Policy implications of spatially differentiated renewable energy promotion: A multi-level scenario analysis of onshore wind auctioning in Germany

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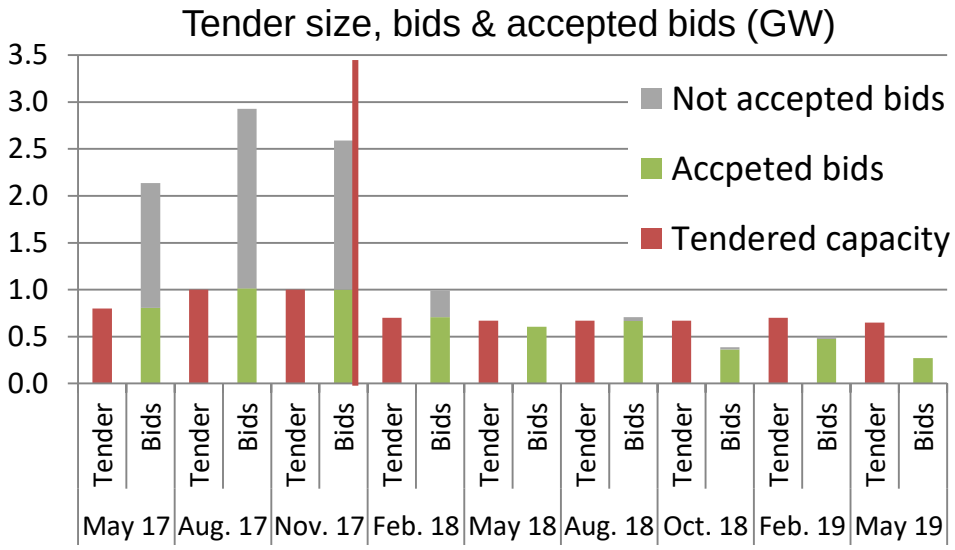
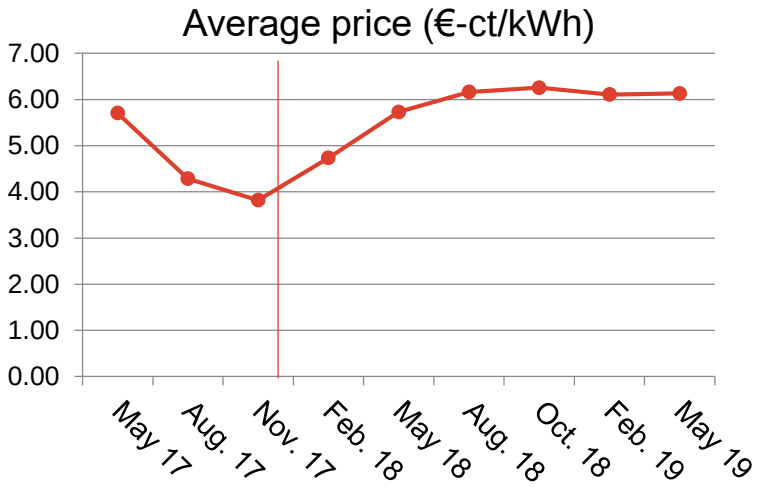
Outline

- Background and research objectives
- Hybrid modeling approach
- Regional renewable auction
- German RES Act (EEG) in HECTOR
- Results
- Conclusions

Onshore Wind Auctioning results 2017, 2018 and 2019 (Germany)

- Current renewable auction designs induce a high share of renewable power plants at efficient sites
- Inefficient allocation without consideration of transmission restrictions, causes an inefficient system configuration in the long term
- Well-designed auctions can counteract these inefficiencies and help to reach regional targets of the federal states [NEP]





Research objectives, Related literature

Wind potential

Can the federal states reach their long-term wind targets?

Market design

- What impact do the current remuneration scheme and auction design have on the regional distribution of wind energy?
- How does regional auction compare to different auction design?
- What regulatory measures and incentives on a German level may be beneficial to reach the regional (state-level) targets?

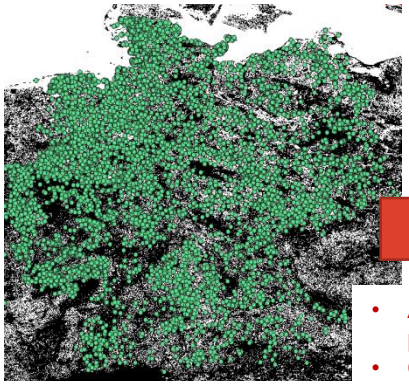
Related literature overview

- Bichler, M., Grimm, V., Kretschmer, S., & Sutterer, P. (2020). Market design for renewable energy auctions: An analysis of alternative auction formats. *Energy Economics*, *92*, 104904.
- Grimm, V., Rückel, B., Sölch, C., & Zöttl, G. (2019). Regionally differentiated network fees to affect incentives for generation investment. *Energy*, *177*, 487-502.
- Anatolitis, V., & Welisch, M. (2017). Putting renewable energy auctions into action–An agent-based model of onshore wind power auctions in Germany. *Energy Policy*, *110*, 394-402.
- Kreiss, J., Ehrhart, K. M., & Haufe, M. C. (2017). Appropriate design of auctions for renewable energy support–Prequalifications and penalties. *Energy Policy*, *101*, 512-520.

