Received: 16 November 2018 | Revised: 28 June 2019 | Accepted: 8 July 2019
DOI: 10.1002/we.2399

RESEARCH ARTICLE

WILEY

Environmental activism and vertical-axis wind turbine preferences in California

Iris Hui[1] | Bruce E. Cain[1] | John O. Dabiri[2]

[1] Bill Lane Center for the American West, Stanford University, Room 172, Y2E2, 473 Via Ortega, Stanford, California 94305, USA

[2] Civil & Environmental Engineering and Mechanical Engineering, Stanford University, Room 169, Y2E2, 473 Via Ortega, Stanford, California 94305, USA

Correspondence
Iris Hui, Bill Lane Center for the American West, Stanford University, Room 172, Y2E2, 473 Via Ortega, Stanford, CA 94305, USA.
Email: irishui@stanford.edu

Abstract

Wind energy is widely recognized as a key element of the worldwide effort to limit greenhouse gas emissions. As compared with the general population, environmental activists have a much higher level of knowledge, interest, and capacity to affect the final outcome of a proposed wind turbine facility. To explore how their opinions on wind energy, particularly on vertical-axis wind turbines, differ from the general public, we administered the same online experimental survey to a general population sample of adult Californians and to a self-selected sample of online energy and environmental activists. We find that support for wind energy increases with the degree of environmental activism and engagement. The general public prefers vertical-axis wind turbines in open spaces, away from one's residence. Location and price sensitivity, however, are weaker among activists. Among activists, attitudes about specific vertical-axis wind turbine technologies are more crystalized and less susceptible to the information effects except on the topic of minimizing bird deaths.

Highlights

- Attitudes toward wind energy differ among environmental activists and general public.
- General public prefers vertical-axis wind turbines (VAWTs) in open space, further from one's residence.
- Location and price sensitivity are weaker among activists.
- The potential of minimizing bird deaths increases support for VAWTs.

KEYWORDS

vertical-axis wind turbine, horizontal-axis wind turbine, environmental activism, public opinion, renewable energy, California

1 | INTRODUCTION

Although wind energy is a critical component of the global strategy to reduce greenhouse gases and decarbonize the global economy, wind energy projects can be controversial with the public. Concerns such as noise, light flicker, ownership, proximity to residences, and bird deaths have held up or prevented wind turbine installation projects in the past. To take a few examples, the prospects of birds being caught in the blades and giant turbines being visible from the shore held up a project in Cape Cod, MA.[1] The potential adverse effect on the grouse population scuttled a wind project in Oregon[2] while concerns about possible noise and adverse health effects garnered opposition to a wind project at Grey-Bruce, Canada.[3]

Some of these problems have been addressed by siting wind farms in remote places or by improving technologies, but others such as the danger of wind turbine blades killing birds persist. Public opposition can delay projects, adding to their expense, or in some instances, causing them to be cancelled altogether. Consequently, public opinion can shape the rate and success of green energy transition in unintended ways at the implementation stage.

There are two especially critical elements to public influence in this regard. First, the public is not uniformly distributed with respect to interest, knowledge, and proclivity to action.[4-6] On almost every issue, but particularly technical ones, there is a wide gap between the general public and the politically engaged subpopulation. The latter are more likely to have firmly held views and to participate regularly in various policy venues for the purpose of advancing their causes.[7,8]

Second, these types of disparities are now more important than ever because there are more transparency requirements and opportunities for public input in energy project licensing and permitting processes at all levels of government. Unless it impacts them directly, the average citizen is unlikely to attend these kinds of hearings or devote sufficient time to studying the issues in order to be effective. A siting decision might bring out only nearby residents to a hearing whereas bird activists or wind advocates from other places are often less deterred by geographic distance. The consequence is "selection bias" at the hearings, overrepresenting the most highly motivated members of the public such as nearby residents, various environmental activists, and specific online activist populations (eg, bird enthusiasts, conservation groups, green energy advocates, etc).

Because the participation gap between the general population and the highly motivated subpopulations matters for energy policy, it is important to understand how their respective attitudes differ, as well as to map out the specific issues over which these divisions occur. California is a good place to study tensions between energy policy and wildlife concerns because the state has both ambitious green energy goals and a robust nonprofit environmental sector. The Global Warming Solutions Act of 2006 (AB 32) requires the state to reduce its statewide greenhouse gas emission back to the 1990 levels by 2020. The Senate Bill 32 further requires the state to reduce emissions to 40% below the 1990 levels by 2030. Employment of clean, renewable energy such as wind and solar energy will play an increasingly important role in the state's energy consumption.

To gauge the types and extent of division in public opinion on wind turbine policies, we administered the same online experimental survey to a general population sample of adult Californians (N = 1966) representing a range of environmental activism and to a self-selected sample of energy and environmental online respondents (which we will call the "online activists") in the state (N = 103). We ask which aspects of wind turbine design would increase or decrease both general public and the online activist support for any given technology and what implications does that have for wind energy strategy in the future.

2 | PUBLIC OPINION AND WIND TURBINES

Among specialists and experts in the discipline, there is considerable debate over the relative merits of horizontal-axis and vertical-axis wind turbines.[9] A horizontal-axis wind turbine has a rotating axis parallel with the ground. In contrast, vertical-axis wind turbine has a rotational axis perpendicular to the ground. The debates focus to a considerable degree on the question of the relative energy efficiencies of horizontal and vertical-axis wind turbines.[10-13] While majority of wind farms in the country utilize horizontal-axis wind turbines for this reason, recent advances in vertical-axis wind turbine technology have made the system more efficient by deploying turbines in clusters.[14]

The whole life cycle performance of a turbine system depends on a number of factors, including the siting of the turbine, availability of wind resource, the design, and the use of materials to construct the blades.[15] Its energy efficiency can be affected by the size of vertical-axis wind turbine. A recent study compares the environmental impacts of electricity generated by vertical-axis wind turbine with 1 and 3-kW nominal power. Results show that the 3-kW turbine has lower values of the environmental impact indicators per unit of produced energy than the 1-kW turbine.[13]

A major concern with wind turbines among environmental activists is the likely impact on birds.[16-18] Two previous studies have documented the impact of bird and bat fatality associated with the horizontal-axis wind turbines.[19,20] Anecdotal evidence suggests that vertical-axis turbines may have an advantage of damaging fewer bird kills over the horizontal-axis turbines, although this claim has not yet been empirically verified. The public also has concerns about potential health hazards associated with wind facilities. Some studies find that the visual evaluation of wind turbines is associated with perception of noise annoyance.[21,22] Furthermore, the level of turbine noise is often associated with potential impacts on physical health and psychological well-being.[23-26] Apart from noise, shadow flicker from turbine blades may precipitate seizures.[27] Among the general population, previous research indicates that while cross-country public support for wind energy is generally high,[28] public understanding of wind power is relatively poor.[29] Support rises with the level of perceived need for wind power.[30] Opposition to wind energy often derives from ideological or aesthetic considerations.[31-33]

