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ORIGINAL PAPER

Blowing Against the Winds of Change? the Relationship Between AW Initiatives and WT in Germany

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Abstract This study investigates the spatial emergence of anti-wind (AW) initiatives in Germany and their relationship to wind turbine (WT) development. Combining information on more than 800 AW initiatives with detailed geolocated WT data, the study develops a novel spatiotemporal perspective on the regional dynamics of AW mobilisation. Using spatial survival models, we analyse how existing WT infrastructure, anticipated WT expansion, and nearby AW initiatives shape the likelihood of new initiative formation. The findings provide no support for the proposition that existing WT stocks themselves systematically increase AW mobilisation. Instead, AW initiative formation appears to be associated more strongly with social diffusion processes. In particular, existing AW initiatives significantly increase the likelihood of nearby initiatives emerging, suggesting important roles for organisational learning, social networks, and supra-local mobilisation structures. Overall, the results suggest that AW mobilisation develops less as an isolated local reaction to existing WT infrastructure than through regional spillovers and diffusion dynamics.

Keywords Local opposition · Wind energy · Acceptance · Anti-wind initiatives

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1 Introduction

The expansion of wind energy is a central pillar of contemporary climate change mitigation strategies (Wiser et al. 2011). In Germany, the introduction of the Renewable Energy Sources Act (EEG 2000) established favourable institutional conditions for renewable-energy expansion and substantially accelerated the deployment of onshore wind energy. Over the subsequent two decades, the number of installed wind turbines (WT) increased from approximately 9000 in 2000 to around 30,000 in 2020 (BWE 2022). At the same time, however, WT deployment has remained highly uneven geographically, with a pronounced north-south gradient reflecting differences in wind conditions and regional planning frameworks (Bunzel et al. 2019; Germer and Kleidon 2019). Since around 2017, the pace of WT expansion has slowed considerably, increasingly accompanied by public and political conflicts surrounding further expansion (Bosch and Schmidt 2020).

Debates surrounding wind energy have increasingly focused on social acceptance and local opposition in Germany (Reusswig et al. 2016a; Schultz 2019) and in many other countries (Enevoldsen and Sovacool 2016; Suškevičs et al. 2019; Walker et al. 2014). Early empirical studies generally reported comparatively high levels of public support for wind energy (Thayer and Freeman 1987; Walker 1995; Wolsink 1988, 1989). However, there are growing tensions between broad societal support for renewable energy transitions and increasing local resistance to specific projects or to further regional expansion (Bell et al. 2005). Existing explanations emphasise a wide range of factors, including landscape change, procedural justice, environmental concerns, distributional conflicts, and local participation processes (Aitken 2010; Devine-Wright 2005, 2009, 2013; van der Horst 2007; Wolsink 2007a, 2018). At the same time, empirical findings remain heterogeneous regarding the extent to which existing WT exposure itself contributes to the emergence of organised local protest.

The present study contributes to this debate by investigating the spatial emergence of formalised anti-wind (AW) initiatives in Germany. While previous research has examined attitudes toward WT and the underlying mechanisms of local opposition in considerable detail (Enevoldsen and Sovacool 2016; Jones and Eiser 2010; Sovacool and Ratan 2012; Swofford and Slattery 2010; Wolsink 2018), comparatively little attention has been devoted to the spatial dynamics underlying the emergence and diffusion of organised AW protest initiatives. Specifically, we examine two potential drivers of AW initiative formation: WT infrastructure in the region and nearby AW initiatives. In contrast to most existing studies, which rely primarily on qualitative case studies or survey evidence, we employ a quantitative spatiotemporal approach using detailed information on more than 700 AW initiatives and time-to-event regression models.

Our findings paint a more differentiated picture of AW mobilisation than commonly assumed in public and academic debates. Existing WT stocks do not exhibit a robust positive relationship with the emergence of AW initiatives once broader future-development dynamics are explicitly accounted for. Instead, the results suggest that AW mobilisation cannot be understood primarily as a direct local reaction to existing WT infrastructure. Rather, initiative formation appears to be embedded in broader spatial diffusion processes, organisational learning, and supra-local mobilisation structures.

The remainder of the paper is structured as follows. Section 1 reviews the theoretical literature on WT acceptance and AW mobilisation and derives the study's hypotheses. Section 2 describes the employed data sources and the construction of the empirical dataset. Section 3 introduces the methodological approach and identification strategy. Section 4 presents the empirical findings. Section 5 concludes by discussing implications for future research and renewable-energy planning.

2 Acceptance of WT and Formation of Local Opposition

Wind energy enjoys broad public support in Germany and other European countries, particularly when considered as part of the transition toward renewable energy systems (TNS Emnid 2014; TNS Emnid 2015; TNS Infratest 2012). At the same time, this general support does not necessarily translate into local acceptance of specific WT projects. Numerous studies document that attitudes toward the local establishment of WT are considerably more ambivalent and may become strongly negative under certain conditions (Schweizer-Ries 2010; Wolsink 2007a; Zoellner et al. 2008), even though more recent work suggests that public attitudes have again become somewhat more positive in recent years (Levi et al. 2023). In many cases, such negative local sentiments are expressed through AW initiatives opposing the construction or expansion of nearby WT and rejecting acceptance-promoting planning approaches (Thayer and Freeman 1987).

The local conflicts surrounding WT are closely related to their character as spatially concentrated land uses. Similar to other forms of locally unwanted land use (LULUs), WT generate both benefits and costs that are unevenly distributed across space (Jobert et al. 2007; Selle 2015). Following Popper (1985), LULUs are infrastructures or facilities considered beneficial or necessary from a broader societal perspective while simultaneously imposing substantial burdens on their immediate surroundings. Conceptualising WT as LULUs provides a broader and less reductionist perspective than the frequently criticised notion of the NIMBY ("Not In My Backyard") syndrome, which has been argued to oversimplify and pathologise local opposition (Devine-Wright 2005; Aitken 2010; Wolsink 2007b). Swofford and Slattery (2010) consequently recommend abandoning the concept altogether in public and policy debates.

WT represent a prominent example of such spatial conflicts in Germany. National and regional policies strongly promote the expansion of renewable energy generation, whereas parts of the local population perceive WT as intrusive due to visual impacts, noise, ecological concerns, or perceived health risks (Wang and Wang 2015). Existing evidence further suggests that WT may negatively affect nearby property values and housing prices (Gibbons 2015; Jensen et al. 2018), thereby intensifying local opposition. WT are also argued to alter landscape aesthetics and potentially reduce tourist attractiveness (Author et al. 2015).