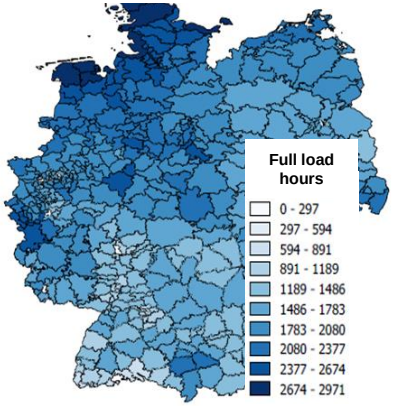
Hybrid modeling approach – Overview

Model 1	Model 2	Model 3
Geodata analysis tool	Renewable Auction Model (RAM)	Energy system model HECTOR

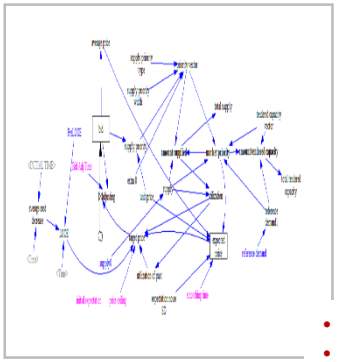
Existing locations



Regional potential



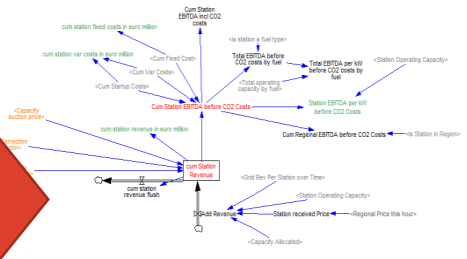
- Available potential
- Costs
- Time series



- Analysis of different auction mechanism
- Investments by regions & wind-speed cluster
- Hourly time series

- Investments
- Auction results
- Costs
- Time series of accepted bids

System dynamics analysis 2017-2030

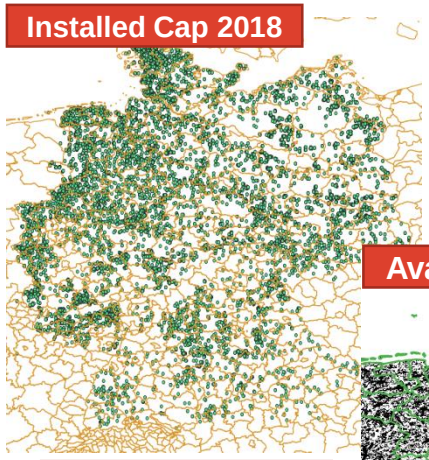


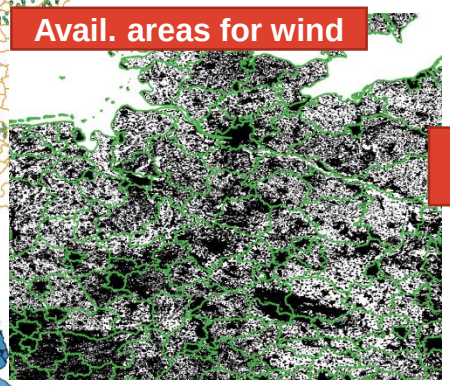
System dynamics
Electricity dispatch
Capacity investment

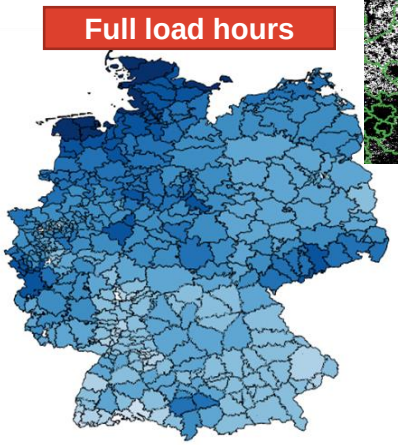
Geodata analysis (ENDAT model)

Geodata analysis

High resolution of regional data







Model output

Typical wind power plants in each region

- Existing capacity and hourly elec. gen.
- LCOE – Levelized costs of electricity
- Revenues based on future electricity prices

Bids in wind capacity auction

Market setup from auction & HECTOR model

- Auction design (Pay as bid)
- Market setup and scenarios

German RES Act (EEG) – Implementation in HECTOR

Renewable Auction Model (RAM)

Reference yield:
Model calculating reference index of wind plants

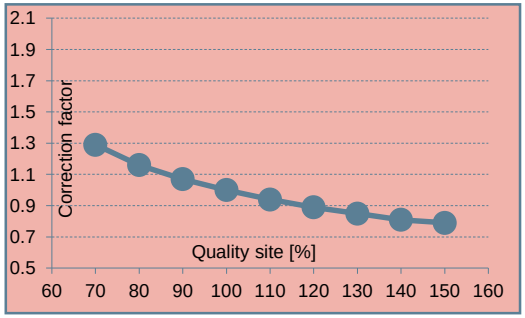
Renewable auction:
Modeling capacity auction (with system dynamics)

HECTOR simulation:
Implementing output of renewable auction in HECTOR

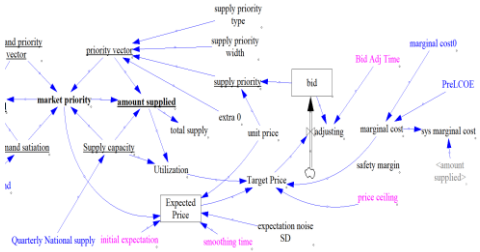
Market Premium Pursuant = Value to be applied - Monthly market value

$$V_{Na} = V_{ref} \times \left(\frac{h_{Na}}{h_{ref}}\right) \propto$$

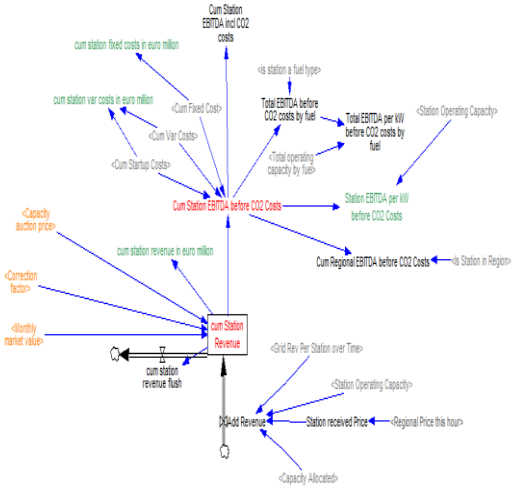
$$Correction\ factor_{[target]} = CF_{[left]} + \frac{CF_{[right]} - QF_{[left]}}{QF_{[right]} - QF_{[left]}} \times (QF_{[right]} - QF_{[left]})$$



