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National Survey of Attitudes of Wind Power Project Neighbors: Summary of Results

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Background and Motivation

The installed U.S. wind power capacity through the end of 2016 was capable of supplying approximately 6.2% of the nation's electricity demand from about 60,000 utility-scale turbines (Wiser & Bolinger, 2017).¹ Through 2015, almost 1.4 million homes were within 5 miles (8 kilometers) of a U.S. utility-scale wind power project, and, each year in the preceding 10 years, turbines placed in large projects (more than 60 turbines) became increasingly close to homes at an average rate of approximately 150 feet (46 meters) per year.²

Experts predict continued reductions in the cost of wind energy (Wiser et al., 2016) and additional wind project deployment in the years ahead (Mai et al., 2017). Achieving this continued deployment will require coordination and cooperation with the communities and community members in which the projects will be located, including local authorities, citizens, landowners, businesses, and non-governmental organizations. These individuals and organizations often look to other communities with wind power projects to understand the potential costs and benefits of moving forward with such a project.

In 2015, the U.S. Department of Energy funded Lawrence Berkeley National Laboratory (LBNL) to lead a 4-year project collecting data from a broad-based and representative sample of individuals living near U.S. wind power projects. The aim was to broaden the understanding of how U.S. communities are reacting to the deployment of wind turbines, and to provide insights to those communities considering wind projects. LBNL led this research in collaboration with University of Delaware, Portland State University, Martin-Luther-University Halle-Wittenberg and Medical School Hamburg (Germany), RSG, and the National Renewable Energy Laboratory.

This summary offers high-level results from five areas of research that have been published as five separate manuscripts, which are available for free (open access) on the publishers' websites and can be accessed through LBNL's website, <https://emp.lbl.gov/projects/wind-neighbor-survey>:

- Review of 30 Years of North American Wind Project Acceptance Literature (Rand & Hoen, 2017)
- Overall Analysis of Attitudes Across 1,700 Wind Power Project Neighbors (Hoen et al., 2019)
- Wind Power Project Planning Process Fairness and Attitudes (Firestone et al., 2018)
- Predicting Audibility and Annoyance to Wind Power Project Sounds Using Modeled Sound (Haac et al., 2019)
- Comparing Annoyance and Stress Effects of U.S. and European Residents Near Turbines (Hübner et al., 2019)

¹ Some of the approximately 60,000 turbines are now more than 15 years old and small, in terms of total height and nameplate capacity, compared with the turbines currently being installed.

² To determine this, we use a dataset of 1.29 million homes within 5 miles of all U.S. wind projects with turbines larger than 364 feet and 1.5 MW ($n = 29,848$ turbines across 604 projects), which were installed between 2004 and 2014. We regress distance to the nearest home from any turbine in the project on year of installation, finding each year during this period, on average, turbines moved approximately 150 feet (46 meters) closer to homes (p -value = 0.000).

Research Objectives and Methods

Despite the significant existing literature on public acceptance of U.S. wind projects, Rand & Hoen (2017) identified various research gaps to be addressed through the study:

- What is the distribution of attitudes and annoyances of those living close to U.S. wind power projects, and what factors help explain those attitudes and annoyances?
- How are U.S. wind power project siting and planning processes perceived by community members, and what helps explain differences in those perceptions?
- How well do modeled sound levels from U.S. wind power projects predict respondent levels of audibility and annoyance related to those sounds, and what additional factors help explain those levels?
- What percentages of individuals living near U.S. wind power projects are “strongly” annoyed—reporting stress-related symptoms caused by turbine sounds, shadow flicker, or visual effects—and what factors help explain those percentages?
- Is there evidence that communities’ attitudes change over time as residents move in and out of the area near U.S. wind power projects?
- How do hosting turbines and/or being compensated by the wind power project owner influence attitudes, annoyances, and perceptions of the planning process?
- How do U.S. attitudes toward local wind power projects compare with those in Europe, and can insights be drawn from any apparent differences?

