Congestion management regimes: long run impacts

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Grand Challenges

- Abandoning nuclear energy requires complete reorientation of power supply schemes.
- Old plants get dismanteld or need repowering.
- A lot of fluctuating renewable sources have been installed.
- We need market rules that generate adequate investment incentives:

  => right capacities

  => right locations

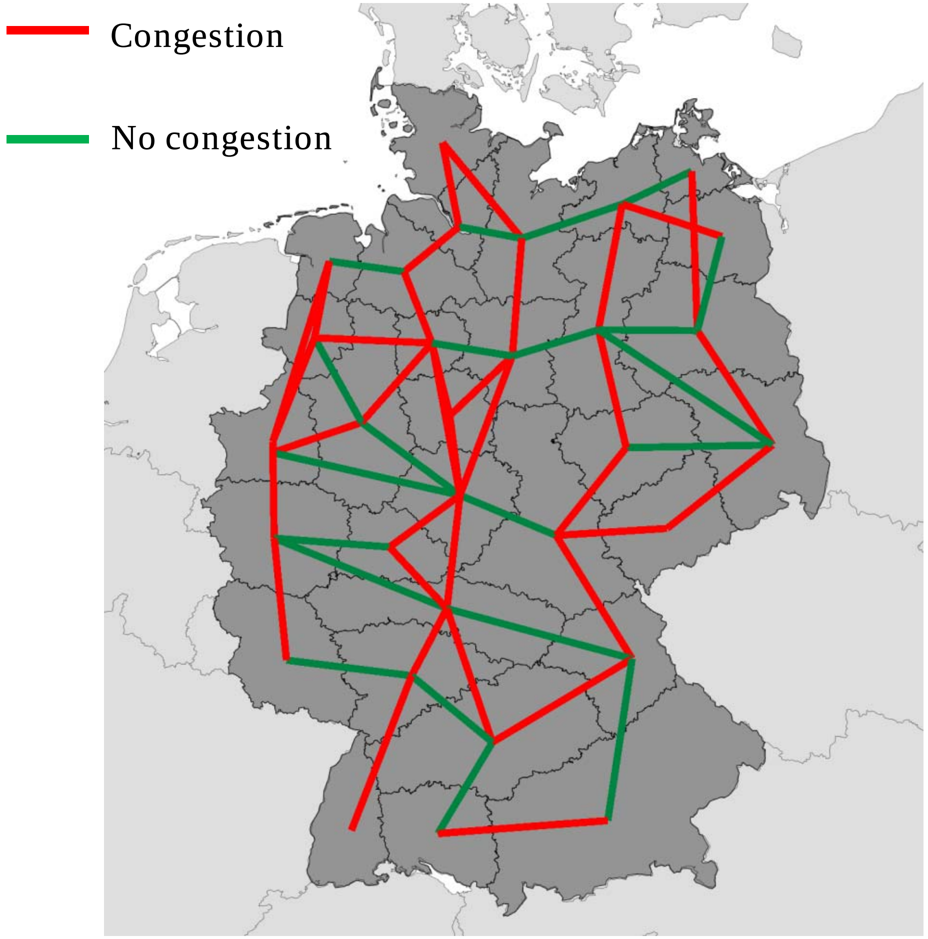
Quelle: Bundesamt für Strahlenschutz

Transmission constraints become an issue

Transmission constraints become relevant – both within and between countries.

Possible solutions include: gas power plants, network capacity, demand side management, storage facilities and smart technologies

The locations and capacities of generation facilities have crucial relevance for the network expansion.



Source: EWI, Trendstudie 2022. Case: high wind in-feed.2022.

The Current Literature

- **Models on optimal transmission and investment planning**
- ➢ Disregards incentives of different agents in liberalized markets

- **Investment models for generation facilities (e.g. peak load pricing literature, "Capacity-market"-discussion).**
- ➢ typically disregards network and network expansion ("copper plate")

- **Models analyzing impact of different network management regimes (nodal pricing, zonal pricing, redispatch)**
- ➢ typically focus on the short run perspective (given network & generation facilities)

✓ For several important policy questions we also need to consider the interdependence of those issues!

Questions we have in mind

- ➢ what is the quantifiable impact of adopting a different transmission management regime (e.g. price zones,…, nodal pricing) taking into account long run investment in generation and network
- ➢ what is the impact of changed way of charging network fees on generation investment and associated network expansion
- ➢ What are the incentives to invest in responsive consumption units and what is the impact on optimal transmission investment?
- ➢ What is the impact of a changed approach to determine regulated network expansion (anticipate redispatch, anticipate blocked RES feed-in)
- ✓ We present a computable equilibrium framework which allows to analyze those issues