Renewable capacity auction



Market Premium Pursuant = Value to be applied - Monthly market value



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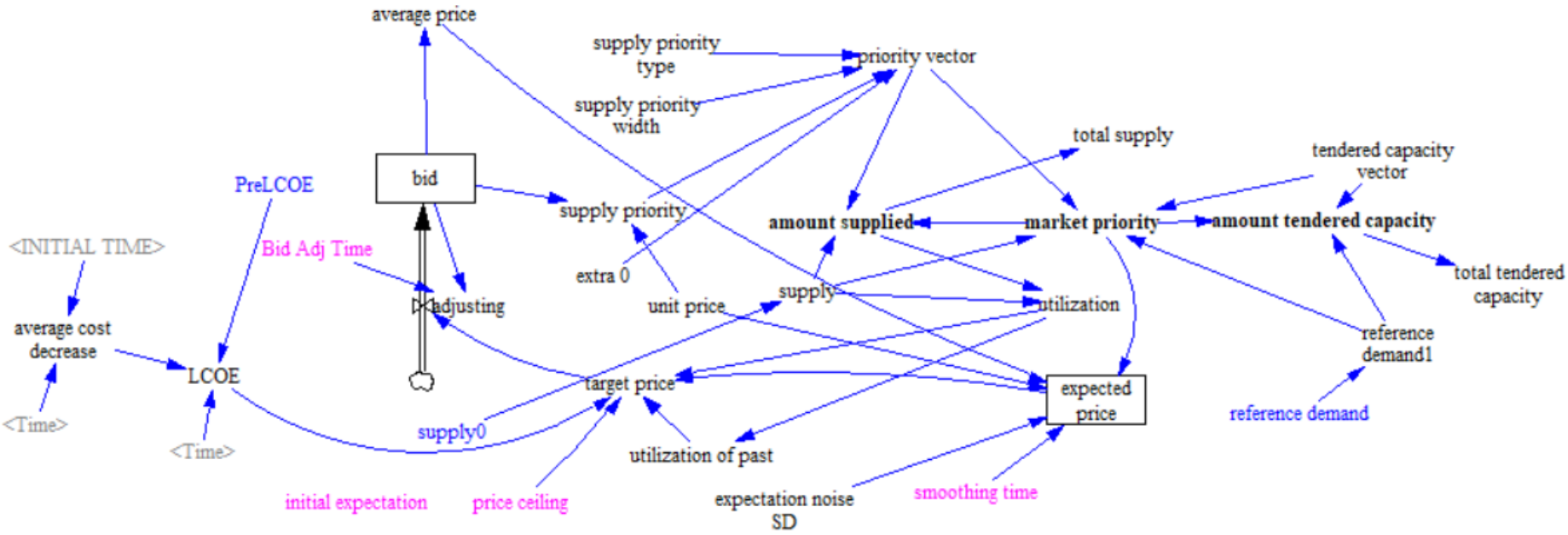
System Dynamics heuristics for auctioning

Renewable Auction Model (RAM)



- **Renewable auction heuristics:**
  - Allocation by priority
  - Learning of bidders
  - As long as the bidders are small relative to the market, they are price takers, and therefore can make money by pushing utilization as high as possible at the clearing price

Model logic of System Dynamics model HECTOR

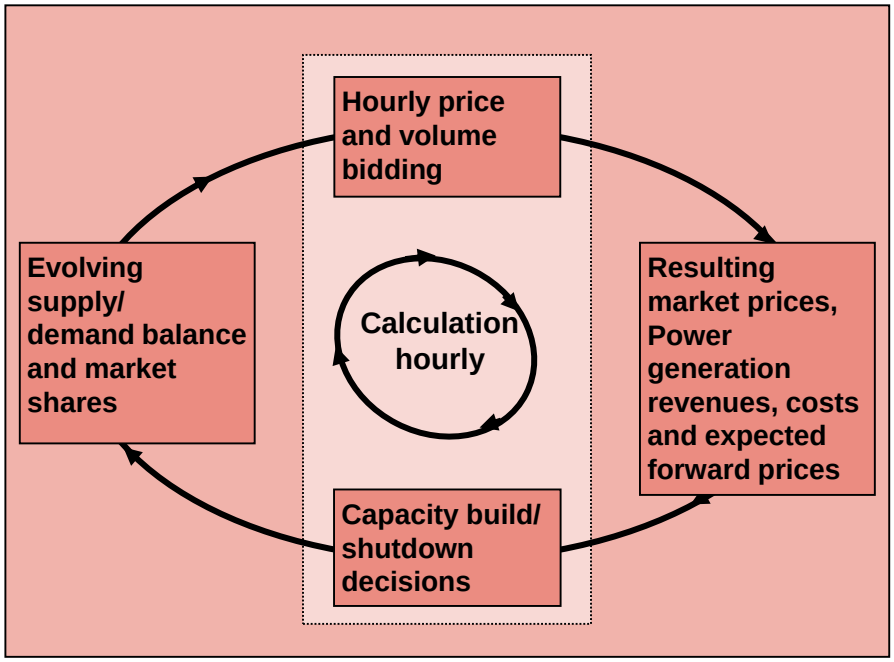
Energy system model HECTOR

Structure | **Conduct** | **Performance**

Inputs

- Generation data
- Transmission data
- Demand data
- Commodity data
- Process commodity data

- **Capacity auction module:**
- Wind speed time series in NUTS 2 level
- Load time series
- Demand for wind onshore in each auction round
- Potential for production from wind onshore sources



Key outputs

- Hourly price data
- Hourly production data
- Profitability data

Auction designs

- **National auction**
  - Benchmark of alternative auctions, reference yield model
  - Four auctions per year (February, May, August, October)
  - Yearly tendered capacity in auction: 2700 MW
- **Regional auction**
  - One regional auction per year, no reference yield model
  - Considering regional target capacities (demand based on regional target)

Auction design elements	Information
Pricing	PAB for all, uniform for energy citizen
Auction volume	2700 MW per year
Remuneration scheme	Energy-related remuneration
Price cap	7 €-ct/kWh in 2017, from 2018 onwards average of highest accepted bid in the last three rounds
Frequency	3-4 times per year
Commitment period	20 years