WT can only be installed in locations fulfilling certain technical and geographical requirements, including sufficient wind conditions and suitable land availability. As a consequence, the costs associated with wind-energy development are disproportionately sustained by specific places and populations, whereas many of the broader benefits of renewable-energy production accrue at regional or national scales. Even within the same locality, benefits and costs are distributed unevenly. Some actors, such as developers, municipalities, landowners, or energy cooperatives, may benefit financially from WT projects, while others primarily experience their negative side effects. Although financial participation can increase local acceptance of nearby WT projects, such compensation mechanisms appear substantially less effective among determined opponents (Knauf 2022). These spatial and social imbalances are therefore likely to contribute to local conflicts surrounding wind-energy development (Walker and Baxter 2017a).

At the same time, responses to WT differ substantially across places and populations. Existing research emphasises the importance of institutional, historical, and geographical context in shaping local acceptance (Simcock 2016). Several studies also show that participation and ownership structures may positively affect local attitudes toward WT. Direct financial participation through community ownership models, active involvement in planning processes, and previous experience with WT have repeatedly been associated with higher levels of local acceptance (Musall and Kuik 2011; Cowell et al. 2011; Johansen and Emborg 2018; Walker and Baxter 2017b; Warren and McFadyen 2010; Süsser and Kannen 2017; Langer et al. 2016). Furthermore, populations may adapt to existing WT over time, perceiving them as less disruptive once they become established elements of the local landscape (Wilson and Dyke 2016). Empirical evidence regarding the spatial range and intensity of such effects remains mixed. For example, Langer et al. (2018) do not identify a significant relationship between residential proximity to WT and local acceptance. In contrast, Stokes et al. (2023) find that taller, and generally more WT, individuals are more likely to oppose in the USA and Canada.

These findings suggest that the relationship between WT and local opposition is neither mechanically positive nor spatially uniform. Nevertheless, the existing literature consistently points toward local exposure to WT as an important factor shaping AW sentiments and mobilisation processes. Ladenburg and Dahlgaard (2012), for example, identify a threshold effect in which acceptance declines substantially once individuals encounter more than 5 WT regularly. Reusswig et al. (2016b) show that local opposition often emerges once concrete WT projects become publicly discussed or planned. Their findings suggest that mobilisation often begins at the planning stage, before additional WT are installed. Similarly, Weber et al. (2017) find that AW initiatives are frequently motivated by concerns about landscape change, environmental impacts, health effects, and potential economic consequences, such as declining property values or reduced tourist attractiveness. While initiatives differ substantially in their goals and intensity, the literature suggests that WT and their planned expansion constitute important triggers of AW mobilisation.

From an empirical perspective, an additional complication arises because existing WT may also indicate favourable conditions for future WT expansion. Municipalities with large existing WT stocks are more likely to see additional projects in the future due to favourable geographical, political, or infrastructural conditions. Consequently, observed relationships between existing WT and AW initiatives may partly reflect expectations regarding future development rather than reactions to existing turbines alone. Distinguishing between these mechanisms is empirically challenging because information on planned future projects is generally unavailable. This issue is addressed explicitly in the empirical strategy below.

Overall, the existing literature suggests that local exposure to WT increases the likelihood of AW mobilisation, even though adaptation and participation mechanisms may weaken or offset these effects in certain contexts. This motivates the first hypothesis:

H1 The emergence of AW initiatives is more likely in spatial proximity to existing WT.

By testing this hypothesis, we seek to contribute systematic empirical evidence to a literature that has so far relied predominantly on qualitative case studies, interviews, or surveys.

Beyond the direct effects of WT themselves, the emergence of AW initiatives may also be shaped by spatial spillover dynamics between initiatives. Reusswig et al. (2016b) point out that existing initiatives may inspire the formation of additional initiatives elsewhere. Such spillovers may emerge through observational learning, imitation, information exchange, or organisational support structures. Individuals opposing WT projects may become aware of existing initiatives in nearby regions, observe their activities and strategies, and subsequently mobilise themselves. Given the inherently spatial character of social interaction and observational learning (Author et al. 2007), nearby initiatives are likely to exert stronger influence than distant ones.

The increasing professionalisation of AW initiatives in Germany may further reinforce these processes. Existing initiatives have increasingly become embedded in regional and national umbrella organisations that provide legal advice, strategic guidance, communication infrastructure, and organisational support. Such structures facilitate contacts between existing initiatives and actors interested in founding new ones, thereby potentially increasing the spatial diffusion of AW mobilisation. If such processes are present, the geographical distribution of AW initiatives may become self-reinforcing over time.

Despite the potentially important implications of these spillover dynamics for the spatial concentration of AW mobilisation, systematic quantitative evidence remains limited. We therefore explicitly consider this mechanism in our second hypothesis:

H2 AW initiatives stimulate the emergence of further AW initiatives in their spatial proximity.

3 Empirical Approach

3.1 Data and Variables

Our study follows Guggenberger (2021) in defining AW initiatives as formalised associations of citizens that organise collective opposition to WT projects to exert political pressure. According to Weber et al. (2018), such initiatives can substantially complicate or delay planning processes, while planners frequently perceive them as particularly problematic actors in local development conflicts (Stegen and Seel 2013). AW initiatives, therefore, represent institutionalised forms of AW protest rather than merely individual expressions of dissatisfaction.

The empirical analysis is based on a newly assembled dataset of AW initiatives in Germany. Information on AW initiatives was initially collected from the protest platform Windwahn.com (as of June 2017), which contains names, contact information, and georeferenced descriptions of initiatives across Germany (Windwahn.com 2017). Since registration on the platform is based on self-reporting, the reliability and completeness of the underlying information are not fully transparent. We therefore conducted extensive manual data cleaning and verification procedures addressing duplicate entries, incomplete information, and obviously incorrect observations.[1] Additional concerns arise from the possibility that self-reported protest platforms systematically overrepresent regions with particularly strong traditions of civic activism or environmental mobilisation.

To improve data reliability, we complemented the platform information using official registry entries, websites, newspaper reports, social media information, and direct contacts with initiatives. In October 2017 and again in January 2018, we contacted all registered initiatives via surveys and short telephone interviews to obtain information on organisational form, founding dates, and relations with other protest groups. Although the response rate remained comparatively low (6.6%), respondents consistently identified Windwahn.com as the central national platform for AW initiatives in Germany and did not indicate major systematic omissions. In total, we were able to determine the founding date, location, and organisational form for 817 of the 910 initiatives we identified. The remaining 93 observations with incomplete information were excluded from the analysis. While some degree of measurement error cannot be ruled out entirely, the resulting database represents the most comprehensive spatiotemporal dataset on AW initiatives currently available for Germany.

