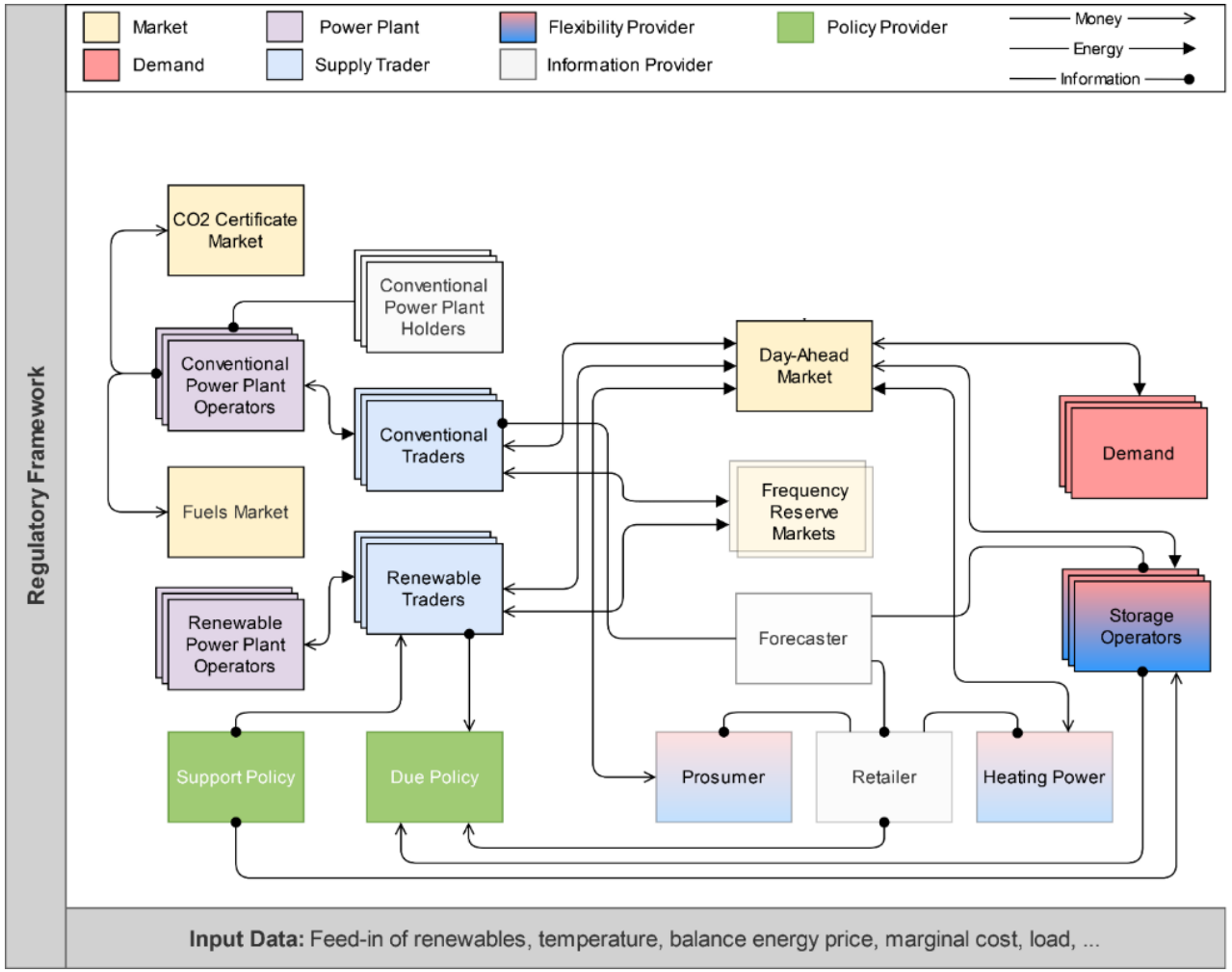
- Electricity market simulation
- Open source (Apache 2)