The study also sought to address methodological gaps in the previous literature:

- Ensuring the sample of wind power project neighbors is randomly drawn from all U.S. wind projects and weighted to the population so it can be considered representative
- Collecting data from multiple survey modes—including phone, mail, and internet—to test for and minimize non-response bias
- Over-sampling certain segments of the population to ensure adequate sample size and allow statistical inferences to be drawn on subpopulations, including those living:
 - nearest to a wind turbine (i.e., within 1 mile (1.6 kilometers))
 - near large projects (often in very rural areas)
 - near the 30 sites (encompassing 61 projects) for which estimates of A-weighted sound levels were modeled³

The sample population included households within 5 miles (8 kilometers) of “modern, utility-scale wind turbines,” which are defined as at least 354 feet (108 meters) tall—from the base of the tower to the tip of the blade at its apex—and at least 1.5 megawatts (MW) in capacity. This resulted in a sample of 1,289,478

³ Modeled A-weighted sounds levels are defined as the overall predicted sound pressure levels at a location, adjusted to the approximate frequency sensitivity of human hearing at nominal levels, expressed as “dBA” or “dB(A)”; dB = decibel.

possible households near 604 wind power projects composed of 28,078⁴ wind turbines built between 1996 and 2014 and totaling 50 gigawatts (GW) of installed capacity (Figure 1). To address the methodological gaps mentioned above, the population was stratified, for example, by distance to a wind turbine and by project size. A 50-question multimode (phone, mail, and internet) survey was distributed to each homeowner in the sample, resulting in a final set of 1,705 residents living within 5 miles of 250 U.S. wind power projects across 24 states. Weighting was employed to account for over-sampling in some strata as well as non-response, thus ensuring the responses accurately represent the population from which the overall sample was drawn.

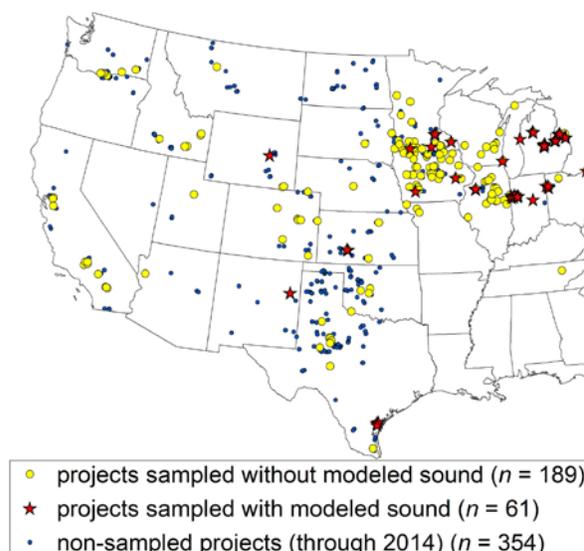


Figure 1: Map of surveyed projects

The survey elicited the following information:

- Respondents' present attitudes toward their local wind power project and their attitudes prior to construction
- Perceptions of and possible stress reactions to the project (related to appearance, landscape changes, turbine sounds, shadow flicker, and lighting)
- Participation in and perceived fairness of the project's planning and siting process
- Relationship to the project (for example, distance to the nearest turbine, presence of turbines on respondent property, compensation received, number of turbines visible, and ability to hear turbines from property and inside home)
- Background information (for example, length of residence in home, awareness of the project development process, attachment to place of residence, noise sensitivity, experiences of acute and chronic stress)
- General attitudes toward sources of electricity, climate change, and wind energy's effectiveness at mitigating climate change
- Demographic information

⁴ The 28,078 turbines include all turbines in any project with at least one turbine within 5 miles of a home. Therefore, some of these 28,078 turbines could be farther than 5 miles from the nearest home.