Roadmap of this talk

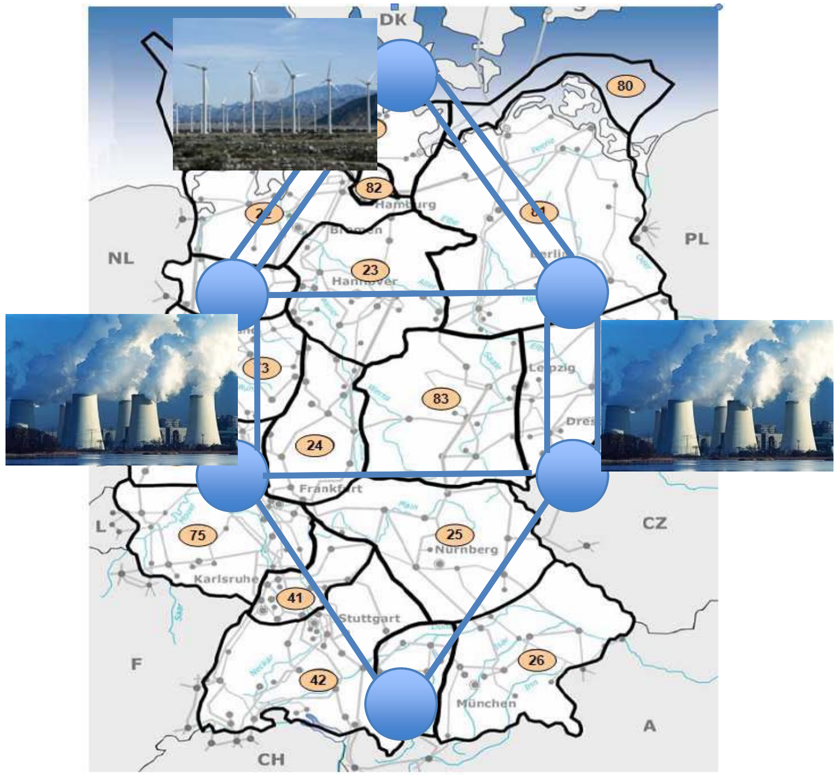
(1) Introduction
(2) Computational Equilibrium Framework
(3) Computational Results for German Market
(4) Conclusion

What we have in mind

Model Components

- Network expansion by social planner
- Competitve Firms invest in different production technologies throughout the network
- Demand at the nodes (net of renewable feed-in) can be fluctuating (uncertain).
- We want to explicitly take into account impact of different network management regimes (redispatch, market splitting)

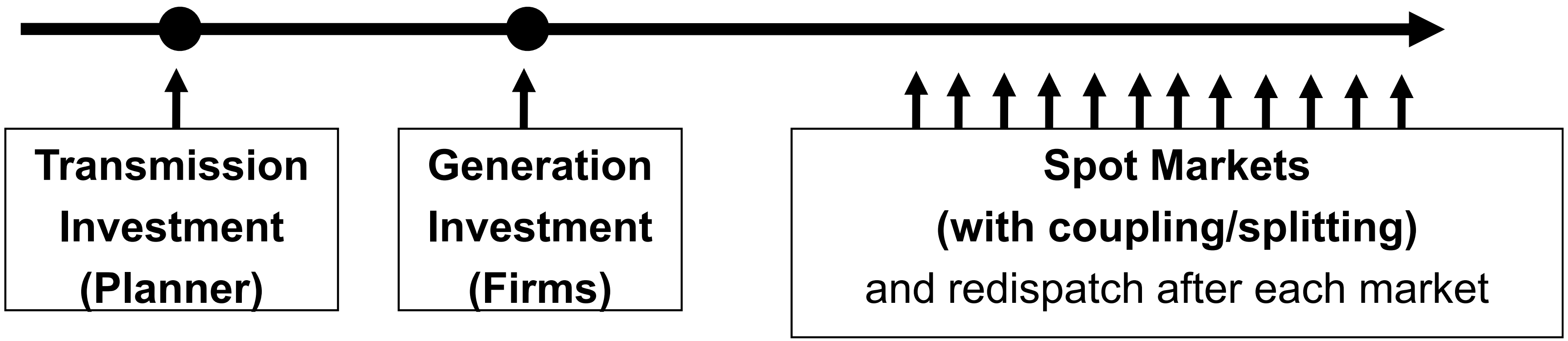
Illustration



Main purpose: to identify the impact of market rules on investment decisions
(overall system optimization is just a benchmark!)

Model: Timing

- The transmission system operator chooses to realize line investments from set of options (integer decisions).
- Competitive firms choose how much to invest in available production technologies at each node t=1,2,… ,each technology (k_t,c_t) has marginal cost of production c_t, marginal cost of investment k_t at the supply node.
- Spot market competition
- Management of network congestion by cost based redispatch.



