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ABSTRACT

Experts predict continuing deployment of wind turbines in the United States, which will create more interactions between turbines and surrounding communities. Policymakers can benefit from analyses of existing wind projects that enable them to better understand likely effects on residents around proposed projects. Our analysis of a randomly drawn, representative national survey of 1705 existing U.S. wind project neighbors provides previously unavailable detail about factors influencing the attitudes of these neighbors toward their local wind projects. Overall, we find positive-leaning attitudes, which improve over time as individuals self-select into communities near existing wind projects. Hearing wind turbines leads to less-positive attitudes, although living very near to turbines does not, nor does seeing wind turbines. In fact, our findings suggest complex relationships among nearby residents' attitudes, their perceptions about the particular fit of turbines within their landscape and community, and their perceptions of wind project impacts on property values. These findings—along with the positive correlation between perceived planning-process fairness and attitude—suggest areas of focus for wind project development that may influence social outcomes and acceptance of wind energy. The concluding discussion provides a number of policy and future research recommendations based on the research.

1. Introduction

Wind energy provided approximately 6.5% of U.S. electricity generation in 2018 (Wiser and Bolinger, 2019), from approximately 59,000 utility-scale turbines (Hoen et al., 2019). Experts predict continued wind deployment pressures driven by technical advancements, related cost reductions, and state renewable energy policies, despite declining federal tax support and the eventual elimination of the federal tax credit for wind after 2020 (Wiser et al., 2016; Wiser and Bolinger, 2019).

Because of the various impacts of wind projects, wind turbine deployment requires cooperation among numerous stakeholders such as local authorities (who control key permitting processes; see NARUC, 2012), residents, landowners, businesses, and non-governmental organizations. In particular, the large number of turbines being deployed is resulting in many people living near those turbines. Through 2015, almost 1.4 million homes were within 8 km of a U.S. wind project (Fig. 1)—about 1 million more homes than in 2010. In addition, wind turbines were, on average, installed 46 m closer to homes each year between 2004 and 2014 (Fig. 2) (Hoen et al., 2018).

Policymakers involved with proposed wind projects often research the experiences of communities already located near turbines, with the goal of understanding and improving processes and outcomes. However, such research is hindered by a lack of adequate data and analysis related to the attitudes of residents living near wind turbines in the United States. To date, studies of nearby-resident attitudes have tended to focus on one or a few discrete wind projects at specific points in time, which can result in case-selection bias—for example, when a project is selected for analysis because of its controversial aspects (Firestone et al., 2018a). Findings from such cases, although valuable, may not apply well to typical projects. More generally, attitudes toward wind projects may differ for a variety of reasons—such as geographic or economic differences, project sizes, and dates of commissioning—that are not captured well by small studies.

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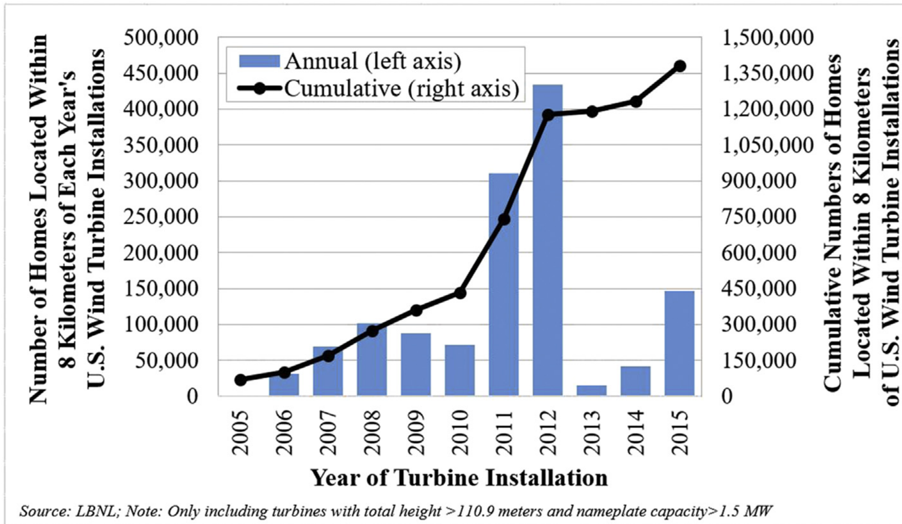

Fig. 1. Cumulative and Annual U.S. Homes within 8 km of Wind Turbines.

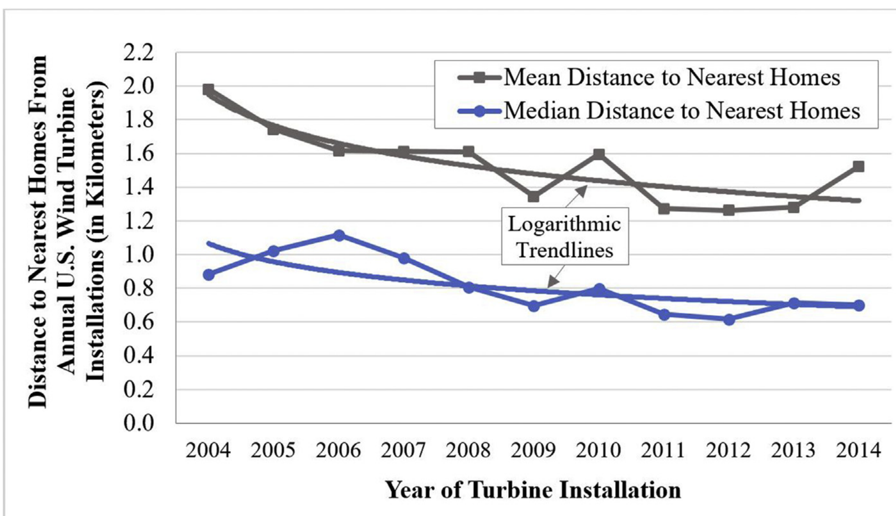

Fig. 2. Mean and median distances to closest homes per wind project by installation year.

To help fill the gap in research on attitudes toward local wind projects, we analyze a large (n = 1705) 2016 random probability sample of U.S. residents living within 8 km of a modern, utility-scale wind turbine, weighted to the underlying population. We stratify the sample by project size and distance from homes to the nearest turbine to ensure representation of the residents most likely to experience proximal effects of the turbines. The large, cross-sectional nature of the study allows us to statistically examine numerous factors that could affect attitudes toward wind projects. The result is the first-ever nationally representative analysis of this topic. The results are meant to help policymakers understand the drivers of local attitudes toward wind projects, which ultimately could help improve the processes, designs, acceptance, and outcomes of future wind projects.

2. Literature review

As part of our ongoing work, Rand and Hoen (2017) reviewed more than 130 papers focused primarily on North America, with the aim of determining major correlates to residents' attitudes toward wind projects, examining other themes in the literature, and identifying research gaps. Key findings from that review are summarized here.