Based on these data, we construct our dependent variable, **FORMATION**, which captures the year in which the first AW initiative emerged in a municipality. In almost all cases, municipalities host only one formalised AW initiative because these organisations typically aggregate local AW sentiment within a single institutional structure. In the few cases in which multiple initiatives emerged within a single municipality ($n=5$), we focus exclusively on the first initiative-formation event.

[1] During the cleanup process, we removed duplicate entries, empty columns, and obviously false information. Initiatives that could not be verified by a register and Internet search were retained.

The second core dataset concerns the geographical distribution of WT in Germany. Information on WT locations was obtained from EnergyMap.info (2019), which compiles data from Germany's four transmission system operators and has been used in previous studies (e.g., Author et al. 2015; Authors 2018). The database was considered highly reliable until mid-2014, after which transmission system operators were no longer required to provide complete information. Consequently, the dataset contains information on approximately 25,138 WT, rather than the roughly 28,675 WT known to exist in Germany by the end of the observation period. Visual inspections and supplementary trend analyses nevertheless did not indicate any major structural break in the installation dynamics around this period.

In a limited number of cases, WT coordinates correspond to municipal centroids rather than exact installation locations. We therefore aggregate all information to the municipal or municipal-association level, which constitutes the spatial unit of analysis. Municipal associations (Gemeindeverbünde) combine smaller municipalities into more comparable administrative units (Bundesinstitut für Bau- and Stadt- and Raumforschung (BBSR) 2018), yielding a final dataset of 4465 spatial observations. Because the average municipal diameter is approximately 5 km, very small-distance calculations would not be meaningful. We therefore operationalise WT exposure using broader distance bands. The variables **WT.5, WT.10, WT.25**, and **WT.50** measure the number of existing WT within 5, 10, 25, and 50 km radii from the centroid of the focal municipality, respectively. Due to the highly skewed distributions of WT counts, all WT variables are log-transformed. Importantly, the selected thresholds should not be interpreted as attempts to identify precise critical distances at which WT influence protest mobilisation. Rather, they represent different regional exposure environments. This is particularly relevant because minimum planning distances between WT and settlements differ substantially across German federal states (Fachagentur Windenergie 2024).

To test H2, we construct variables that capture the number of existing AW initiatives in surrounding municipalities at different spatial radii. The variables **INI.10, INI.25**, and **INI.50** measure the number of existing initiatives within 10, 25, and 50 km, respectively. Preliminary analyses showed that **INI.5** was nearly identical to **INI.10**, which is why INI. 5 was excluded from subsequent analyses. Additional robustness analyses using **INI.50** rather than **INI.25** yielded substantively similar results.

The empirical models further include a range of regional control variables. **POPULATION** captures municipal population size, while **POPULATION.DENSITY** approximates the degree of urbanisation. Since WT deployment is strongly associated with wind conditions, we additionally include **DISTANCE.COAST**, measuring the shortest geographic distance to the North Sea or Baltic Sea coastline (Jung and Schindler 2018). Protected landscapes may generate particularly strong local resistance to WT projects (Nordman and Mutinda 2016). We therefore include **DISTANCE.PROTECT**, measuring the distance between a municipality and the nearest protected area (indicated by codes "71006" and "71011") based on the Digital Landscape Model (DLM250) provided by the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie and Geodäsie 2018).

To capture broader landscape characteristics, we include the variable **ATTRACTIVITY**, an index developed by the Federal Institute for Research on Building, Urban Affairs, and Spatial Development (Bundesinstitut für Bau- et al. 2019). The index summarises regional landscape attractiveness based on relief energy, forest coverage, water surfaces, coastlines, and uninterrupted open spaces. Since local socio-demographic structures may shape environmental attitudes and protest mobilisation (Cloutier et al. 2018; Devine-Wright 2005; Reusswig et al. 2016a, 2016b; Thaler and Seebauer 2019), we additionally include the share of the population aged 65 years or older (**AGE**) and the electoral vote share of Bündnis 90/Die Grünen (**GREENS**) in federal elections between 1994 and 2017. We interpret the latter primarily as a proxy for broader environmental orientations and civic mobilisation potential rather than as a direct measure of party-political influence on WT planning.

The analysis covers the period from 1990 to 2017. Since the explanatory variables differ in their temporal structure, the data combine both time-invariant and time-varying information. Variables such as distance to the coast remain constant over time, whereas population-related variables vary annually. Election results are only observed intermittently; for years without elections, we linearly interpolate the corresponding values between adjacent election years.

3.2 Methods

We seek to identify regional factors influencing the probability of AW initiatives forming. Correspondingly, we analyse how spatial-structural factors shape variation in the occurrence of AW initiative formation across municipalities and over time. To do so, we employ survival models, also referred to as event-history analysis. Originally developed in medical research to model the occurrence of events such as infection or death conditional on explanatory variables (Fox and Weisberg 2011), survival models are now widely used across the social sciences. Examples include the analysis of the diffusion of political ideas (Darmofal 2009) or company entries (Buenstorf 2007).

More specifically, we estimate mixed-effects Cox proportional hazards models (Cox 1972) in counting-process form using annual start-stop intervals. The dataset is structured as a municipality-year panel in which each municipality is observed annually from 1990 until either the first formation of an AW initiative or the end of the observation period. Municipalities, therefore, remain "at risk" until the first occurrence of the event, after which they exit the risk set. This specification naturally accommodates both time-varying and time-invariant explanatory variables. Variables such as the number or density of WT are therefore measured separately for each municipality-year observation, whereas variables such as distance to the coast or landscape attractiveness enter as baseline regional characteristics.

The Cox model can be written as:

$$h(t) = h_0(t)\exp(\beta\prime x(t))$$

where $h(t)$ represents the hazard rate of event occurrence at time t, i.e., the instantaneous likelihood that an AW initiative forms at time t conditional on no prior formation; $h_0(t)$ denotes the baseline hazard; $x(t)$ is the vector of explanatory variables; and β represents the corresponding coefficients (Perkins and Neumayer 2005).

The reason for employing survival models rather than OLS or standard binary logistic regression is the censoring structure inherent in the data. In this context, censoring implies that some municipalities do not experience AW initiative formation during the observation period, even though such events may occur later outside the observed time window. Survival models explicitly account for this feature, thereby reducing the likelihood of biased estimates (Mills 2011).

We use semi-parametric Cox models because they do not require assumptions regarding the functional form of the baseline hazard, thereby reducing the risk of model misspecification. Compared to fully parametric alternatives such as Weibull or Gompertz models, this flexibility may come at the cost of lower estimation efficiency when the true underlying hazard distribution is correctly specified (Box-Steffensmeier and Jones 2012; Darmofal 2009). Given the absence of strong theoretical expectations regarding the shape of the baseline hazard in this context, the Cox specification offers a suitable compromise between flexibility and interpretability.

