



# *The impact of renewable energy auctions on renewable energy promotion taking the spatial dimension into account*

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FCN | Future Energy Consumer  
Needs and Behavior



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# Outline

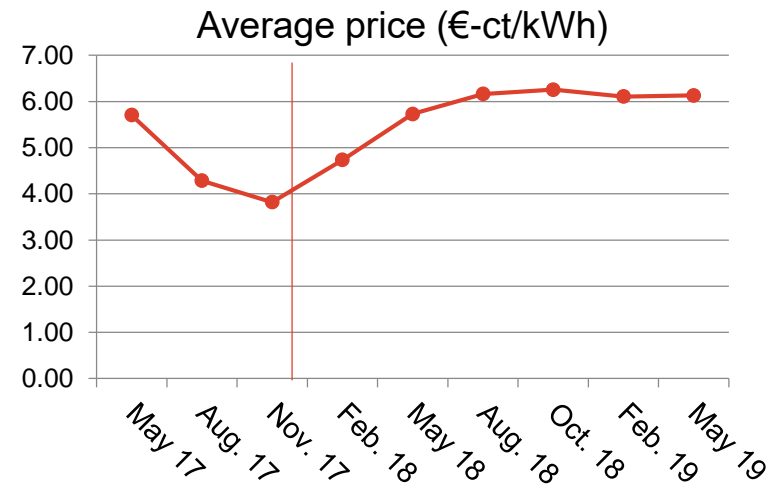
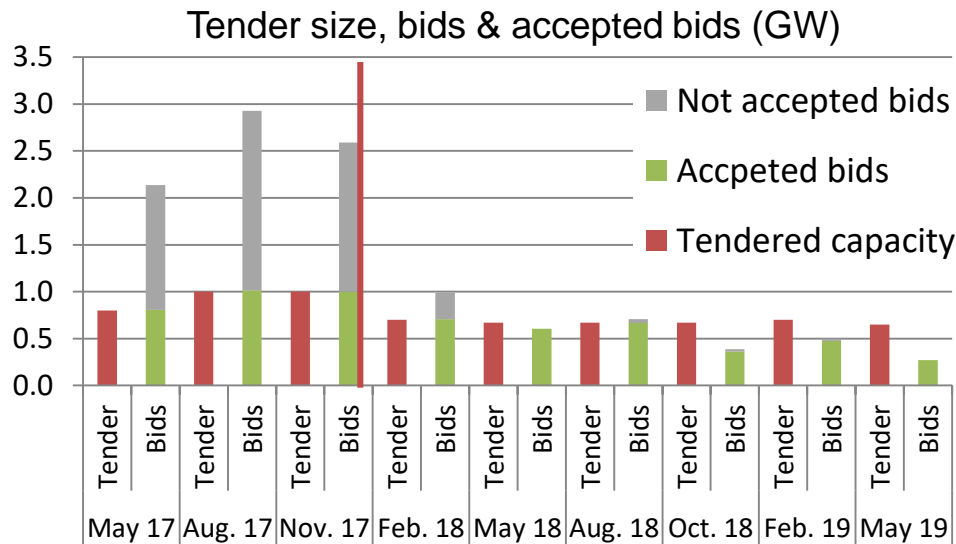
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- Background and research objectives
- Modeling approaches
- Regional renewable auction
- German RES Act (EEG) in HECTOR
- Results
- Conclusions

# Background and research objectives

## Wind onshore energy auction results 2017, 2018 and 2019 (Germany)

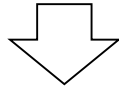
- Current renewable auction designs induce a high share of renewable power plants at efficient sites
- Inefficient allocation without consideration of transmission restrictions, causes an inefficient system configuration in the long term
- Well-designed auctions can counteract these inefficiencies and 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 and European level may be beneficial to reach the regional (state-level) targets?

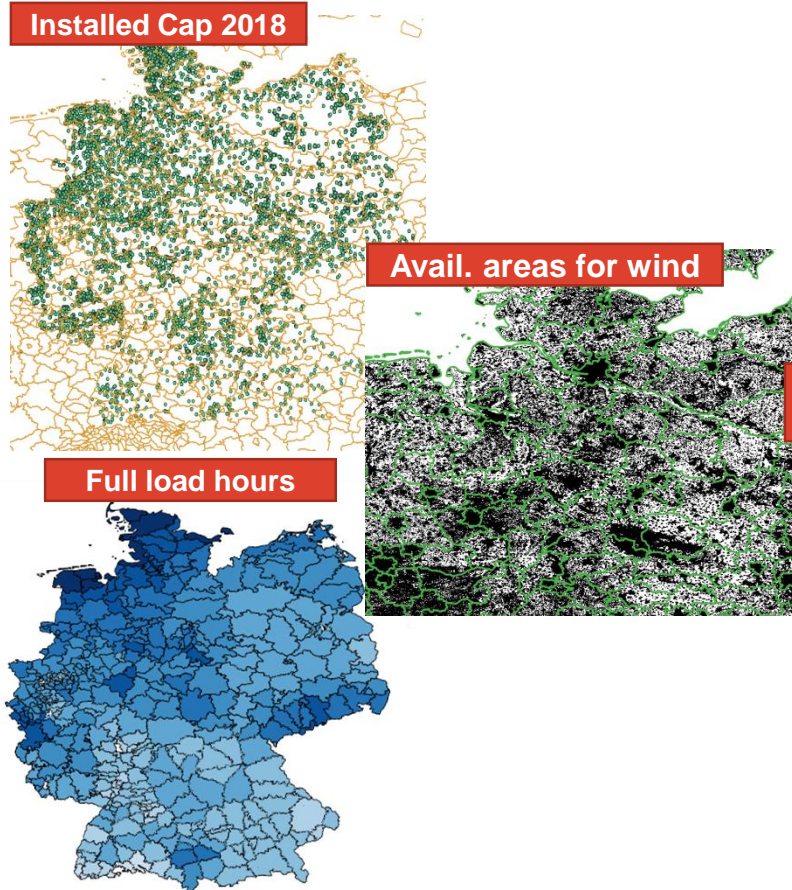
## Related literature overview

- 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.
- Bichler, M., Grimm, V., Kretschmer, S., & Sutterer, P. (2019). Market Design for Renewable Energy Auctions: An Analysis of Alternative Auction Formats. Available at SSRN 3417550.
- 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.
- Grimm, V., Rückel, B., Sölch, C., & Zöttl, G. (2019). Regionally differentiated network fees to affect incentives for generation investment. *Energy*, 177, 487-502.