Typically, researchers have found local attitudes to be largely positive (Baxter et al., 2013; Fergen and Jacquet, 2016; Mulvaney et al., 2013a; Petrova, 2014; Slattery et al., 2012), although for the most part they have not distinguished among residents who (a) moved in prior to construction and continue to live nearby, (b) moved to another community, or (c) arrived after construction. Some researchers (Firestone et al., 2018a; Hoen et al., 2015) theorize, though, that people moving into communities with existing turbines might have more positive attitudes toward those turbines than do people already living there because of self-selection, as follows from the seminal work of Tiebout (1956), on what is colloquially known as "Tiebout sorting," and that of Rosen (1974). Rosen argued that public goods, such as the environment, are likely to be considered among a suite of characteristics during the home buying process. Therefore, buyers who are more positive to wind turbines might be more likely to buy homes near them and therefore the cohort of our survey respondents moving in after construction of the turbines will be more positive than those there prior to construction. If this is true, it suggests that prior work may overstate levels of community acceptance levels and that it is important to isolate these populations from one another when analyzing data.

In terms of reasons behind various acceptance levels, the literature has focused largely on project opposition. Of relevance, Pasqualetti (2011) has identified common issues that arise when local community members resist wind developments: immobility of good wind power sites; immutability (a belief that the landscape would remain unchanged); solidarity (with the land); imposition (local impacts for wider benefits); and place identity/attachment.[1] Pasqualleti's rubric is consistent with intuition given that the most defining characteristic of wind turbine infrastructure is its effect on landscapes, places, and people (Thayer and Freeman, 1987; Firestone et al., 2018b). In a related vein, Devine-Wright (2009) posits that opposition may be best understood as community members engaging in principled, place-protective action, rather action motivated by selfish reasons. Of course, opposition to (or support of) a proposed project, is different than a negative (or positive) attitude toward an existing project, although the correlates with opposition and support may be similar to those for negative and positive attitudes.

To that end, researchers have evaluated the influence of a number of factors that may contribute to project attitudes, including proximity, visual aesthetics, and concern for the environment along with process fairness and project participation. Turning to this last factor first, the evidence is mixed on whether or not resident participation in a wind project (turbine hosting) and compensation is linked to more positive attitudes (Jacquet, 2012). Indeed, compensation of some but not all community members may increase conflict (Baxter et al., 2013; Walker et al., 2014a) and even be perceived as bribery (Gipe, 1995). The linkage between distance to the nearest turbine—a metric often used as a proxy for expected levels of audio and visual impacts (and compensation)—and attitudes is also unclear. Some studies show a positive correlation between distance and attitude, with attitudes becoming more positive as distance from the turbine increases (Swofford and Slattery, 2010; Thayer and Freeman, 1987). Others show the opposite (Groth and Vogt, 2014; Baxter et al., 2013; Warren et al., 2005).

Although sound annoyance correlates with more negative attitudes (see Hübner et al., 2019; Haac et al., 2019), being annoyed by wind turbine sounds may be influenced by a person's perceptions of a wind project's aesthetics, which include its visibility, appearance, and fit within the landscape (Pasqualetti, 2011; Olson-Hazboun et al., 2016; Fast et al., 2016; Firestone et al., 2015; Pedersen and Waye, 2004; Pohl et al., 2012; Pohl et al., 2018). Indeed, visual effects may predominate over sound effects, and are likely more widely experienced. But what do we mean by visual effects? Wolsink (2018) contends the visual effect of a wind turbine is not so much an assessment of its infrastructure, but of a change in the quality of the landscape. Yet, issues of appearance and fit are in the eye of the beholder, and may be considered by some local residents to not be negative, but rather, positive (Jacquet and Stedman, 2013; Mulvaney et al., 2013b; Brannstrom et al., 2011; Gipe, 1995). In contrast to landscape effects (or economic opportunities, for that matter), environmental beliefs appear to correlate more weakly with attitudes (Olson-Hazboun et al., 2016), and indeed the evidence is mixed (Mulvaney et al., 2013a; Fergen and Jacquet, 2016).

Processes and stakeholders that are perceived as open, inclusive, fair, and trustworthy can lessen conflicts related to project development (Bidwell, 2016) and result in more-positive outcomes, and as such, they have been found to correlate with positive project attitudes (Jami and Walsh, 2014; Fast and Mabee, 2015; Groth and Vogt, 2014). Having a developer that is open and transparent with the local public has been found to be particularly important (Firestone et al., 2018a).

The ability of residents to influence the project outcome (e.g., the number or location of turbines) also has been found to be an important correlate with attitude (Firestone et al., 2018a). As a result, community engagement has to rise above being a mere 'dog and pony show' (Walker, Baxter and Ouellette, 2014b, p. 737), where a developer unduly controls and restricts the flow of information (Aitken et al., 2016), and with its project affectively being a *fait accompli* (Haggett, 2008, p. 300), without regard to the local community opinion. Together, these considerations suggest that engagement with the public ought to begin early in the development process.

Proper engagement also may have an additional benefit in that local citizens who consider a wind turbine siting process to have been fair, may more be likely to accept a project even if it its design does not eliminate all apprehensions (Aitken, 2010). Looked at in another way, if community members have not been given a say in the outcome, those who are predisposed to support the project could join the opposition (Wolsink, 2007a).

The literature review (Rand and Hoen, 2017), the key points of which are described above, laid out a number of possible correlates of attitudes for those living near turbines (e.g., process fairness, proximity to turbines, and aesthetic impacts). We summarize them below as we describe the development of the survey, which was meant to capture multiple influences on attitudes about wind power simultaneously.

3. Data and methods

Here we describe our survey instrument, sample preparation and data collection, data weighting, and analysis methods.

3.1. Survey instrument

The survey instrument - the full version of which is included in the supplemental materials - was designed to capture the following information from respondents:

- Present attitude about the nearby wind project and attitude prior to construction
- Participation in and perceived fairness of the project's planning and siting process
- Relationship to the project (e.g., presence of turbines on property, compensation, numbers of turbines visible, and ability to hear turbines from property and inside home)
- Perceptions of and reactions to project impacts (e.g., appearance, landscape changes, turbine sounds, shadow-flicker, lighting)
- Background information (e.g., length of residence, awareness of project development, place attachment, noise sensitivity, acute and chronic stress)
- General attitudes toward sources of electricity, climate change, and wind energy's effectiveness at combating it
- Demographic information

We obtained human subjects' approval from institutional review boards at Lawrence Berkeley National Laboratory, Portland State University (PSU), and the University of Delaware. PSU's Survey Research Lab conducted telephone surveys and administered follow-on internet (using Qualtrics software) and mail surveys. The internet and mail surveys generally followed Dillman et al. (2014) guidelines. There were no differences among the telephone, internet, and mail surveys other than those necessitated by use of the specific modes. The telephone survey was piloted in December 2015, the final telephone survey was administered in March and April 2016, and mail and internet surveys were administered through July 2016. Respondents required approximately 22 min to complete the survey. All respondents who completed the survey were entered into a drawing to win one of four $500 gift cards.

