Investments and Market Outcomes under Regulatory Uncertainty: A Case Study of German Electricity Bidding Zones

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Chapter 01

Motivation

The source for regulatory uncertainty in future bidding zone configuration

Current status:

Structural north-south bottleneck for transmission in the German bidding zone without regional prices (Trepper et al., 2015)

Short-Term effects:

technically infeasible market results due to network constraints, high level of congestion management and increasing system costs (Neuhoff et al., 2013)

Mid/Long-Term effects:

inefficient regional investment incentives for transmission projects, generation capacity, electricity storages and large consumers (Egerer et al. 2016, Grimm 2016)

Political discussion:

Splitting the German bidding zone

01. Motivation

Impact of regulatory uncertainty on bidding zones

- **Long-running discussion:** possible divisions of the German bidding zone *(ENTSO-E, 2025)*
- Extensive political process causing
  - uncertainty whether bidding zones will be introduced
  - in what configuration they will be implemented
- **Initial papers show:** degree of uncertainty about possible bidding zone configurations can influence
  - (dis)investment
  - operational decisions *(Ambrosius et al., 2020)*

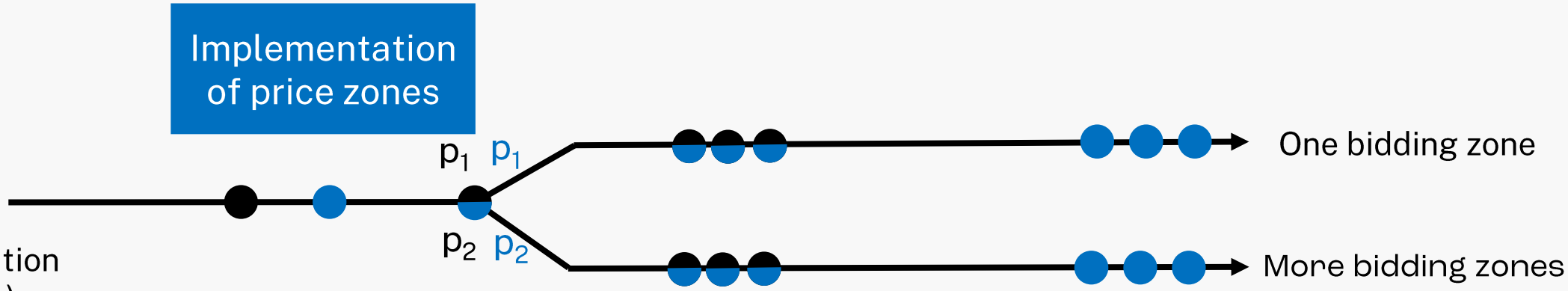
How can we contribute to the ongoing discussion?

- What are the effects of uncertainty:
  - (dis)investment decisions
  - market rents of various players
  - redispatch costs
  - the overall efficiency
- **Research Question:**
  - How are investments and rents affected by regulatory uncertainty and realizations regarding the future design of bidding zones in Germany?

Chapter 02

Modeling approach

Timing of decisions under uncertainty



Timing

1) Before implementation (uncertainty)
2) After implementation (certainty)

Generation investment plan: Zonal (dis)investment decisions

Spot market: Trading in multiple subsequent periods with zonal pricing

Redispatch: cost-based redispatch of generation levels and back-up operation after each period

$p_1 = 1$, $p_2 = 0$ $p_1 = 0.9$, $p_2 = 0.1$ ... $p_1 = 0$, $p_2 = 1$	→	$p_1 = 1$	$p_2 = 0$
		$p_1 = 0$	$p_2 = 1$

UTN

Model structure – three-stage stochastic optimization problem

1. Stage: max. Investment welfare

s.t.
- generation/ storage/ electrolyzers (dis)investment
- production/ storage constraints
- NTC – trade restrictions (interzonal)
- Zonal balance

2. Stage: max. Spot market welfare

s.t.
- production/ storage constraints
- NTC – trade restrictions (interzonal)
- Zonal balance

3. Stage: min. redispatch cost

s.t.
- production constraints for Redispatch
- production constraints for Backup generators
- Nodal electricity balances (Kirchhoff's 1st law)
- DC - power flow constraints (Kirchhoff's 2nd law)

Assumptions:
- Perfect competition
- Perfect foresight: Storage and demand flexibilization optimized over 8760 hours