# Geodata analysis (ENDAT model)

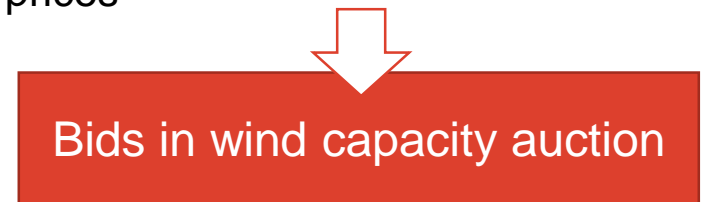
## High resolution of regional data



## 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



### Market setup from auction & HECTOR model

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

# German RES Act (EEG) in HECTOR

**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

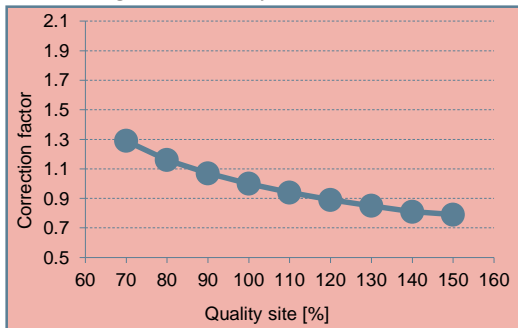
Market Premium Pursuant = **Value to be applied** - Monthly market value

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

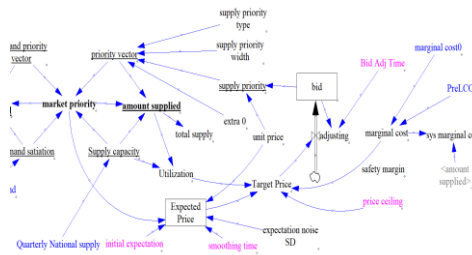
Correction factor<sub>[target]</sub>

$$= CF_{[left]} + \frac{CF_{[right]} - QF_{[left]}}{QF_{[right]} - QF_{[left]}}$$

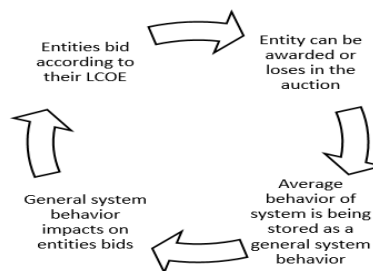
$$\times (QF_{[right]} - QF_{[left]})$$



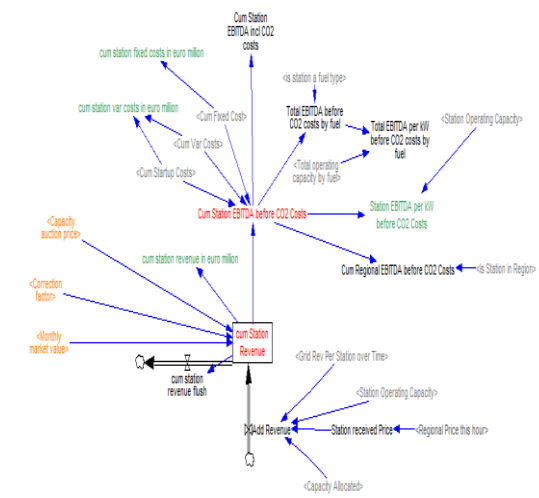
## Renewable capacity auction



## Learning process



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



# Model logic of System Dynamics model HECTOR

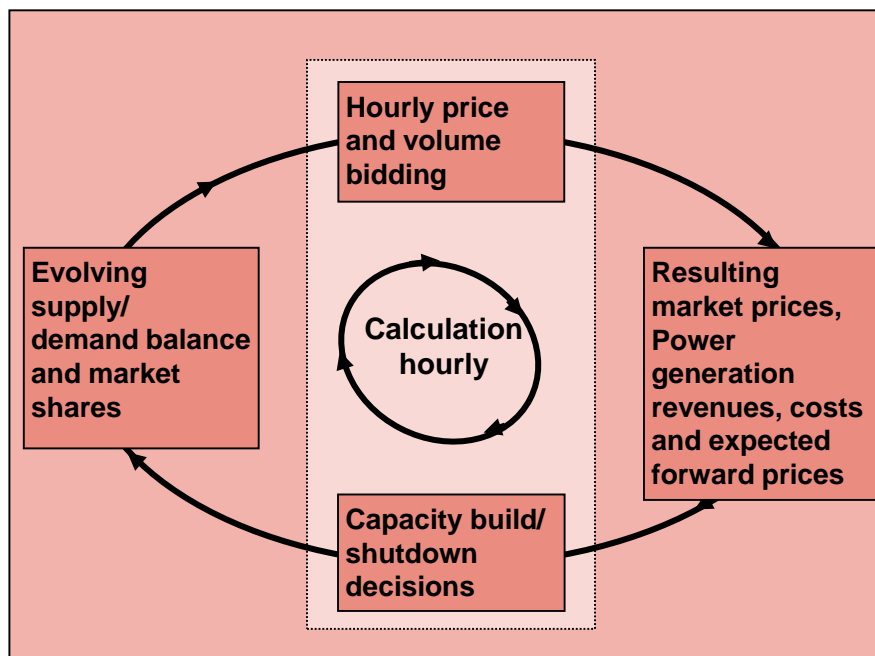
## Structure

## 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

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- **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)