- **Model setup**

➢ Bidders are price takers

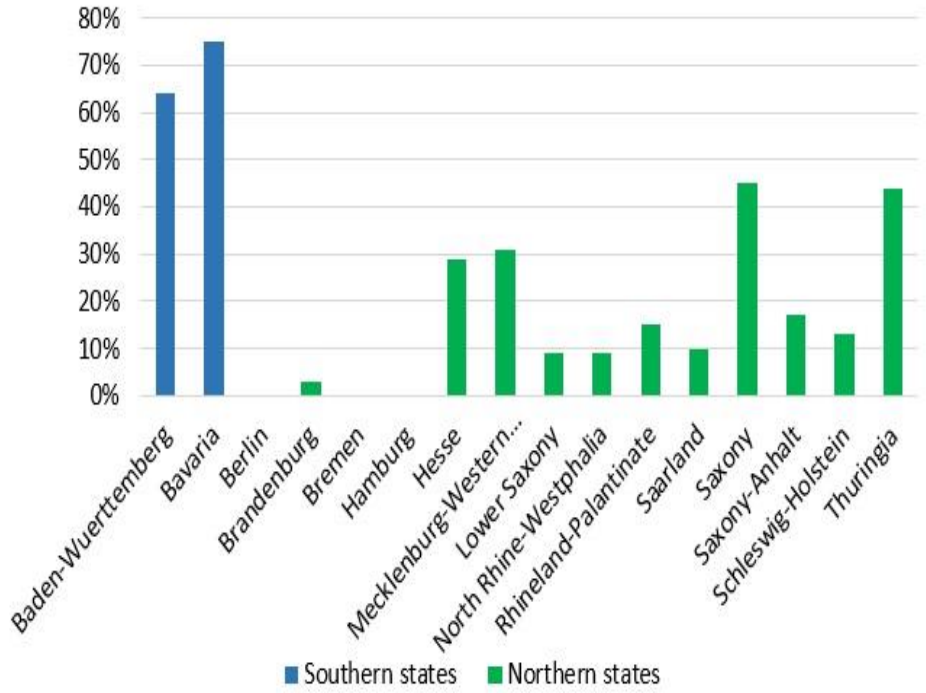
➢ 42 different technology groups based on wind speed classes

➢ Implementing learning process of bidders from global behavior of the system

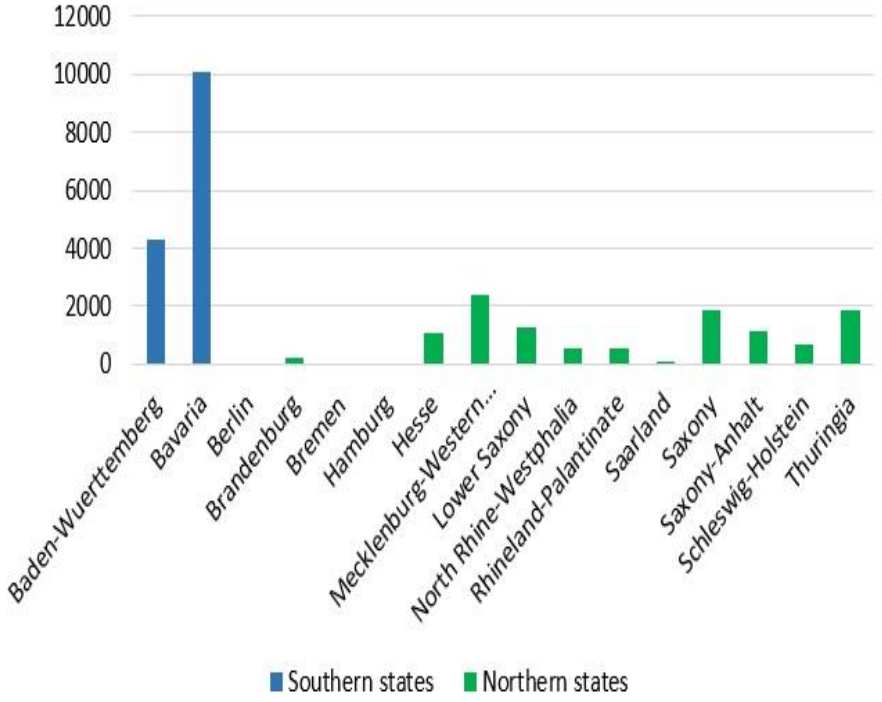
Setting up the model: Market observation & Simulation results

Remaining wind potential in each state – based on current regulation

Share of remaining potential onshore wind sites



Number of wind energy assets (WEA) that can be installed in each federal state



Market Observation #1: Cumulative and awarded capacity (till 2017)

Cumulative capacity till 2017

Historical data

States	Installed Capacity[MW]
Baden-Württemberg	1529
Bavaria	2515
Brandenburg	7081
Hesse	2201
Mecklenburg-Vorpommern	3366
Lower Saxony	11,156
North Rhine-Westphalia	5773
Rhineland-Palatinate	3589
Saarland	476
Saxony	1227
Saxony-Anhalt	5139
Schleswig-Holstein	6964
Thuringia	1567
Sum	52583

Distribution of awarded capacity in 2018

Available potential according to **NEP**

States	Installed Capacity[%]
Baden-Württemberg	7.7
Bavaria	0
Brandenburg	5.4
Hesse	2.8
Mecklenburg-Vorpommern	16.6
Lower Saxony	19
North Rhine-Westphalia	4.9
Rhineland-Palatinate	7.2
Saarland	0
Saxony	8.1
Saxony-Anhalt	8.8
Schleswig-Holstein	10.2
Thuringia	9.2
Sum	100