Agents

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

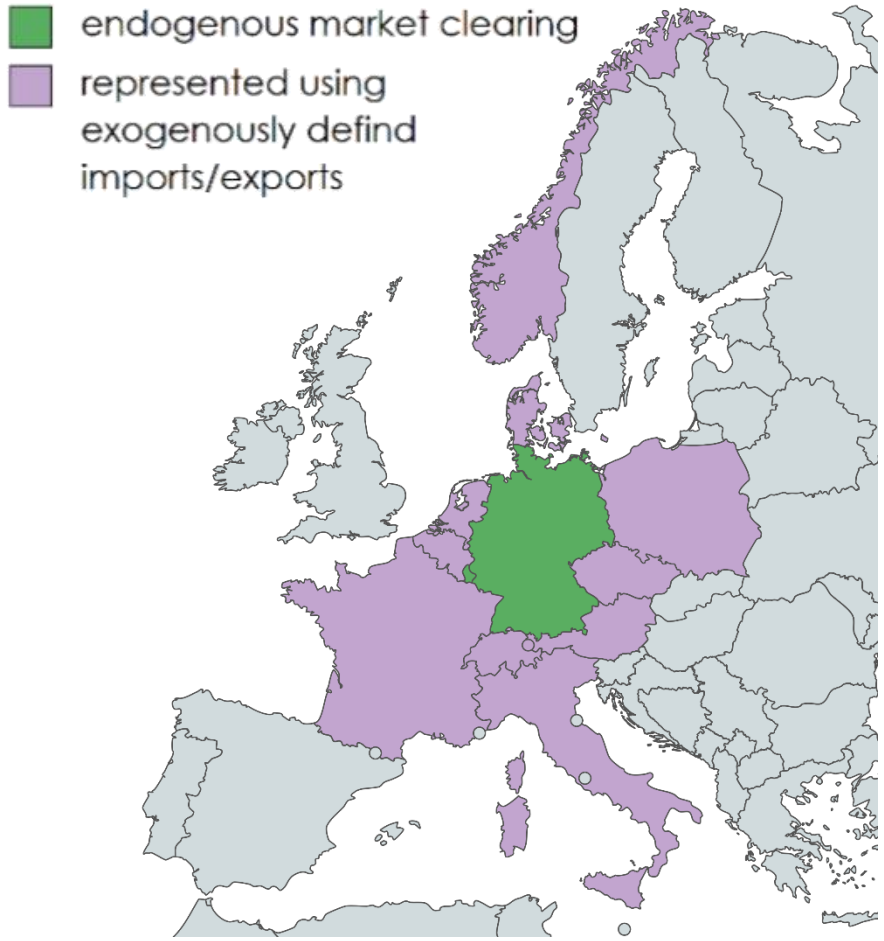
Calculates

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



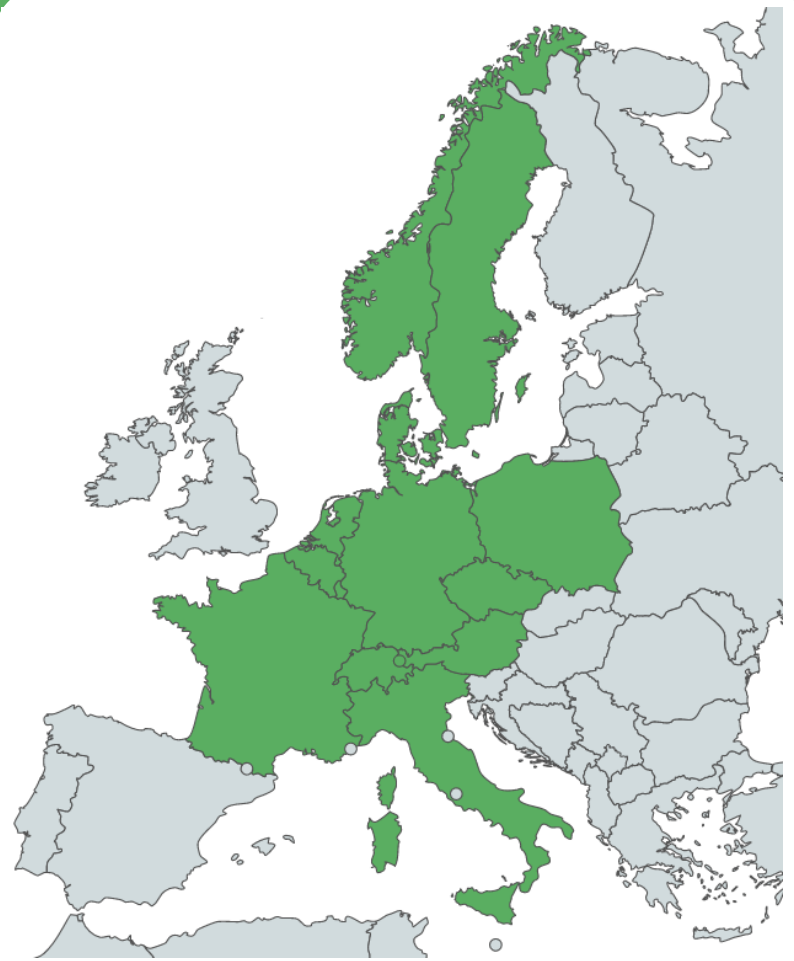
Schimeczek et al. (2023a). 10.21105/joss.05041
Schimeczek et al. (2023b). 10.21105/joss.05087
Nitsch et al. (2023a). 10.21105/joss.04958