In what is known as "not-in-my-backyard" (NIMBY), some people evaluate a wind farm project primarily based on its location and proximity to their home.[22,34,35] Others may have concern for spoiled scenery.[36] Some of these objections have been met by siting wind farms in remote places and away from environmentally sensitive areas, while others have been met by technological advances (eg, noise reduction). Nonetheless, as new proposals for wind developments may disrupt preexisting emotional attachments and threaten place-related identity processes,[37,38] they can engender many objections from citizens and stakeholder groups even when the majority of them are committed to meeting the challenges of climate change.[39]

We conducted a public opinion poll in California to examine public receptiveness. In our previous work,[40] we used experimental design to assess the willingness to accept vertical-axis turbines in certain rural versus urban settings. We find that the visual differences between the vertical and conventional wind turbines did not matter very much in any of the hypothetical settings in which we placed them. However, the prospect of killing fewer birds registered strongly with our survey respondents, although it could be outweighed by concern for cost.

For this paper, we further dissect how perception varies with environmental activism. By mapping the division within the general population, we can anticipate the responses of various subpopulations when a wind farm site is proposed. The question we address in this study is to what degree does opinion about and receptivity to the influence of different types of information diverge between the general public and online activists with respect to wind turbine choices.

Drawing from literature on public opinion, we would expect the following hypotheses. First, the more environmentally active and informed individuals should be more likely to view wind energy favorably. Since the environmental community as whole is overwhelmingly committed to reducing greenhouse gases and mitigating future human-induced climate change, we hypothesize that individuals in that community might be more likely to accept as necessary some drawbacks associated with wind turbines such as noise, the size of the footprint, light flicker, appearance, and the like.

Second, we would expect that the less engaged members of the public should be more affected by considerations of cost and proximity to the turbines. The weaker the commitment to countering climate change, the lower the willingness to pay more for wind energy or to have turbines and their transmission lines sited closer to their residence. We would expect that any solution that minimizes an adverse tradeoff between two environmental goals (eg, between preventing bird death and achieving green energy goals) should resonate with all three subgroups.

Finally, we expect that the online activists will be more entrenched in their general disposition towards one technology or the other. Zaller introduces the "receive-accept-sample" (RAS) model.[41] His theory predicts conditions under which a message is received and if received, accepted, or rejected. The reception of a message depends on the intensity of the message and the general level of awareness of an individual. The most sophisticated and knowledgeable respondents would be more likely to resist a message that contradicts with their predispositions. Hence, the more an individual becomes knowledgeable about or worked with a particular technology, the higher the intellectual sunk costs and initial resistance to information that does not confirm their prior beliefs. This does not mean that their views cannot be changed by evidence, but only that it would take more evidence to counter what has been learned and observed in the past.

3 | RESEARCH DESIGN AND DATA COLLECTION

We drew our survey samples from two sources. The first dataset was collected by Qualtrics, a commercial survey company that specializes in web-based data collection and partners with over 20 web-based panel providers to supply specific respondents as requested. We created a 15-minute online opt-in survey. Then, we recruited through Qualtrics to obtain a representative sample of California residents who were at least 18 years old (N = 1966) by drawing from a quota sampling based on race, sex, and age. Since the online responses varied substantially in response quality, Qualtrics screened out incomplete surveys, repeated respondents, and straight-lining responses (ie, respondents who rush through the survey by clicking on the same response every time). In addition, we also screened out respondents who failed the attention check tests.

In Table 1, we compare the characteristics of our sample to the general population. The percentages within each subsection add to 100%. For example, for Table 1, in our sample, 38% of respondents were Hispanic. Sixty-two percent of respondents were non-Hispanic. Take racial and ethnic composition, our sample has 56% white and 38% Hispanic respondents. The composition is comparable with that in the general population (also 56% white and 38% Hispanic). Relative to the general population, our sample has a larger proportion of college-educated respondents and slightly higher household income. Other than that, our sample is similar to the general population in terms of racial, ethnic, age, sex, and political composition.

We also conducted a survey of California's environmental and energy online activists. Since there is no comprehensive registry of wind energy activist groups, the second sample (N = 103) was recruited through an email announcement circulated to a few dozen environmental nonprofits and wind energy online forums in California. Participation in the survey was limited to those with valid California zip codes. The second column in the Table 1 provides a summary of their background characteristics. This group also exhibits a higher concentration of white (81% white as compared with 58% in the general population), college-educated respondents (89% received college and/or graduate education) than the general population as well as a higher share of independents (36% reported as independent or with a third party) and Democrats (55% of the respondents in the online activists reported themselves as Democrats).

As both groups comprise of opt-in sample respondents, likely selection biases limit our ability to make generalized inferences about our findings. In particular, since there is no comprehensive census or registry on environmental activists, it is not possible to draw a probabilistic sample of our online activists. Hence, we do not claim that our online activist sample is a truly representative sample of all activists in the state of California. Despite its limits, however, our sample does provide a glimpse into how the nonprofit environmental and energy online activists perceive wind turbine issues as compared with other segments of the population.

TABLE 1 Comparison between our sample and general population

	General Population Sample, %	Online Activist Sample, %	California Adult Population, %
Partisanship			
% Democrat	49	55	44
% Republican	22	9	28
% Independent/other party	30	36	29
Age composition			
% Age between 18 and 34	32	16	33
% Age between 35 and 54	38	26	37
% Age 55 or above	30	58	30
Income composition			
% Income <$50k	39	21	47
% Income $50k-<$100k	33	23	33
% Income over $100k	23	47	20
% Income not stated	5	10	N/A
Marital composition			
% Married	48	55	48
% Not married	52	45	52
Racial composition			
% White	56	81	58
% Nonwhite	44	19	42
Ethnicity composition			
% Hispanic origin	38	8	38
% Non-Hispanic	62	92	62
Education composition			
% High school or less	16	1	43
% Some college	37	10	30
% College or more	47	89	27
Gender composition			
% Male	49	54	50
% Female	51	46	50
Home ownership composition			
% Own home	56	72	54
% Not own home	44	28	46
Sample size	1966	103	

Note. The cells in each subsection may not add up to 100% due to rounding.

Given the potential self-selection bias in our samples, we rely on the use of experiments to gauge the receptiveness of vertical-axis wind turbines (VAWTs) and increase the internal validity of our study. The use of online survey experiment is akin to conducting focus groups of two different populations. We are especially interested in how these respondents react to different information cues given about the technology.

The full design of the survey was reported in Hui et al.[40] Our survey began with questions about receptiveness toward the more prevalent horizontal-axis wind turbines versus the newer generation of vertical-axis systems. Respondents were presented with three paired scenarios featuring HAWTs and VAWTs in ocean, rural, open space. They were asked to rate, on a scale from 0 to 10, whether they prefer installing HAWTs/VAWTs in each scenario. The pictures are shown in Online Appendix 1.