The spatial structure of the data suggests spatial dependence among municipalities. In principle, this could be addressed using Bayesian spatial survival models (Zhou and Hanson 2018). However, the practical implementation of such approaches remains challenging in many standard software environments, particularly when combining time-varying covariates and large panel structures. We therefore employ mixed-effects Cox regression models with random intercepts. Specifically, we estimate random intercepts at the district level to account for unobserved heterogeneity and shared contextual conditions among municipalities within the same district (Therneau et al. 2003).

We do not include municipality fixed effects. Such fixed effects would absorb all time-invariant municipality-level variation and are less suitable in settings where the event of interest can occur at most once per observational unit. In the present context, the relevant variation lies in explaining why some municipalities form an AW initiative first while others do not.

Districts are used as grouping units because broader spatial, political, and economic structures are expected to matter in this context. Districts (NUTS3 regions comprising roughly 30 municipalities) are Germany's key regional administrative units with important planning and policy responsibilities. Consequently, the random-effects specification partially accounts for shared institutional and political contexts that may generate spatial dependence between municipalities within the same district. In addition, the explicit modelling of WT and existing AW initiatives in neighbouring municipalities, as well as time-invariant spatial characteristics such as distance to the coastline, further absorbs relevant spatial dependencies.

The estimated coefficients are logarithmic hazard ratios that are transformed into hazard ratios for easier interpretation. Hazard ratios larger than one indicate that increases in the corresponding explanatory variable raise the likelihood of AW initiative formation, whereas values below one indicate a reduction in the hazard. The WT variables are log-transformed using $\log(1 + x)$. Consequently, the estimated

Table 1 Determinants of FORMATION, WT 5 and 10 km

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
POPULATION	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)
DISTANCE.COAST	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)
DISTANCE.PROTECT	0.978* (0.011)	0.978* (0.011)	0.978* (0.011)	0.980+ (0.010)	0.979* (0.010)	0.979* (0.010)	0.978* (0.011)	0.977* (0.010)	0.979* (0.010)	0.980+ (0.010)
ATTRACTIVITY	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)
POPULATION.DENSITY	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)
AGE	1.069 (0.045)	1.044 (0.052)	1.046 (0.052)	1.055 (0.050)	1.080* (0.040)	1.071+ (0.044)	1.096* (0.041)	1.097* (0.040)	1.099** (0.035)	1.083* (0.038)
GREENS	1.132*** (0.027)	1.138*** (0.028)	1.136*** (0.027)	1.126*** (0.025)	1.120*** (0.025)	1.135*** (0.027)	1.130*** (0.028)	1.128*** (0.028)	1.116*** (0.026)	1.123*** (0.025)
WT.5	1.059 (0.056)	1.221 (0.174)	1.220 (0.173)	1.218 (0.169)	1.024 (0.054)	–				
WT.10	–					0.978 (0.040)	0.854 (0.118)	0.854 (0.117)	0.856 (0.113)	0.949 (0.038)
FUTURE.WT.5	–	1.546** (0.207)	1.538** (0.206)	1.520** (0.203)	1.496** (0.200)	–				
FUTURE.WT.10	–						1.294** (0.124)	1.289** (0.124)	1.282** (0.122)	1.293** (0.123)
PROB.FUTURE.WT.5	–	0.245 (0.272)	0.244 (0.270)	0.236 (0.256)	–					
PROB.FUTURE.WT.10	–						2.089 (1.846)	2.064 (1.806)	1.998 (1.679)	–

Table 1 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
INI.10	–		1.131+ (0.083)	–				1.131+ (0.083)	–	
INI.25	–			1.109*** (0.024)	1.108*** (0.024)	–			1.110*** (0.024)	1.109*** (0.024)
Random intercept district	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Events	618	618	618	618	618	618	618	618	618	618
Observations	121079	121079	121079	121079	121079	121079	121079	121079	121079	121079

hazard ratios should be interpreted as the effects of proportional rather than absolute increases in local WT exposure.

In the first set of models (Table 1), we explain the likelihood of AW initiative formation at the municipality-year level. Of the 817 identified AW initiatives, 617 represent first observed formation events at the municipality level during the observation period. These municipalities are evaluated against 3847 municipalities in which no AW initiative formation occurred during the observed period.

We differentiate between several spatial scales of exposure to WT and existing AW initiatives. Specifically, we estimate separate models using counts of WT within radii of 5 km, 10 km, 25 km, and 50 km around each municipality (**WT.5, WT.10, WT.25,** and **WT.50**). Analogously, we model the number of existing AW initiatives within different spatial radii (**INI.10, INI.25,** and **INI.50**). Following standard practice in event-history analysis, the municipality-year panel includes only years prior to the first formation of an AW initiative within a municipality. Consequently, municipalities leave the sample after the first observed event occurrence.

As discussed in the following section, existing WT stocks may partly proxy anticipated future WT expansion. We therefore additionally incorporate measures related to future WT development to reduce potential omitted-variable bias in the estimated relationship between existing WT and AW initiative formation.

3.3 Omitted Variables Concerns

Figure 1 summarizes the structural model underlying our analysis. The shapes represent the core variables or sets thereof. We distinguish between the existing stock of WT (**WT$_t$**) and future WT installations (**Future WT$_{t+x}$**). Our dependent variable is the formation of anti-WT initiatives (**FORMATION$_t$**). Existing AW initiatives refer to initiatives outside the focal municipality but within specified spatial radii

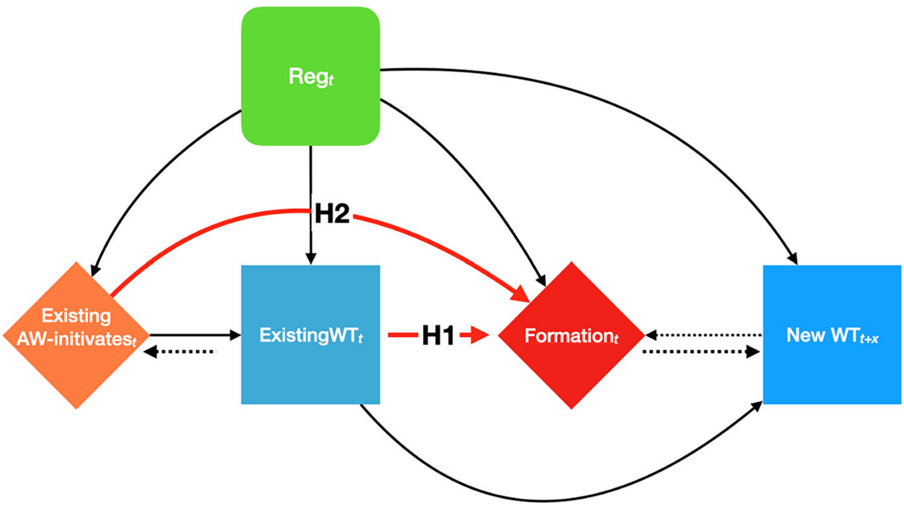

Fig. 1 Empirical model

(10, 25, and 50 km). $\mathbf{Reg_t}$ summarizes the broader set of regional control variables. The arrows indicate the assumed directions of influence. The two red arrows represent the relationships corresponding to hypotheses **H1** and **H2**. Dashed arrows indicate relationships that are potentially endogenous or bidirectional and therefore not interpreted causally within our empirical framework.