- **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

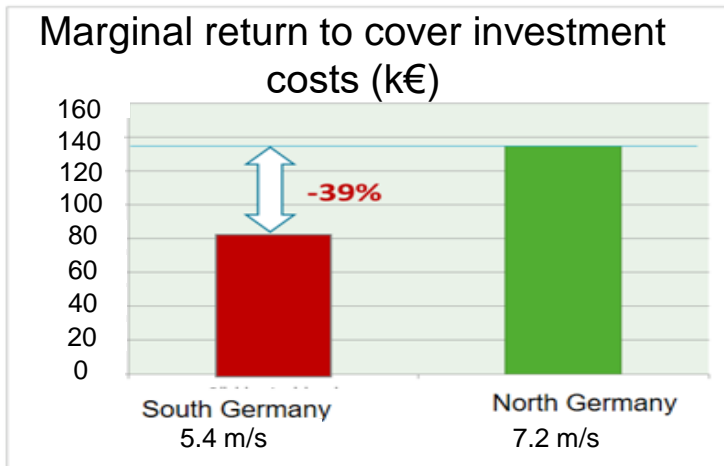
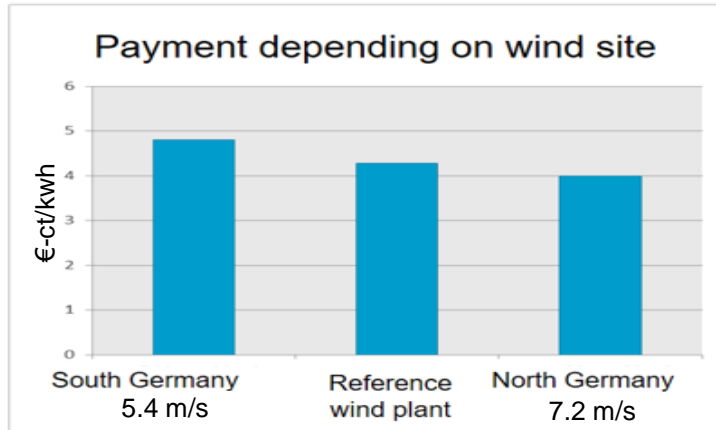
| Auction design elements | Information  |
|-------------------------|--|
| Pricing                 | PAB for all, uniform for energy citizen  |
| Auction volume          | 2700 MW per year   |
| Remuneration scheme     | Energy-related remuneration  |
| Price cap               | 7 €-ct/kWh in 2017,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

# Setting up the model: Market observation & Simulation results

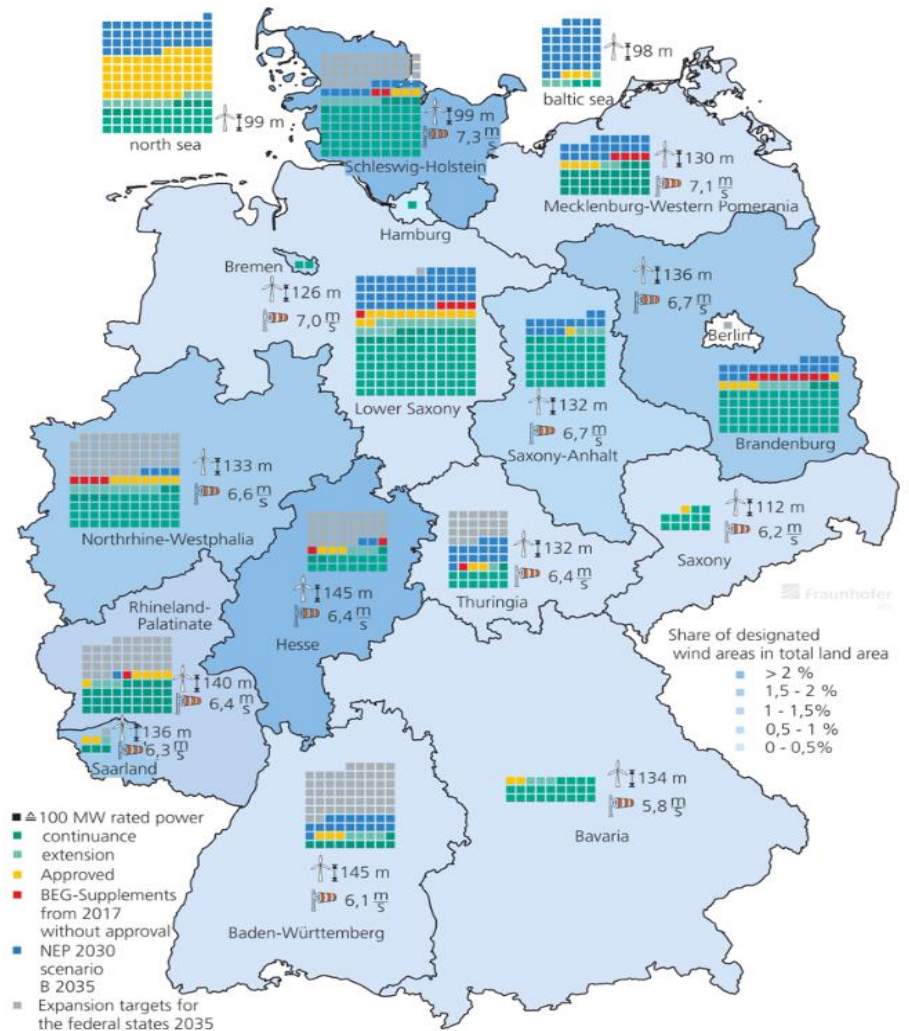
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# Market Observation #1: Good sites still benefit from correction factor