Research Findings

A high-level summary of the key findings is presented below. As with other studies of this nature, a number of limitations and considerations apply to the findings, including the following:

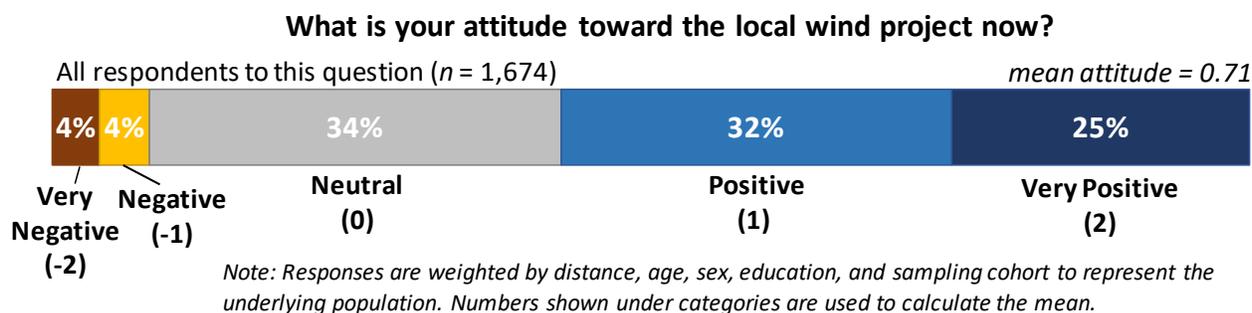
- Results may not be generalized to areas beyond the population, such as areas near turbines smaller than 354 feet (108 meters), larger than 492 feet (150 meters), smaller than 1.5 MW, or larger than 3.1 MW, or areas outside the United States—unless other research that encompasses those data supports such generalization.
- Results only permit limited conclusions about causality and instead focus on correlations.
- Results should be considered in the context of all published peer-reviewed literature on the subject.

In the summary of findings below, all responses are weighted to the overall population and only include those respondents who answered the specific question(s).⁵

Present attitude toward local wind project

Each of the more than 1,700 survey respondents was asked, “What is your attitude toward your local wind power project now?”

- A total of 1,674 respondents responded as follows: very negative (4%), negative (4%), neutral (34%), positive (32%), and very positive (25%)—see Figure 2. These results equate to a mean attitude between neutral and positive, and a median of positive.
- The distribution of responses differs by the distance the respondent was from the nearest turbine. For example, those who lived within 0.5 miles (0.8 kilometers) of the nearest turbine responded as follows: very negative (12%), negative (13%), neutral (23%), positive (25%), and very positive (27%)—see Figure 3. This equates to a mean between neutral and positive, and a median of positive. When controlling for other covariates, attitudes of those living closer to turbines were found to be statistically slightly more positive than the attitudes of those living farther away.



⁵ For example, we asked respondents if they had ever heard sound from the wind project. If they had not, then they were not asked a question on sound annoyance. Additionally, almost every question had some missing responses. In either case, these non-responses are not considered in the results presented.

Figure 2: Distribution of responses from all respondents about present attitude toward their local wind power project