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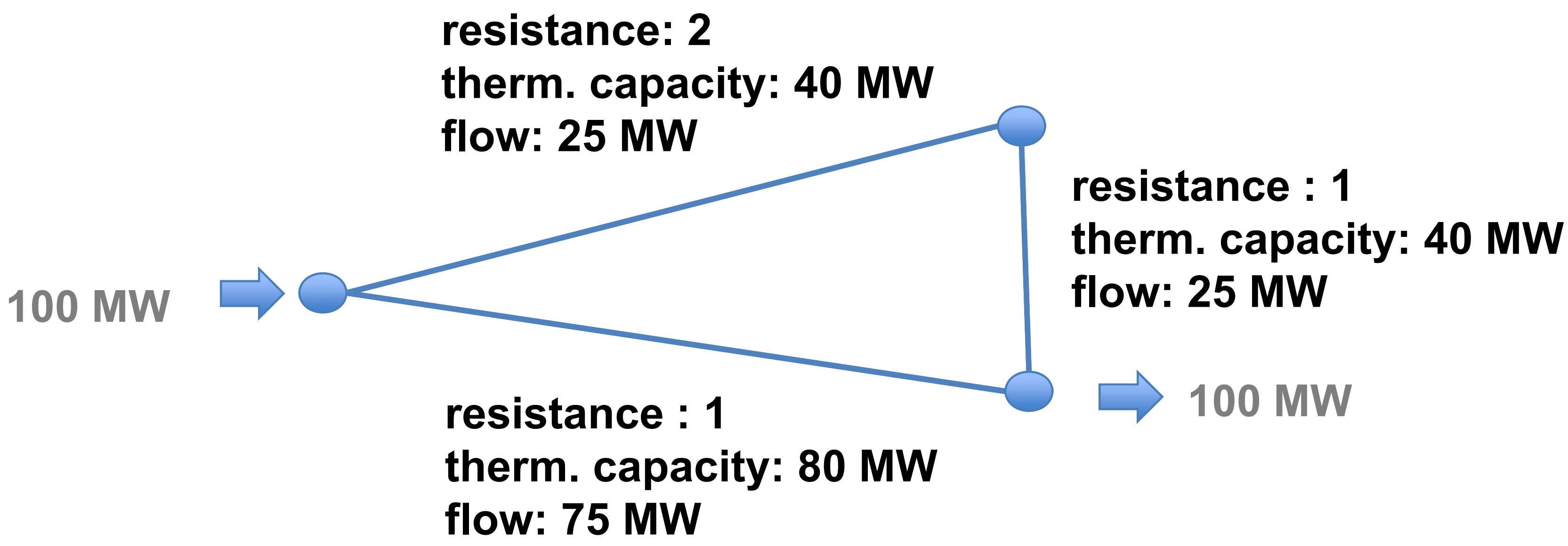
Model Components: modelling the physical network

- We consider the usual linear **lossless** DC-Approximation:



Model Components: Network Management Regimes

Cost based Redispatch:

- All bids at the spot markets are made entirely independently of network constraints, we obtain a uniform price accross the entire market.
- Quantities traded may be physically unfeasible. Then the TSO has to find the cheapest possible re-dispatch to make final quantities physically feasible.

Market Splitting:

- The market region is divided into price zones, potential congestion among zones (but not within zones!) is already taken into account at the spot markets.
- Remaining physical infeasibilities are still resolved through redispatch.

Model Components: Network Fees

The TSO is facing the following cost:

- Network expansion investment
- Cost of redispatch

In our framework TSO is supposed to not make any profits, the above spendings have to be recovered by network fees. We consider the following cases:

- Fees paid by consumers only (L-Component)
- Fees paid also by generators (G-Component), potentially regionally differentiated to properly direct generation investment

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Illustration of our 3-stage approach

Network Expansion
(social planner)

Investment in Generation Facilities
Trading at Spot Markets
(competitive companies)

Redispatch taking into account renewable production
(social planner)

Our 3-stage approach, more formally

Max Welfare(**N**,K,S,R)

s.t.

K,S is competitve equilibrium,

s.t.

Traded quantities S can be produced by capacities K

Min REDCost(N,K,S,**R**)

s.t.

quantities can be transmitted by network and can be produced by plants

Network expansion-stage: Social planner chooses network(expansion) maximizing **WF**

Market-stage: Competitive Firms choose capacities and Spotmarket-bids to maximize profits.

Redispatch-stage: Social planner chooses Redispatch R to minimize Redispatchcost **REDCost,** s.t. all quantities are feasible.

Benchmark: system optimization / first best

Max Welfare(**N**,K,S,R)

s.t.

