IAEE European Conference

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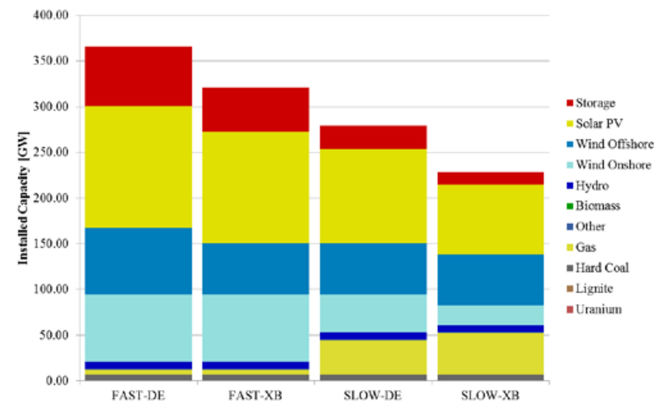
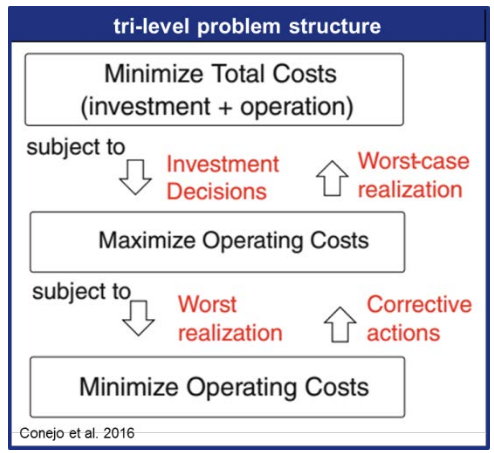
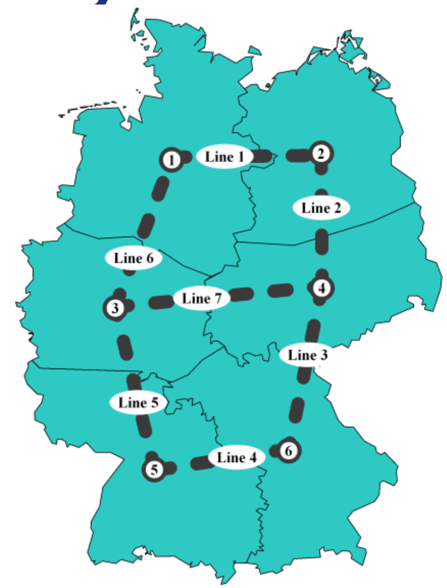
Robust Transmission Planning – An Application to the Case of Germany in 2050







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German Federal Ministry for Economic Affairs and Energy

lkDEU langfristige Planung und kurzfristige Optimierung des **Elektrizitätssystems in Deutschland** im europäischen Kontext

Motivation and Research Question

How should uncertainty be tackled in transmission planning?

- What role can robust optimization play?
- What decision calculus is appropriate from a social perspective?

Introduction: Robust Optimization

Some Decision-Making Strategies

- **(Deterministic)**
- **Stochastic Optimization; Expected value**
  - Minimize the average (expected) cost.
- **Robust Optimization**
  - Minimize the cost of the worst case realization
  - Alternatively: “Minimax Regret” to minimize the highest extra cost of „not-knowing“

Types of Uncertainties

- **(Certainty)**
- **Risk vs. Knightian Uncertainty**
  - Sometimes, this may be a data problem...
- **“High” vs. “low” frequency uncertainties**
  - “High frequency” uncertainties allow for bad outcomes to be compensated by good outcomes

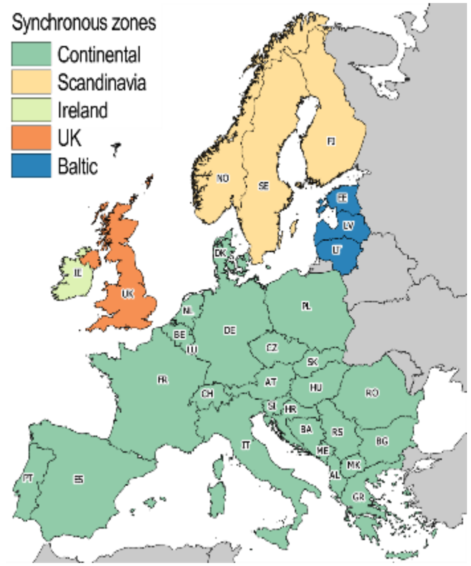
Other Issues

- Implementation of solution subject to “tolerances”
- Problem/Model very sensitive to (small) parameter changes

dynELMOD –Investment and Dispatch model for Europe

dynELMOD: dynamic Electricity Model

- **Open source** (soon)
  - ➢ diw.de/elmod
- Objective: **System Cost minimization**
  - Investment
  - Operation and Maintenance
  - Generation
  - Cross-border line expansion