**Investment model shows: No incentives for investment in the south of Germany**

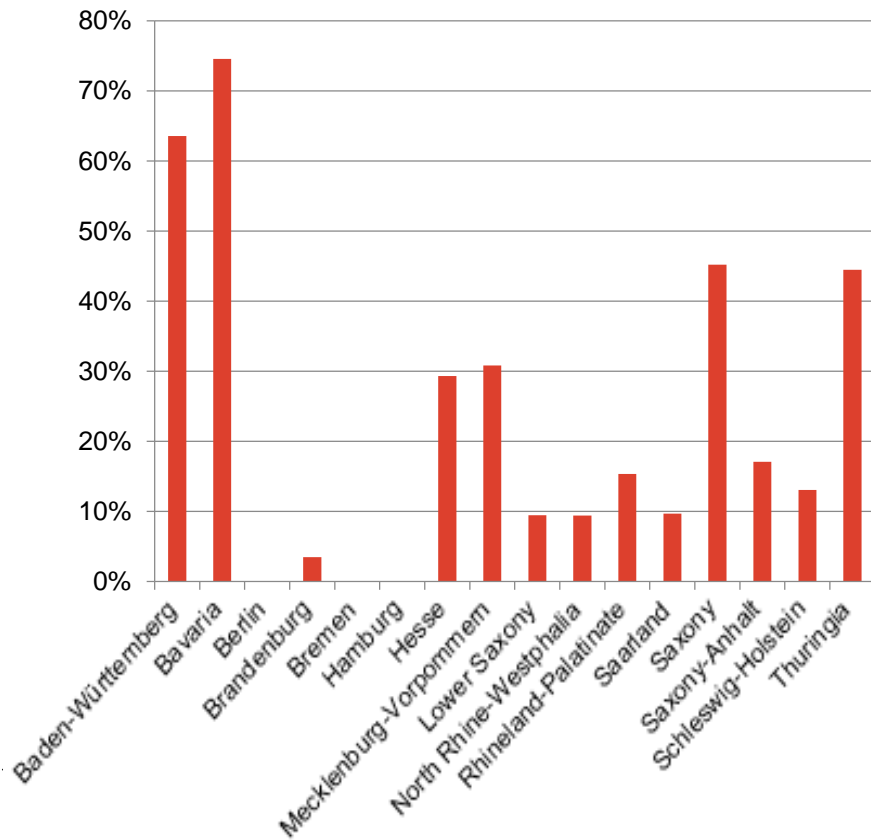


Source: Federal Network Agency (2019b)

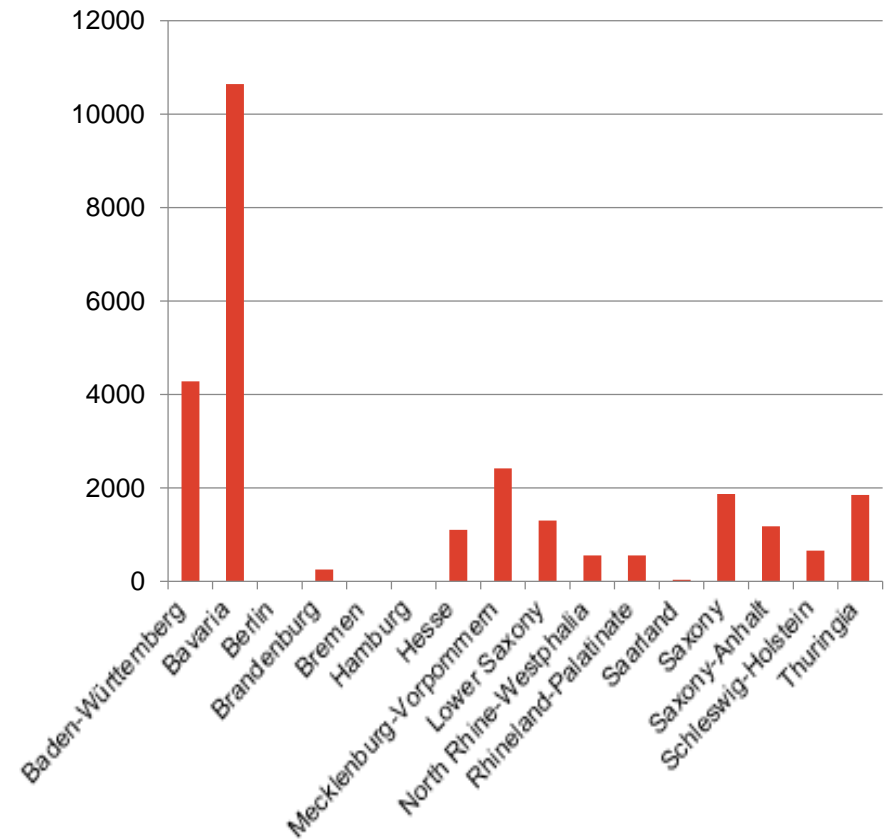
# Results: Geodata Analysis

## Remaining wind potential in each state – based on current regulation

Share of potential wind sites that remain



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



# Market Observation #2: 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                    | 52,583                 |

## 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

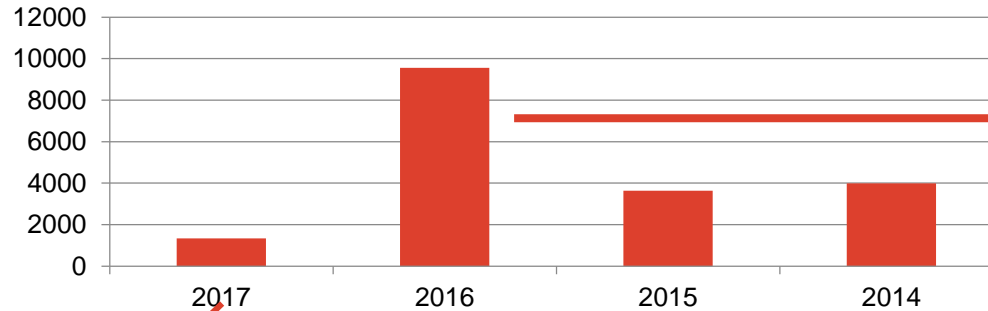
Available potential according to **MaxW**

| 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 #3: Scenario building based on observation of previous auctions