3.2. Sample preparation and data collection

To prepare the sample frame, we matched a data set of U.S. wind turbines (n = 29,848)—installed through 2014, of at least 111 m in total height (to blade tip at its apex), and with a nameplate capacity of

[1] In some schools of thought, place attachment is contextualized as having emotional, functional and social components (van Veelen et al., 2016), while others separate out the emotional ("place identity") and the functional ("place dependency") (Lewicka, 2010).

1.5 MW or greater—to real estate data from CoreLogic.[2] CoreLogic's database returned all residential structures from any county with at least one turbine ($n \sim 22$ million) as well as structure and property characteristics including—but not limited to—home size, age, recent sale dates and prices, and location (address and latitude/longitude). We limited these data to single-family residences, condominiums, duplexes, and apartments with complete addresses (all of which we refer to as "homes" here) that were within 8 km of the nearest turbine from which we drew our sample (n = 1.29 million).[3] We believe this is the largest sample of homes that has been used for wind-attitude analysis anywhere in the world.

To ensure a representative sample encompassing residents who are near turbines and most likely to experience the effects of sound and shadow-flicker from which to draw our sample, we stratified the sample by project size (greater than 10 turbines, or less than or equal to 10 turbines) and distance from a home to the nearest turbine (0 - ≤0.8 km, > 0.8 - ≤1.6 km, > 1.6 - ≤4.8 km, and > 4.8 - ≤8 km). Based on sound modeling under a companion research efforts (Haac et al., 2019 and Hübner et al., 2019), we over-sampled 15 discrete wind project sites to provide a diversity of turbine manufacturers, geographies, project sizes, background sound levels, population densities, and topographies (see Fig. 3).[4] Finally, to ensure the sample included a sufficient dispersion of homes across the country, we under-sampled four projects around which a disproportionately large portion of the sample was located. In total, we prepared a sample of 13,845 records to use for the survey.

In our final stratified sample, 7845 records were matched to residents' telephone records provided by Marketing System Group[5] and used for the telephone survey and 6,000 records were used for the mail/internet survey (750 telephone non-responding homes and 5250 records that did not have a matching telephone number or were excluded because of locational disagreement). We received a total of 1705 valid responses across all survey modes, for an effective response rate of 17.9% (after accounting for the failure to reach a portion of the sample frame owing to undeliverable mail, reaching voice mail, etc.). Of the 1705 responding homes, 621 were less than 0.8 km from a turbine, 500 were at least 0.8 km but less than 1.6 km away, and the remainder were at least 1.6 km away (Table 1). Homes accounting for 607 responses surrounded small projects of 10 or less turbines, while 1098 were near large projects. Fig. 3 shows the location of wind projects near which responding homes are located, with and without modeled sound, as well as projects existing as of 2014 that we did not sample.

3.3. Data weighting

Sample weights were prepared to address over- and under-sampling and differential response rates by stratum, gender, age, and education using United States Census Bureau (2016) Census-tract-level household and demographic data. Because the sampling frame (homes within 8 km of a wind turbine) does not align with Census tract boundaries, we estimated the percentage of homes in a given Census tract included within our sampling frame. Weighting followed the method known as "iterative raking" or "sample balancing" (Battaglia et al., 2009; Deming, 1943). More detailed discussions of sample preparation and weighting are contained in Firestone et al. (2018a).

3.4. Methodology

We analyze possible correlates to attitudes toward local wind projects, as surveyed via the following categorical question: "What is your attitude toward your local wind project now?" Survey respondents could choose between the responses very negative, negative, neutral, positive, very positive, and don't know. This question is the dependent variable in all of our analyses. We refer to it simply as "attitude," with directionality referred to as more positive, positive, more negative, or negative; for example, "attitude is more positive for those who cannot hear the turbines."

We performed the analysis using Stata. We use simple ordinary least squares regression (*reg*) and ordered logistic regression (*ologit*) to examine the full set of independent variables (IV).[6] The main or "full" regression encompasses six categories of IVs that are listed in Equation (1) and Table 2.

$$A_i = \alpha + \sum_a \beta_1(C_i) + \sum_b \beta_2(P_i) + \sum_c \beta_3(PA_i) + \sum_d \beta_4(A_i) + \sum_e \beta_5(D_i) + \sum_f \beta_6(S_i) + \varepsilon_i \quad (1)$$

where.

- A_i represents the attitude for respondent i,
- α is the constant or intercept across the full sample,
- C_i is a vector of a nearest wind project, home, and community arrival year characteristics for respondent i,
- P_i is a vector of b audio and visual sensory perceptions of the wind project for respondent i,
- PA_i is a vector of c fixed effects for perceived planning process fairness for respondent i,
- A_i is a vector of d related attitudes for respondent i,
- D_i is a vector of e demographic characteristics for respondent i,
- S_i is a vector of f fixed effects to control for the sampling strata from which respondent i was drawn, and the following are vectors of parameter estimates
- β_1 for wind project, home, and arrival characteristics a,
- β_2 for audio and visual sensory perceptions b,
- β_3 for planning process effects c,
- β_4 for related attitudes d,
- β_5 for demographic characteristics e,
- β_6 for sampling stratum f, and
- ε_i is a random disturbance term for the attitude for respondent i.

Except for the vector of β_6 estimates, all are variables of interest.

3.5. Variable definitions and summary statistics

Fig. 4 presents weighted summary statistics for the dependent variable, attitude. Approximately 4% of the respondents have a very negative (*for the purposes of calculating the mean attitude, the value of this category is 1) attitude toward the local turbines*), 4% negative (2), 32% positive (4), and 25% very positive (5). The remainder (34%) have a neutral attitude (3). The ratio of positive to negative is approximately 7:1. The mean attitude among all respondents is 3.71.

Table 2 shows the definitions and the weighted means and proportions for the full set of variables of interest for the final analysis sample, which we briefly describe here. Table 2 also includes which of the four regression models the variables are included in, which will be

[2] CoreLogic is a real estate data aggregator. See https://www.corelogic.com/ for more info.

[3] Distance was determined using Stata's *geonear* function.

[4] Acoustic modeling occurred at these sites, which was not possible over the entire sample. More details of this process, and the resulting analysis, are contained in Haac et al. (2019).

[5] Marketing Systems Group is a survey data aggregation and services company. For more information: www.m-s-g.com.

[6] We also estimated Stata's multiple-imputation of missing values model (*mi*) (Rubin, 1987; Schafer, 1997) and a generalized ordered logit model (*gologit2*) to, respectively, examine results when the full sample was used and control for possible violations of the proportional odds assumption, with little change in the results. Model results not presented are available from the authors.