Assumptions:
- Cost-based redispatch: pos. adjustments are reimbursed, neg. adjustments are saved

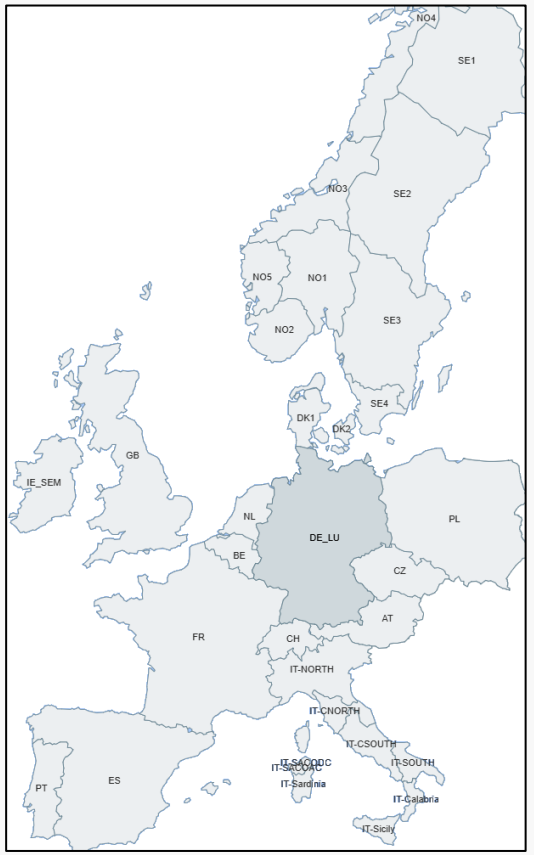
Chapter 03

Case Study

Application

- Target year 2030 with 2 scenarios about the bidding zone configuration (next slide)
- European electricity market with zonal representation of Germany and its neighboring countries, incl GB,UKNI,IE,NO,SE,IT, ES and PT – all with their current bidding zones
- Main source: TYNDP 2022/2024 and status quo data

Exogen Input	Endogen Output
• Expansion of renewable energies • Existing conventional power plants • Existing storage power stations • Network expansion • Demand and time series	• (dis)Investments in fossil generation capacities • Investments in batteries and electrolysis • Spot market results • Dispatch decisions • Congestion management



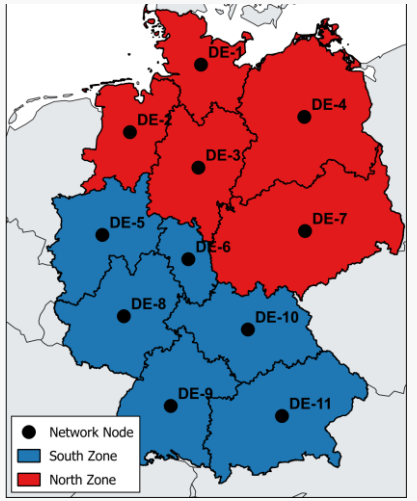
Scenarios

Scenario 1

Uncertainty about whether there are one or two bidding zones in the future

(probability of one or two zones occurring increases from 0 to 1 in ten per cent increments)

- **Realization of one bidding zone**
- **Realization of two bidding zones**

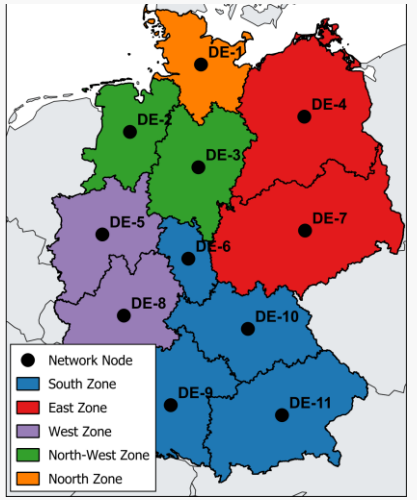


Scenario 2

Uncertainty about whether there are one or five bidding zones in the future

(probability of one or five zones occurring increases from 0 to 1 in ten per cent increments)