## Observation: Approved wind farm sites per year - MW



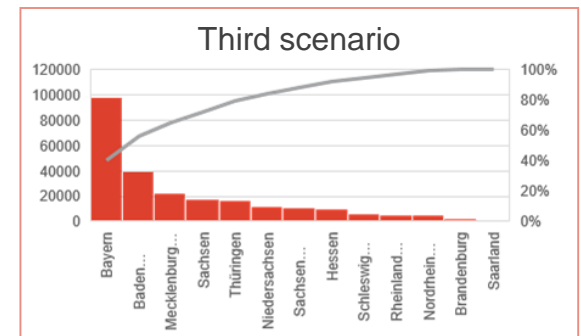
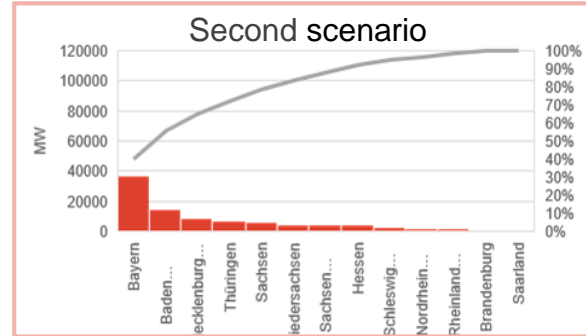
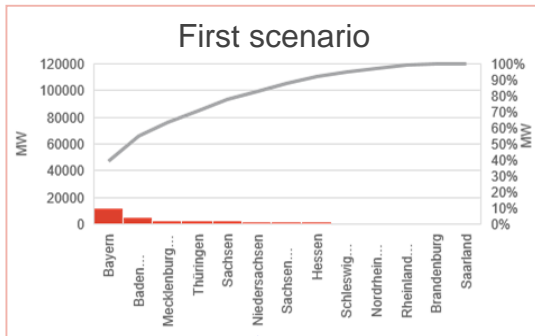
### Assumption 1: Investments based on potential area

Scenario 1: 2222 [MW]

Scenario 2: 6611 [MW]

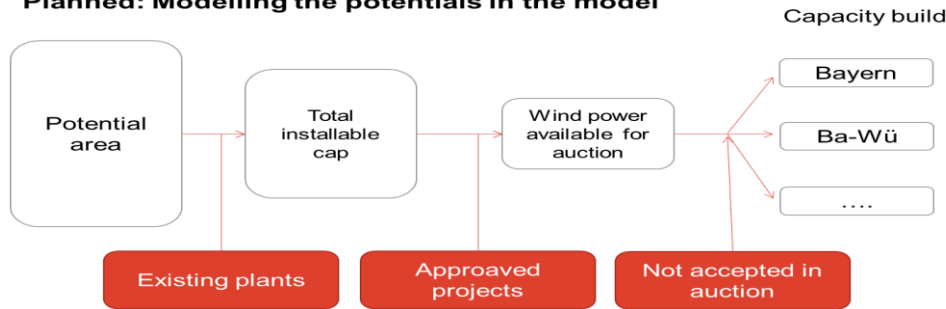
Scenario 3: 17,622 [MW]

### Assumption 2: Distribution based on available area



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

## Planned: Modelling the potentials in the model



## 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] |
|--------------------------|------------------------|
| <b>Baden-Württemberg</b> | <b>284</b>             |
| <b>Bavaria</b>           | <b>716</b>             |
| 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

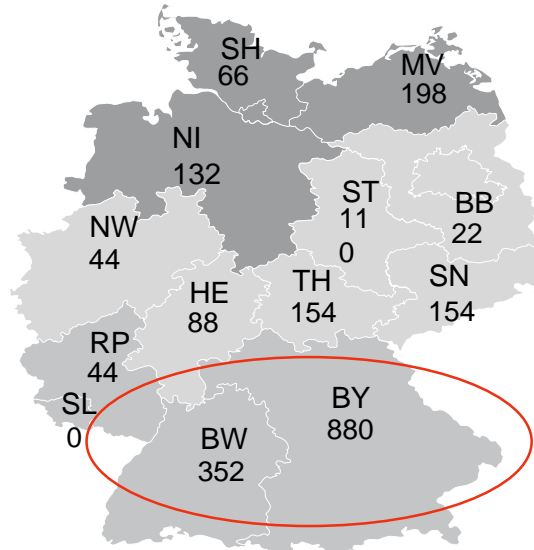
| States                   | Installed Capacity[MW] |
|--------------------------|------------------------|
| <b>Baden-Württemberg</b> | <b>864</b>             |
| <b>Bavaria</b>           | <b>2156</b>            |
| Brandenburg              | 54                     |
| Hesse                    | 225                    |
| 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

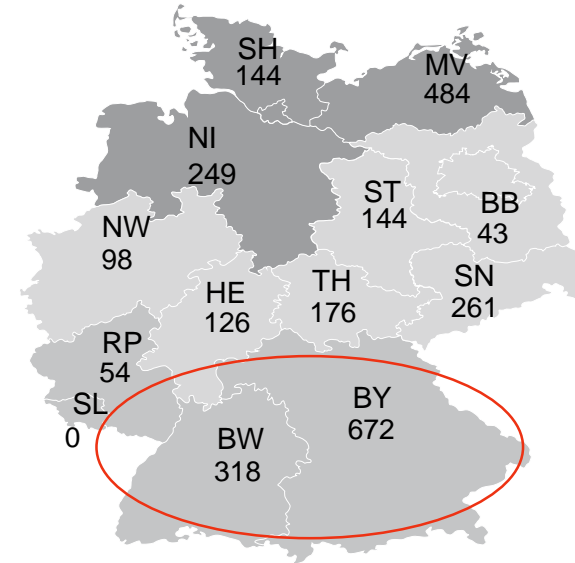
| States                   | Installed Capacity[MW] |
|--------------------------|------------------------|
| <b>Baden-Württemberg</b> | <b>2309</b>            |
| <b>Bavaria</b>           | <b>5747</b>            |
| Brandenburg              | 140                    |
| Hesse                    | 594                    |
| 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 in NATIONAL auction