Distribution of awarded capacity in 2018

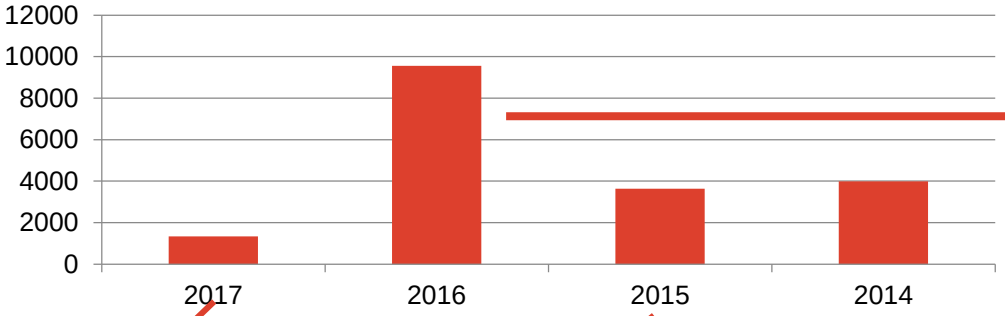
Available potential according to **MaxW**

States	Installed Capacity[%]
Baden-Württemberg	13.7
Bavaria	35.2
Brandenburg	0
Hesse	16.2
Mecklenburg-Vorpommern	7.8
Lower Saxony	0
North Rhine-Westphalia	11.5
Rhineland-Palatinate	6.7
Saarland	3.5
Saxony	4.9
Saxony-Anhalt	0
Schleswig-Holstein	0
Thuringia	0
Sum	100

Sources: Federal Network Agency (2019b), Grimm et al. (2017)

Market Observation #2: Scenario building based on observation of previous auctions

Observation: Approved wind farm sites per year (MW)



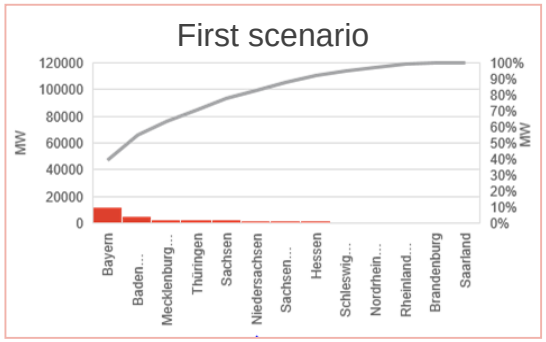
Assumption 1: Investments based on potential area

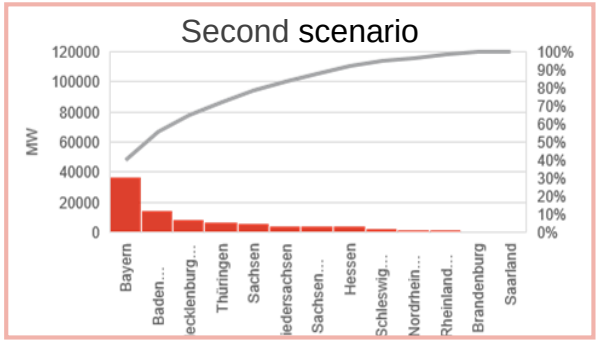
Scenario 1: 2222 (MW)

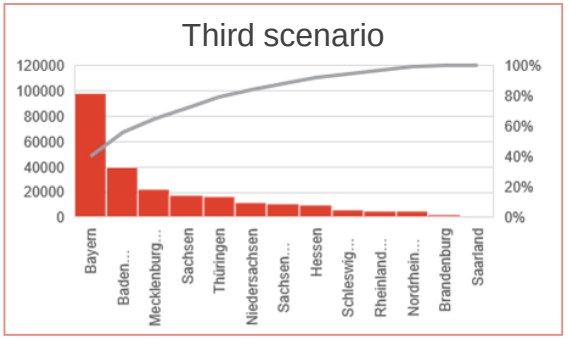
Scenario 2: 6611 (MW)

Scenario 3: 17,622 (MW)

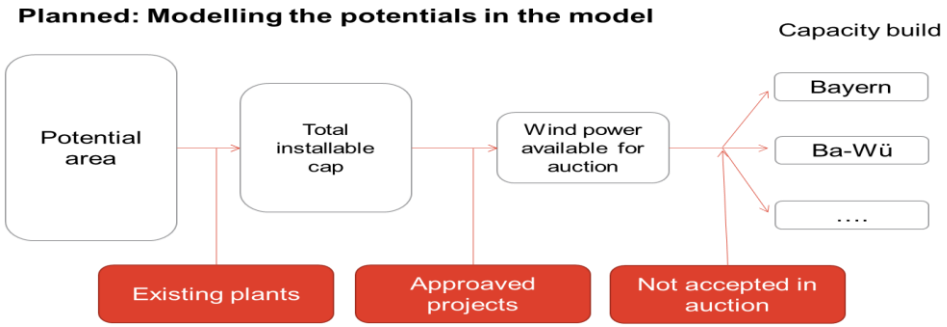
Assumption 2: Distribution based on available area







Results: Number of approval varies highly (Geo data tool)



Main results:

- All scenarios indicate more potential for southern states in Germany
- Regulatory restrictions for distances to residential areas, signal towers, roads etc., in different regions is considered

Total available potential Scenario 1

States	Installed Capacity(MW)
Baden-Württemberg	**284**
Bavaria	**716**
Brandenburg	18
Hesse	77
Mecklenburg-Vorpommern	162
Lower Saxony	95
North Rhine-Westphalia	41
Rhineland-Palatinate	36
Saarland	0
Saxony	126
Saxony-Anhalt	86
Schleswig-Holstein	50
Thuringia	131