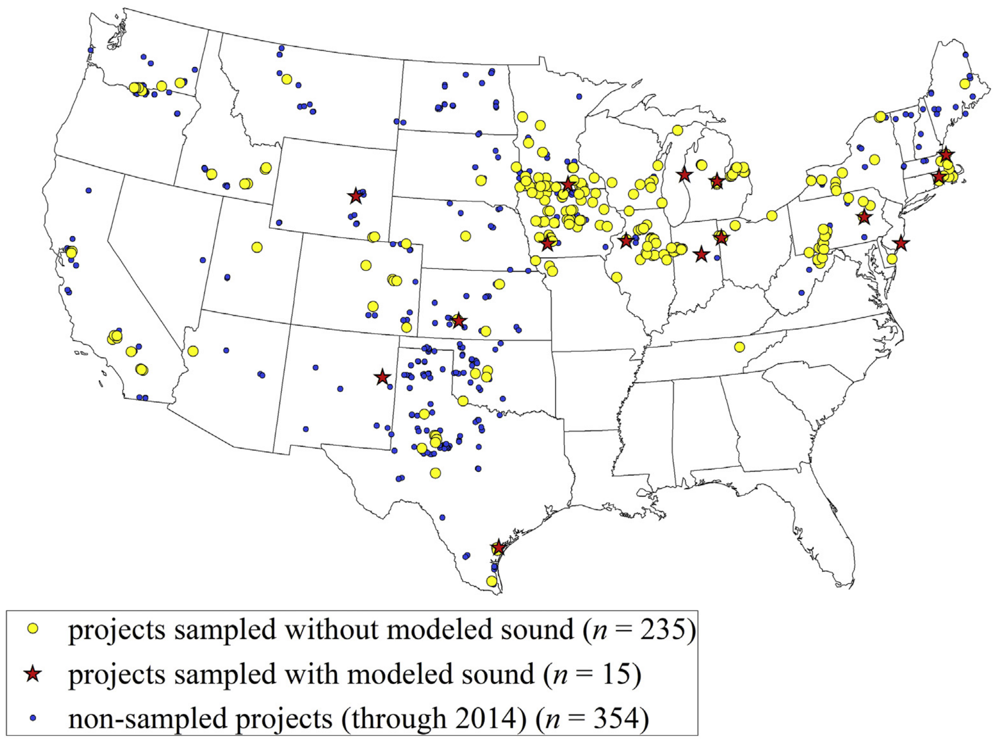

Fig. 3. Map of respondent and wind project locations.

Table 1
Unweighted distribution of survey responses by distance bin and project size.

Distance to Nearest Turbine Bin	Small Project (≤10 turbines)	Large Project (> 10 turbines)	Total
< 0.8 km	188	433	**621**
0.8 - < 1.6 km	183	317	**500**
1.6 - < 4.8 km	142	178	**320**
4.8 - < 8.0 km	94	170	**264**
Total	**607**	**1098**	**1705**

discussed in more detail below.

Approximately 45% of the sample moved in after the local turbine's construction. About 0.5% have a wind turbine on their property and receive compensation, with another 2% not hosting but still receiving some compensation. With regard to the nearest turbine, 1% live within 0.8 km, and another 4% live between 0.8 and 1.6 km. Most of the sample (94%) cannot hear a wind turbine either in their home nor on their property, which is not surprising given a mean distance of 4.78 km; only 1% can hear a wind turbine with the windows closed. Similarly, only 1% perceive shadow-flicker in their home. As for the wind turbines themselves, the mean year of installation was 2010, and the average turbine height is 124 m.

Respondents primarily live in what the U.S. Census Bureau defines as urban or rural areas, rather than highly rural areas (USDA, 2018). For demographics, 79% identify as white, the average number of children living in the home of a respondent is 0.78, and average annual family income is just over $54,000. With weighting, the sample reflects the sample frame population in terms of age, education, and gender.

Respondents tend to be attached to the place in which they live, have positive attitudes about wind development generally, see wind energy as an effective means to mitigate climate change, and like the look of the turbines but are mixed on how the turbines in the local project fit within the landscape. Additional details can be found in Firestone et al. (2018a) regarding the subsample who moved in prior to construction and more generally on perceptions of process fairness.

4. Results

Here we first present correlations of various factors with attitude about wind projects and then our multivariate regression analysis results.

4.1. Correlations with attitude

To identify potential influences on the dependent variable, attitude, we examine correlations between it and our set of independent variables (Table 3). Although some variables have strongly statistically significant correlations with attitude, most are either not significant or their correlations are weak (< |0.3|). The clear exceptions (shown in bold) are perceiving the wind project planning process as fair, that the turbines fit well with the landscape, the wind power is effective at mitigating climate change, that property values are negatively affected by proximity to turbines, and having a generally positive attitude about wind power development. To disentangle some of the potentially competing effects of these and other variables, we employ multivariate regressions in the following sections.

Additionally, included in the supplemental materials are bivariate analysis of attitudes across various parameters. In these we find evidence of correlations between the mean attitudes of residents and whether those residents moved into the community before or after wind project construction, whether they can hear a turbine, whether they host a turbine on their property, if they are renting their home, whether they live near a large project, and whether they are located in an urban setting. These further reinforce the correlation results and encourage the multivariate analysis presented in the next section.

4.2. Multivariate regression analysis results

Table 4 presents the results of three unweighted linear regression models (1–3) and an ordered logistic regression model (4). All of the models are estimated using the same 1331 respondents (those respondents who had no missing data for any variable included in the full

Table 2
Regression variable names, descriptions, means, and proportions.

