***Market Design for Renewable Energy Auctions: An Analysis of***

***Alternative Auction Formats***

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## Overview

Auctions are widely used to determine the remuneration for renewable energies (RES). They typically induce a high concentration of renewable energy plants at very productive sites far-off the main load centres, leading to an ineffcient allocation as transmission line capacities are restricted but not considered in the allocation, resulting in an inefficient system configuration in the long run. To counteract these tendencies effectively, we propose a combinatorial auction design that allows to implement regional target capacities, provides a simple pricing rule and maintains a high level of competition between bidders by permitting package bids.

## Methods

By means of extensive numerical experiments we evaluate the combinatorial auction as compared to three further RES auction designs, the current German nationwide auction design, a simple nationwide auction, and regional auctions. the focus of this paper is to assess and evaluate the impact of different RES auction designs on the resulting allocative efficiency and subsidy payments, i.e. the cost for the taxpayer. The short time span since most RES auction schemes are in place and the limited data availability renders an empirical evaluation of different RES auction designs infeasible. Moreover, since combinatorial auctions have not been used for this purpose in practice, a counterfactual analysis of different auction designs with field data is impossible. We therefore conduct extensive numerical experiments,with our analyses based on the case of RES auctions in Germany. Germany constitutes an excellent starting point for our study, as both comprehensive market data as well as information on system-optimal RES locations are available to calibrate the numerical model.

In our numerical study, we focus on onshore wind auctions, as onshore wind power is the capacity-wise largest renewable energy technology in Germany (section 28 EEG, 2017; Federal Ministry for Economic Affairs and Energy, 2018). We compare the current design, a nationwide auction with reference yield model (REM), to (i) a simple nationwide auction design, (ii) a regional auction design that implements the desired regional capacities and (iii) a combinatorial auction design that implements the desired regional target capacities but maintains a sufficient level of competition. The regional target capacities are taken from a study by Grimm et al. (2017), who determine the optimal RES locations in Germany accounting for the location of load centres and available network capacities.

## Results

We find that if bidders benefit from high enough economies of scale, the combinatorial auction design implements system-optimal target capacities without increasing the average remuneration per kWh as compared to the current German auction design. This is surprising, given that the combinatorial auction exactly implements regional target capacities at less productive sites closer to demand centres, while the current nationwide auction design does not face those constraints. Notably, this remunerations does not even include long-run cost savings resulting from lower redispatch and network investment requirements when regional target capacities are met, the cost for which easily exceed a billion Euro per year (e.g. €1.5bn in 2017) and are largely caused by the regional mismatch of supply and demand (Federal Network Agency and Federal Cartel Office, 2019).

The prices resulting from the combinatorial auction are linear and anonymous for each region whenever possible, while minimal personalised markups on the linear prices are applied only when necessary. We show that realistic problem sizes can be solved in seconds, even though the problem is computationally hard.

## Conclusions

Combinatorial auctions come at the cost of computational complexity for the auctioneer since the allocation problem that needs to be solved is an NP-hard combinatorial optimisation problem. In our experiments, we show that realistic problem sizes can be solved in seconds due to the large number of relatively small bidders. For bidders, combinatorial auctions are strategically simpler than having to bid in a sequence of auctions.

In particular, institutional bidders can bring their scale economies to bear with package bids, which reduces costs. Overall, the combinatorial auction design proposed in this paper is a viable alternative to location-specific auction mechanisms like the German REM. Furthermore, it constitutes a candidate design for renewable energy auctions not only in Germany, but also in other countries worldwide where auctions are used to support the expansion of renewable energy capacity.

## References

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