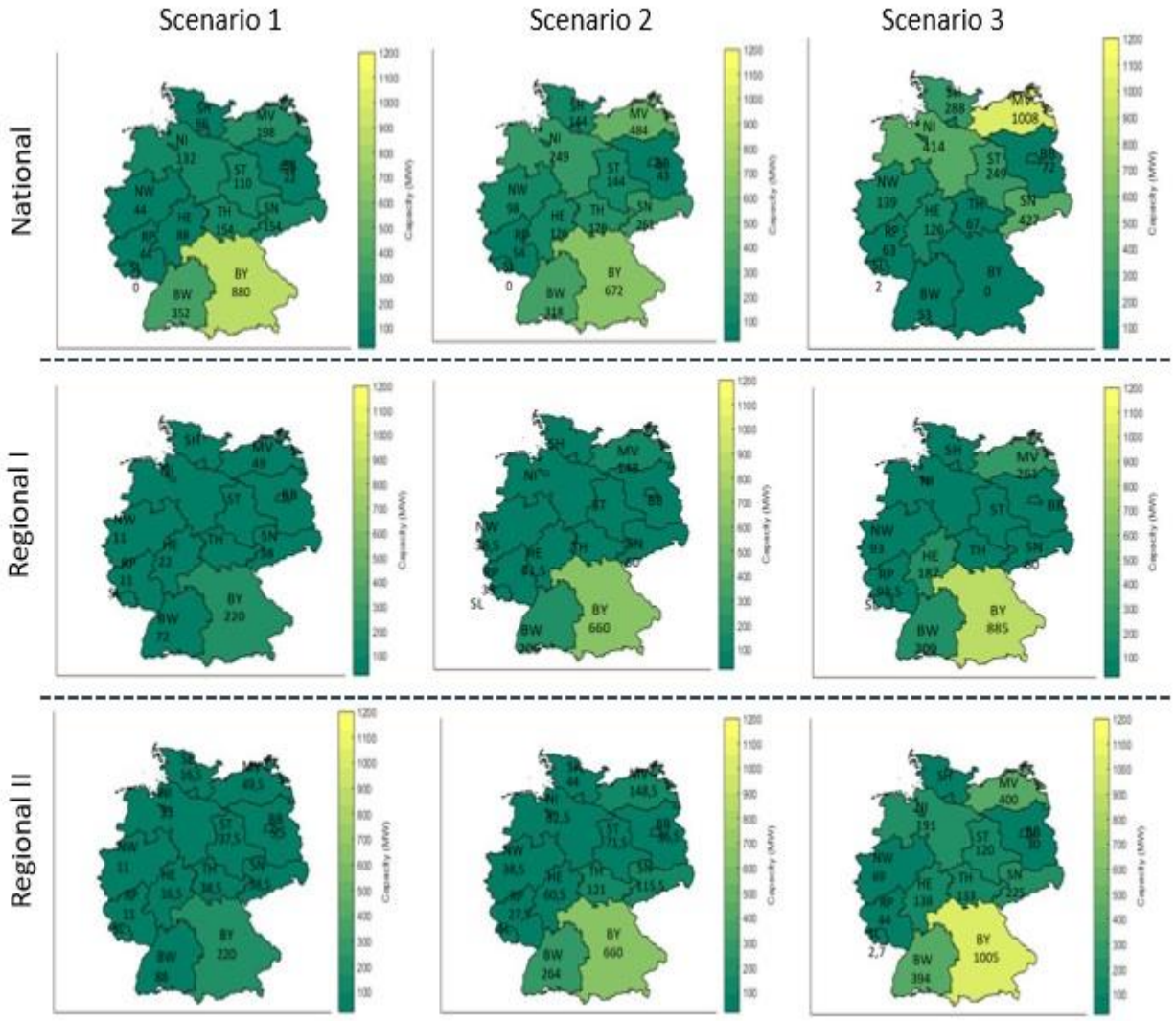
Total Available potential Scenario 2

States	Installed Capacity(MW)
Baden-Württemberg	**864**
Bavaria	**2156**
Brandenburg	54
Hesse	225
Mecklenburg-Vorpommern	491
Lower Saxony	266
North Rhine-Westphalia	113
Rhineland-Palatinate	113
Saarland	5
Saxony	374
Saxony-Anhalt	239
Schleswig-Holstein	131
Thuringia	383

Total Available potential Scenario 3

States	Installed Capacity(MW)
Baden-Württemberg	**2309**
Bavaria	**5747**
Brandenburg	140
Hesse	594
Mecklenburg-Vorpommern	1314
Lower Saxony	702
North Rhine-Westphalia	297
Rhineland-Palatinate	302
Saarland	18
Saxony	1013
Saxony-Anhalt	630
Schleswig-Holstein	356
Thuringia	999