Production schedule is feasible

Transmission is feasible

Integrated perspective: Social planner chooses network(expansion), generation investment and production to maximize **Welfare**

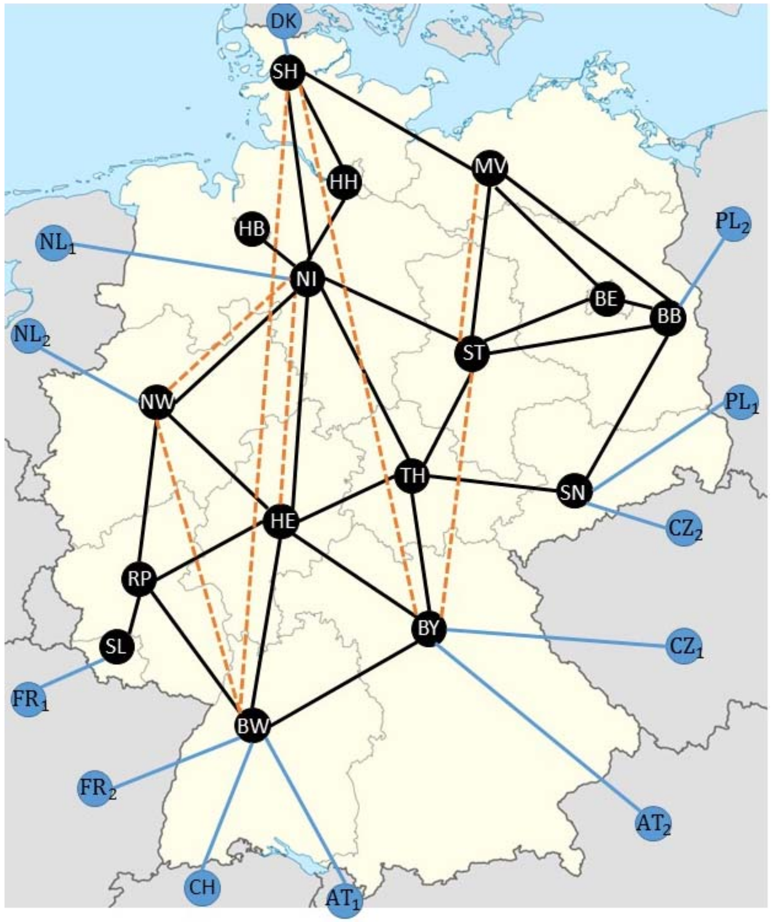
s.t. feasibility constraints.

Computable Equilibrium Model of the German Market (Grimm, Rückel, Sölch, Zöttl 2015, conducted partially in cooperation with the **German Monopolies Commission)**

Input Data

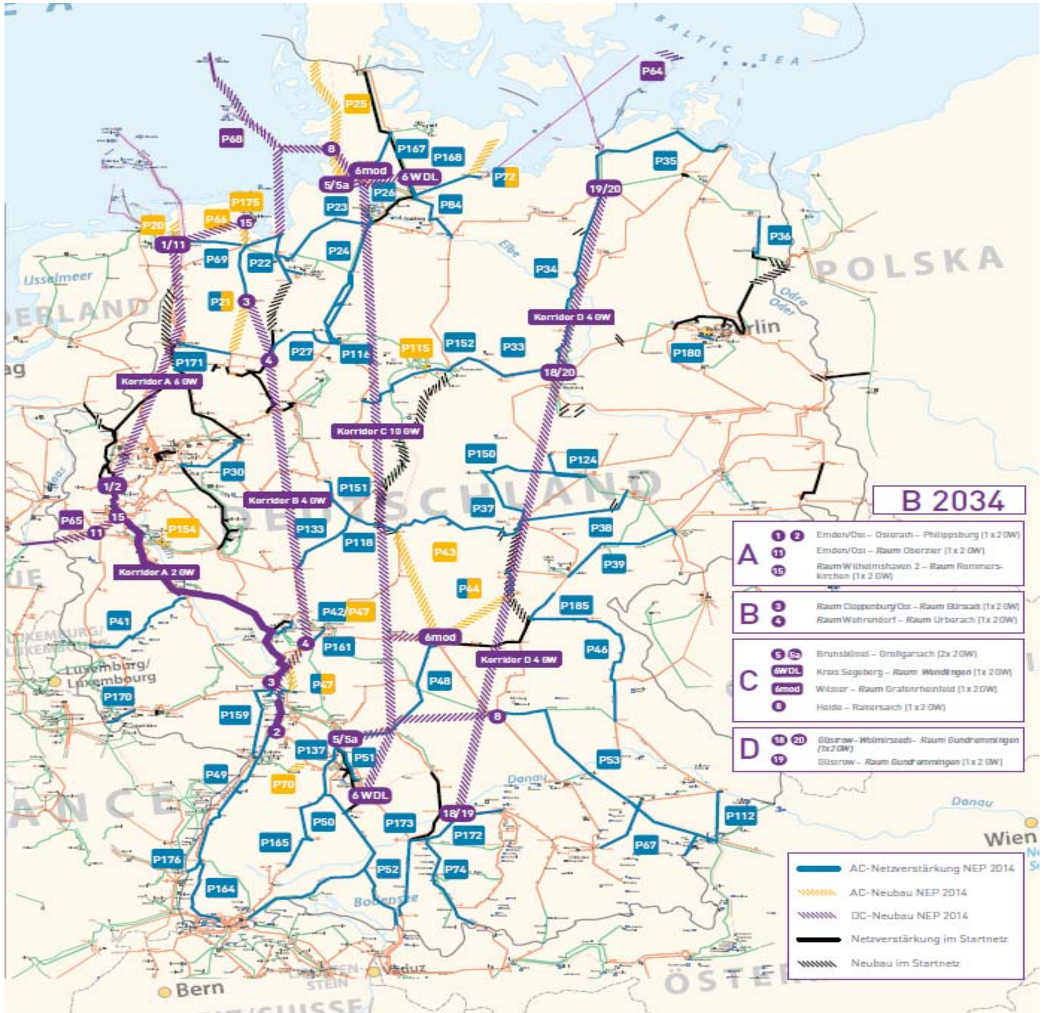
- Projection for 2035, with hourly spotmarkets (8760h).
- Hourly demand values for Germany and export/Import to neighboring countries from Entso-E.
- Hourly wind and solar production from ÜNB and “Szenariorahmen für den Netzentwicklungsplan” (NEP).
- Production cost of different conventional technologies from NEP
- …….