Subsequently, respondents were told a random subset of three properties about the VAWTs. They were then asked to evaluate the VAWTs, as well as to consider potential siting and pricing options. Respondents were also presented three additional hypothetical siting scenarios for the VAWTs, including along a highway and two urban settings. We were particularly interested in the last two settings because, relative to the conventional wind turbine system, VAWTs offer a unique opportunity to be integrated into more densely populated urban environments. The photos are presented in the Online Supplementary Appendix. The survey then followed up with an open-ended question that invited our respondents to express their thoughts, comments, and concerns that were not captured by our close-ended questions. It ended with batteries of questions that measure the respondents' sociodemographic background and their level of environmental activism.

We expected the levels of activism to vary more in the general population sample than in the online activist sample. We also thought that attitudes might be harder to change with new information in the online activist sample as those respondents were likely to be better informed and have more settled views on wind energy issues. Hence, we further dissect our samples by levels of environmental activism and analyze their attitudes. We used two batteries of questions to measure environmental activism. The first battery asked, “How often do you do the following things?” These eight items measure the extent of “green behavior” respondents practice in their daily life. The responses were given on a four-point Likert scale. We coded the responses with the following coding scheme: 0 if a respondent never does that activity, 0.33 if a respondent does it sometimes, 0.67 if a respondent does it often, and 1 if does it always.

In random order, respondents were presented with a list of eight items:

1. Talk or communicate with friends and/or family about protecting the environment.
2. Bring your own reusable shopping bag when shopping.
3. Take public transit, bike, or walk when possible instead of driving.
4. Buy only energy-efficient light bulbs.
5. Buy organic or locally grown food.
6. Follow environmental issues in the news (prints, radio, online, or social media).
7. Recycle newspapers, glass, aluminum, motor oil, or other items.
8. Pursue outdoor activities, such as hiking, fishing, and camping.

The second battery of questions focuses on external efficacy. The leading question was the following: “Have you done the following tasks in the past year?” We coded the responses in a binary format (1 = yes, 0 = no). Again, six items were presented in random order.

1. Attended local political meetings, such as school board or city council.
2. Contacted a business to complain about its products because they harm the environment.
3. Voted or worked for electoral candidates because of their position on environmental issues.
4. Contributed money to political parties or political candidates.
5. Contributed money to an environmental conservation or advocacy group.
6. Contacted a public official about an environmental issue.

The Cronbach alpha for these items is 0.81, indicating high internal consistency. We also ran factor analysis with two dimensions. The result shows that the first and second components have SS loadings of 4.13 and 1.55, respectively. Since the first dimension explained 73% of the

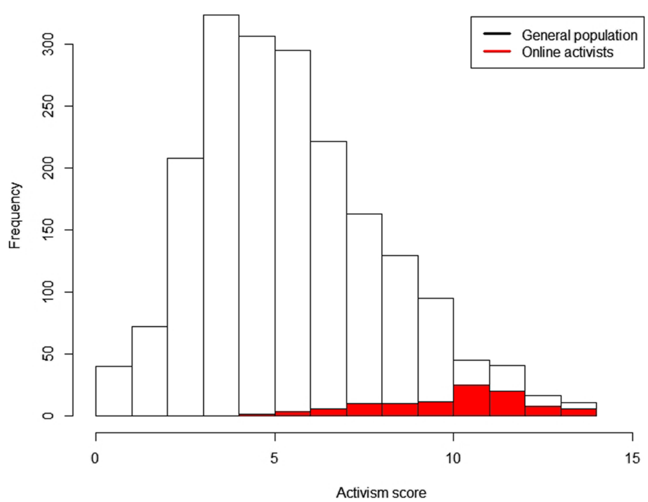

FIGURE 1 Distribution of environmental activism scores in our two samples [Colour figure can be viewed at wileyonlinelibrary.com]

variance, we decided to combine these survey items. Combining the scores from the first and second batteries results in our "environmental activism score" which ranges from 0 to a maximum of 14 points. We then further subdivided our respondents into three groups based on their environmental activism score. Group 1 consists of those who scored between 0 and 4 points; group 2 consists of those who scored above 4 to 10 points; group 3 consists of those who scored more than 10 points. We use this scale to distinguish the level of activism in both the general and online activist samples.

4 | RESULTS

We know from previous political science research that there is a strong correlation between policy interest and knowledge and the proclivity to participate in politics.[42-44] This is important because it can create a gap between what the general public wants and what activists and

TABLE 2 Demographic composition of subgroups

	General Population Sample			Online Activists	
	Group 1	Group 2	Group 3	Group 2	Group 3
Partisanship composition					
% Democrat	33%	53%	67%	45%	63%
% Republican	30	19	16	16	3
% Independent/other party	37	28	18	39	34
Age composition					
% Age between 18 and 34	32	32	36	25	9
% Age between 35 and 54	39	37	45	25	27
% Age 55 or above	29	31	19	50	64
Income composition					
% Income <$50k	44	37	27	16	24
% Income $50k-<$100k	31	33	42	25	21
% Income over $100k	17	25	30	55	41
% Income not stated	7	5	1	5	14
Marital composition					
% Married	43	48	64	43	46
% Not married	57	52	36	57	54
Racial composition					
% White	52	57	64	77	83
% Nonwhite	48	43	36	23	17
Ethnic composition					
% Hispanic origin	41	37	35	11	9
% Non-Hispanic	59	63	65	89	91
Education composition					
% High school or less	21	14	7	0	2
% Some college	43	36	29	7	12
% College or more	35	50	64	93	86
Gender composition					
% Male	46	49	70	63	47
% Female	54	51	30	37	53
Home ownership composition					
% Own home	51	57	70	68	74
% Not own home	49	43	30	32	26
Number of respondents	538	1314	114	44	59

Note. The cells in each subsection may not add up to 100% due to rounding.

stakeholders prefer, which can then lead to a policy skew because public policy is more heavily influenced by those who participate at every stage of policymaking as opposed to those who simply vote. Does this gap between the less and more engaged and knowledgeable individuals exist with respect to wind energy policy as well?