Results: Diversity of bidders

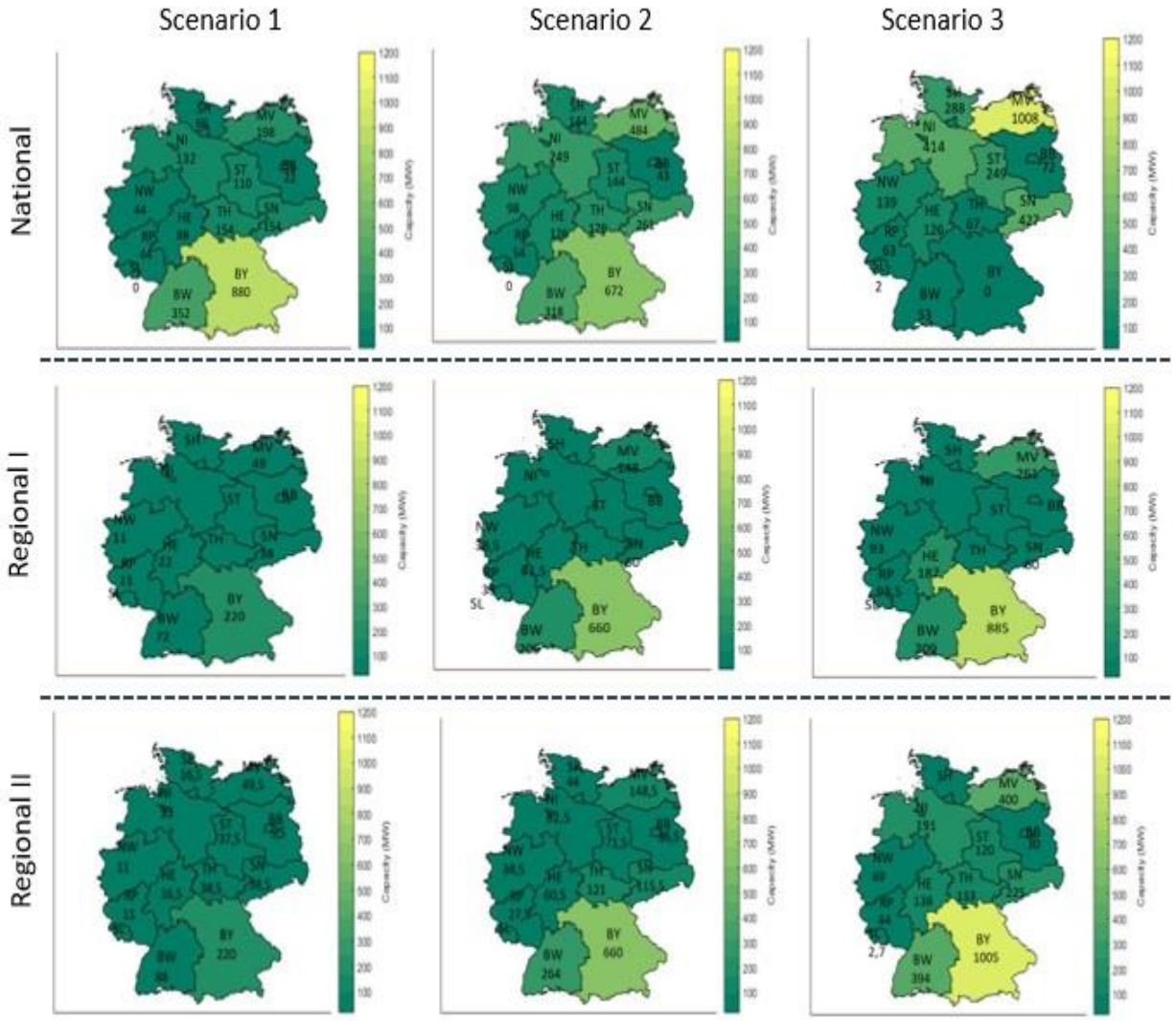


Main results:

❑ **National auction:**

- There is a relationship between award numbers and amount of investment in regions with lower chance of winning in national auction.
- Increasing award numbers leads to less investment in southern states
- Northern states are dominant in this auction design

Results: Diversity of bidders



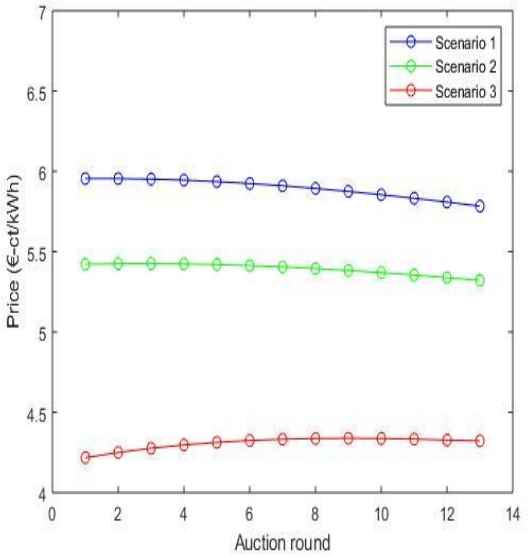
Main results:

❑ **Regional auction:**

- Regional auctions can promote the regions with a lower wind quality
- Regional auction shows less possible tendered capacity for northern states
- At least 70% of allocated capacity in southern states belong to Bavaria
- Investors tend to install their plants in these regions much more frequently because they are competing with rivals with similar wind potentials in their state
- Some states (SA, BB) produce very low in all scenarios

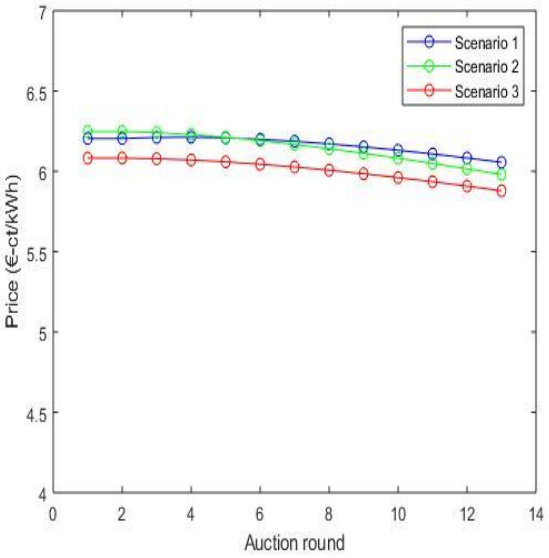
Results: Average price in different auction designs

NATIONAL auction



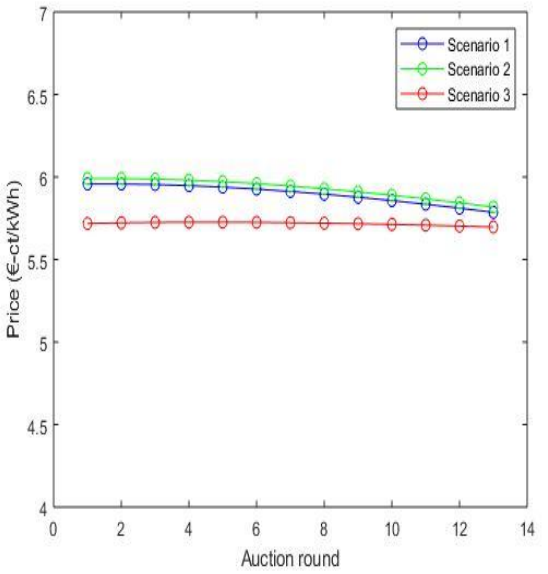
- Higher award numbers leads to lower price
- In scenario three, bidders bid near to their MC (the more competitive the market is, the more allocative efficiency is found)
- Higher number of auctions and increase of learning stabilize price development

STATE-level auction



- Average price of southern states can reach higher level in scenario one and two (near to 7 €-ct/kwh)
- Increasing no. of awards in regions with higher wind potential (e.g. southern states) leads to lower prices
- Higher growth price development; increase of bidders' awarded prices