Variable	Variable Description/Definition	Weighted Means/ Proportions	Included In Models
Dependent Variable			
Present attitude toward project	5 categories: "1" very negative; "2" negative; "3" neutral; "4" positive; "5" very positive; "don't know" and refused omitted	3.7	1–4
Independent Variables			
Wind Project, Home, and Arrival Characteristics			
Move-in prior to construction	"1" if yes; "0" if no	0.45	1–4
Homeowner	"1" if own home; "0" if rent	0.79	1–4
Primary home	"0" if secondary; "1" if unknown; "2" if primary	1.6	1–4
Nearest turbine operation year	Year turbine began operation (1997 treated as year 1)	14 (2010)	1–4
Nearest turbine total height	Height to blade tip at apex (after subtracting 111 m)	13 m (124 m)	1–4
Compensation			
No Compensation	"1" if not receiving compensation; "0" otherwise *(omitted category)*	0.975	1–4
Receiving compensation; no host	"1" if family received compensation; "0" otherwise	0.02	1–4
Hosting wind turbine on property	"1" if on respondent's property; "0" otherwise	0.005	1–4
Audio and Visual Sensory Perceptions			
See turbine from home	"1" if yes; "0" no	0.18	1–4
Shadow-flicker in home	"1" if yes; "0" if no	0.01	1–4
Hear wind turbine			
Cannot hear	"1" if yes; "0" if no *(omitted category)*	0.94	1–4
Hear with windows closed	"1" if yes; "0" if no	0.01	1–4
Hear on property, not in home	"1" if yes; "0" if no	0.05	1–4
Demographics			
Female	"1" if female; "0" male	0.51	1–4
Age	Age in years	49	1–4
College	"1" if obtained a college degree; "0" otherwise	0.27	1–4
White	"1" if race is white; "0" otherwise	0.79	1–4
Children	Number of children living in household	0.78	1–4
Ln(income)	Predicted natural log of median income of survey-selected Census categories (7 categories: < \$25,000 to > \$250,000)	\$54,066[a]	1–4
Population density	"1" if < 3 per km^2 (*highly rural*); "2" if 3–386 per km^2 (*rural*); "3" if > 386 (*urban*)	2.4	1–4
Planning Process Fairness Perceptions			
Not at all fair	"1" if process not at all fair; "0" otherwise	0.07	2–4
Slightly fair	"1" if process slightly fair; "0" otherwise	0.07	2–4
Somewhat fair	"1" if unaware or process somewhat fair; "0" otherwise *(omitted category)*	0.61	2–4
Moderately fair	"1" if process moderately fair; "0" otherwise	0.16	2–4
Very fair	"1" if process very fair; "0" otherwise	0.09	2–4
Related Attitudes			
Climate change concern	"0" if not concerned; "1" if slightly concerned; "2" if somewhat concerned; "3" if concerned; "4" very concerned	2.4	3, 4
Wind effective at reducing climate change effects	"0" if no; "1" if don't know; "2" if yes	1.4	3, 4
Place attachment	9 category composite of "Identity" and "Regret" (2–10)	7.2	3, 4
General attitude toward wind development	"1" if prohibited; "2" if not sure; "3" in appropriate circumstances; "4" encouraged and promoted	3.4	3, 4
Negative property value perception	"1" if perceive project negatively effects property values, "0" otherwise	0.05	3, 4
Landscape fit	"1" if don't like look and does not fit, "2" if don't like look, but fits; "3" if neutral or no opinion on look; "4" if like look but does not fit; "5" if like look and fits landscape	3.9	3, 4
Stratification Variables			
Large project	"1" if nearby project > 10 turbines; "0" otherwise	0.29	1–4
Sound modeled project	"1" if sound modeled project and therefore was over-sampled; "0" otherwise	0.13	1–4
Dominant project	"1" if project has high percentage of all households within 8 km, and therefore was under-sampled; "0" otherwise	0.23	1–4
Distance to Nearest Turbine Bins			
≤0.8 km	"1" if home is in specified distance range; "0" otherwise *(omitted category)*	0.01	1–4
> 0.8 and ≤1.6 km	"1" if home is in specified distance range; "0" otherwise	0.04	1–4
> 1.6 and ≤4.8 km	"1" if home is in specified distance range; "0" otherwise	0.37	1–4
> 4.8 and ≤8 km	"1" if home is in specified distance range; "0" otherwise	0.58	1–4

[a] Weighted mean expressed as income rather than ln(income).

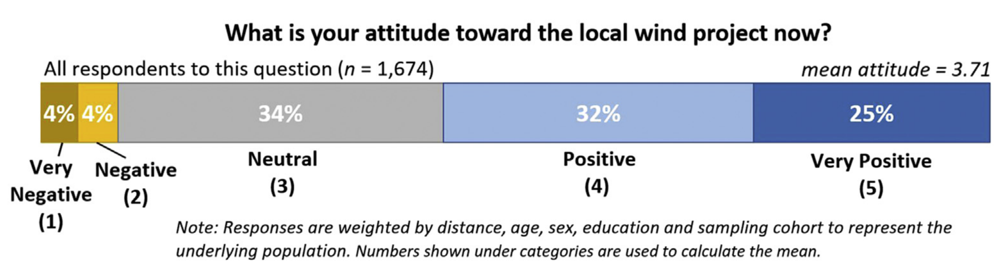

Fig. 4. Statistics for weighted attitudes toward local wind project (the dependent variable).

Table 3
Correlations between attitude and key independent variables.

Variable	Pearson's^	p-value	Spearman's^	p-value
Wind Project, Home and Arrival Characteristics				
Move-in prior to construction	−0.165	0.000***	−0.143	0.000***
Own residence	−0.248	0.000***	−0.098	0.000***
Primary home	0.024	0.324	−0.086	0.000***
Nearest turbine operation year	−0.047	0.054+	−0.069	0.005**
Wind turbine on property	0.063	0.011*	0.159	0.000***
Compensation; turbine not on property	−0.005	0.835	0.056	0.028*
Audio and Visual Sensory Perceptions				
See turbine from residence	−0.108	0.000***	−0.104	0.000***
Shadow flicker in residence	−0.057	0.02*	−0.168	0.000***
Hear turbine from property	−0.276	0.000***	−0.19	0.000***
Hear turbine with windows closed	−0.151	0.000***	−0.247	0.000***
Demographics				
Female	−0.015	0.557	0.017	0.549
Age	−0.142	0.000***	0.009	0.724
College	0.089	0.000***	0.103	0.000***
Median income (log)	−0.02	0.421	−0.008	0.724
Population density	0.311	0.000***	0.128	0.000***
Planning Process Fairness Perceptions				
Perceived process as fair	**0.635**	**0.000*** **	**0.693**	**0.000*** **
Related Attitudes				
Climate change concern	0.419	0.000***	0.177	0.000***
Wind effective at combatting climate change	**0.523**	**0.000*** **	**0.38**	**0.000*** **
Place attachment/identity	0.094	0.000***	0.044	0.076+
General attitude toward wind energy	**0.435**	**0.000*** **	**0.555**	**0.000*** **
Negative property value perception	**−0.389**	**0.000*** **	**−0.492**	**0.000*** **
Landscape fit	**0.565**	**0.000*** **	**0.647**	**0.000*** **
Stratification				
Distance to nearest turbine	−0.078	0.013**	0.046	0.057+
Large project (> 10 turbines)	−0.117	0.000***	−0.161	0.000***

^ Pearson correlations are weighted; Spearman's are unweighted, the only option available in Stata. Spearman's correlations are typically used with Likert data. Bolded correlations are considered strong (Spearman's > |0.3|). ***p < 0.001 **p < 0.01, *p < 0.05, + p < 0.10.

model). Model 1 is "constrained," including only objective independent variables such as turbine size, commissioning year, when the respondent moved into the community, and whether the respondent can see or hear a wind turbine. Model 2, the "fairness" model, adds a procedural fairness perception measure to the constrained model. The "full" Model 3 adds variables of perceptions related to climate concern, wind power effectiveness, place attachment, general attitudes, perceived property value effects, and fit of the wind turbines in the landscape. Finally, Model 4 estimates an ordered logistic regression using the same regressors as the "full" Model 3. For all models we include coefficients (Coef.), standard errors (SE), and *p*-values. For Models 1–3 the coefficients are unstandardized ordinary least squares (OLS) estimates but we also include the standardized coefficients (Std. Coef.). Any coefficients significant below the 0.10 level are bolded. The variables included in the various models are shown in the first column of Table 4 (and were previously defined in Table 2).