First, we compare the distribution of activism scores in our two samples in Figure 1. On a scale between 0 and 14, the mean activism score for the general population sample is 5.6 (with standard deviation of 2.6), whereas the mean for the online activist sample is 10.1 (standard deviation of 2.2). Members from the latter sample who were willing to take the time to fill out our questionnaire were much more highly engaged in environmental activism generally, as expected. When we divide both samples into three groups, our online activist sample only contains respondents who were in group 2 or 3. In the general population sample, 27% belongs to group 1, 67% belongs to group 2, and 6% belongs to group 3. Even in California, a state known for its efforts in mitigating climate change and improving the environment, the highly engaged group of citizens is a very small subset of citizens. By comparison, 43% and 57% were classified into groups 2 and 3, respectively, in the online activist sample. Figure 1 serves as a reminder that with respect to public engagement, there is no homogenous, monolithic general public, but rather widely varying degrees

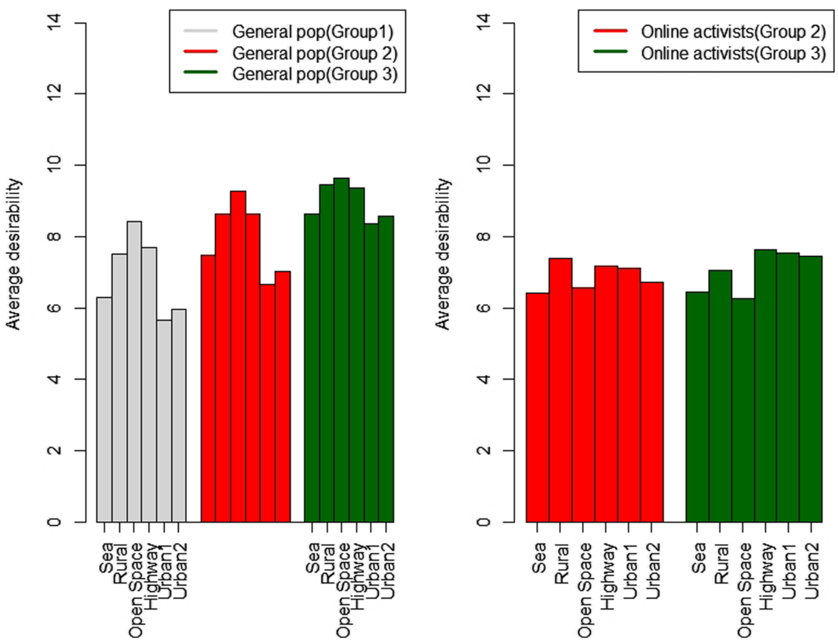

FIGURE 2 Siting preferences across groups in our two samples [Colour figure can be viewed at wileyonlinelibrary.com]

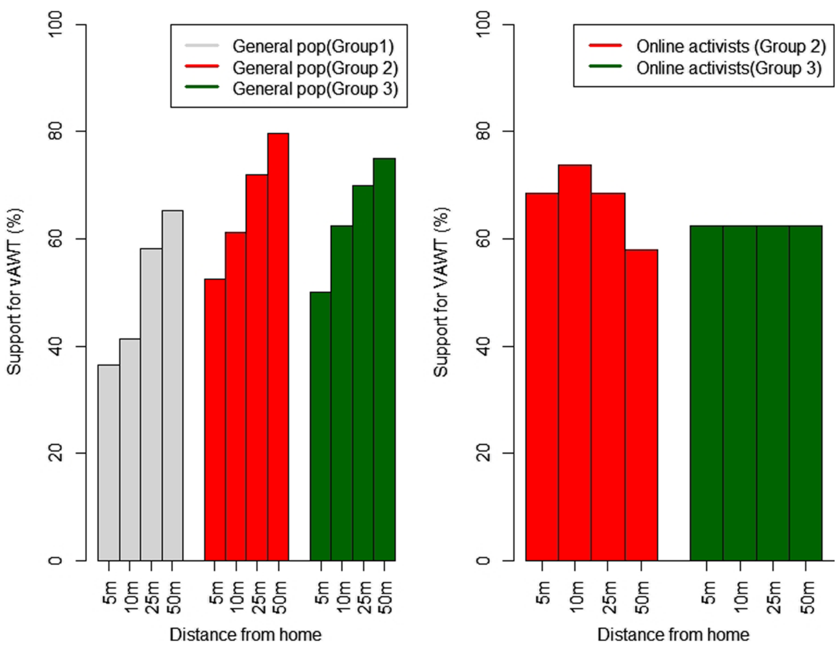

FIGURE 3 Sensitivity to distance across groups in our two samples [Colour figure can be viewed at wileyonlinelibrary.com]

of public engagement. This is a critical point when designing democratic opportunities for citizen input at the implementation stage of either policy or technology.

Table 2 shows the demographic composition of these groups. Members of group 3, in either the general population sample or the online activist sample, are more likely to be Caucasian, more highly educated, and have higher household income. They are also more likely to self-identify as Democrats.

4.1 | Evaluating specific siting choices

We examined more closely the aspects of wind turbine design that seem to have the most impact on public receptivity. One possibility is that the visual difference between the horizontal and vertical designs might alleviate some environmental and NIMBY concerns around siting wind energy facilities. We tested this in the following way.

Respondents were given six photos of different places where VAWTs could be located. Figure 2 presents the siting preferences among the respondents in our two samples (the general population in the left panel and the online activist sample in the right panel). Respondents were asked to rate on a scale from 0 to 10 (most preferred) the desirability of each location. The *y*-axis plots the average desirability score by group. Note that among the general population sample, higher levels of environmental activism increase support for VAWTs in all sites.

Respondents who are in group 3 (most environmentally active group) consistently give the highest rating in all six scenarios. Out of the six scenarios, the open space siting is the most preferred. The two urban settings are the least preferred by the respondents. The results suggest that even if the VAWT technology could be installed in urban settings, it will likely encounter some public resistance and will require some persuasion to overcome initial psychological resistance.

The online activist sample on the right panel displays a much smaller range of change across the six alternatives, which suggests that siting is less important to their support as a group and that there is little or no difference across their activism levels. Highway and rural setting are only slightly preferred by the respondents, and support for siting in open spaces is particularly low as compared with the general population. Based on the open-ended responses, this likely reflects a greater interest in protecting wildlife and preserving natural environments in the online activist sample.

Another common concern with siting wind energy is the NIMBY attitude. Figure 3 shows four hypothetical scenarios where the VAWTs were to be installed 5, 10, 25, or 50 mi from home (or 8, 16, 40, 80 km when expressed in kilometer). NIMBYism is more profound in the general population sample than our online activist sample. Support for the VAWTs increases by almost 20% points if the VAWTs were to be installed 50 mi instead of 5 mi from the respondents' residence. By comparison, the lines in the online activist sample are relatively flat and indistinguishable across activity levels. This relates to our earlier point that public hearings related to siting will stir neighbors who are not generally engaged in energy issues, but the nonprofit and energy communities will have a broader and less geographically oriented interest in siting controversies.