Spatial Scope of AMIRIS



Currently:
- German market zone
- Imports & exports: predetermined timeseries

Goal:
- German & neighboring market zones
- Endogenous modelling of imports & exports



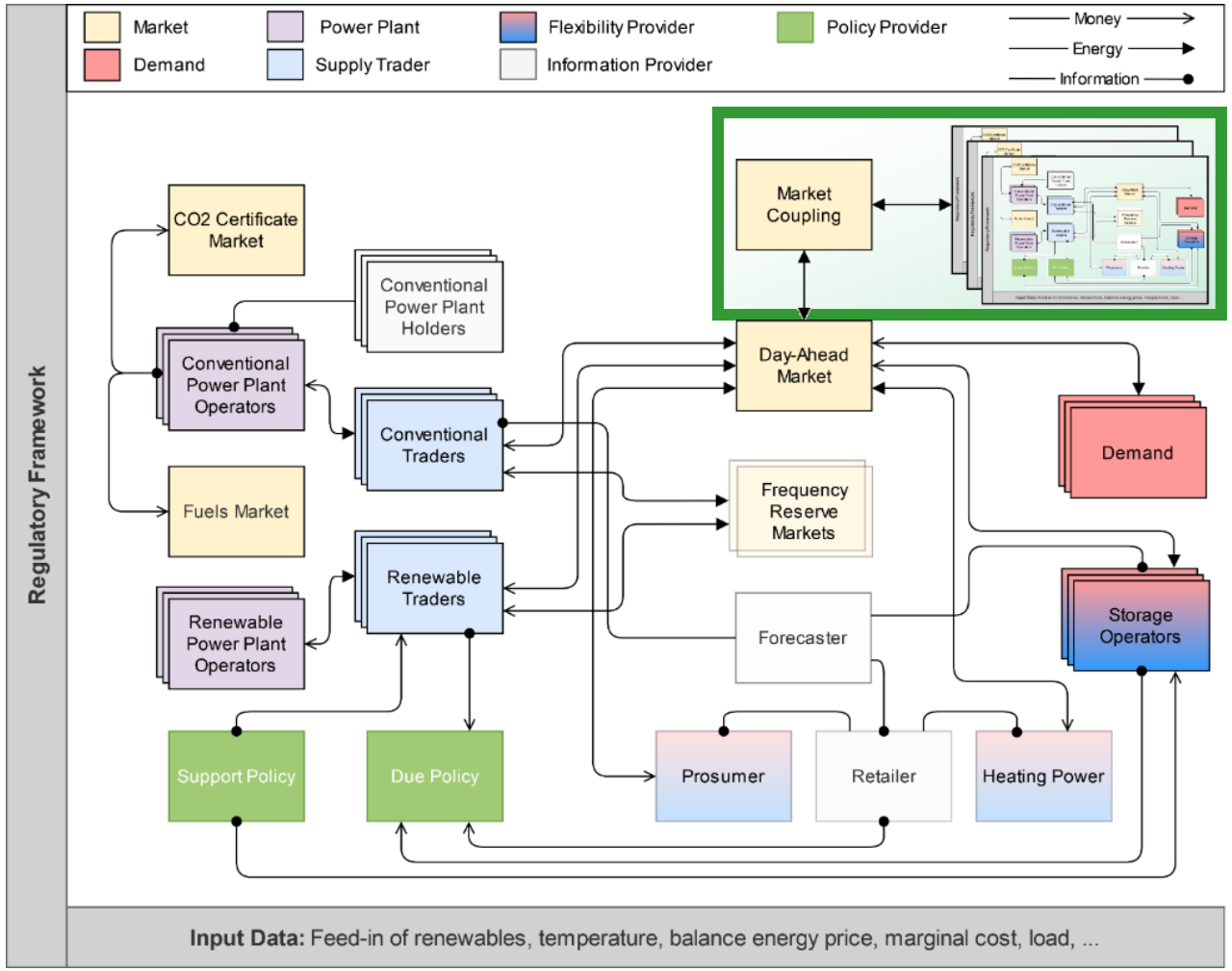
Integrating Market Coupling in AMIRIS

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. Market coupling result is sent back to traders via their local day-ahead market agents