Because the models are unweighted, stratification variables are included as independent variables in all models to control for unequal probability of selection. Similarly, demographic variables are included in all models to account for nonresponse bias and because they may correlate with the dependent variable.

As we move from Model 1 (Constrained) to Model 2 (Fairness) to Model 3 (Full), the explained variation (i.e., Adjusted R^2) increases from 18% to 66%, although with the full model there is some concern for endogeneity. For example, the same respondent characteristics that explain attitudes toward the project may explain general wind power attitudes, perceptions of a project's effectiveness in mitigating climate change, or perceptions of the project's impact on property values. Model 4, the ordered logit model, results in similar intuitions as the OLS Model 3 and because the coefficients are more difficult to interpret we will focus on Models 1–3 for the remainder of the results discussion.

We now briefly summarize some of the main results before delving more deeply into them in the Discussion section.

Consistent with Tiebout sorting, individuals who moved in after construction have a more-positive attitude toward their local project; this variable is highly statistically significant in all models. Project participation—hosting a wind turbine or otherwise receiving compensation—is statistically and positively associated with a more-positive attitude in the constrained and fairness models, but not in the full model. Audio and visual sensory variables have mixed results. Seeing a turbine is not significant in any models. However, hearing a turbine on the property or in the home with windows closed is associated with more-negative attitudes in all models, with strong statistical significance. The connection between more-negative attitudes and shadow-flicker, on the other hand, loses its significance in the full model with subjective variables introduced.[7] Demographic variables are for the most part insignificant, although respondents with college degrees tend to have more-positive attitudes.

Individuals who live in the two closest distance bins (< 0.8 and 0.8–1.6 km) consistently have more-positive attitudes than those who live further away. Individuals have more-positive attitudes near smaller projects for the constrained and fairness models, but not for the full model. Population density is weakly negatively correlated with attitudes in the full model, which contradicts the bivariate analysis.

Consistent with Firestone et al. (2018a), we find that perceiving the public process leading to the local wind project was fair is significantly associated with a more-positive attitude toward the project. Moreover, as the process fairness categories transition from not at all fair to very fair, the results transition monotonically from a more-negative relationship with attitude to a more-positive relationship.

Related attitudes are introduced in the full models (3 and 4), where we find significance with all but one of the added variables—climate change concern. However, considering wind power as effective for mitigating climate change is strongly significant and positive, indicating it is a more powerful correlate with attitude than is concern about climate change. Although the effect of seeing a wind turbine from home is not significant, the effect of perceptions about how wind turbines fit within the landscape is. Additionally, attachment to place is correlated with more-positive attitudes while the perception that wind turbines result in lower property values for homes nearby is associated with more-negative attitudes. Finally, one's general attitude toward wind development is strongly correlated with attitude.

5. Discussion

Land-based wind power has become an important source of U.S. electricity, particularly in some areas of the country. In 2018, wind power already supplied at least 25% of generation to five states: Kansas (36%), Iowa (34%), Oklahoma (32%), North Dakota (26%), and South Dakota (25%) (Wiser and Bolinger, 2019). Various trends suggest that wind deployment may continue for many years, including falling wind energy prices, improving wind technology, and a public and corporate environment that often encourages renewable energy, as exemplified by California's commitment to 100% "clean" electric power by 2045 (California Senate, 2018). This growth increasingly will create

[7] There is likely some multicollinearity between some regressors added in the full model and shadow flicker. Two variables added in the "full" model are correlated with shadow-flicker: negative property value perception (Pearson's r 0.13, p-value 0.000; Spearman's ρ 0.32, 0.000) and landscape fit (r −0.07, 0.003; Spearman's ρ −0.14, 0.000). Without them, the shadow-flicker variable comes close to being significant at the 5% level (β −0.14, p-value 0.069).

Table 4
Regression Model of Respondents' Attitude toward Local Wind Power Project.