Network: Each Bundesland represented as a node



Inputdata: NEP (BNetzA)

- In our framework we only consider the big DC-lines (HGÜ) to be endogenously built.
- Further expansions considered in the NEP are already taken as exogenously given
- There are 4 main corridors (Trassen)
- In total we consider 15 lines along those corridors.
- Capacity of each line is 2 GW



Szenarios considered

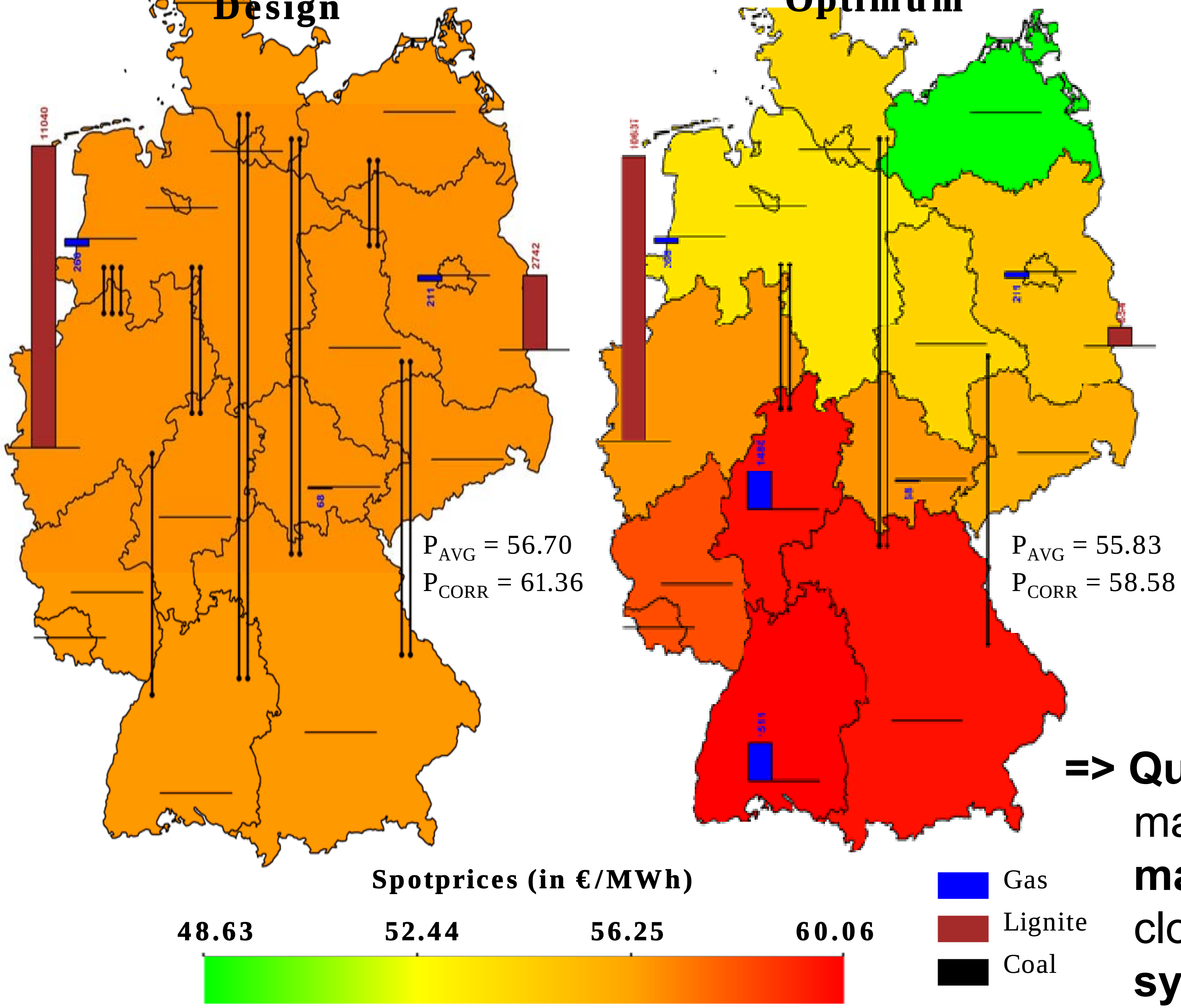
We compute the following scenarios

- **Current:** current market design with a single price zone and cost based redispatch
- **2 Zones:** Splitting of the spot market in two price zones.
- **Optimum:** The welfare optimum (presumably obtained by a system of nodal prices)