The central empirical challenge concerns the potential confounding role of future WT expansion. As argued above, AW mobilization may not only emerge in response to already existing WT but also in anticipation of planned or expected future projects. Municipalities with favourable conditions for wind energy production are likely to exhibit both a larger existing stock of WT and a higher probability of additional future installations. Consequently, empirical estimates of the relationship between existing WT and AW initiative formation may partly capture anticipatory dynamics related to future expansion rather than the effects of the existing turbine stock alone.

Unfortunately, we do not observe planned WT projects, local planning procedures, or regional expectations concerning future installations directly. We only observe realized WT installations. Nevertheless, this information can still be used to reduce the risk of omitted-variable bias in estimating the relationship between existing WT and AW initiative formation.

We operationalize this strategy in two alternative ways. First, we directly include the number of newly installed WT in the subsequent period (**Future** $\mathbf{WT_{t+x}}$ **expansion**) as an explanatory variable. This specification captures whether future WT expansion is associated with a higher probability of AW initiative formation and allows us to assess the robustness of the estimated relationship between existing WT and mobilization.

However, future WT expansion is itself not exogenous. As illustrated in Fig. 1, municipalities with many existing WT are also more likely to experience future WT expansion because both are shaped by common regional characteristics favourable to wind energy production. Existing WT therefore partly signal a broader regional suitability and development trajectory of wind energy. Directly conditioning on realized future installations may consequently absorb part of the variation associated with the existing WT stock itself and thereby mask its relationship with AW initiative formation.

We therefore estimate a second specification in which we replace observed future WT installations with the estimated probability that at least one additional WT will be installed in the subsequent period.[2] This probability is obtained from a logistic regression including the same regional explanatory variables as the main model, with future WT installation as dependent variable. The resulting variables (**PROB.FUTRUE.WT.5, PROB.FUTRUE.WT.10, PROB.FUTRUE.WT.25**, and **PROB.FUTRUE.WT.50**) capture the structural propensity for future WT expansion at different spatial scales.

Importantly, this strategy is not intended to identify the causal effect of future WT installations on AW initiative formation. Rather, it serves to reduce omitted-variable bias in the estimation of the relationship between the existing stock of WT

[2] We also tested considering a lead of 2- and 3-years. The results did not change significantly. They can be obtained from the authors upon request.

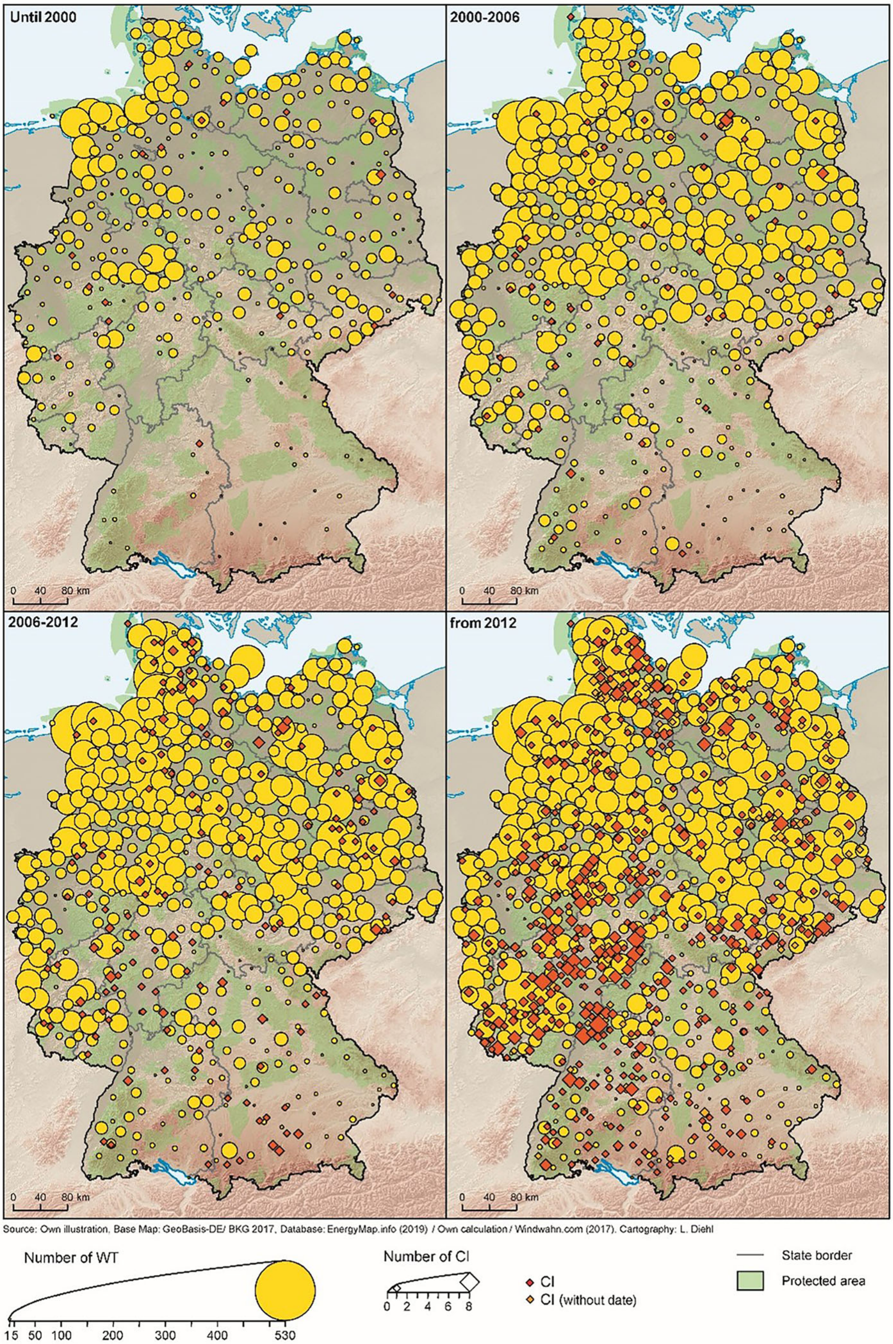

Fig. 2 Spatiotemporal development of WT and AW-initiatives in Germany from 1997 to 2017 Source: Own calculation

