WIND POWER DEVELOPMENT IN GERMANY: SPATIAL PLANNING INSTRUMENTS AND EXTERNALITY TRADE-OFFS

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Overview

By 2030, the German government aims at producing 80% of gross electricity consumption from renewable energies [1]. To reach this goal, a substantial expansion of wind power onshore is necessary. Yet, while wind power production reduces carbon dioxide emissions in the power sector, wind turbines may also excert negative exteranlities for humans and nature. For example, turbines can be associated with noise emissions, reduced scenic quality or negative effects on wind power sensitive bird and bat species [2]. The level of these effects varies at a spatial scale, e.g. due to different levels of scenic quality or bird habitat quality [3,4]. To reduce the negative externalities from wind turbines, the selection of ares for wind power development is usually governed by spatial planning tools, such as distance regulations or the exclusion of specific areas. In Germany, for example, depending on the federal state of interest, wind power development is restricted in forest areas or at certain distances to settlements. While such spatial planning tools can be very effective in reducing the level of individual externalties, they typically do not account for changes in the level of other exteranlities that they provoke. In a spatial context, this aspect is especially relevant when it comes the the above described externalities. For example, excluding forest areas from wind power development can imply that instead, wind turbines need to be installed closer to settlements, thereby increasing associated negative effects for residents. In addition, the combined effect of individual spatial planning policies on the overall availability of areas for wind power development can be critical when specific expansion targets are in place. Against this background, we analyse the economic, social and environmental effect of wind power development for different spatial planning policy scenarios in Germany. We quantify the trade-offs between the levels of different externalities that are associated with spatial planning tools targeted at indivudal externalities only, with and without a power production target in place. Likewise, we quantify the combined effect of all spatial planning tools considered on the availability of areas for wind power deployment and on the levelized cost of electricity (LCOE) generation for a specific production target.

Methods

The analysis relies upon a multi-criteria GIS-based assessment of potential areas for onshore wind power development in Germany. To capture the social and ecological externalities associated with wind power production in a specific area, several area characteristics are identified. These include the distance to settlements as well as whether an area is located in the forest or a bird protection zone. In addition, average LCOE are calculated for each area based on the respective average wind yield. The spatially-explicit GIS data is then used as input for the statistical analysis of area characteristics under different policy scenarios. Thereby, we quantify the externality trade-offs and changes in average LCOE associated with specific spatial planning instruments. This analysis is conducted for all potential areas for onshore wind power production as well as only for those areas that are selected in an optimization scenario. In the latter, we assume that a certain electricity production target for wind power should be reached and select potential areas such that the LCOE of wind power production are minimized. We then assess the externality characteristics of the selected areas to quantify the trade-offs between policy scenarios. The optimization scenario is carried out for targets of 151 TWh and of 309 TWh onshore wind power production, which correspond to the estimated amount of onshore wind power that is necessary by 2030 and 2045, respectively, to reach the German goal of climate neutrality by 2045 [5].

Results

The preliminary results of our analysis show that addressing spatial externalities of wind power deployment with spatial planning tools can cause considerable externality trade-offs. The level of these trade-offs relies upon two factors: the spatial correlation and the spatial heterogeneity of area characteristics. For example, excluding forest areas from wind power development results on average in smaller distances between turbines and residents, thereby increasing respective negative externalities such as noise emissions or shadowing. This effect is based on the negative spatial correlation of the two area characteristics “distance to settlements” and “location in a forest”. Yet, the forest ban is not associated with significantly higher costs of wind power production (LCOE), because the spatial correlation between wind yield and forest areas is negative. In addition, the increase in externality costs from residential disamenities caused by the exclusion of forest bans is rather high, due to the considerable spatial heterogeneity in residential externalities across potential areas for wind power production. The described effects are even stronger in the optimization scenarios.

The externality trade-offs and the associated change in average LCOE are calculated for several policy scenarios:

- the exclusion of all forest areas or of only broadleaf and mixed forests
- two different ecological approaches for the exclusion of protection zones for wind power sensitive bird species
- minimum distances between wind turbines and settlements of 800m, 1km, 1,5km and 2km
- the implementation of a 70% or 80% reference yield model in the auctioning process for wind power projects

Each of these policy scenarios results in a reduction of the potential areas for onshore wind power deployment that aims at reducing a specific externality. Yet, we find that when the considered spatial planning instruments are implemented simultaneously, the availability of the potential area is reduced significantly, such that the production targets for 2030 or 2045 can not be achieved.

Conclusions

The negative spatial externalities of large infrastructure projects, such as onshore wind turbines, are usually regulated with spatial planning instruments, especially with area exclusions or distance regulations. While these policies can be very effective in reducing one externality, they typically ignore their impact on other spatial externalities. We show that these indirect effects of spatial planning instruments cause significant externality trade-offs in the case of onshore wind power deployment in Germany. By quantifying these trade-offs, we demonstrate the opportunity costs associated with spatial planning tools designed to govern individual externalities. We find that the level of externality trade-offs depens on both the spatial correlation and the spatial heterogeneity of area characteristics.

So far, the externality trade-offs associated with individual spatial planning instruments are mainly neglected in public and political debates about policy design for the spatial regulation of wind power deployment. With our analysis, we want to inform this debate and create transparency regarding the opportunity costs of individual spatial planning tools. In addition, we find that the simultaneous implementation of several spatial planning tools addressing different externalities results in a significant reduction of areas for the development of onshore wind power, such that national wind power expansion targets cannot be reached.

References

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