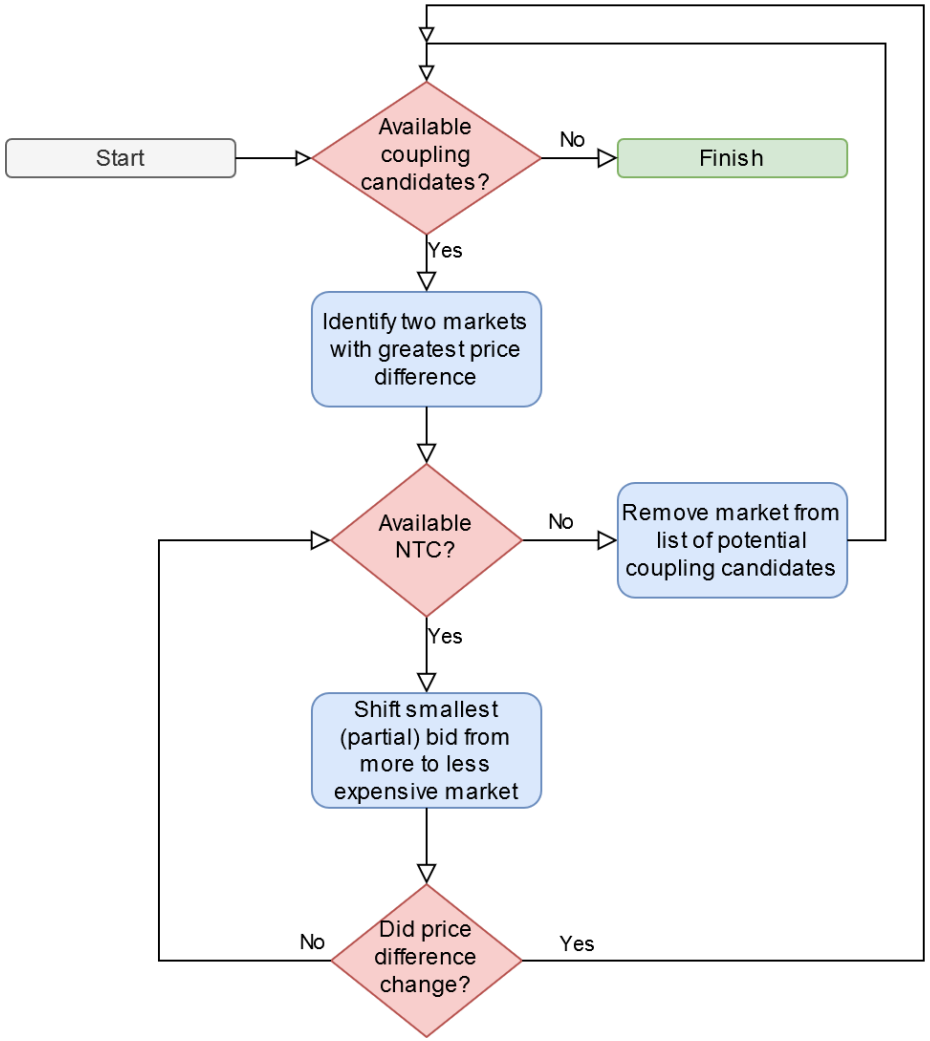


Market Coupling Implementation

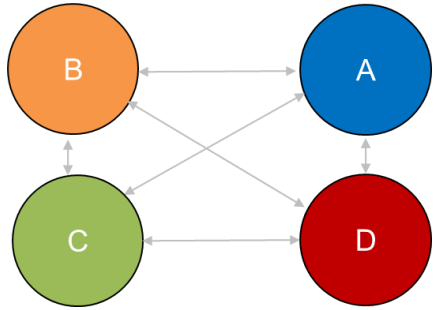
- Identifying candidates of market pairs
- Finding best coupling pair by highest price difference
- Decreasing price difference by smallest possible load shift
- Re-evaluation of best candidates for next coupling iteration