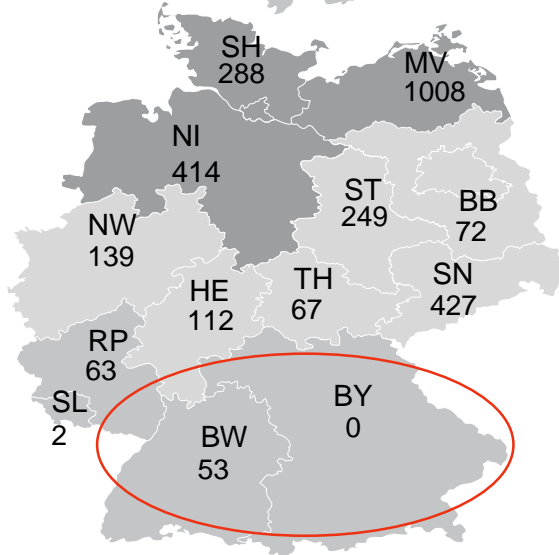
Scenario 1



Scenario 2



Scenario 3



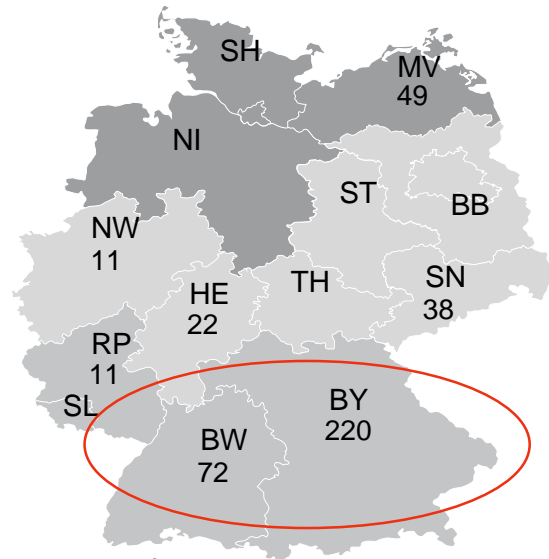
## Main results:

- Increasing permission number leads to less investment in southern states
- Some states (SA, BB) produce very low in all scenarios