Note: under the current network planning mechanism the network has to be built such that no redispatch occurs, RES are never switched off. We thus further consider:

- **RED:** Network plans allow for redispatch
- **EE&RED:** Network plans allow for redispatch and interrupted RES
- **Opt.EE:** Welfare optimum when RES can be interrupted

Results Current Market Design | **Results Overall System Optimum**

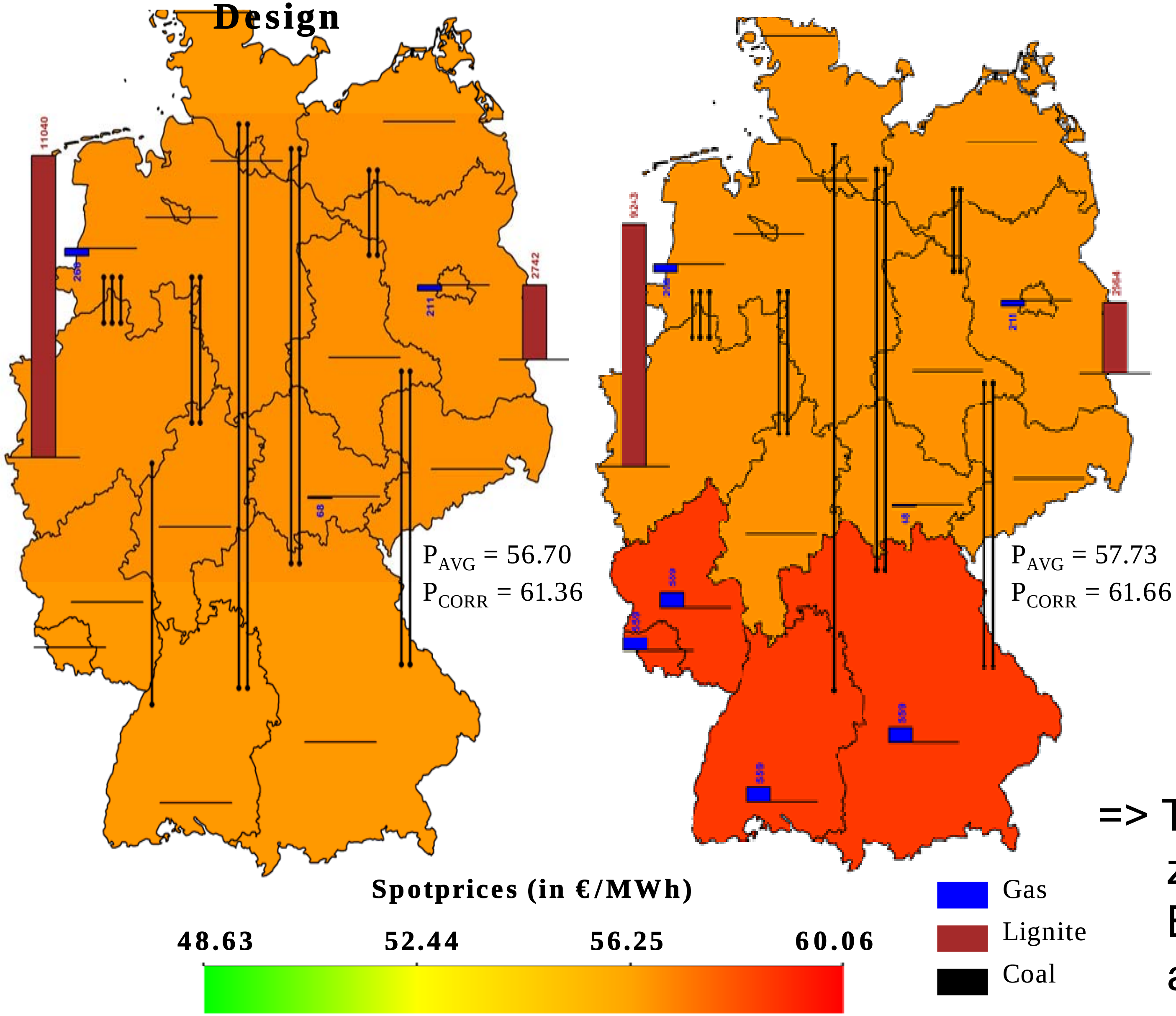


- The overall system optimum would lead to regionally differentiated spot market prices.
- In the system optimum Gas plants are built in the south and less lignite in the North.
- The overall average price (after correcting for the changed network fees in the system optimum) is lower.