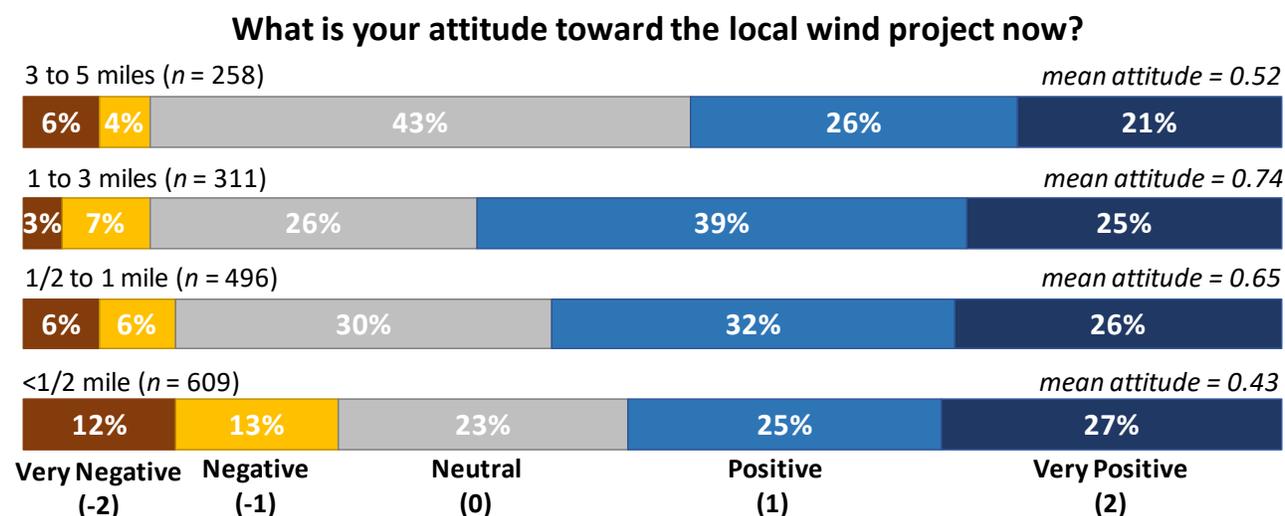


Figure 3: Distribution of responses about present attitudes toward local wind power projects, by distance from nearest turbine

- Most demographic and wind power project characteristics are not correlated with attitudes, including gender, age, income, and race as well as the turbines' height. Respondent education is weakly correlated with attitude. The attitudes of respondents with more formal education were slightly more positive, and respondents tended to view large projects (> 10 turbines) slightly more negatively.
- Attitudes toward the local wind project are positively correlated with⁶:
 - Respondents being compensated
 - The perception of the planning process as fair
 - Respondents' perceptions that wind power is effective at combating climate change
- Attitudes toward the local wind project are negatively correlated with:
 - Respondents hearing the turbines on their property or in their home
 - Respondents perceiving that the wind turbines fit poorly within the landscape
 - Respondents perceiving that property values near the turbines had been negatively affected
 - Respondents' attachment to the local community
- Individuals who moved to their home after wind project construction had significantly more positive attitudes than those who lived in their homes prior to construction.

Perceived planning process fairness

Each survey respondent who was living in the area during the wind project planning period and was aware of the process was asked, "To what extent do you believe the planning process was fair?"

⁶ In this context, positive correlation means attitudes become more positive as the listed factors become more true or positive. Negative correlation means attitudes become more negative as the listed factors become more true or positive.

- Responses were as follows: not at all (15%), slightly (14%), somewhat (17%), moderately (35%), and very (19%)—see Figure 4. This equates to a mean fairness between *somewhat* and *moderately*, and a median of *moderately*.

To what extent do you believe the planning process was fair?

Respondents (n = 787)



Note: Responses are weighted by distance, age, sex, education, and sampling cohort to represent the underlying population.

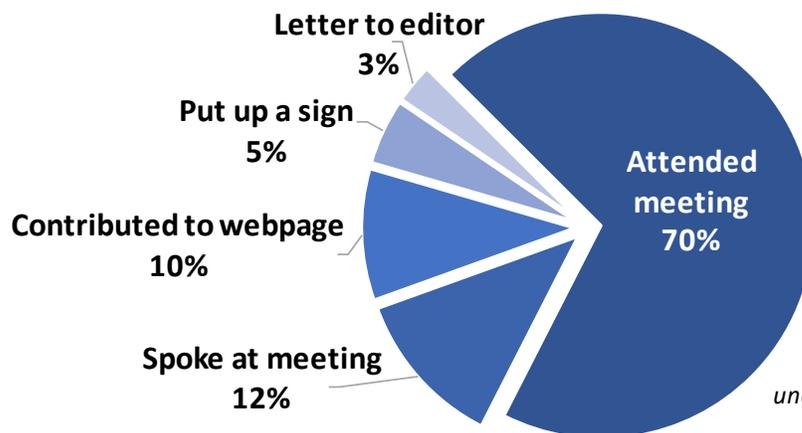
Figure 4: Distribution of responses about planning process fairness

- The most important component of perceived planning process fairness is developer transparency and openness. The ability of the community or individual to influence the outcome of the project (for example, the number or location of the wind turbines) is also significantly related to beliefs about planning process fairness. Planning process fairness, along with developer transparency and ability to influence the outcome, are in turn significant predictors of having a positive attitude.
- Compensation is not an indicator of perceived planning process fairness.