Characteristics

- 33 European Countries
- **Flow-based** market coupling
- **Investment**: five-year steps 2020 – 2050
- **Dispatch during optimization**: hourly resolution for about 2 weeks
- **Dispatch during validation**: hourly resolution for entire year: 8760 hours

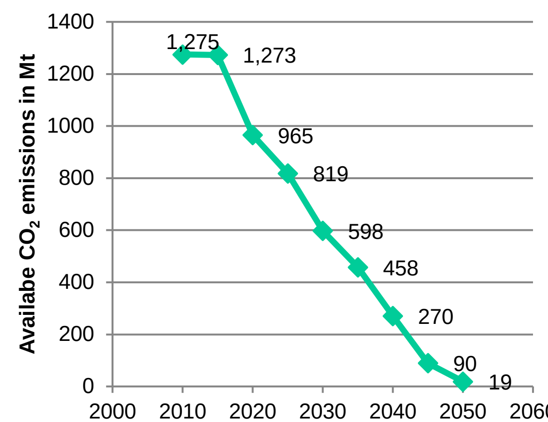
Investment options

- **Conventional** power plants
- **Renewables** (PV, Wind On/Offshore, CSP)
- **Storage** and **DSM** technologies (endogenous P/E Ratio)
- **Grid** expansion (increase of NTCs)

Boundary conditions

- Electricity demand development
- CO_2 budget over time
- CO_2 storage potential per country
- Renewable availabilities
- Renewable investment potentials