=> **Question:** how to change market rules such that the **market outcome** gets closer to the **overall system optimum!**

Results Current Market Design

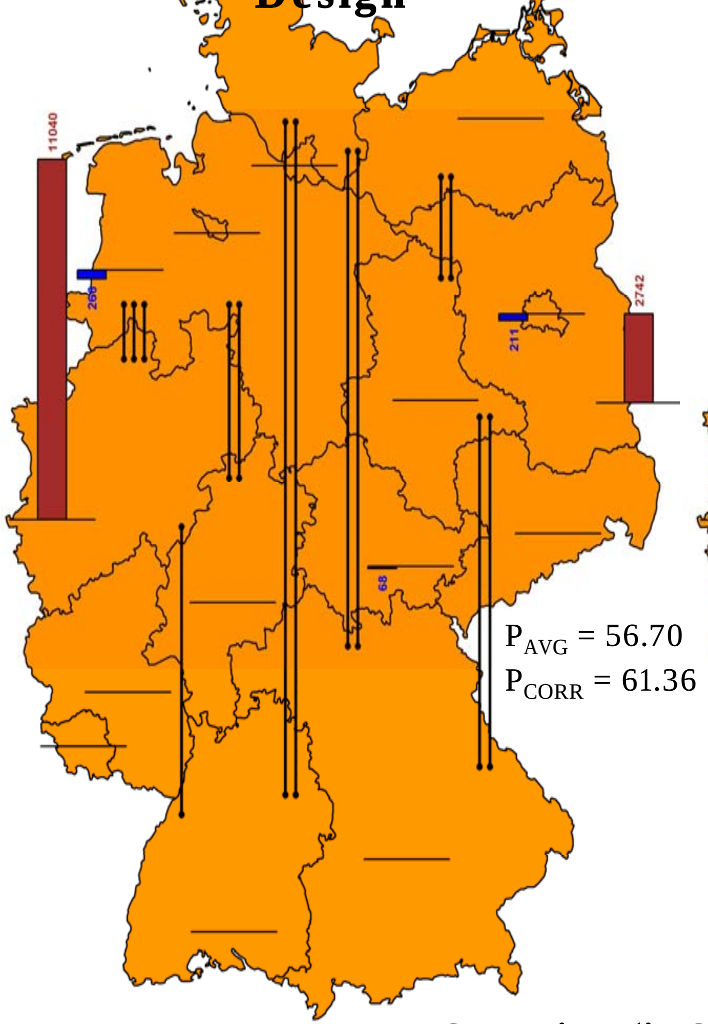
Results 2 Zones



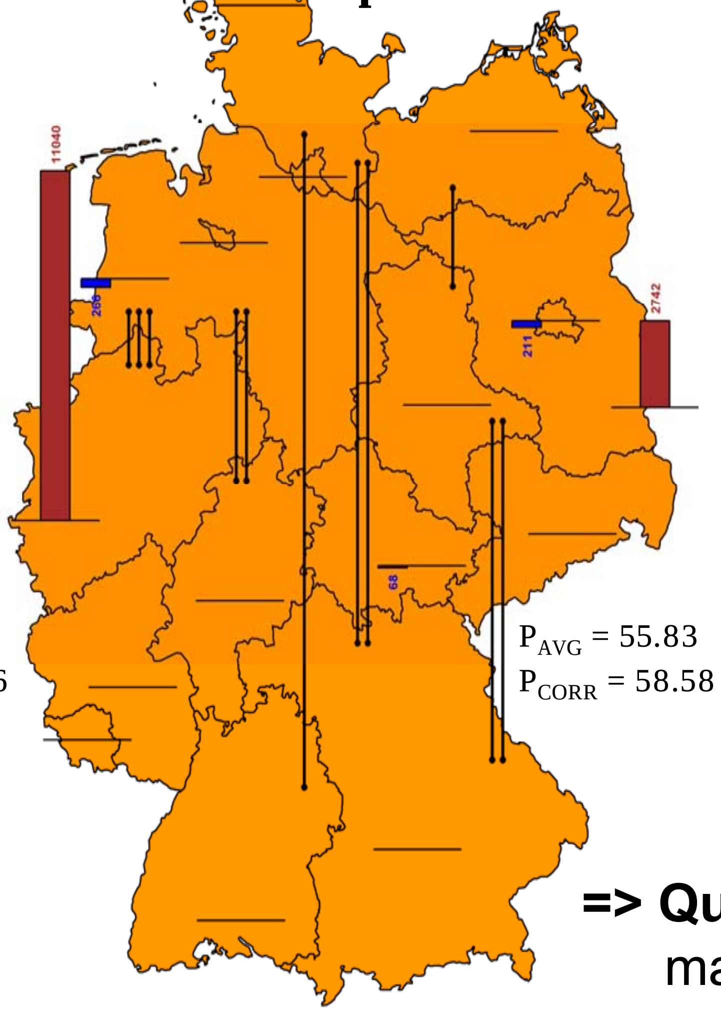
- We consider the introduction of **two price zones** at the spot market.
- This induces more investment in gas plants south (less lignite north)
- we need slightly less transmssion lines (SH-BW and NW-BW)
- Corrected spot prices in the south are higher than under the current market design