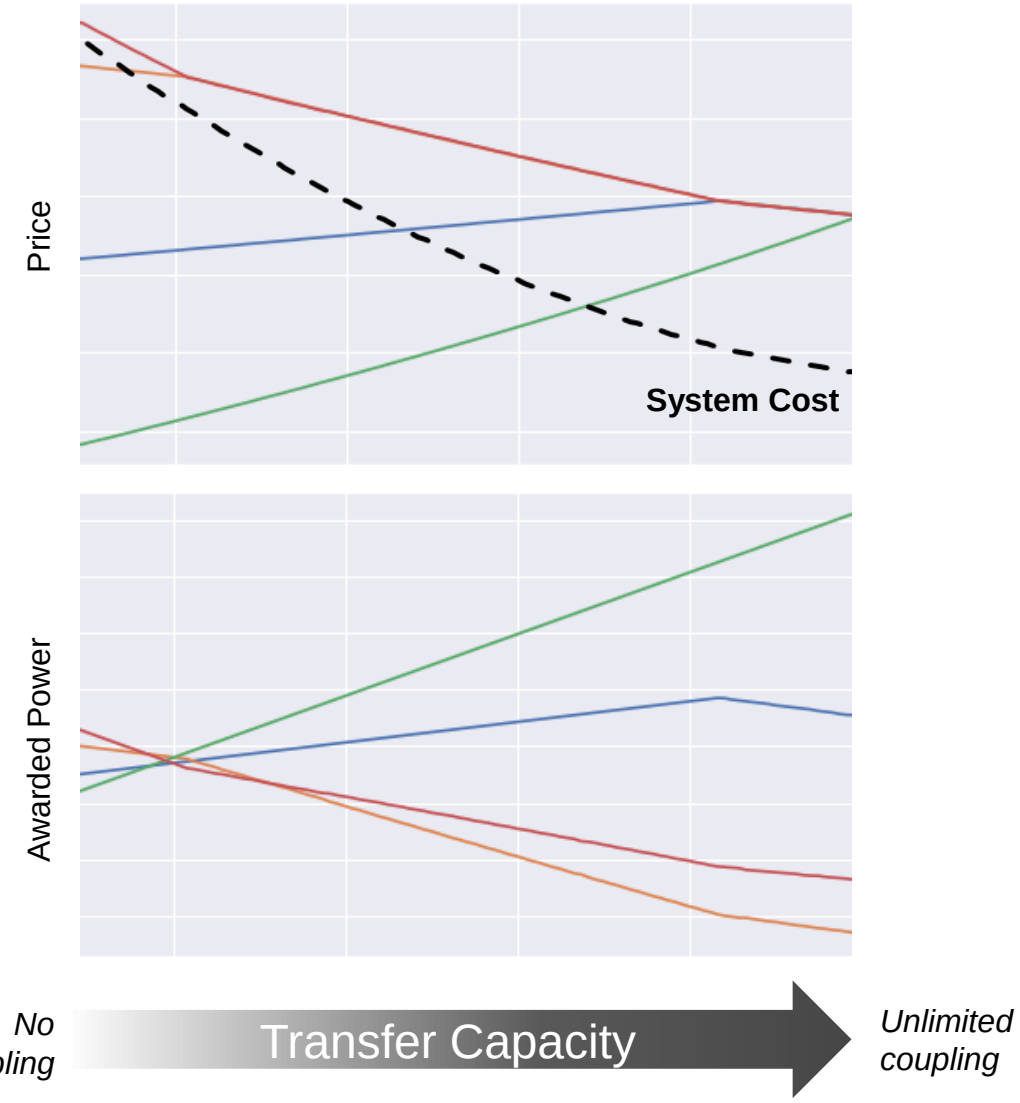
- Termination when price differences cannot be minimized anymore, e.g.:
  a) price differences are zero, or
  b) all NTC are used

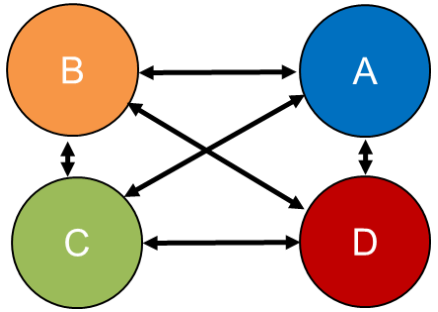
- Solution considered as *global* optimum