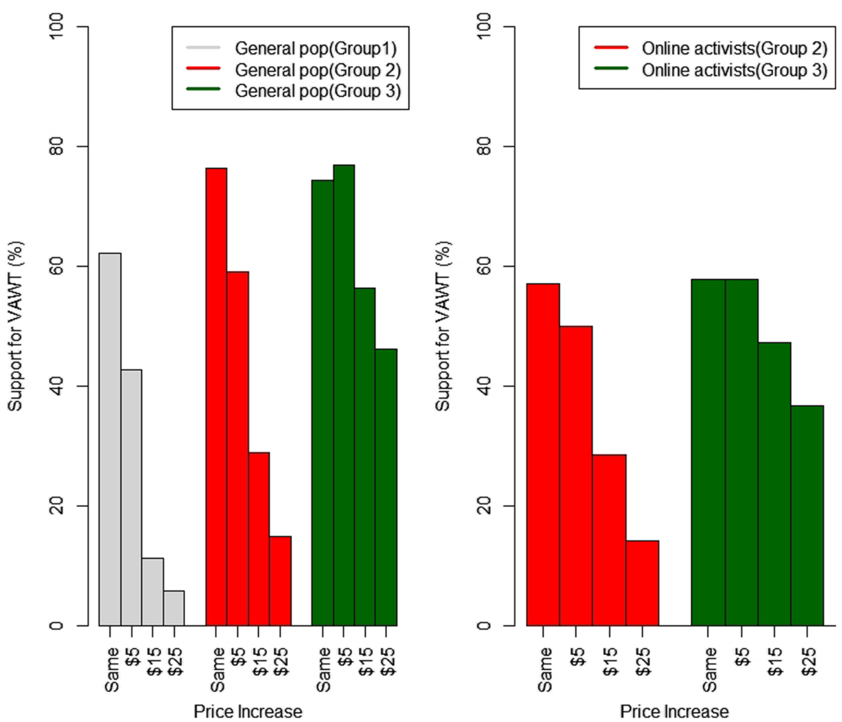

FIGURE 4 Price sensitivity across groups in our two samples [Colour figure can be viewed at wileyonlinelibrary.com]

4.2 | Price sensitivity

We further explored cost sensitivity across groups and in both samples by asking respondents if they would support the VAWTs given the cost would "stay the same," "increases by $5 per month," "increases by $15," and "increases by $25." Figure 4 plots the support under these four different scenarios. While potentially higher price would dampen support across all groups, there is substantial price elasticity difference by environmental activism. Respondents who were more environmentally active were less sensitive to price increases.

4.3 | Evaluating other attributes

Aside from siting and pricing issues, it is also possible that preferences could shift as the result of information shared with the respondents about other points of comparison related to vertical and wind technologies. As described earlier, we introduced a battery of suggested VAWT properties as compare with conventional horizontal wind turbines at random. Specifically the suggested features were that, compared with conventional wind turbines, VAWTs

- Is 90% shorter (ie, 1/10 of the height).
- Can be installed without specialized equipment.
- Would require more units to generate power (ie, smaller turbines but more numerous).
- May kill 90% fewer birds and bats.
- Is 50% quieter.
- Per kilowatt-hour electricity cost may be 25% more expensive.

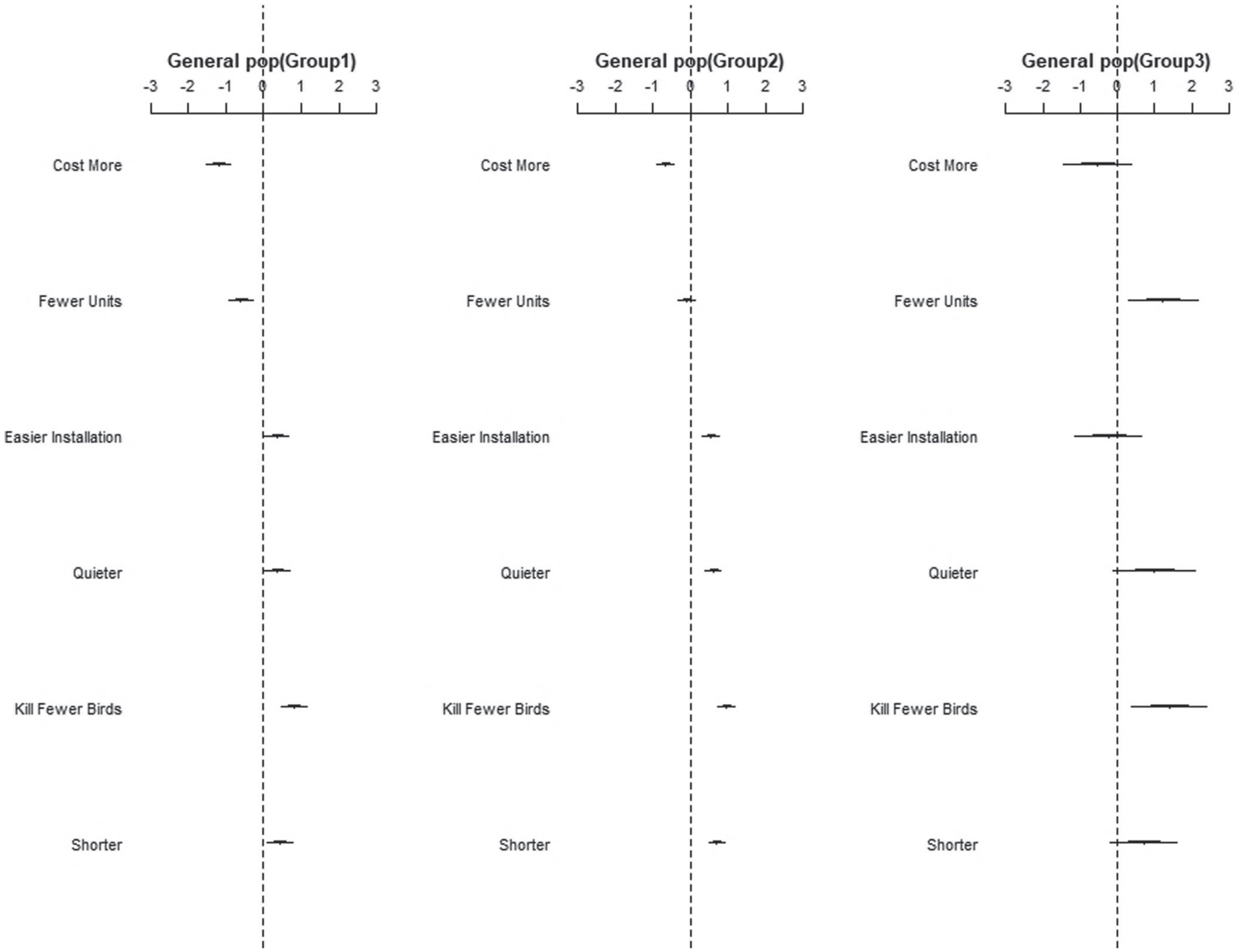

FIGURE 5 Logistic regression coefficient plots by group in the general population sample

The first three items were features established in previous studies.[45,46] The latter three items were hypothetical features that have not yet been empirically verified but could potentially influence the support of VAWTs. Respondents were then asked if they prefer the VAWTs over the conventional turbine. Through manipulating the information given to our respondents, we can test how they react to different cues.