In addition, survey respondents were asked, “During the planning process for the wind project did you take any actions?” And they were asked, “Were your actions supportive or opposed to the wind project?”

- Only one third of respondents who were aware of the planning process reported taking any action. The most common action was attending a meeting (70%), followed by speaking at a meeting (12%) and contributing to a web page (10%)—see Figure 5.

During the planning process for the wind project did you take any of the actions?



Note: Responses are weighted by distance, age, sex, education, and sampling cohort to represent the underlying population. Sample includes 389 actions among 311 respondents

Figure 5: Distribution of actions taken during the wind project planning process

- Although almost five times as many individuals had a positive or very positive attitude toward their local project as compared to negative or very negative, only about twice as many actions were wholly supportive versus wholly opposing.
- Of those who spoke at a meeting, the ratio of those opposed to those supportive was roughly 1 to 1.

Annoyance related to sound

Each survey respondent was asked, “Have you ever heard sound from the wind power project?”

- Not surprisingly, respondents who were closer to a turbine more frequently reported hearing project sounds than those who were farther away—see Figure 6. Of all respondents living within 5 miles (8 kilometers), 84% reported not hearing sound, and 16% reported hearing sound. When the sample is limited to those living within 1 mile (1.6 kilometers), 44% reported not hearing sound, and 56% reported hearing sound. Of those living within 0.5 miles (0.8 kilometers), 19% reported not hearing sound, and 81% reported hearing sound.

Those who reported ever hearing sound (16% of all respondents) were asked if they heard sound from the turbines from inside their home “with the windows open” or “with the windows closed.”

- To the question of whether turbines can be heard with the windows open, 60% said yes, and 40% said no. Thus, 10% of all respondents within 5 miles of a turbine reported hearing turbine sounds inside their home with the windows open.
- To the question of whether turbines can be heard with the windows closed, 33% said yes, and 67% said no. Thus, 5% of all respondents within 5 miles of a turbine reported hearing turbine sounds inside their home with the windows closed.

Have you ever heard sound from the wind power project?

Within 5 miles ($n = 1,688$)



Within 1 mile ($n = 1,112$)



Within 1/2 mile ($n = 619$)



No

Yes

Note: Responses are weighted by age, sex, education, and sampling cohort to represent the underlying population. Distances represent the distance from the nearest turbine.

Figure 6: Distribution of respondents who reported hearing the turbines, by distance

The 16% who reported ever hearing sound were also asked, “To what extent do you feel annoyed by the sounds of the local wind power project?” (*Note: This single question does not take into account stress symptoms, which are examined below under “Strongly Annoyed Individuals.”*)

- Responses were as follows: not at all (51%), slightly (11%), somewhat (15%), moderately (5%), and very (18%)—see Figure 7. This equates to a mean annoyance level among those who had heard sound from their local wind project just above “slightly”, and a median of “not at all”. Of all

respondents who lived within 0.5 miles of a turbine, 19% reported being somewhat, moderately, or very annoyed by turbine sound

- Reported annoyance levels among those living within 0.5 miles of a turbine who reported ever hearing sound were: not at all (43%), slightly (19%), somewhat (6%), moderately (11%), and very (20%). This equates to a mean annoyance level among those who had heard sound from their local wind project between “slightly” and “somewhat”, and a median of “slightly”.

To what extent do you feel annoyed by the sounds of the local wind project?

Respondents who could hear turbine sounds (*n* = 910)



Note: Responses are weighted by distance, age, sex, education, and sampling cohort to represent the underlying population.

Figure 7: Distribution of respondents reporting annoyance to turbine sounds

Landscape change

Each survey respondent was asked, “Do you like the way the wind power project looks?”

- Among the respondents, 14% indicated no, 17% neutral, and 69% yes.