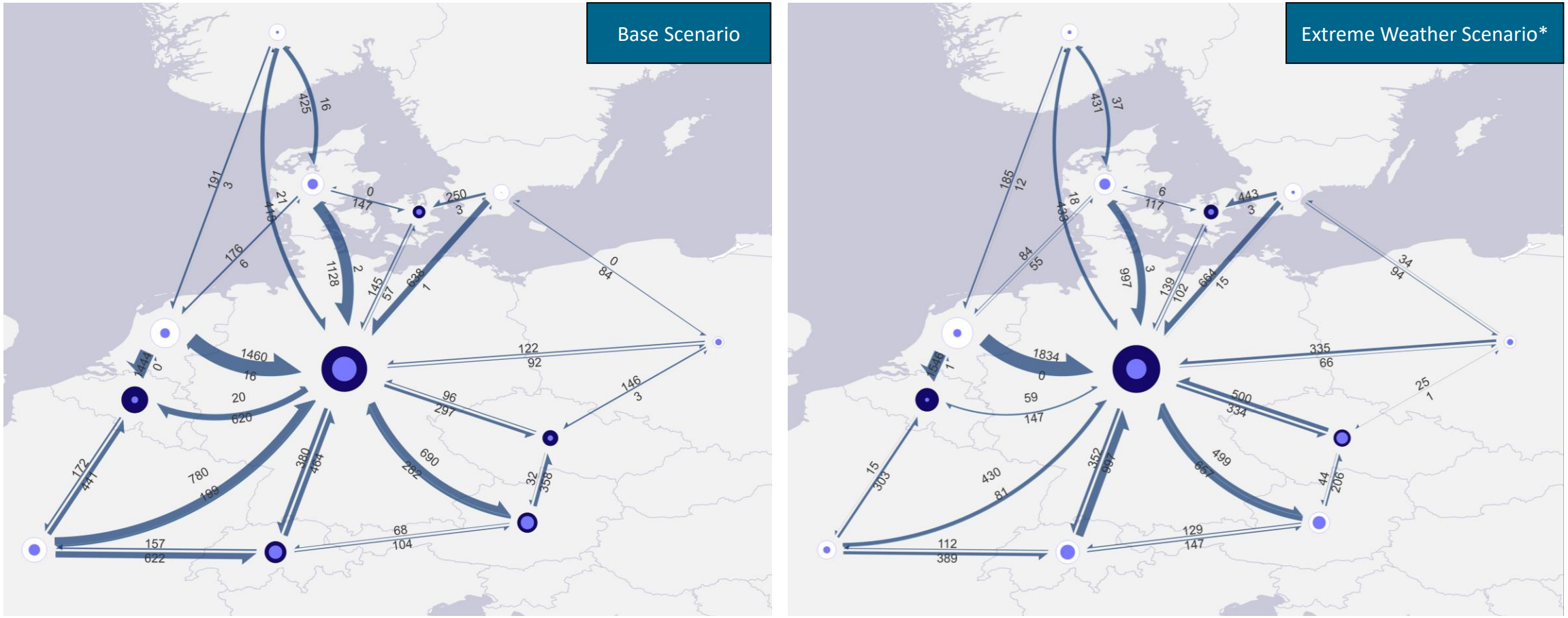
Impact of Market Coupling on Prices and System Costs