and the formation of AW initiatives. The relationship between AW initiatives and future WT installations remains potentially bidirectional, as successful mobilization against WT may itself delay, alter, or prevent subsequent projects. Figure 1, therefore, distinguishes explicitly between the hypothesized directional relationships of interest (**H1** and **H2**) and the broader set of structurally interdependent relationships surrounding future WT expansion. The empirical focus of our analysis therefore remains on the relationship between existing WT exposure, spatial spillovers between AW initiatives, and the emergence of new AW mobilization.

4 Results and Discussion

Figure 2 illustrates the spatiotemporal evolution of AW initiatives and WT in Germany between 1997 and 2017. The figure contains four snapshots covering the periods up to 2000 (panel 1, top left), 2000–2006 (panel 2, top right), 2006–2012 (panel 3, bottom left), and 2012–2017 (panel 4, bottom right). For visualization purposes, WT were aggregated within a radius of 10 km and AW initiatives within a radius of 5 km.

Panel 1 in Fig. 2 confirms the early concentration of WT in the windy coastal zones along the North and Baltic Seas. By 2000, approximately 5460 WT were operating in Germany, while only 18 AW initiatives existed, primarily in northern Germany. Between 2000 and 2006, WT numbers increased substantially to 15,162 and expanded beyond the traditional northern core regions into south-western Germany. During the same period, the number of AW initiatives rose moderately to 63. Between 2006 and 2012, WT deployment continued to expand geographically and numerically, reaching 20,617 installations, accompanied by a stronger increase in AW initiatives (184). Finally, the period after 2012 witnessed a sharp increase in the formation of AW initiatives (783 initiatives) alongside continued WT expansion. Particularly notable is the emergence of AW initiatives in areas with comparatively limited recent WT development, including parts of southern Germany.

These descriptive patterns already suggest that the relationship between WT deployment and protest formation is unlikely to be purely local or linear. Existing research often argues that regions with a longer history of wind-energy production tend to exhibit higher levels of acceptance due to learning, adaptation, or institutional normalisation processes. However, the descriptive patterns indicate that AW initiative formation is not confined to regions with little prior WT exposure. New initiatives also emerge in regions characterised by already substantial WT presence. One possible explanation is that populations in these areas increasingly perceive the spatial distribution of WT as procedurally or distributively unfair (Bosch and Schmidt 2020; Liljenfeldt and Pettersson 2017; Simcock 2016; Walker and Baxter 2017a). Moreover, opposition may be directed less toward WT presence as such than toward continued or anticipated expansion.

The results of the multivariate survival analyses are presented in Table 1 for WT within a 5 and a 10 km radius and in Table 2 for WT within a 25 and a 50 km radius.

The likelihood of AW initiative formation decreases with increasing distance to the coast (**DISTANCE.COAST**), increasing landscape attractiveness (**ATTRAC-**

Table 2 Determinants of FORMATION, WT 25 and 50 km radius

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
POPULATION	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)	1.000*** (0.000)
DISTANCE.COAST	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.000)	0.998*** (0.001)	0.998*** (0.001)	0.998*** (0.000)	0.998*** (0.000)
DISTANCE.PROTECT	0.979* (0.010)	0.978* (0.010)	0.978* (0.010)	0.980+ (0.010)	0.980+ (0.010)	0.978* (0.010)	0.976* (0.011)	0.976* (0.011)	0.978* (0.010)	0.980* (0.010)
ATTRACTIVITY	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.001)	0.999* (0.000)
POPULATION.DENSITY	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)
AGE	1.073+ (0.044)	1.068 (0.080)	1.070 (0.078)	1.075 (0.064)	1.084* (0.037)	1.070 (0.045)	0.972 (0.116)	0.972 (0.115)	0.972 (0.114)	1.082* (0.038)
GREENS	1.140*** (0.027)	1.143*** (0.028)	1.141*** (0.027)	1.130*** (0.026)	1.129*** (0.025)	1.144*** (0.027)	1.142*** (0.028)	1.140*** (0.028)	1.128*** (0.026)	1.133*** (0.025)
WT.25	0.961 (0.030)	0.948 (0.123)	0.947 (0.119)	0.947 (0.106)	0.928* (0.029)	–				
WT.50	–					0.938* (0.027)	1.018 (0.123)	1.019 (0.123)	1.029 (0.123)	0.909*** (0.026)
FUTURE.WT.25	–	1.179** (0.073)	1.177** (0.073)	1.173** (0.072)	1.172* (0.072)	–				
FUTURE.WT.50	–						1.146** (0.060)	1.144** (0.060)	1.144** (0.059)	1.150** (0.059)
PROB.FUTURE.WT.25	–	0.904 (0.774)	0.897 (0.750)	0.865 (0.643)	–					
PROB.FUTURE.WT.50	–						0.388 (0.389)	0.380 (0.380)	0.347 (0.343)	–

Table 2 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
INI.10	–		1.137+ (0.084)	–				1.141+ (0.084)	–	
INI.25	–			1.112*** (0.024)	1.112*** (0.024)	–			1.115*** (0.024)	1.114*** (0.024)
Random intercept district	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Events	618	618	618	618	618	618	618	618	618	618
Observations	121079	121079	121079	121079	121079	121079	121079	121079	121079	121079

TIVITY), and increasing population density (**POPULATION.DENSITY**). Although the estimated hazard ratios remain comparatively close to one, the coefficients are consistently estimated with high statistical precision across specifications. In Cox proportional-hazard models, such patterns are common because the models exploit the exact timing of events across many observations.

The substantive interpretation of these coefficients nevertheless requires caution. Since the models already control for regional WT exposure, these variables should not be interpreted simply as proxies for the geography of WT deployment. Rather, they likely capture broader regional characteristics associated with the emergence of organised protest. More densely populated or highly attractive regions may, for example, exhibit different planning environments, land-use structures, or mobilisation dynamics than rural WT-intensive regions. Similarly, municipalities located further inland may generally experience lower salience of WT-related conflicts. However, the comparatively small effect sizes suggest that these variables primarily operate as contextual background conditions rather than major drivers of AW initiative formation.