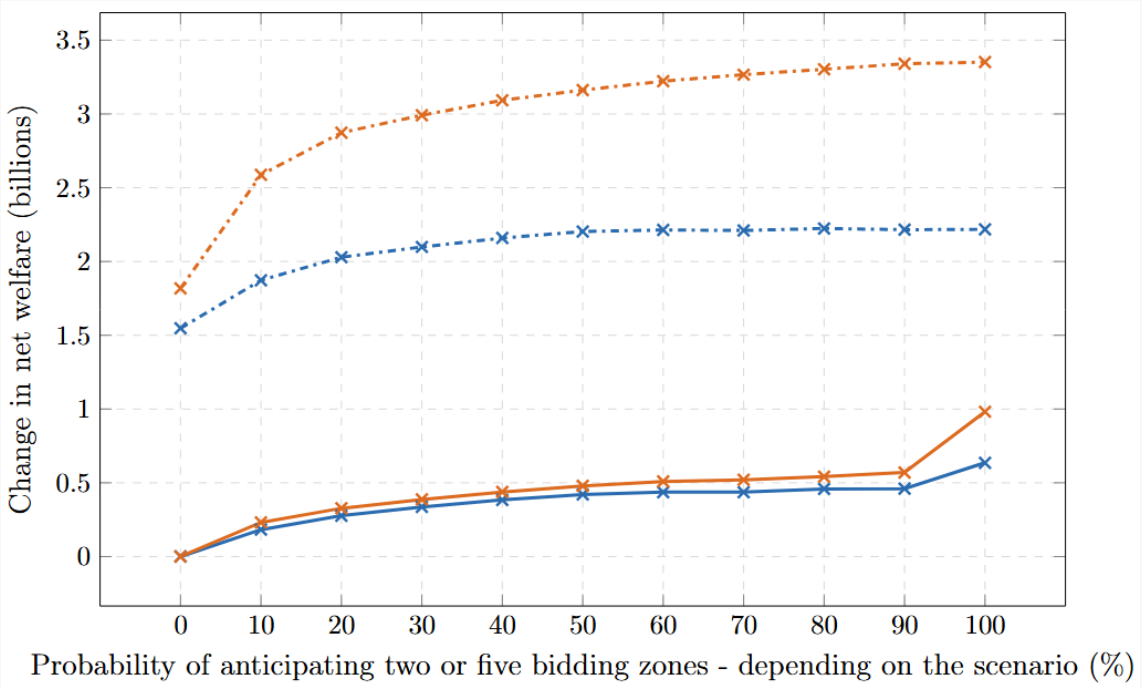
- **Realization of one bidding zone**
- **Realization of five bidding zones**