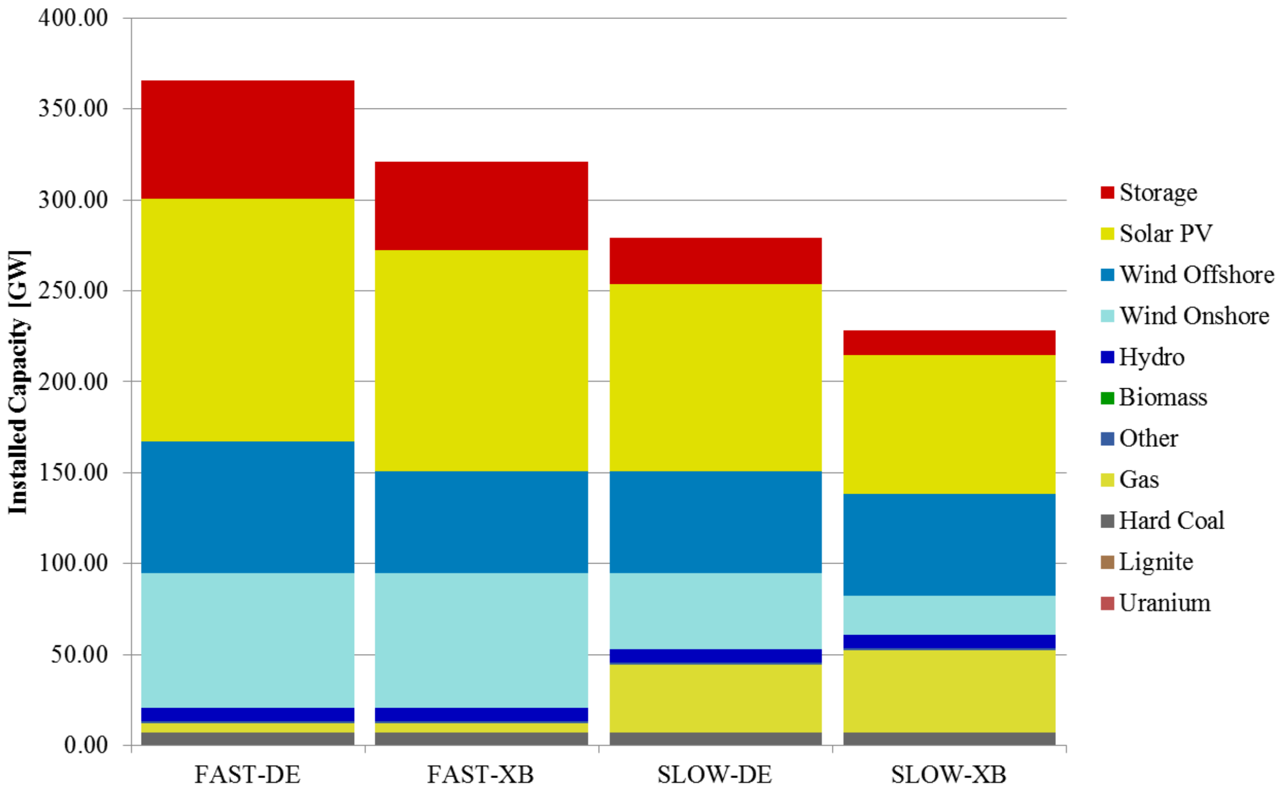
CO_2 Emission Constraint



The Case of Transmission Planning in Germany

- **Scenarios for generation and exchanges are generated using “dynELMOD” (Gerbaulet & Lorenz, 2017)**
  - European-scale, country-level fully fledged generation and transmission investment model (EU-28 + CH + NO + Balkans)

- **Scenarios (2x2)**
  - “FAST” -> 2050 carbon emission reduction of 98% (rel. to 2015)
  - “SLOW” -> only 80% reduction
  - “DE” no interconnector expansion
  - “XB” cost-minimal interconnector expansion

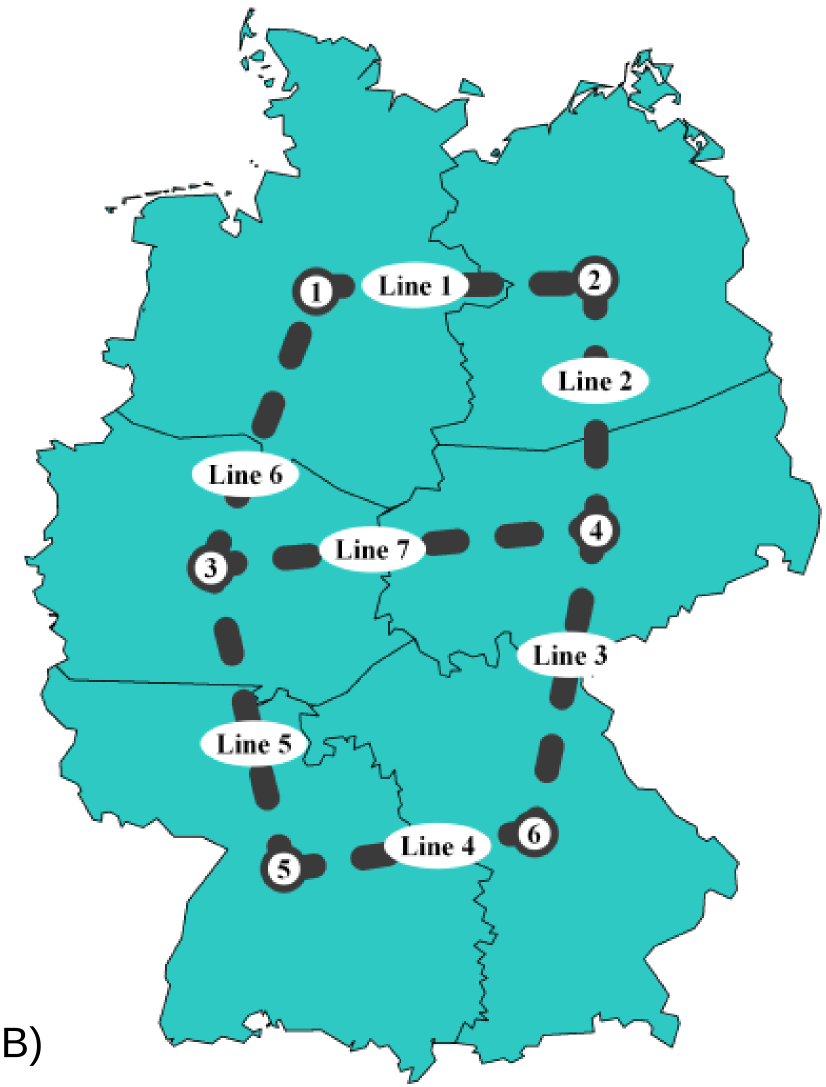


Transmission Planning in Germany: Model

- **Model**
  - Simple 6-node Model (transport, zero initial transport capacity)
  - Int'l Exchanges fixed
  - 179 time steps
  - Allocation of generation capacities using potential maps/existing sites; Storages at RES-Sites