The coefficients for average population age (**AGE**) are positive in some specifications, although generally only weakly significant. This finding is broadly consistent with earlier research suggesting that older populations may be more likely to support or participate in protest activities (Reusswig et al. 2016a). At the same time, the effect may also reflect the comparatively strong concentration of older populations in rural regions characterised by higher WT exposure.

The coefficient for population size (**POPULATION**) remains positive and highly significant across all specifications in Tables 1 and 2. Because the models simultaneously control for population density, this variable primarily captures municipalities' absolute size and, indirectly, the potential scale of WT development. Larger populations also increase the pool of potential protesters and facilitate the mobilisation processes underlying collective action and initiative formation (Kim 2018). Likewise, the coefficient for the Greens' electoral success (GREENS) is consistently positive and highly significant across all specifications. While this may initially appear counterintuitive given the Greens' generally pro-renewable policy orientation, the variable likely captures broader patterns of environmental awareness, civic engagement, and mobilisation capacity that facilitate collective action around environmental conflicts, including conflicts surrounding renewable-energy infrastructure. Existing qualitative research on AW mobilisation in Germany suggests that such conflicts frequently emerge as "green-on-green" conflicts, in which local actors frame their opposition in terms of landscape protection, biodiversity conservation, procedural justice, and environmental stewardship rather than general opposition to renewable energy (Arifi and Winkel 2021; Reusswig et al. 2016b; Warren et al. 2005). Furthermore, highest voter shares for the green party are generally found in urban municipalities. The positive coefficient for GREENS should therefore not be interpreted as evidence that pro-renewable voters oppose wind energy per se. Rather, regions with stronger Green electoral support may also possess denser civic networks, greater mobilisation capacity, and stronger traditions of environmental participation that facilitate organised protest when specific projects are perceived as conflicting with local environmental or landscape concerns. This interpretation is also consistent with Reusswig's (2016a) notion of "self-confident protests of local elites," although the precise underlying mechanism cannot be identified with the present data.

The findings regarding existing WT stocks provide no robust support for **H1**. The results differ considerably across spatial scales and specifications. In the 5 km models reported in Table 1, the coefficient for **WT.5** remains statistically insignificant throughout all specifications, including the fully controlled models in columns (4) and (5). Similarly, the coefficients for **WT.10** in columns (6)–(10) remain insignificant across all specifications. These findings suggest that the mere local presence of WT within relatively small spatial radii does not systematically increase the likelihood of AW initiative formation.

The picture changes somewhat for broader regional WT exposure. In Table 2, the coefficient for **WT.25** becomes significantly smaller than one in the specification that includes direct future WT controls and regional initiative diffusion but excludes **PROB.FUTURE.WT.25** (column 5). Likewise, **WT.50** is significantly smaller than one in the corresponding specification in column (10). In addition, **WT.50** also shows some statistical significance in specifications without direct future WT controls. This does not support the expectation that existing WT stocks generally stimulate protest mobilisation. Rather, they suggest that extensive WT presence within broader regional radii of 25 and especially 50 km is, if anything, associated with somewhat lower probabilities of new AW initiative formation. This differs from findings for the USA and Canada, where taller and generally more numerous WT have been found to predict stronger opposition dynamics (Stokes et al. 2023).

Yet, this interpretation requires caution. The WT coefficients capture the association between existing WT stocks and AW initiative formation, conditional on the other variables in the model, including future WT development in several specifications. As discussed above, future WT expansion is likely correlated with planning processes, anticipated developments, and regional conditions that simultaneously affect both WT deployment and protest mobilisation. The inclusion of **FUTURE.WT.x** and **PROB.FUTURE.WT.x** therefore primarily serves to separate the association with existing WT stocks from broader future-development dynamics. Under this conditional interpretation, the results suggest that existing WT stocks themselves do not act as a robust positive trigger of AW initiative formation. The negative coefficients at broader spatial scales should not be read as strong causal evidence that WT exposure reduces protest. They are more cautiously interpreted as indicating that regions with extensive established WT infrastructures may differ systematically from regions currently undergoing or anticipating expansion, possibly because of habituation, institutional normalisation, or prior conflict selection.

The direct future WT controls (**FUTURE.WT.x**) are consistently positive and statistically significant across nearly all specifications in which they are included. In Table 1, **FUTURE.WT.5** is positive and significant in columns (2)–(5), while **FUTURE.WT.10** is positive and significant in columns (7)–(10). Similarly, in Table 2, both **FUTURE.WT.25** and **FUTURE.WT.50** remain positive and statistically significant across all corresponding specifications. However, these variables should not be interpreted causally. They primarily capture anticipated or ongoing expansion dynamics that are correlated with both future WT installations and current protest mobilisation. Their role in the model is therefore chiefly methodological: they reduce omitted-variable bias in the estimation of WT stock effects rather than identifying the independent causal effect of future WT installations. The probability-based controls (**PROB.FUTURE.WT.x**) remain statistically insignificant throughout all specifications. Nevertheless, their inclusion contributes to the broader identification strategy by accounting for municipalities' general propensity to experience future WT expansion.

In contrast to **H1**, our findings provide considerable support for **H2**. Existing AW initiatives in surrounding municipalities increase the likelihood of further initiative formation, particularly at broader regional scales. **INI.10** remains only weakly significant in both Table 1 (**columns 3 and 8**) and Table 2 (**columns 3 and 8**). The effects for **INI.25**, however, are consistently positive and highly significant across all corresponding specifications in both tables (**columns 4–5 and 9–10**). Additional analyses using **INI.50** instead of **INI.25** yielded results that were substantively almost identical and are therefore not reported separately. These findings suggest that protest diffusion operates less through highly localised neighbourhood effects than through broader regional learning and mobilisation dynamics. Existing initiatives appear to create organisational templates, informational infrastructures, and social networks that facilitate the emergence of further initiatives in nearby municipalities.

The magnitude of the **INI.25** effect is substantively meaningful. In the fully specified models reported in Table 1, columns (4) and (5), the estimated hazard ratios of 1.109 and 1.108 imply that an additional AW initiative within a 25 km radius is associated with approximately a 10.8–10.9% higher hazard of first initiative formation in a municipality. Similarly, in Table 2, columns (4), (5), (9), and (10), the corresponding coefficients range between 1.112 and 1.115, implying increases in the hazard of initiative formation of approximately 11.2–11.5%. Given that the emergence of new AW initiatives represents a comparatively rare event, these effect sizes are substantial. Additional analyses using **INI.50** instead of **INI.25** produced substantively very similar results, suggesting that these spillover dynamics operate at broader regional rather than highly localised spatial scales.