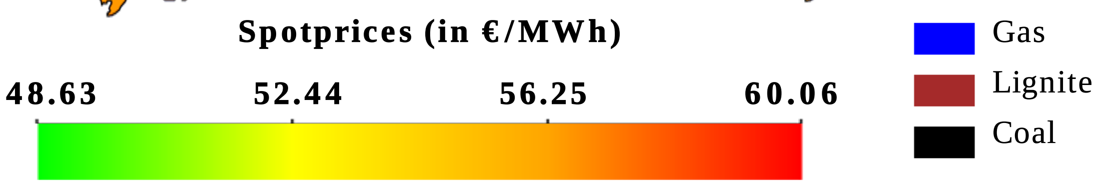
=> The introduction of 2 zones increases welfare. But market outcomes still are far from the system optimum.

Results Current Market Design



Results anticipated Redispatch





- The current practice of network planning in Germany (NEP) does not anticipate later possibilities of redispatch.
- If the possibility of redispatch is taken into account when planning the network this yields significant gains and reduces network expansion.

=> **Question:** how to change market rules such that the **market outcome** gets closer to the **overall system optimum!**

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Results, summary

	∆ Welfare [Mio €/a]	p_{Avg} [€/MWh]	Networkfee [€/MWh]	P_{CORR} [€/MWh]	Lines [GW]	∆ Gas [MW]	∆ Lignite [MW]	Descpiption
Current	0	56,70	4,66	61,36	28	-606	15.314	Current Market Design
2 Zones	111	57,73	3,93	61,65	24	1.876	13.230	2 bidding zones at the Spot market
Optimum	672	55,83	2,75	58,58	10	2.717	12.545	System optimum
RED	256	56,70	4,12	60,82	22	-606	15.314	Redispatch considered for Network planning
EE&RED	692	57,47	3,25	60,72	12	-606	15.314	Flexible Renewables, and Redispatch considered for Network planning
Optimum_{EE}	832	57,22	2,13	59,35	6	5.023	10.709	System optimum with flexible renewables

Detailed lines built in the scenarios

Lines which are built under the different regimes:

Lines [GW]	NI - NW (A01, A11, A15)	NW – BW (A02)	NI - HE (B03, B04)	SH – BW (C05, C05a, C06WDL)	SH – BY (C06mod, C08)	ST - BY (D18, D19a)	MV - ST (D19b, D20)	Sum
NEP 2014	6	2	4	6	4	4	4	30
Current	6	2	4	4	4	4	4	28
2 Zones	6	0	4	2	4	4	4	24
Optimum	0	0	4	0	4	2	0	10
RED	6	0	4	2	4	4	2	22
EE&RED	0	2	4	0	4	2	0	12
Optimum_{EE}	0	0	4	0	2	0	0	6

Conclusion and outlook: Market design in electricity markets at FAU and EnCN

- We have seen that the market outcome under the current market design is far from the outcome which obtains in the overall system optimum.
- Those discrepancies indicate that market rules should be adapted to obtain a better organization of our electricity system, yielding market outcomes as close as possible to the overall system optimum.
- We have seen that several measures might be suited to improve market efficiency:
  - the introduction of price zones would lead to improved but far from optimal results.
  - Allowing for the anticipation of redispatch when planning the network leads to quite drastic improvements.
  - Our results further indicated that renewable production should also be allowed to be subject to redispatch, this would allow to avoid a large portion of the German grid expansion

Conclusion and outlook: Market design in electricity markets at FAU and EnCN

- The Models and tools which we are currently developing at FAU and EnCN allow us:
  - to predict and quantify the potential consequences of changed market design.
  - to assess how close the obtained market outcomes are relative to the system optimum.
- Our work thus allows to analyze the impact of different proposals in the debate on Electricity markets and quantify their impact:
  - Have regionally differentiated network fees for generators to stimulate better locational choices for plants.
  - Include wind and solar investment in such locational incentive scheme to also foster the “right” location of those units.
  - ….