Figure 5 shows the logistic regression result groups by level of environmental engagement in the general sample. The dependent variable is binary (1 = prefer VAWTs, 0 = otherwise). The dots in the logistic coefficient plots denote the regression coefficients, and the lines display the

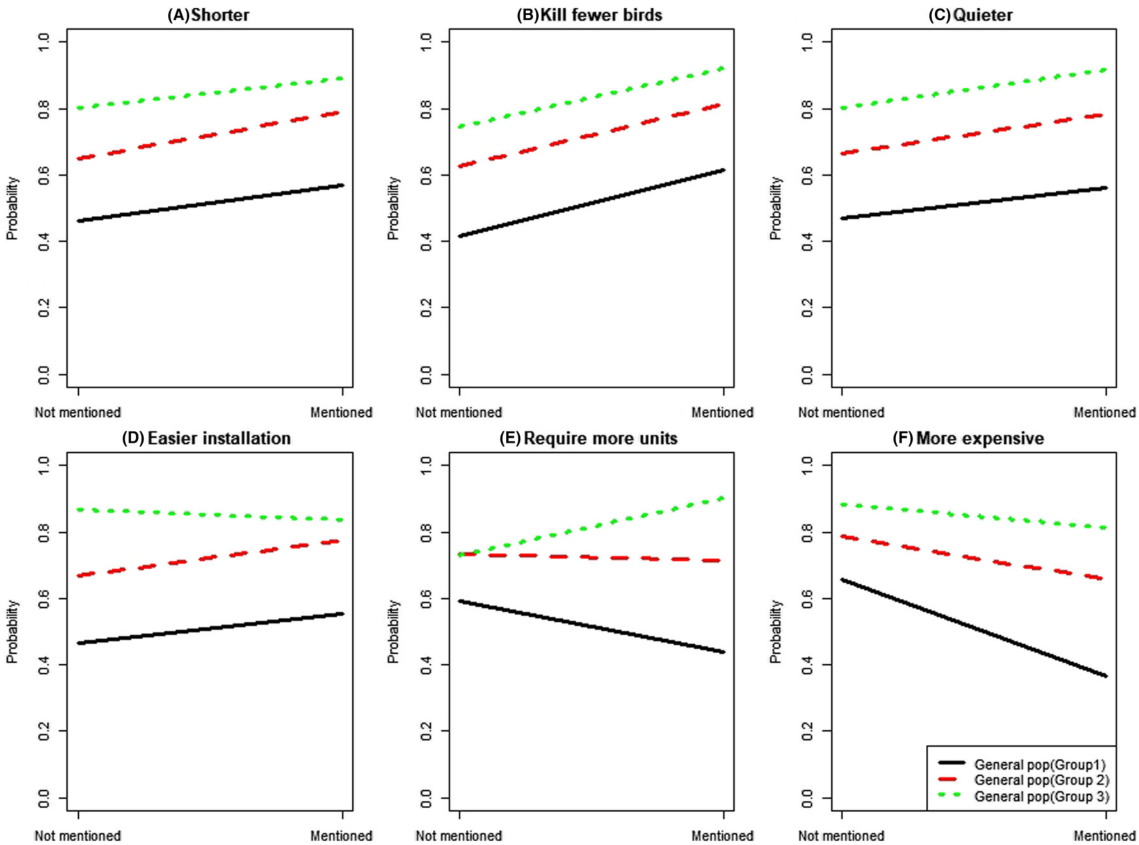

FIGURE 6 Effect plots by group in the general population sample [Colour figure can be viewed at wileyonlinelibrary.com]

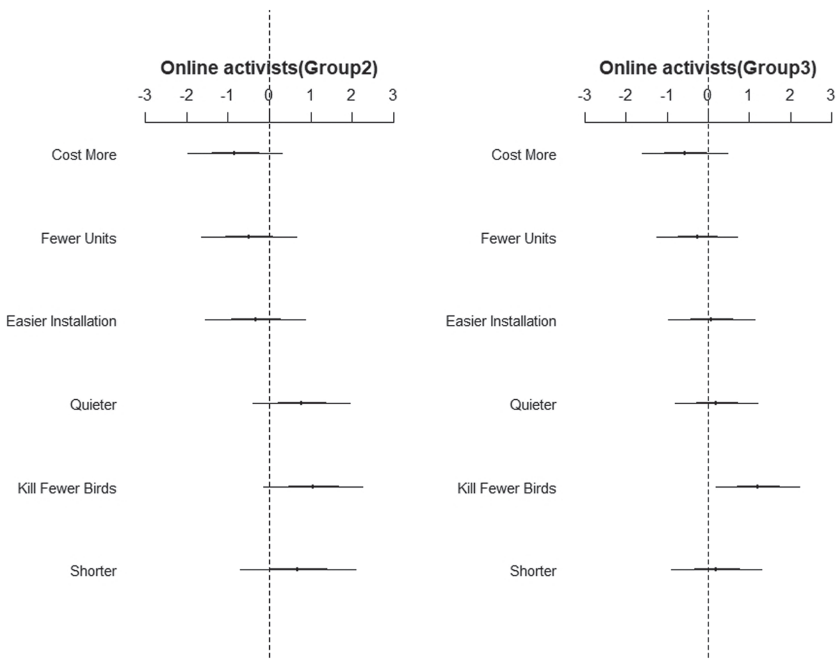

FIGURE 7 Logistic regression coefficient plots by group in the online activist sample