These findings provide quantitative support for the qualitative argument advanced by Reusswig et al. (2016b), according to which AW initiatives increasingly operate through shared experiences, organisational learning, and supra-local support structures. The results are also consistent with the increasing professionalisation of AW initiatives and the emergence of umbrella organisations that facilitate the diffusion of strategies, information, and mobilisation resources across municipalities.

Overall, the results suggest that AW initiative formation is driven less by WTs' static local presence and more by broader regional mobilisation dynamics and anticipated expansion processes. **H1** therefore receives no empirical support in its original formulation. Existing WT stocks do not exhibit a robust positive relationship with the formation of AW initiatives. In contrast, **H2** is comparatively consistently supported, particularly at broader regional scales, indicating that protest diffusion and regional mobilisation processes constitute an important mechanism underlying the spatial emergence of AW initiatives.

The heterogeneous findings across spatial scales nevertheless point toward a more differentiated relationship between WT exposure and protest formation than is often assumed in the literature. Existing research frequently argues that regions with long-standing WT exposure tend to exhibit comparatively higher acceptance rates (Wolsink 2007a). Our findings are broadly compatible with this interpretation insofar as extensive WT stocks do not translate into systematically higher probabilities of AW initiative formation. At the same time, the continued emergence of new initiatives across different phases of WT expansion suggests that protest mobilisation cannot be reduced to a simple exposure-response mechanism. Instead, initiative formation appears to depend more strongly on regional mobilisation dynamics and anticipated future development than on the mere presence of existing WT infrastructure. The multidimensionality of acceptance through different stakeholders, land conversion for WT, and specific location show the individuality of every single siting event of WT (Greßhake et al. 2025). Most of these aspects we could not investigate in this study. However, the multidimensionality of WT siting can play a crucial role on why protest appears locally or not. E.g., visual impacts of the siting of WT were not analysed and are vital in terms of acceptance of WT. Installing WT where they fit in size and aesthetic of the landscape and serve a common good can be accompanied by discussions with local population, showing community benefits of WT sitings and demonstrating alternatives, e.g. through planning competitions (Schöbel 2012: 137–149). This could significantly improve acceptance of WT in the future.

5 Conclusion

This study provides one of the first large-scale spatiotemporal analyses of the emergence of formalised AW initiatives in Germany. By combining detailed information on the geographical distribution of WT and AW initiatives over time, the present study offers a more generalizable empirical perspective on the regional dynamics underlying AW mobilisation.

Our findings show a more differentiated picture of the relationship between WT deployment and protest formation than much of the existing literature suggests. We do not find robust empirical support for the proposition that the existing stock of WT systematically increases the likelihood of AW initiative formation. In some broader regional specifications, extensive WT exposure is even associated with slightly lower hazards of new initiative formation. While these negative coefficients should not be interpreted causally, they suggest that the relationship between WT exposure and protest mobilisation cannot be reduced to a simple linear exposure-response mechanism.

At the same time, the analysis provides comparatively consistent support for the importance of regional mobilisation dynamics. Existing AW initiatives significantly increase the likelihood of additional initiatives emerging nearby, particularly within broader regional radii. The results, therefore, support the argument that AW mobilisation diffuses through processes of organisational learning, social interaction, and supra-local coordination (Reusswig et al. 2016a, 2016b). Existing initiatives appear to provide informational infrastructures, strategic repertoires, and mobilisation resources that facilitate the emergence of additional initiatives in surrounding municipalities. The findings are also consistent with the increasing professionalisation of AW initiatives and the emergence of umbrella organisations coordinating protest activities across local contexts.

Even more importantly, the empirical results further suggest that protest mobilisation is associated less with the static presence of WT infrastructure itself than with broader dynamics of anticipated or ongoing expansion. However, the present study does not directly identify the causal effect of future WT expansion. Rather, the future WT variables serve primarily as part of an identification strategy intended to isolate more clearly the relationship between existing WT stocks and the formation of AW initiatives. Consequently, the findings should not be interpreted as evidence that future WT projects mechanically trigger protest mobilisation. Instead, they indicate that local protest formation is embedded in broader regional development dynamics, planning expectations, and mobilisation environments.

Several limitations of the study should be acknowledged. Most importantly, the analysis observes realised WT installations and formalised AW initiative formation, but not planned WT projects, informal opposition, or projects that may have been prevented before realisation. Consequently, the study cannot determine which specific WT projects triggered mobilisation or whether AW initiatives successfully delayed or prevented future installations. Likewise, the data do not contain information on the size, organisational structure, or effectiveness of individual initiatives. Future research should therefore combine large-scale quantitative approaches with more detailed qualitative analyses of local mobilisation processes and planning conflicts as well as data on successful and failed WT planning and installation processes.

An additional limitation concerns the temporal scope of the underlying data. The analysis covers the period up to 2017, whereas the political, societal, and regulatory context surrounding WT expansion has evolved considerably since then. In particular, the energy policy debates following the Russo-Ukrainian war, the acceleration of decarbonisation efforts, and changes in planning regulations may have altered both public attitudes toward WT and the organisational structure of AW initiatives. At the same time, the investigated period captures a critical phase in the institutionalisation and regional diffusion of AW initiatives in Germany. Moreover, the study's primary objective is not merely to describe contemporary attitudes toward WT, but to identify broader spatial and organisational mechanisms underlying AW initiative formation. Future research should therefore examine to what extent the mechanisms identified here remain stable under more recent political and regulatory conditions.

The findings nevertheless carry several implications for planning authorities and policymakers. For instance, they suggest that protest mobilisation is not merely a localised reaction to existing WT infrastructure but also shaped by regional social spillovers and diffusion processes. Planning conflicts surrounding WT expansion, therefore, cannot be addressed solely at the level of individual projects. Procedural justice, transparent communication, regional coordination, and the perceived fairness of the spatial distribution of WT infrastructure are likely to play an important role in shaping local acceptance and protest dynamics (Vuichard et al. 2022). In particular, the strong spatial spillover effects identified in the analysis suggest that conflicts surrounding WT expansion may diffuse regionally once mobilisation structures become established. Therefore, the individuality of every single siting event should be accompanied by profound stakeholder involvement, landscape aesthetics recognition and discussions with local population to increase acceptance, especially where regional protest already exists (Schöbel 2012). Future research should therefore investigate more explicitly how local planning institutions, political networks, land-use conflicts, and regional governance structures shape these diffusion dynamics (Schweizer-Ries 2010; Wirth and Leibenath 2017). Comparative studies across countries would also help clarify to what extent the German case reflects general dynamics of renewable-energy conflicts or more specific institutional and political conditions within Germany.

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Declarations

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