- **Four scenarios**
  - FAST-DE and FAST-XB
  - SLOW-DE and SLOW-XB

- **Four optimization strategies**
  - "Pure" Robust Optimization
  - minimax Regret ("pure" and min regret)
  - Deterministic (FAST-DE/-XB, SLOW-DE/-XB)
  - expected costs (uniform probability)



Applications of Robust Optimization to Transmission Planning

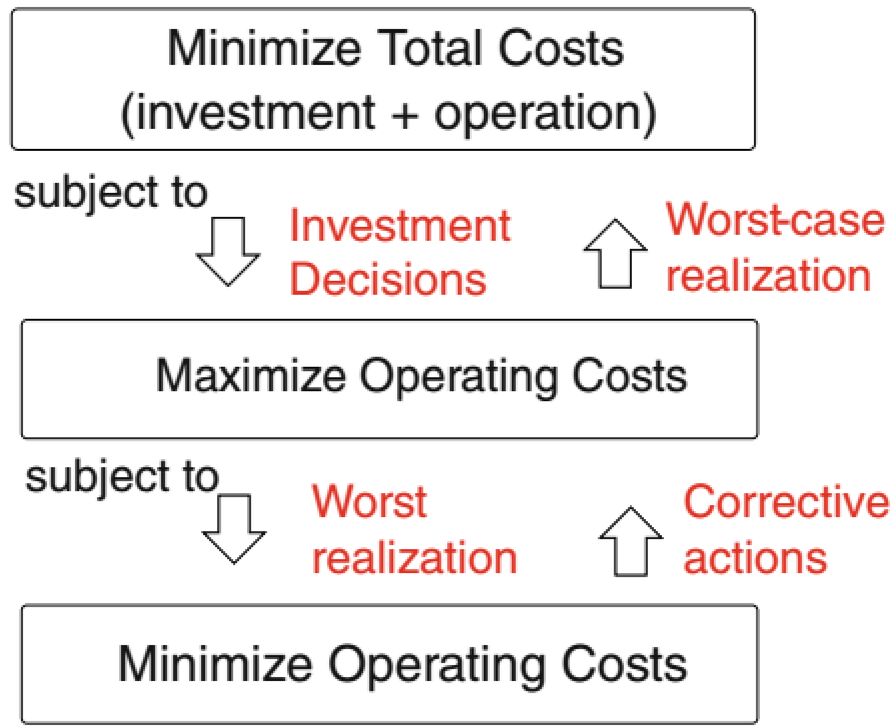
Backup

There are only few 'advanced' publications on robust TEP

- Jabr (2013)
  - Uncertainty set: Load and Generation (continous)
  - 24/96 nodes
- Ruiz/Conejo (2015)
  - (smaller) extension to Jabr (2013), investment budgets, larger uncertainty set
- Chen/Wang (2016)
  - Uncertainty set: generation retirements and replacement (large discrete set)
  - 240 nodes
  - 5 investment periods