	(1)				(2)				(3)				(4)		
Model	Constrained - OLS				Fairness - OLS				Full - OLS				Full - OLogit		
R^2	0.19				0.37				0.66				0.33*		
***n* = 1331**	**Coef.**	**SE**	***p*-value**	**Std. Coef.**	**Coef.**	**SE**	***p*-value**	**Std. Coef.**	**Coef.**	**SE**	***p*-value**	**Std. Coef.**	**Coef.**	**SE**	***p*-value**
Wind Project, Home, & Arrival Characteristics															
Moved-in after construction began	**0.29**	**0.08**	**0.000**	0.10	**0.42**	**0.08**	**0.000**	0.14	**0.28**	**0.06**	**0.000**	0.10	**0.75**	**0.16**	**0.000**
Homeowner	−0.10	0.12	0.431	−0.02	−0.10	0.11	0.385	−0.02	−0.03	0.09	0.720	−0.01	−0.07	0.26	0.795
Primary home	0.00	0.06	0.981	0.00	−0.02	0.05	0.732	−0.01	−0.04	0.04	0.230	−0.02	−0.10	0.10	0.314
Turbine operation year	**−0.03**	**0.02**	**0.060**	−0.06	**−0.03**	**0.02**	**0.064**	−0.05	−0.02	0.01	0.172	−0.03	−0.04	0.03	0.216
Turbine total height	0.00	0.00	0.400	−0.03	0.00	0.00	0.681	−0.01	0.00	0.00	0.434	0.02	0.00	0.00	0.852
Project participation (no participation omitted)															
Compensation; no host	**0.53**	**0.11**	**0.000**	0.14	**0.20**	**0.09**	**0.027**	0.05	0.07	0.07	0.272	0.02	0.18	0.19	0.327
Host wind turbine	**1.00**	**0.13**	**0.000**	0.19	**0.53**	**0.10**	**0.000**	0.10	0.09	0.10	0.333	0.02	0.39	0.28	0.164
Audio and Visual Sensory Perceptions															
Ssee turbine from home	−0.02	0.08	0.805	−0.01	−0.04	0.07	0.571	−0.02	−0.03	0.05	0.565	−0.01	−0.05	0.14	0.719
Shadow-flicker in home	**−0.35**	**0.10**	**0.001**	−0.12	**−0.18**	**0.09**	**0.040**	−0.06	−0.05	0.07	0.438	−0.02	−0.21	0.18	0.250
Hear (cannot hear omitted)															
Hear on property	**−0.48**	**0.09**	**0.000**	−0.18	**−0.30**	**0.08**	**0.000**	−0.12	**−0.10**	**0.06**	**0.076**	−0.04	**−0.32**	**0.17**	**0.056**
Hear in home, windows closed	**−1.13**	**0.14**	**0.000**	−0.30	**−0.69**	**0.12**	**0.000**	−0.18	**−0.25**	**0.09**	**0.007**	−0.06	**−0.73**	**0.25**	**0.003**
Demographics															
Female	0.07	0.07	0.315	0.03	0.04	0.06	0.530	0.01	0.04	0.04	0.285	0.02	0.09	0.12	0.458
Age	0.00	0.00	0.788	0.01	0.00	0.00	0.573	−0.02	0.00	0.00	0.864	0.00	0.00	0.00	0.957
College	**0.18**	**0.08**	**0.026**	0.07	**0.18**	**0.07**	**0.012**	0.07	**0.15**	**0.05**	**0.005**	0.06	**0.41**	**0.14**	**0.004**
White	0.00	0.11	0.971	0.00	0.01	0.10	0.930	0.00	0.01	0.08	0.936	0.00	0.04	0.22	0.871
No. of children in home	0.04	0.03	0.161	0.03	0.02	0.03	0.365	0.02	0.02	0.02	0.275	0.02	0.07	0.06	0.219
LN (income)	−0.04	0.09	0.709	−0.01	−0.05	0.09	0.560	−0.02	0.02	0.07	0.724	0.01	0.09	0.17	0.585
Population density	−0.02	0.07	0.790	−0.01	−0.02	0.07	0.738	−0.01	−0.07	0.05	0.115	−0.03	−0.21	0.12	**0.090**
Stratification Variables															
Distance bins (4.8–8.0 km omitted)															
< 0.8 km	**0.40**	**0.13**	**0.002**	0.16	**0.30**	**0.12**	**0.012**	0.12	**0.17**	**0.09**	**0.058**	0.07	**0.54**	**0.25**	**0.028**
0.8–1.6 km	**0.43**	**0.11**	**0.000**	0.16	**0.35**	**0.10**	**0.000**	0.13	**0.19**	**0.07**	**0.012**	0.07	**0.53**	**0.20**	**0.010**
1.6–4.8 km	0.09	0.10	0.389	0.03	0.11	0.10	0.273	0.03	0.04	0.07	0.589	0.01	0.14	0.19	0.445
Large project	**−0.20**	**0.08**	**0.013**	−0.08	**−0.20**	**0.07**	**0.006**	−0.08	−0.03	0.05	0.577	−0.01	−0.04	0.15	0.767
Case study project	0.07	0.07	0.349	0.03	0.05	0.06	0.391	0.02	0.04	0.05	0.345	0.02	0.08	0.13	0.510
Dominant project	0.05	0.13	0.697	0.01	0.11	0.12	0.353	0.02	0.04	0.08	0.628	0.01	0.10	0.23	0.657
Planning Process Fairness Perceptions															
Process fairness (somewhat/unaware omitted)															
Not at all					**−1.12**	**0.12**	**0.000**	−0.27	**−0.37**	**0.09**	**0.000**	−0.09	**−1.02**	**0.26**	**0.000**
Slightly					**−0.28**	**0.13**	**0.027**	−0.05	−0.08	0.10	0.439	−0.01	−0.15	0.25	0.543
Moderately					**0.40**	**0.08**	**0.000**	0.11	**0.13**	**0.06**	**0.038**	0.04	**0.25**	**0.16**	0.118
Very					**1.15**	**0.08**	**0.000**	0.33	**0.55**	**0.07**	**0.000**	0.16	**1.56**	**0.21**	**0.000**
Related Attitudes															
Climate concern									−0.02	0.02	0.339	−0.02	−0.03	0.05	0.546
Wind effective									**0.16**	**0.03**	**0.000**	0.11	**0.42**	**0.08**	**0.000**
Place attachment									**0.02**	**0.01**	**0.027**	0.04	**0.07**	**0.03**	**0.023**
General attitude									**0.34**	**0.03**	**0.000**	0.20	**0.95**	**0.10**	**0.000**
Negative property value perception									**0.55**	**0.07**	**0.000**	0.17	**1.44**	**0.20**	**0.000**
Landscape fit									**0.32**	**0.02**	**0.000**	0.38	**0.80**	**0.06**	**0.000**
Constant	**4.71**	**1.07**	**0.000**		**4.57**	**1.01**	**0.000**		0.40	0.75	0.592				

Note: In models (2)–(4), the variable "moved in after construction" is included as part of the fair process variable, as individuals who moved in prior to construction were instructed to skip the question on fair process. As such, moving in post-construction is compared to the omitted fairness variable, which combines those who found the process "somewhat" fair—the middle option—with those who moved in prior to the commencement of construction but who were unaware of the project prior to construction. In model (1), the omitted case is moved in prior to construction, which is a slightly different omitted cohort than for models (2)–(4). * represents the pseudo R^2.

interactions between turbines and the neighbors who surround them.

Our results clarify the impacts of interactions between wind turbines and nearby residents to date, and they may inform policymakers about critical community considerations as wind projects continue to be developed. Our survey is unique because it draws on a national cross section of wind turbine neighbors—rather than focusing on individual case studies—and thus mitigates concerns about case-selection bias. In addition, our analysis is as concerned with factors that produce positive attitudes about wind projects as it is with factors that produce negative ones.

On average, we find mostly positive-leaning attitudes toward local wind projects across the sample and for almost every sub-cohort we investigated. The ratio of those with positive (32%) or very positive (25%) attitudes to those with negative (4%) to very negative (4%) attitudes across the whole sample is 7:1. Therefore, it appears that wind turbines are considered good neighbors for the overwhelming majority.

We discover a number of correlates to these attitudes; many of which we discussed in our literature review (Section 2) and briefly in the preceding section. Here we discuss our findings within the context of those correlates.

Local attitudes: Across our entire sample and the large majority of cohorts we investigated, mean attitudes toward local wind projects are positive, which is consistent with the literature. Moreover, the attitudes of residents moving in after wind project construction are consistently more positive than of those who moved in before construction, implying that community attitudes will become more positive over time.

Given these findings, accounting for Tiebout sorting in future analyses of this kind is, therefore, critical.

Sound and visual effects: Respondents who hear wind turbines are less likely to have positive attitudes toward the turbines, and this effect is more pronounced among respondents who hear the turbine in their home with the windows closed. This finding is consistent with past research as well as intuition. The effects of seeing a wind turbine are more complex. Although some evidence suggests that those who see a wind turbine are more likely to have negative attitudes (e.g., see Table 3), this relationship does not hold when we apply regression analysis. Perhaps the issue revolves not around seeing a turbine per se, but rather around more aesthetic and socially constructed phenomena that account for how individuals evaluate a turbine's appearance and fit within the landscape. Based on our regression analysis, attitudes move from negative to positive as respondent attitudes move from not liking the look of the turbines and thinking they fit badly within the landscape to liking the look and believing they fit well.[8]

Project participation: Residents who receive compensation linked to wind project development—with or without hosting a turbine on their property—may be more likely to hold a positive attitude toward the project, as evidenced by two of our regression models (the constrained and fairness models). However, the effects of such compensation are not significant in our full model, which accounts for related attitudes about wind energy and the environment. In addition, our constrained and fairness models show the effect on attitude is roughly halved when there is compensation without hosting versus compensation with hosting. Overall, these findings suggest that compensation is not a panacea to improve attitudes.