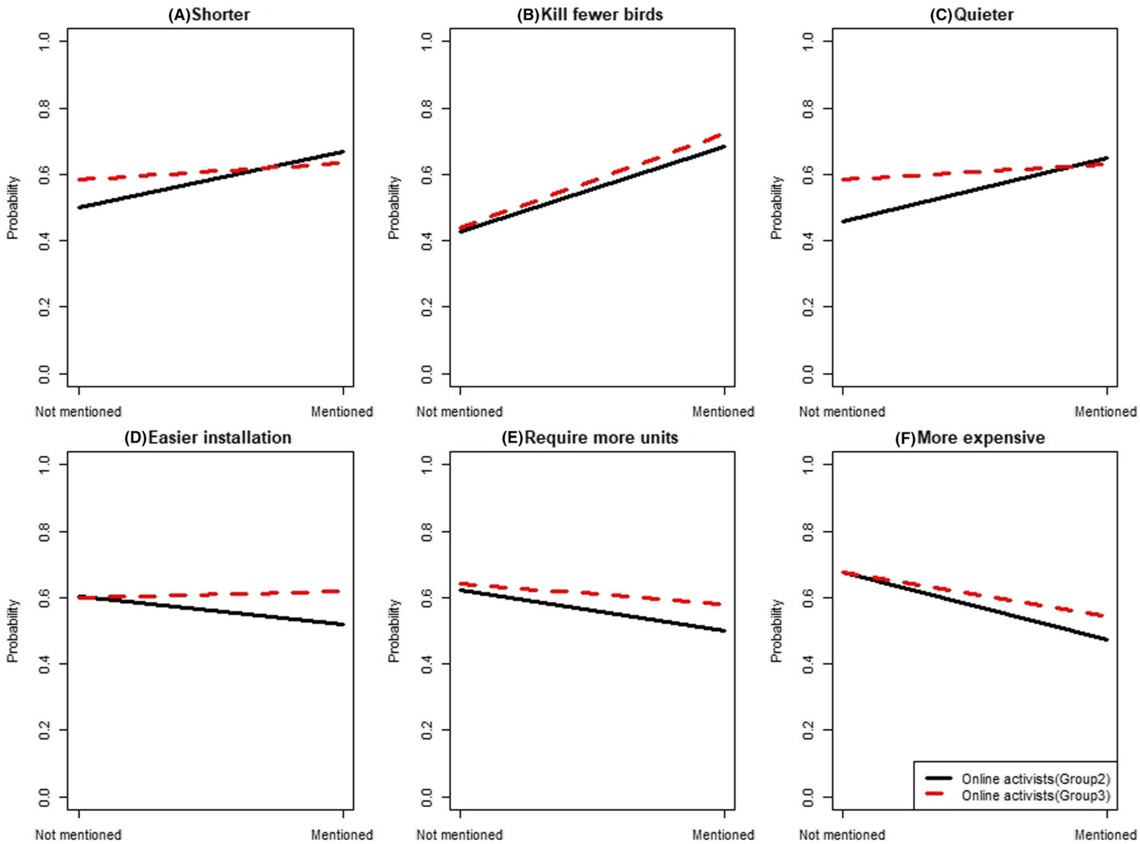

FIGURE 8 Effect plots by group in the online activist sample [Colour figure can be viewed at wileyonlinelibrary.com]

95% and 50% confidence intervals. Positive coefficients indicate a positive relationship with the outcome variable. To facilitate interpretation, Figure 6 plots the marginal effects when each of the six features was presented to the respondent. The *y*-axis shows the predicted probability of supporting the VAWTs when a feature was mentioned versus not mentioned.

The first three properties are seen as "advantages" of the VAWTs over the conventional system, especially among online activists. All three groups in the general population sample regard killing fewer birds as a desirable VAWT feature. Killing fewer birds is seen as an advantage, and the coefficients are statistically significant at 0.05 level for all three groups. Potentially higher cost, by contrast, is not favored by all respondents. Costing more is a major drawback for respondents in groups 1 and 2 but less so for group 3, the most environmentally active. As one might expect, this suggests that more environmentally committed people exhibit a greater willingness to pay for green energy than the less engaged respondents. The more active respondents are also less bothered by the bigger on the ground footprint of more units for VAWTs.

We repeated the above analyses with the online activist sample. Figure 7 shows the coefficient plots, and Figure 8 displays the effect plots. Because of a smaller sample size, the coefficients have wider confidence intervals. In contrast to the general population, the differentiation between group 2 and group 3 respondents is minimal. Moreover, the lines are generally flatter meaning that the treatment effects are much weaker in general for the online activist sample with one important exception: They too regard killing fewer birds as an advantage of the VAWTs, and the coefficients are statistically significant at 0.05 level.

5 | CONCLUSION

There are several important conclusions to draw from this study. In general, we find that the higher the level of environmental activism, the greater the support for wind energy. It is also clear that across all levels of citizen environmental engagement, including the online activists, any reduction in associated bird fatalities will strengthen support for VAWTs, a technology with the potential for reduced avian impacts.

As we discussed, it is impossible to draw a representative sample of online activists since the population characteristics are unknown. What we have done is to document the variation in opinions and preferences among the activists who participated in our study. By identifying the diversity of opinions, we can anticipate the future tensions and adversaries when a proposal of vertical-axis wind farm comes up. While these activists may comprise a small subpopulation in the state, in our qualitative analyses of comments (presented in the Online Supplementary Appendix 2), these activists articulated much firmly held and polarized opinions than average citizens. They were more divided along their preferences for a particular turbine technology and less sensitive to issues of price and siting than the general population. They can assert disproportional amount of influence as opinion leaders in public discourse and polarize debates about the deployment of VAWTs.

Our data analysis reveals that as the environmental and green energy communities have evolved and matured, they have fractured along specific environmental concerns and preferences about technology. Environmental activists and members of bird groups may care about climate change mitigation, but will oppose forms of energy production that might harm birds. Some energy proponents take the opposite perspective and believe that priority should be given to the goal of mitigating carbon emissions. It is beyond our scope and capacity to resolve these tensions, but the data do reveal a way forward for those who seek a compromise solution. If indeed vertical wind turbines are proven to be significantly safer for birds, then VAWTs may be deployed in areas with high densities of migrating or native bird populations.

More generally, some features of energy systems—such as decreasing the costs of producing energy or siting in preferred place—appeal to a broad spectrum of public opinion. But other features seem to matter more intensely to specific segments of the public than they do to the public generally, such as the physical appearance of the turbines or the effects that they have on wildlife and the environment. Experience is teaching us that if we are going to achieve ambitious goals of climate change mitigation, we will have to pay close attention to the preferences of both general public and the online activist communities.

Lastly, our survey was limited to California residents. In terms of public opinion toward climate change and adaptation, on average, residents in coastal states (or "blue states") tend to be more proenvironment, progreen energy than their counterparts in the inland states (or "red states"). It would be interesting to repeat this survey and reveal any geospatial variation in perception toward HAWTs and VAWTs across states. Future works can also explore what role public opinion plays in influencing the deployment of wind turbines across states. Nevertheless, while red states' residents may show *less* support for wind energy, paradoxically, there are *more* large-scale wind farms in the red states. It is unclear whether that was due to more favorable physical landscape, better availability of wind resources, stronger wind energy industrial advocacy, or less restrictive government regulation in the red states. More work is called for to explain this intriguing paradox.

CONFLICT OF INTEREST

We do not have any conflict of interest.