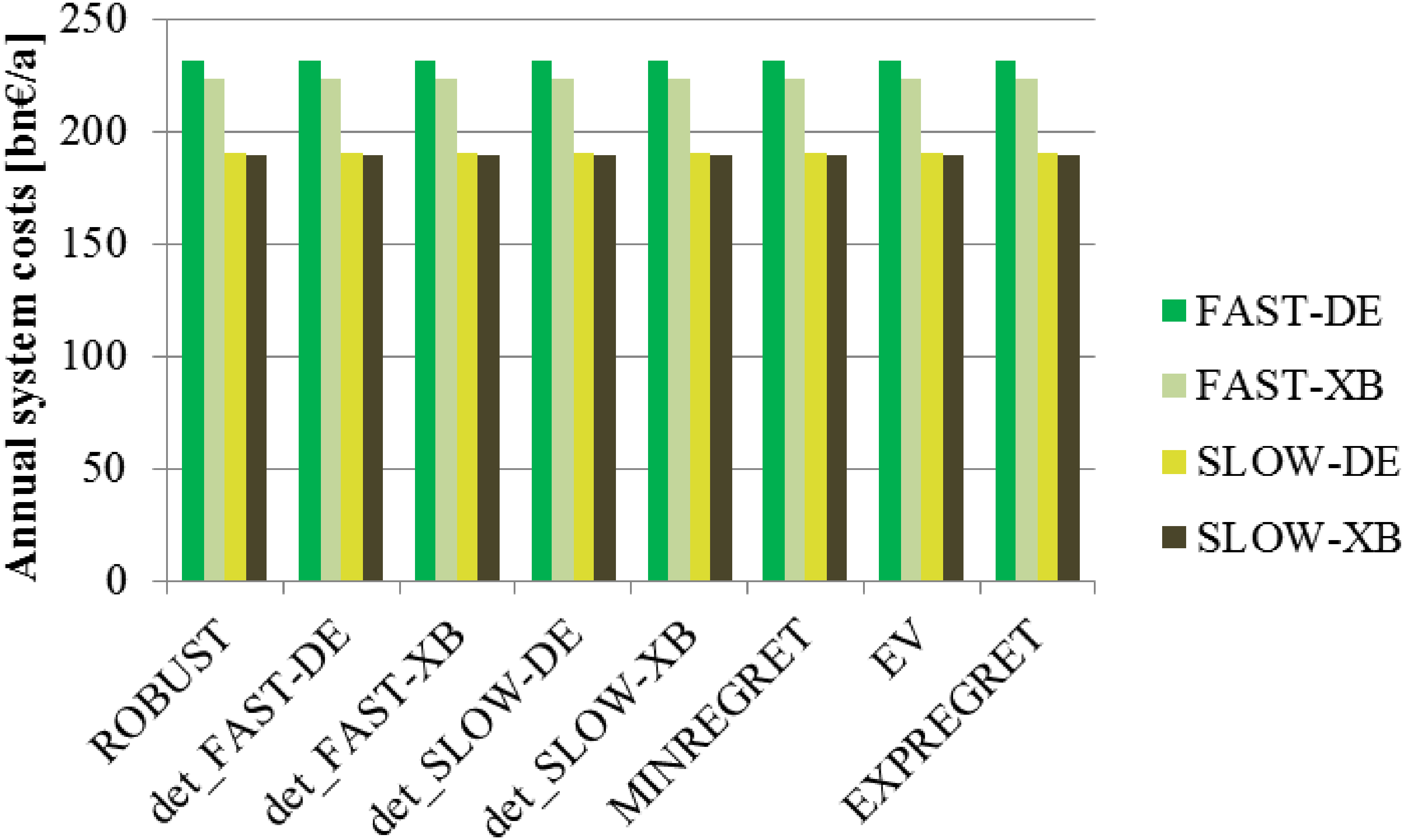
- **Challenges**
  - Tri-level structure
  - Adequate uncertainty sets!