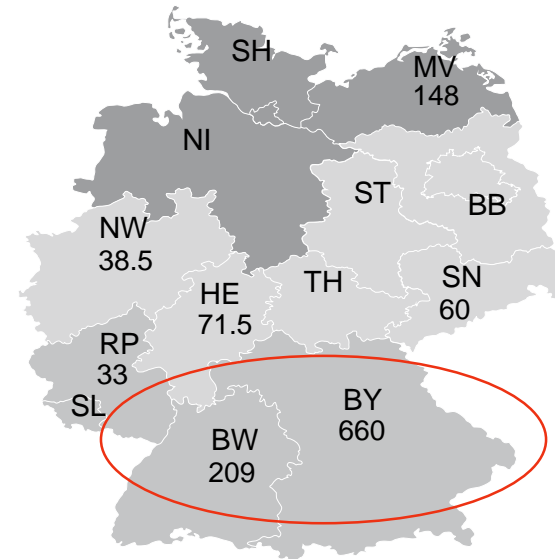


# Results: Diversity of bidders in REGIONAL auction

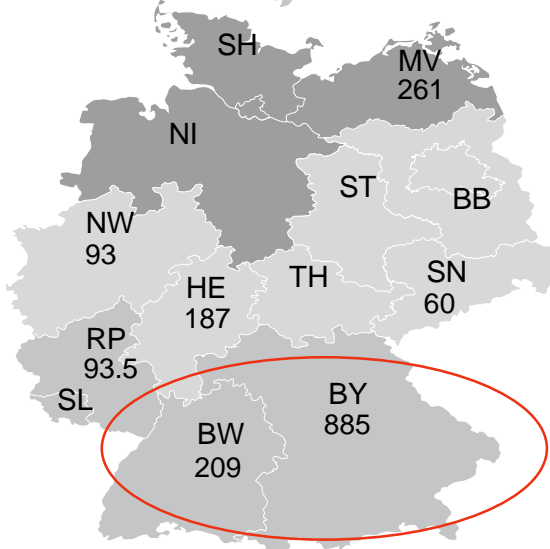
Scenario 1



Scenario 2



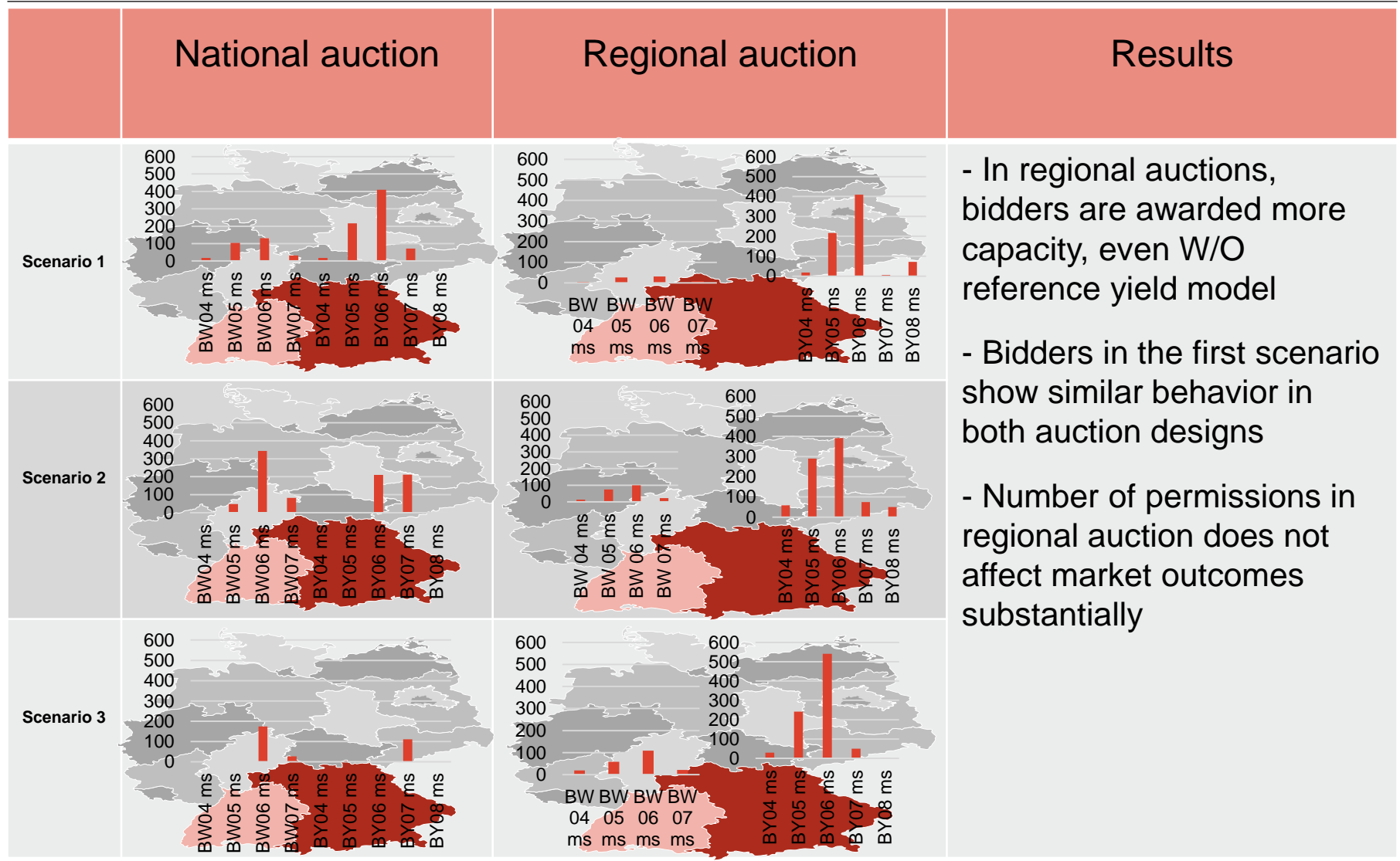
Scenario 3



## Main results:

- Regional auction shows less possible tendered capacity for northern states
- At least 70% of allocated capacity in southern states belong to Bavaria

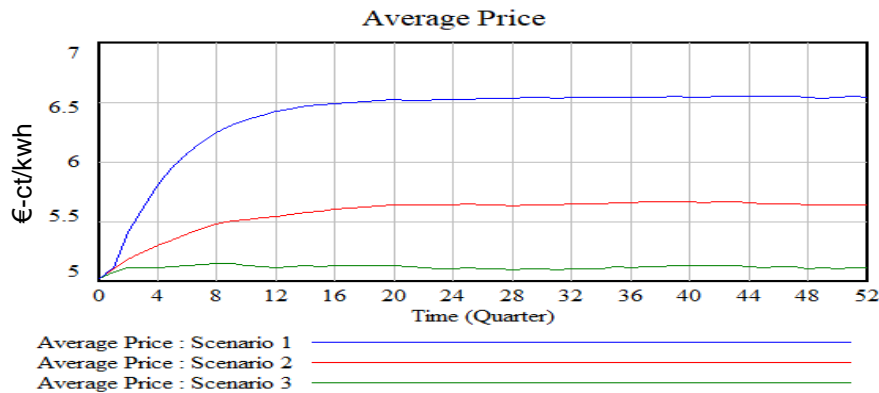
# Results: Diversity of bidders in southern states (2018)



# Results: Average price in different auction designs

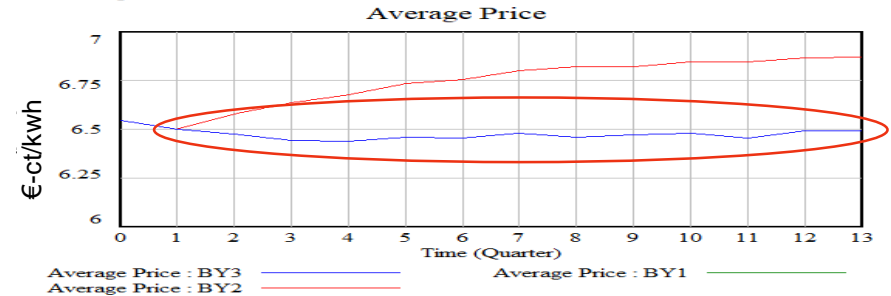
## Average price in NATIONAL auction

- Higher permission number 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)



## Average price in REGIONAL auction

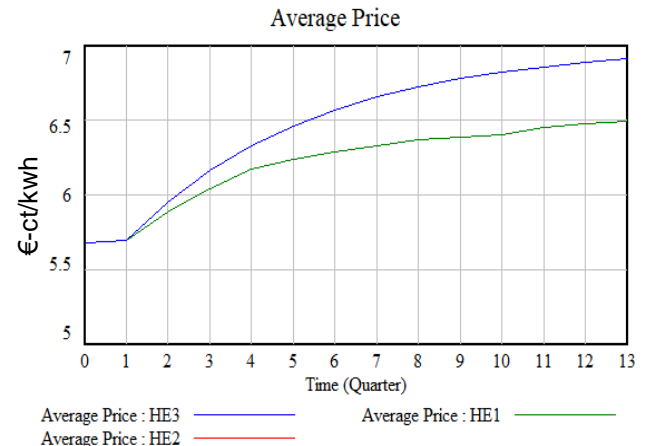
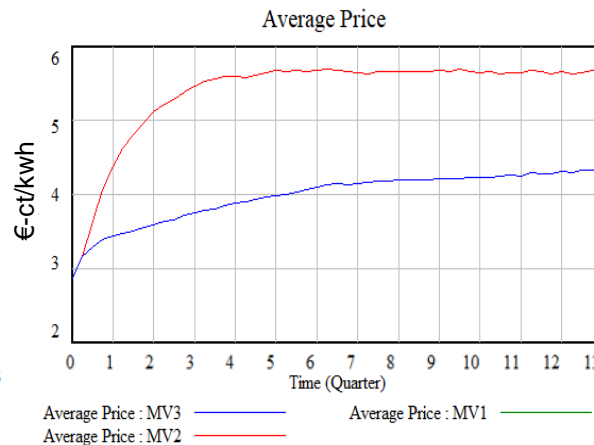
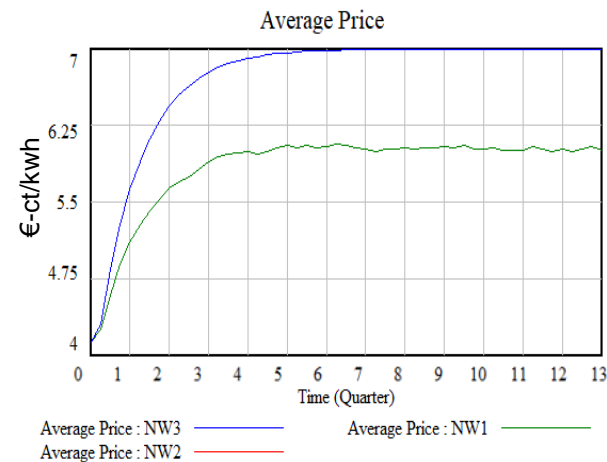
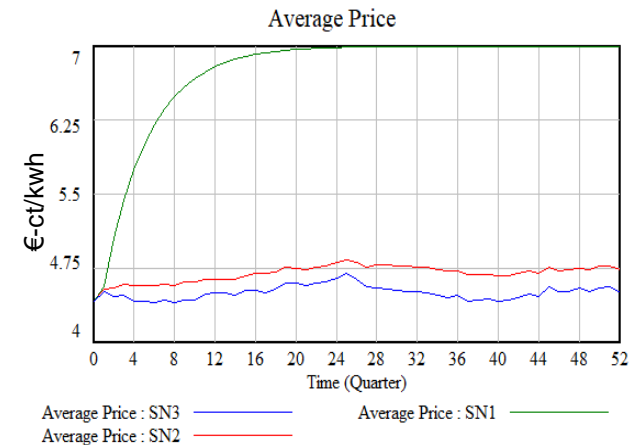
- Average price of southern states can reach higher level in scenario one and two (near to 7 €/ct/kwh )
- Increasing no. of permission in regions with higher wind potential (e.g. southern states) leads to lower prices