ORCID

Iris Hui https://orcid.org/0000-0003-3351-7957

REFERENCES

1. Onion A. *Wind proposals whips up controversy*. ABC News. 2002 (https://abcnews.go.com/Technology/story?id=97849&page=1) Accessed January 20,2018.
2. Urness Z. Federal court kills large wind energy project in southeast Oregon. *Oregon Environmental News*. 2017. (http://www.oregonlive.com/environment/index.ssf/2017/04/federal_court_kills_large_wind.html) Accessed January 20, 2018.
3. Owen Sound Sun Times.com. Two local wind farm projects now on hold. 2016. http://www.owensoundsuntimes.com/2016/09/29/two-local-wind-farm-projects-now-on-hold) Accessed January 20, 2018.
4. Converse PE. The nature of belief systems in mass public. In: Apter D, ed. *Ideology and Discontent*. New York: Free Press; 1964.
5. Verba S, Schlozman KL, Brady HE. *Voice and Equality: Civic Voluntarism in American Politics*. Harvard University Press; 1995.
6. Neuman WR. *The Paradox of Mass Politics: Knowledge and Opinion in the American Electorate*. Harvard University Press; 1986.
7. Campbell AL. Self-interest, social security, and the distinctive participation patterns of senior citizens. *American Political Science Review*. 2002;96(3):565-574.
8. Campbell AL. *How policies make citizens: senior political activism and the American welfare state*. Princeton University Press; 2011.
9. Bhutta MMA, Hayat N, Farooq AU, Ali Z, Jamil SR, Hussain Z. Vertical axis wind turbine—a review of various configurations and design. *Renewable energy*. 2012;16(4):1926-1939.
10. Pope K, Dincer I, Naterer GF. Energy and exergy efficiency comparison of horizontal and vertical axis wind turbines. *Renewable energy*. 2010;35(9):2102-2113.
11. Howell R, Qin N, Edwards J, Durrani N. Wind tunnel and numerical study of a small vertical axis wind turbine. *Renewable energy*. 2010;35(2):412-422.
12. Bhutta MMA, Hayat N, Farooq AU, Ali Z, Jamil SR, Hussain Z. Vertical axis wind turbine—a review of various configurations and design techniques. *Renewable and Sustainable Energy Reviews*. 2012;16(4):1926-1939.
13. Lombardi L, Mendecka B, Carnevale E. Stanek W. Environmental impacts of electricity production of micro wind turbines with vertical axis. *Renewable Energy*. 2018;128(B):553-564.
14. Dabiri JO. Potential order-of-magnitude enhancement of wind farm power density via counter-rotating vertical-axis wind turbine arrays. *Journal of Renewable and Sustainable Energy*. 2011;3(4):043104.
15. Allen SR, Hammond GP, McManus MC. Energy analysis and environmental life cycle assessment of a micro-wind turbine. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*. 2008;222:669-684.

16. Drewitt AL, Langston RH. Assessing the impacts of wind farms on birds. *Ibis*. 2006;148(s1):29-42.
17. Smallwood KS, Thelander C. Bird mortality in the Altamont Pass wind resource area, California. *Journal of Wildlife Management*. 2008;72(1):215-223.
18. Erickson WP, Johnson GD, Young DP Jr. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. *USDA Forest Service General Technical Report*. 2005;PSWGTR-191:1029-1042.
19. Wang SF, Wang SC. Impacts of wind energy on environment: a review. *Renewable and Sustainable Energy Reviews*. 2015;49:437-443.
20. Saidur R, Rahim NA, Islam MR, Solangi KH. Environmental impact of wind energy. *Renewable and Sustainable Energy Reviews*. 2011;15(5):2423-2430.
21. Pedersen E, Larsman P. The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. *Journal of Environmental Psychology*. 2008;28(4):379-389.
22. Langer K, Decker T, Menrad K. Public participation in wind energy projects located in Germany: which form of participation is the key to acceptance? *Renewable Energy*. 2017;112:63-73.
23. Bolin K, Bluhm G, Eriksson G, Nilsson ME. Infrasound and low frequency noise from wind turbines: exposure and health effects. *Environmental research letters*. 2011;6(3):035103.
24. Salt AN, Kaltenbach JA. Infrasound from wind turbines could affect humans. *Bulletin of Science, Technology Society*. 2011;31(4):296-302.
25. Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W, Bouma J. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. *Science of the Total Environment*. 2012;425:42-51.
26. Michaud DS, Feder K, Keith SE, et al. Exposure to wind turbine noise: perceptual responses and reported health effects. *Journal of the Acoustical Society of America*. 2016;139(3):1443-1454.
27. Harding G, Harding P, Wilkins A. Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them. *Epilepsia*. 2008;49(6):1095-1098.
28. Krohn S, Damborg S. On public attitudes towards wind power. *Renewable energy*. 1999;16(1-4):954-960.
29. Klick H, Smith ER. Public understanding of and support for wind power in the United States. *Renewable Energy*. 2010;35(7):1585-1591.
30. Devlin E. Factors affecting public acceptance of wind turbines in Sweden. *Wind Engineering*. 2005;29(6):503-511.
31. Devine-Wright P. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind energy*. 2005;8(2):125-139.
32. Johansson M, Laike T. Intention to respond to local wind turbines: the role of attitudes and visual perception. *Wind Energy*. 2007;10(5):435-451.
33. Ellis G, Barry J, Robinson C. Many ways to say 'no', different ways to say 'yes': applying Q-methodology to understand public acceptance of wind farm proposals. *Journal of Environmental Planning and Management*. 2007;50(4):517-551.
34. Jones CR, Eiser JR. Understanding 'local' opposition to wind development in the UK: how big is a backyard? *Energy Policy*. 2010;38(6):3106-3117.
35. Swofford J, Slattery M. Public attitudes of wind energy in Texas: local communities in close proximity to wind farms and their effect on decision-making. *Energy policy*. 2010;38(5):2508-2519.
36. Devine-Wright P, Howes Y. Disruption to place attachment and the protection of restorative environments: a wind energy case study. *Journal of environmental psychology*. 2010;30(3):271-280.
37. Devine-Wright P. Rethinking NIMBYism: the role of place attachment and place identity in explaining place-protective action. *Journal of community applied social psychology*. 2009;19(6):426-441.
38. Pasqualetti MJ. Opposing wind energy landscapes: a search for common cause. *Annals of the Association of American Geographers*. 2011;101(4):907-917.
39. Bell D, Gray T, Haggett C. The 'social gap' in wind farm siting decisions: explanations and policy responses. *Environmental politics*. 2005;14(4):460-477.
40. Hui I, Cain BE, Dabiri JO. Public receptiveness of vertical axis wind turbines. *Energy Policy*. 2018;112:258-271.
41. Zaller J. *Nature and Origins of Mass Public Opinion*. Cambridge Press; 1992.
42. Verba S, Schlozman K, Brady HE. *Voice and Equality: Civic Voluntarism in American Politics*. Harvard University Press; 1995.
43. Carpini MXD, Keeter S. Measuring political knowledge: putting first things first. *American Journal of Political Science*. 1993;37:1179-1206.
44. Zukin C, Keeter S, Andolina M, Jenkins K, Carpini MXDA. *New Engagement?: Political Participation, Civic Life, and the Changing American Citizen*. Oxford University Press; 2006.
45. Dabiri JO. Emergent aerodynamics in wind farms. *Physics Today*. 2014;67:66-67.
46. Araya DB, Craig AE, Kinzel M, Dabiri JO. Low-order modeling of wind farm aerodynamics using leaky Rankine bodies. *Journal of Renewable and Sustainable Energy*. 2014;6:063118.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Hui I, Cain BE, Dabiri JO. Environmental activism and vertical-axis wind turbine preferences in California. *Wind Energy*. 2019. https://doi.org/10.1002/we.2399