tri-level problem structure

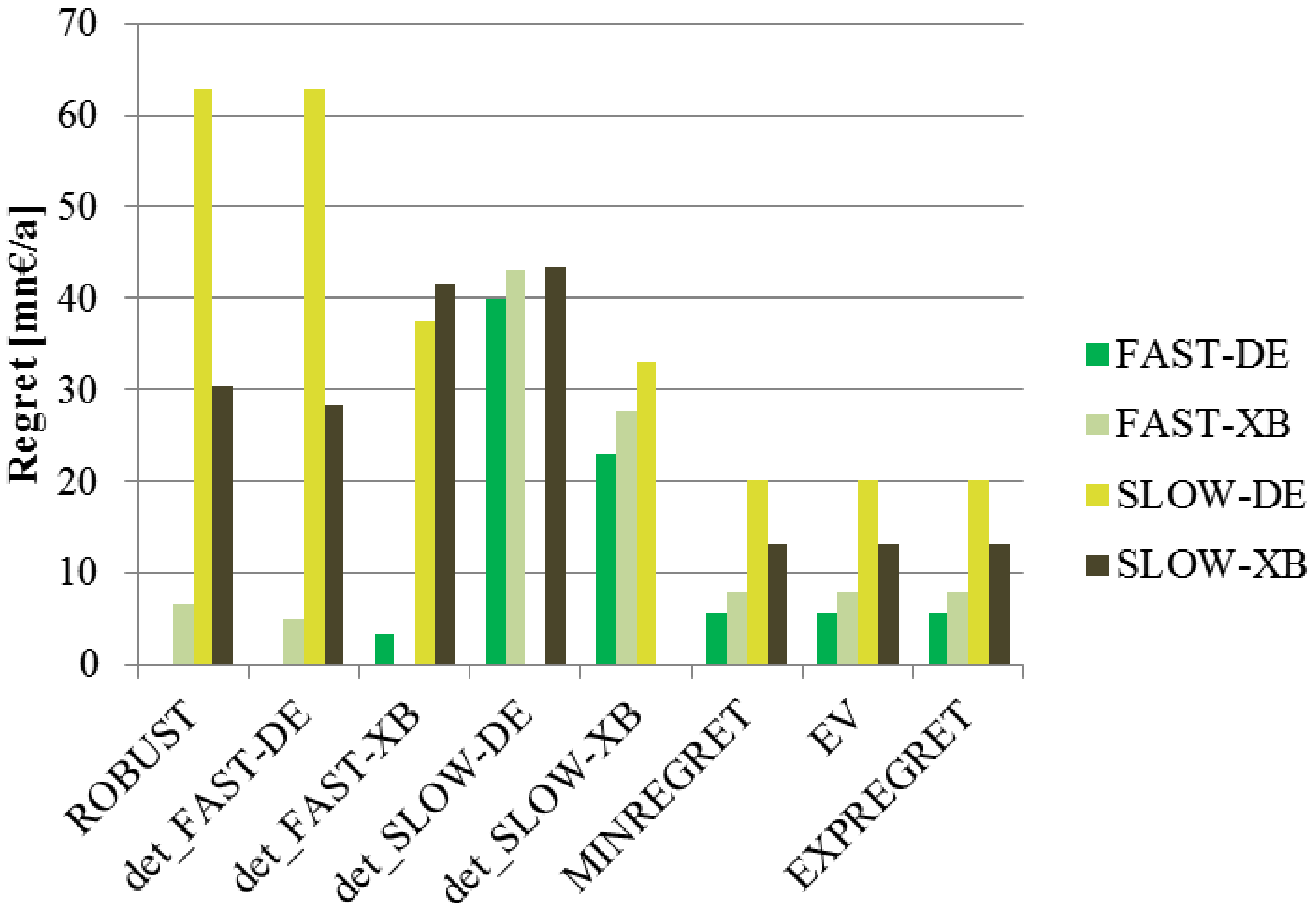


Conejo et al. 2016

Results: Annual System Costs (1/2)



Results: Annual System Costs (2/2)



Results: Transmission Investment

Decision Strategy	Line investment levels [GW]							Line cost [bn€]
	#1	***#2***	***#3***	***#4***	***#5***	***#6***	***#7***	
ROBUST	2	9	7	4	19	29		**70**
det_FAST-DE	2	9	7	4	19	29	2	**72**
det_FAST-XB	2	9	8	5	18	28	2	**72**
det_SLOW-DE	1	13	11	8	15	25		**73**
det_SLOW-XB	3	10	7	4	19	29		**72**
MINREGRET	3	9	7	4	19	29		**71**
EV	3	9	7	4	19	29	1	**72**
EXPREGRET	2	10	8	5	18	28	[illegible]	[illegible]

Results: Transmission Investment

- **Conclusion**
  - Basic application of robust optimization to TEP in Germany
  - Scenarios have a high “intrinsic” cost impact => different transmission expansion strategies play are comparatively narrow role. (Full DCLF may change this)
  - When overall costs are targeted at, robust optimization will direct all its efforts on the alternative which is – overall – most expensive.
    - => “minimum regret” strategies may be more adequate here

- **Further extensions**
  - Full transmission network representation (should increase value of robust decision making)
  - Adaptive decision-making! (should decrease reduce the contribution of robust decision making while increasing overall efficiency)

- **“Philosophical”(?) question:**
  - From a “social” perspective – what is the correct decision calculus?
    - “Robust” vs. “Minimax Regret” vs. X?
    - Is there a well-grounded concept of social decision-making under uncertainty (except for the notion of risk-neutrality)?

Literature

Chen, B. & Wang, L. (2016). Robust Transmission Planning Under Uncertain Generation Investment and Retirement. *IEEE Transactions on Power Systems*, PP(99), pp. 1–9.

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