Proximity: Correlation analysis suggests weak evidence that attitudes differ based on proximity to wind. Yet, when we control for project attributes, whether a wind turbine can be seen or heard, and demographics, we find those living closer to wind turbines have significantly more-positive attitudes than those living farther away. This is counterintuitive but supported by some case-study findings (Baxter et al., 2013; Groth and Vogt, 2014); greater familiarity (as a proxy of closer proximity) seems to lead to more-positive attitudes. Further, we find attitudes toward local projects correlated with attitudes toward wind energy in general. Therefore, respondents' attitudes toward their "local" project (i.e., in the respondent's backyard) are significantly correlated with their attitudes toward wind energy in general. Together with the proximity findings, this reinforces the findings of others (e.g., Wolsink, 2000) that "not-in-my-backyard" (NIMBY) might not be an appropriate explanation for negative attitudes locally.

Place attachment: Our finding that residents with higher levels of place attachment have more-positive attitudes contrasts with findings in much of the literature, which has focused on place attachment and its relationship to opposition as well as the place-protective motivations of opponents. Our interpretation is that attitudes are more driven by whether wind turbines are considered to be consistent with a local resident's notion of place (Bates and Firestone, 2015). For example, some local residents may describe wind turbines located proximate to their homes as industrial; while others may provide a more socially-constructed description, seeing them as representative of a clean energy future (Firestone et al., 2018b). The former may see wind turbines as "out-of-place," and the latter as "in-place" (Devine-Wright and Howes, 2010).[9]

Process fairness: Consistent with the more in-depth analysis in Firestone et al. (2018a), we find that attitudes toward local wind projects are strongly intertwined with perceptions about the fairness of the wind-development process. All else being equal, the fairer a process is perceived to be, the more positive the attitudes are. Therefore, researchers might continue to account for both distributive and procedural fairness in their models.

Environmental concern: Although attitudes toward local wind projects do not correlate significantly with concern about climate change, attitudes are more positive when wind energy's effectiveness at combating climate change is perceived to be higher. This result suggests that the public places more emphasis on practical solutions than it does on emotional responses to a changing climate. Alternatively, it may be because the former is specific to wind energy while the latter is not.[10] It also may imply a preference for turbines that are consistently generating power for (i.e., making a difference/operating in) the community, echoing Thayer and Freeman (1987) results from California about the importance of turbine "reliability" in the public's support of wind energy. It also is consistent with recent trends in public policy in the United States, with more focus on renewable energy targets.

6. Conclusions and policy implications

We assume that policymakers involved with wind project development aim to create positive outcomes, including acceptance of and positive attitudes toward wind projects among local community members. This research provides evidence that should assist policymakers in guiding wind power developments in ways that achieve those social goals at the same time as technical, economic, or environmental goals are achieved.

Overall, we find mostly neutral to very positive attitudes across the sample, with those attitudes tending to improve over time as individuals self-select into communities near existing wind projects. Indeed, our findings suggest that many residents who live near wind turbines incorporate them into their communities. In that sense, wind turbines may make good neighbors. However, we also find that differences across our sample can lead to more-negative or more-positive attitudes.

Hearing wind turbines leads to less-positive attitudes, suggesting that sound-reduction research and development (R&D) supported by government, turbine manufacturers, and other industry participants may lead to improved social outcomes for wind projects. In addition, developers are an important part of the equation, because they influence turbine model selection and project layout. State and local governments also play a role in devising appropriate setbacks based on sound output, although our findings show that proximity alone does not lead to less-positive attitudes.

Seeing wind turbines does not produce less-positive attitudes, but perceiving that wind turbines are unattractive or fit poorly within the landscape does. At the same time, residents' attachment to their local area is associated with more-positive attitudes. These findings suggest that wind project developers may promote better outcomes by considering how local residents perceive turbines and their communities, rather than focusing on turbine visibility alone. Firestone et al. (2018a) found that, when individuals feel their community has been able to influence a wind project's layout and number of turbines, they are more likely to perceive the public process leading to approval as fair and to have more-positive attitudes toward the built project. This finding also is relevant to developers, who may benefit from emphasizing local engagement over merely reducing turbine visibility.

Compensation may help to improve attitudes in individual cases, but our results indicate that it is not a panacea. That said, if nearby residents find compensation and the accompanying closer relationship with the developer as an element of having had a say in the project that they otherwise would not have had, it could lead to more-positive

[8] Although the landscape-fit variable is included as a continuous variable for reasons of parsimony, it was tested as a categorical variable and the coefficients were all statistically significant and monotonically ordered moving from landscape fit 1 to 5, and with little effect on the other variables.

[9] Our survey instrument did not contain a question about place consistency, and therefore we cannot test this interpretation directly.

[10] Suggested by an anonymous reviewer.

attitudes (Jacquet, 2014).

Finally, people living near wind turbines appear to care more about effective solutions to environmental problems like climate change than about the environmental problems themselves. For this reason, a continued industry focus on turbine performance and reliability may have benefits beyond lowering the levelized cost of energy. If people perceive that wind turbines are an effective environmental solution, they may be predisposed to a positive attitude toward nearby wind projects.

Further research

As noted, our results depart somewhat from the mainstream in a couple of places, e.g., place attachment, although some departure is expected given that prior work was primarily case based. In that regard, we consider our most important contributions to be methodological - a national cross section rather than being case based, which also can suffer from researcher selection bias; weighting of descriptive survey data in a manner that takes into consideration the sample design and differential rates of response by demographic characteristics; accounting for Tiebout sorting; and, including a wide range of covariates in the model.

Promising areas of future research include more focused and, ideally, experimental research on process fairness and compensation, accounting for those who can or are likely to hear turbines. We also recommend duplicating our data-collection process in other countries or across whole states to examine differences compared with our U.S. national sample. Our study focuses on residents near built wind projects only; failed projects are not included in the data set. Failed projects may be associated with higher percentages of negative attitudes. They also may represent situations in which people with negative attitudes—although potentially a minority—had the project withdrawn or rejected owing to, for example, organizational skill, financial resources, and/or missteps by the developer or unique situational/environmental factors. Therefore, if possible, both failed and successful projects should be included in future analyses. Finally, our research is not longitudinal, and although we did attempt to ameliorate this by asking respondents to consider their attitudes at a previous point in time, a longitudinal study would better capture these time-sensitive changes. This is important because these attitudes might modulate during the wind development process (see e.g., Wolsink, 2007b).

Data availability

The data that support the findings of this study are available on request from the corresponding author, with appropriate limitations to protect privacy/confidentiality of the human subjects. The full set of data is not publicly available owing to the presence of personally identifiable information that could compromise research participant privacy/consent and institutional review board (IRB) protocols. See supplemental materials for data request details.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2019.110981.

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