# Results: Average price in different auction designs

## Average price in regional auction

- Higher growth price development; increase of bidders' awarded prices
- There is no relation between the number of permissions and the price development
- **Policy implication:** Auctions in federal states need a region-specific design that considered available potential, wind classes, technological characteristic of wind mills



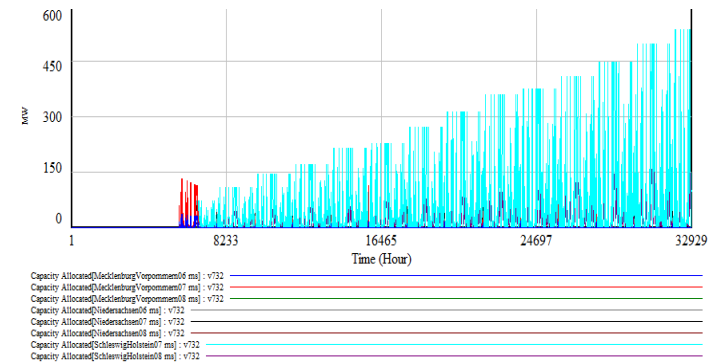
# Results: Overall saving in different auction designs

## Market Premium (MP = MW – AW)

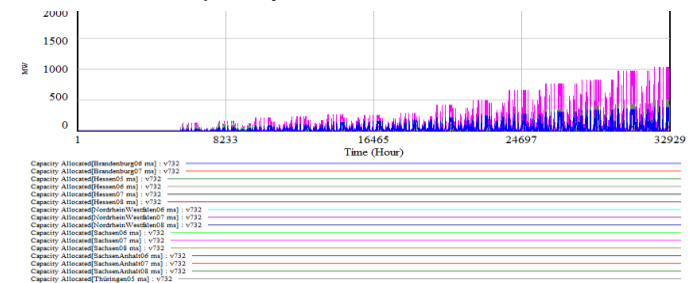
- Full load hours p.a. vary from 735 to 2732 among different regions (42 time series for regions at NUTS-2 level in Germany)
- Installed capacity based on the allocated capacity of the capacity auction module
- Average monthly market value is extracted from HECTOR
- **Policy implication:** Regional auction has lower societal mechanism except for scenario three

| [bn €]     | Support Payment during 20 years |                  |
|------------|---------------------------------|------------------|
|            | National auction                | Regional auction |
| Scenario 1 | 1.5                             | 0.47             |
| Scenario 2 | 1.6                             | 1.44             |
| Scenario 3 | 1.2                             | 1.82             |

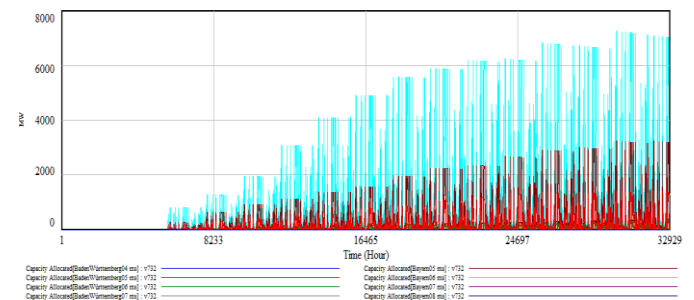
Capacity allocated in north



Capacity allocated in center



Capacity allocated in south



S. Sheykha, F. Borggreffe, R. Madlener, The impact of renewable energy auctions on renewable energy promotion taking spatial dimension into account, IAEE European 2019, Ljubljana, Slovenia, August 25-28, 2019

# Conclusions and next steps

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## Conclusions:

- Auction design **can affect** the promotion of onshore wind significantly; depending on the aim of auctioneer or bidders
- We recommend using **different scenarios** based on previous **permitted capacity** for analyzing capacity auctions
- **Regional auction** helps to promote wind power in the **southern states of Germany**
- Current **reference yield model** is not a **sufficient** tool for the promotion of wind onshore in Germany
- **Regional target** of wind onshore in Germany cannot be reached with current auction design

## Next steps:

- Simulating bidders' behavior to **disruptive changes** (e.g. nuclear or coal phaseout of Germany) in the market
- Inclusion of **transmission congestion** between the federal states
- Using a more **efficient reference yield model**

Many thanks for your attention – any questions?



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