Cross-Border Trades



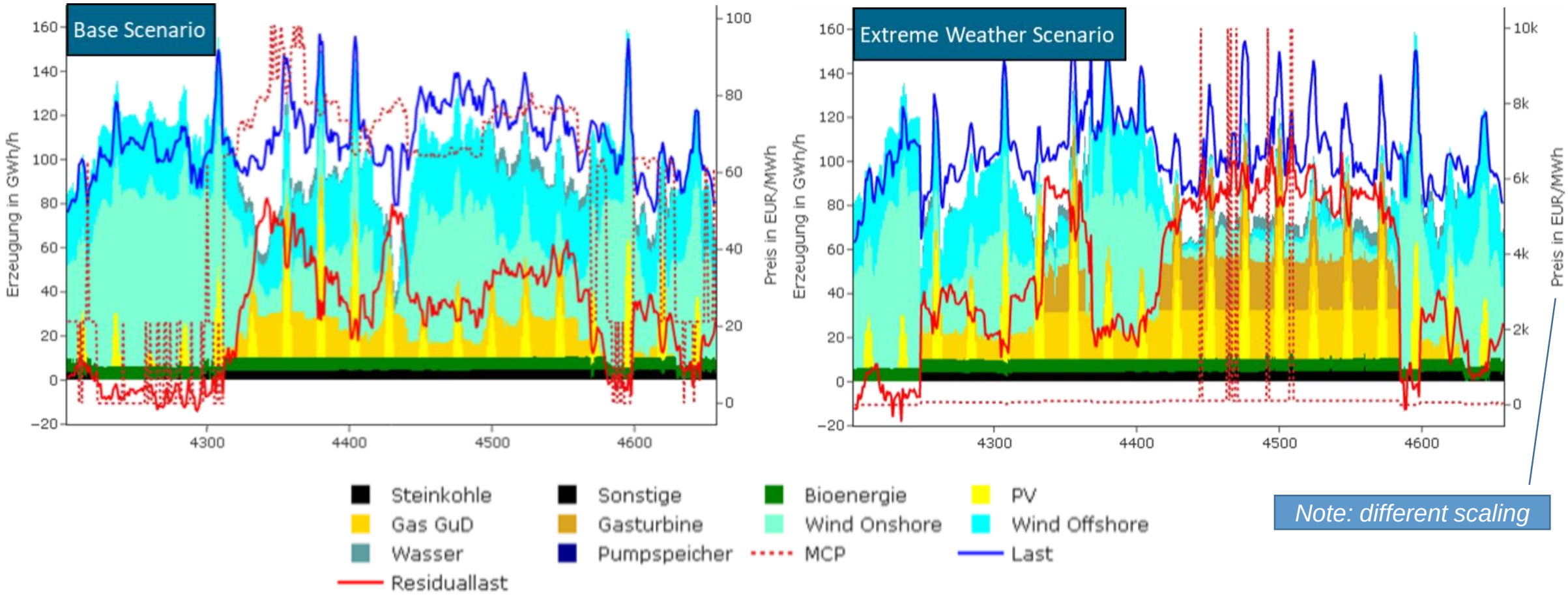
Comparison of cumulative trade flows between the simulated market zones during a 14-days extreme weather period in GWh.

* Assessment of historical weather data and various climate projections revealed periods of
low combined wind and solar power generation and high residual load, here: “Extreme Weather Event”

Nitsch F. & El Ghazi AA., Institute of Networked Energy Systems, 08/2023

Nitsch et al. (2023b). VERMEER – Project Report. https://elib.dlr.de/196641/

Powerplant Dispatch in German Market Zone



Comparison of power plant dispatch, load, and day-ahead electricity prices (MCP) during a 14-days extreme weather period in GWh.

* Assessment of historical weather data and various climate projections revealed periods of low combined wind and solar power generation and high residual load, here: “Extreme Weather Event”

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Cross-Border Trading Mitigating Scarcity Effects

Comparison of the supply situation in German market zone under different assumptions regarding weather year, load, and available transmission capacities (NTC).

#	Weather	Load	NTC	Hours with Load not Covered	Mean Share of Load not Covered in %	Mean Load not Covered in MWh/h	Minimum Load not Covered in MWh/h	Maximum Load not Covered in MWh/h
1	Base	Flexible	FBMC	0		*NAN*		
2	Extreme Weather	Flexible	FBMC	7	0,7%	761	8	1 553
3	Extreme Weather	Flexible	TYNDP	6	3,2%	3 915	205	9 167
4	Extreme Weather	No Flexible Load	TYNDP	49	6,7%	8 242	158	23 228
5	Extreme Weather	No Flexible Load	TYNDP + 10%	39	6,5%	8 085	78	22 163
6	Extreme Weather	No Flexible Load	TYNDP + 20%	33	6,2%	7 639	247	20 473
7	Extreme Weather	No Flexible Load	TYNDP + 30%	29	5,7%	7 122	17	18 939
8	Extreme Weather	No Flexible Load	TYNDP + 40%	25	5,5%	6 852	426	17 989
9	Extreme Weather	No Flexible Load	TYNDP + 50%	21	5,9%	7 315	362	16 939

* Assessment of historical weather data and various climate projections revealed periods of low combined wind and solar power generation and high residual load, here: “Extreme Weather Event”

Nitsch et al. (2023b). VERMEER – Project Report. https://elib.dlr.de/196641/

Conclusions

- 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

- Assess delta to flow-based market coupling
- Feature to be published to AMIRIS, see https://dlr-ve.gitlab.io/esy/amiris/home/

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Imprint

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