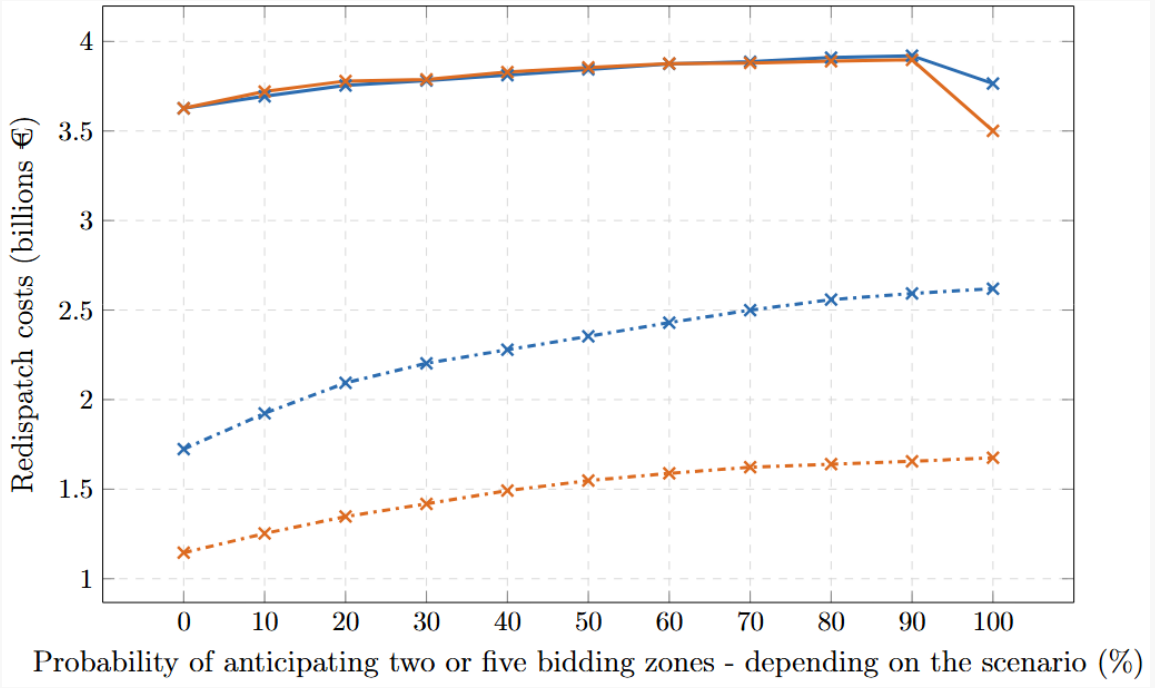


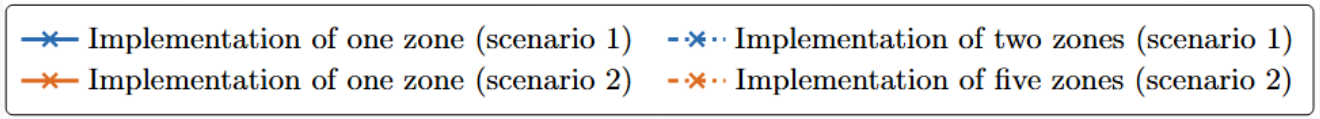
Chapter 04

Results

Change in net welfare and redispatch costs in Germany

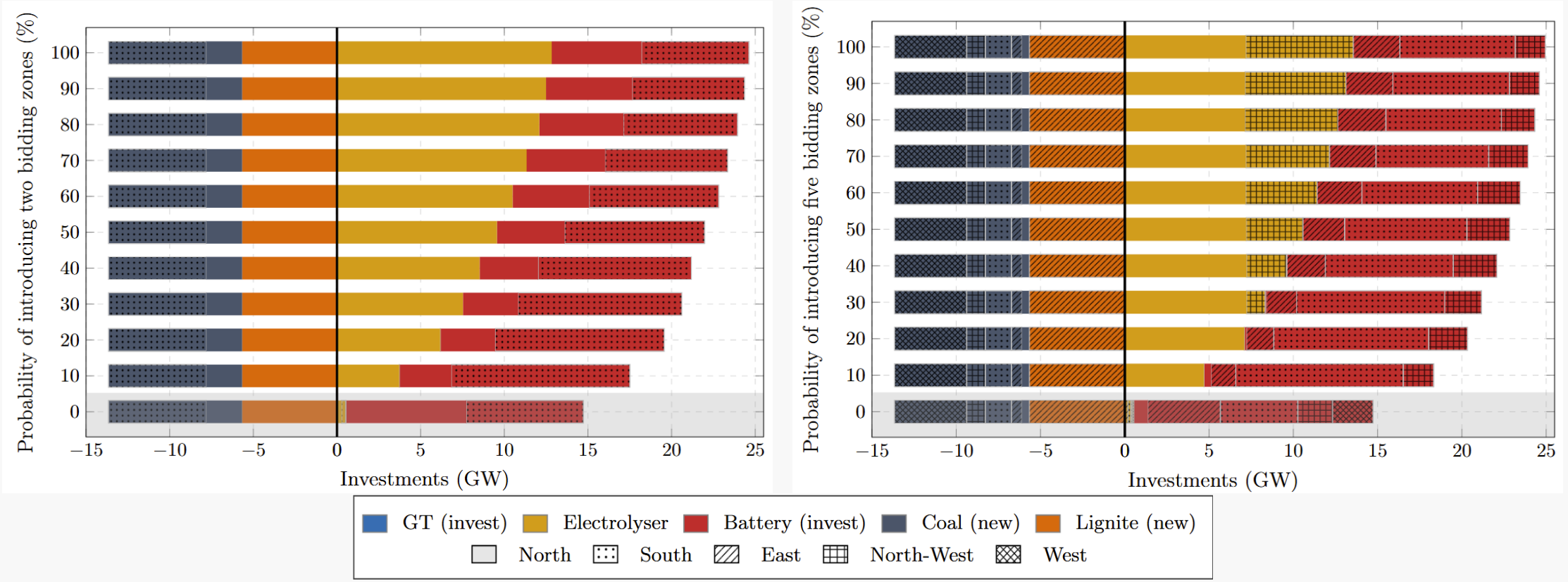






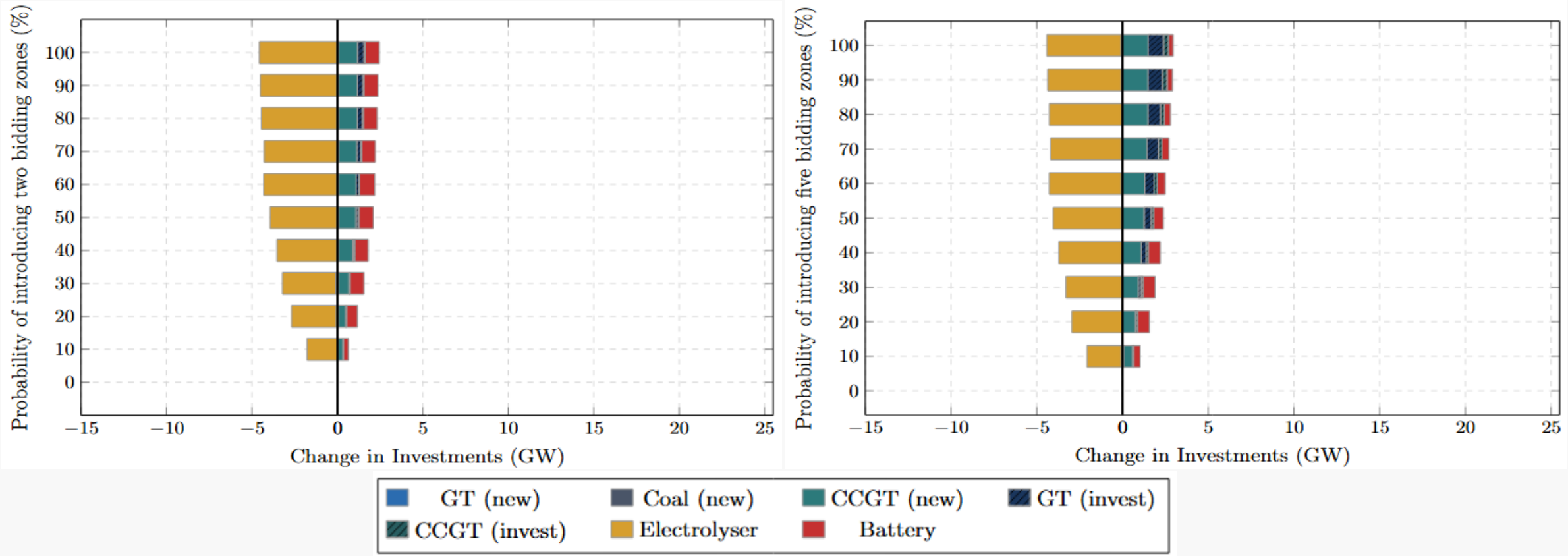
- Net welfare: market welfare (stage 2) minus redispatch costs (stage 3) in Germany
- The anticipation of this split for investment increases welfare gains
- Rising redispatch costs due to additional consumption from electrolysis

(Dis)Investment decisions in Germany



- For an expansion of the electrolysis plants, there must be a low probability of more than one bidding zone
- Increasing probabilities of more than one bidding zone influence the regional distribution of new batteries
- Conventional: no new investments in all scenarios and bidding zones have no effect on disinvestments (phase out of coal)

Change in aggregated (dis)investment decisions in Europe



- Electrolysis investment in Germany with likelihood of zones reduces investment in neighboring countries
- If probability exceeds 50% (Scenario 1) or 40% (Scenario 2), additional new gas-fired power plants will be built
- Higher probability of multiple bidding zones increases battery storage investment, varying by scenario

Chapter 05

Conclusion

Summary of the results

- The expectation of a bidding zone split for investments increases welfare gains in all realised zone configurations
- A significant expansion of electrolyser capacity by 2030 requires a low probability of the bidding zone being divided
- Abroad, a higher likelihood of multiple bidding zones leads to fewer electrolysis investments and more gas-fired capacity being available on the market

Outlook

- Welfare of individual technologies (regional)
- Impact on neighboring countries (prices etc.)

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