NORTH-SOUTH auction



- Lower price development especially for scenario three
- Higher share of southern (states with higher costs) lead to lower average price→ Because of decrease in bid-shading

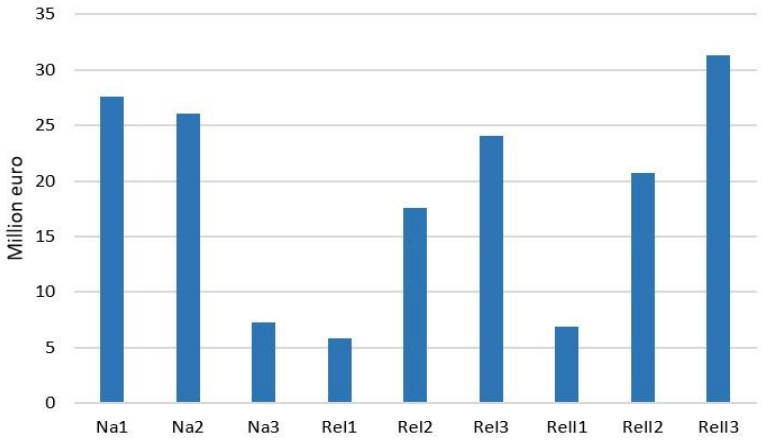
Results: Overall saving in different auction designs

Results:

- **National auction**: simulation results show a 2% and a 73% reduction in support payments in Scenarios 2 and 3, respectively
- **Regional auction**: the support payment increase in regional auctions when more contracts are issued by auctioneer
- **Policy implication**: Regional auction has lower societal mechanism except for scenario three
- When the **level of participation** of bidders is **low/medium, regional auction** designs have **superiority** over the national auction design (from the perspective of **saving on support payments**)

Support payment over the 20 years' lifetime of a wind farm [million €]

Region	Na1	Na2	Na3	Rel1	Rel2	Rel3	RelI1	RelI2	RelI3
Baden-Wuerttemberg	6.13	5.37	0	1.29	3.76	3.75	1.58	4.74	7.31
Bavaria	16.28	13.43	0	4.08	12.24	16.42	4.08	12.24	18.41
Berlin	0	0	0	0	0	0	0	0	0
Brandenburg	0.08	0.15	0.25	0	0	0	0.02	0.06	0.12
Bremen	0	0	0	0	0	0	0	0	0
Hamburg	0	0	0	0	0	0	0	0	0
Hesse	1.09	1.34	0.56	0.27	0.84	2.19	0.04	0.64	0.87
Mecklenburg-Western Pomerania	0.002	0.005	0.01	0	0	0	0	0	0
Lower Saxony	0.22	0.41	0.69	0.04	0.14	0.34	0.05	0.15	0.31
North Rhine-Westfalia	0.17	0.36	0.53	0.04	0.14	0.19	0.04	0.14	0.26
Rhineland-Palatinate	0.40	0.47	0.55	0.10	0.37	0.98	0.10	0.25	0.41
Saxony	0.75	1.32	1.90	0.017	0.02	0.02	0.18	0.59	1.06
Saxony-Anhalt	0.66	0.94	1.31	0	0	0	0.16	0.43	0.75
Saarland	0	0	0.01	0	0	0	0	0	0
Thuringia	1.76	2.19	1.07	0	0	0	0.44	1.47	1.68
Schleswig-Holstein	0	0	0	0	0	0	0	0	0
Sum of regions	27.6	26.02	7.30	5.85	17.52	24.09	6.86	20.75	31.27



Results: Overall saving in different auction designs

Results:

- **Regional auctions** do not cause markedly higher support payments per unit of installed capacity in **any region**
- **Support payment per unit of installed capacity** does not change markedly for the three scenarios of the **regional auctions**

Support payment per unit of installed capacity (k€/MW)

Region	Na1	Na2	Na3	ReI1	ReI2	ReI3	ReII1	ReII2	ReII3
Baden-Wuerttemberg	17.41	16.88	0	17.91	17.99	17.94	17.95	19.03	18.55
Bavaria	18.50	19.98	0	18.54	13.83	18.55	18.52	18.54	18.31
Berlin	0	0	0	0	0	0	0	0	0
Brandenburg	3.63	3.48	3.47	0	0	0	3.88	3.63	4
Bremen	0	0	0	0	0	0	0	0	0
Hamburg	0	0	0	0	0	0	0	0	0
Hesse	12.38	10.63	4.59	12.27	11.74	11.71	10.74	10.57	6.30
Mecklenburg-Western Pomerania	0.01	0.01	0.009	0	0	0	0.003	0	0
Lower Saxony	1.66	1.64	1.66	0	0	0	1.73	1.81	1.62
North Rhine-Westphalia	3.86	3.67	3.81	3.63	3.63	2.04	3.97	3.63	3.76
Rhineland-Palatinate	9.09	8.70	8.73	9.09	11.21	10.48	9.26	9.09	9.31
Saxony	4.87	5.05	4.44	0.44	0.33	0.33	4.93	5.10	4.71
Saxony-Anhalt	6	6.52	5.26	0	0	0	4.43	6.01	6.250
Saarland	0	0	3.70	0	0	0	0	0	0
Thuringia	11.42	12.44	15.97	0	0	0	11.48	12.14	12.63
Schleswig-Holstein	0	0	0	0	0	0	0	0	0

Conclusions

1. Auction design **can affect** the promotion of onshore wind significantly

2. Current **reference yield model** is not a **sufficient** tool for the promotion of wind onshore in Germany

3. We recommend using **different scenarios** based on previous **permitted capacity** for analyzing capacity auctions

4. **Regional auction** helps to promote wind power in the **southern states of Germany**

5. There is a **trade-off** between increasing shares of **bidders from the southern states** (a higher LCOE) and the **average auction price**

6. The regional auctioning can lead to **support payment savings**, and should thus be considered in renewable energy support policy design

Many thanks for your attention – any questions?

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