TRADE-OFFS ASSOCIATED WITH THE SPATIAL ALLOCATION OF FUTURE ONSHORE WIND GENERATION CAPACITY – A CASE STUDY FOR GERMANY

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Overview

The expansion of renewable energies is a key requirement to global climate protection efforts. However, especially the use of wind energy can be associated with negative local effects. With the continuous expansion of onshore wind energy, such conflicting objectives and trade-offs become apparent, for example, between low electricity generation costs and negative effects on the local environment or humans living in direct vicinity to wind turbines. In this paper, we analyze how significant these trade-offs are. We aim to understand to what extend they depend on the spatial allocation of wind turbines and the overall level of wind power deployment.

Methods

A GIS-based approach to answer these questions first assesses the overall generation potential of onshore wind energy in Germany [1-4]. About 106,000 potential wind turbine sites with an annual energy generation potential of 778 TWh are identified, which is almost 10 times the energy provided by onshore wind power in Germany in the year 2017 [5]. Subsequently, each individual site is evaluated with respect to electricity generation and residential costs. Electricity generation costs are determined as the levelized costs of electricity of a 20-years-live span of a representative wind turbine [6]. Residential costs are computed using previous willingness-to pay studies and considering both the distance to and the population of neighboring communities [7, 8]. Next, two separate numerical optimizations are carried out [9] to show to what extend trade-offs can be identified when either generation costs or costs for residents are targeted by the optimization.

Results

The results of the optimizations show a significant trade-off between electricity generation costs and residential costs (Figure 1). Accordingly, a generation cost minimal allocation has to be traded for higher resident costs and vice versa. Trade-offs increase up to a deployment level of 500 TWh per year, and start declining again beyond this level. In general, residential costs increase sharply the more priority is given to the minimization of electricity generation costs (see pareto frontiers in Figure 1). This suggest that socially optimal spatial allocation (minimizing both types of costs) is relatively close to the one that minimizes residential costs.

The associated spatial allocation pattern of wind turbines for an annual wind generation of 200TWh were likewise visualized (Figure 2). The resulting spatial allocation patterns of a residential cost minimal allocation differs likewise significantly in comparison to a generation cost minimal allocation.

Conclusions

From the obtained results, we conclude that a significant and increasing trade-off between a generation cost minimal spatial allocation and a residential cost minimal spatial allocation exists which is potentially increasing wih the further expansion of wind power in Germany. Consequently, policies promoting wind power development solely on the basis of generation cost – an approach strongly promoted by the European Commission, for example – need to be scrutinized critically from a cost-effectiveness perspective.

In the further course of a multi-year research project on the assessment of multiple externalities associated to renewable energies, this approach will be expanded by including additional cost components and sustainability objectives, in particular with regard to non-monetarized impairments like visual impacts on the landscape and nature conservation. The overall goal is to improve the scientific knowledge base regarding externalities of renewable energy sources and to provide policy makers with recommendations to address the various trade-offs associated with renewable energies.

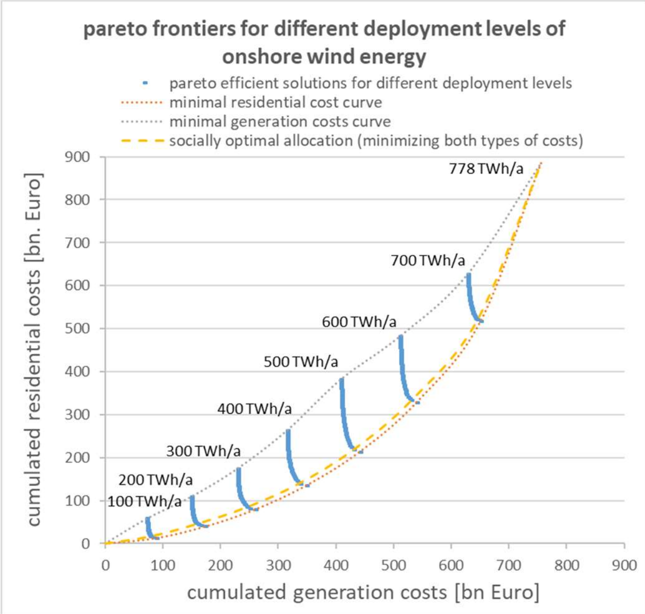

Figure 1: Cost curves and pareto frontiers of an allocation of onshore wind turbines in Germany for different deployment levels of wind energy in TWh.

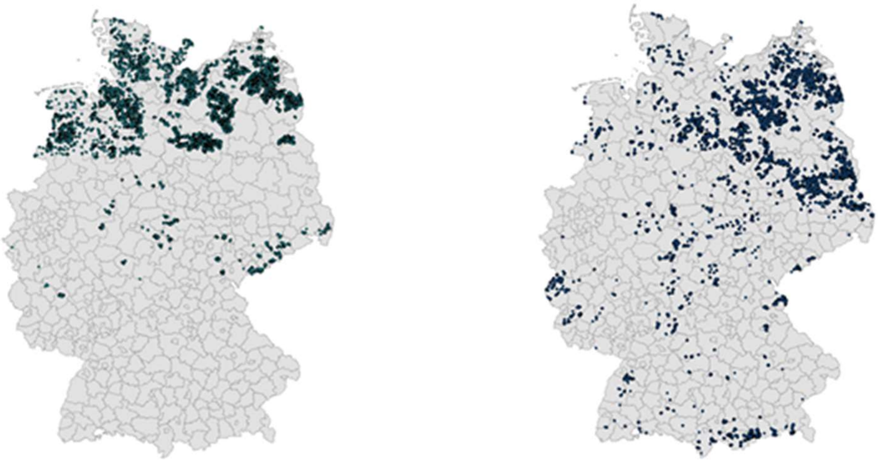

Figure 2: Resulting distribution pattern of onshore wind turbines in Germany for a generation cost minimal allocation (left side) and a residential costs minimal allocation (right side) for a wind generation target of 200TWh/a.

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