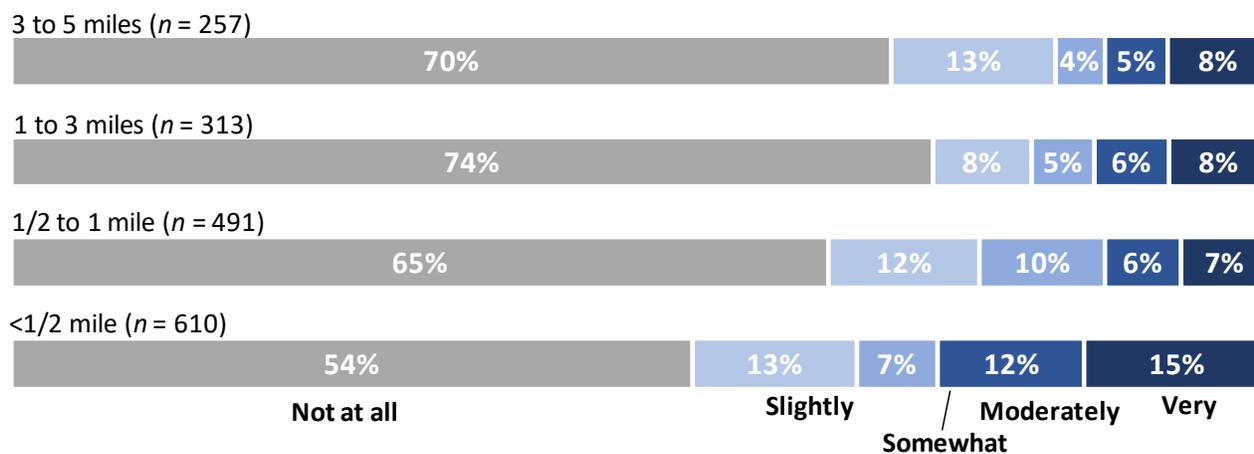
Respondents were also asked if the project “fits with the landscape in the local area” (among other explanations for their response).

- Of those who liked the way their local wind power project looks, 57% said the project fit within the local landscape. In contrast, of those who did not like the way the wind power project looks, 65% said the project did not fit within the local landscape.

Further, each respondent was asked, “To what extent do you feel annoyed by the change to the landscape of the local wind power project?” (*Note: This single question does not take into account stress symptoms, which are examined below under “Strongly Annoyed Individuals.”*)

- Responses among all respondents were as follows: not at all (73%), slightly (11%), somewhat (4%), moderately (5%), and very (7%). This equates to a mean annoyance level between *not at all* and *slightly*, and a median of *not at all*.
- Reported annoyance levels related to landscape change were slightly higher among respondents living within 0.5 miles (0.8 kilometers) of a turbine than among those living farther away—see Figure 8.

To what extent do you feel annoyed by the change of the landscape?



Note: Responses are weighted by age, sex, education, and sampling cohort to represent the underlying population. Distance groups represent the distance respondent is from the nearest turbine.

Figure 8: Distribution of respondents reporting annoyance to landscape change, by distance

Modeled sound levels

The survey data were used in a regression model to predict wind turbine audibility and noise annoyance in two separate models. Covariates in the regression included: modeled sound levels; background sound; meteorological data (to capture predominant wind direction, speed and frequency); wind project and turbine characteristics, and a suite of objective and subjective variables collected as part of the survey. Wind turbine and background sound levels were estimated at the locations of 1,043 respondents near 61 existing wind power projects. Short-term wind turbine sound levels were modeled, and summer daytime background sound levels were estimated using the National Park Service national geospatial sound model. An annual average day-night sound level adjustment was calculated using site-specific meteorological data. The regression model results (summarized in Figure 9) revealed the following:

- Using sound levels alone, the modeling successfully predicted roughly 80% of whether respondents would report hearing turbine sound.
- Sound levels alone, though, could not reliably predict respondent noise annoyance levels; for example, none of the “very” annoyed were correctly predicted.
- The prediction of noise annoyance, which peaked at 62% of the responses (and 52% of the “very” annoyed, and 83% of the “not at all” annoyed), heavily relied on including objective and subjective variables in the model—such as when a respondent moved into the area, if they were compensated for the project, if they could see a turbine from their home/property, their individual noise sensitivity, and their prior attitude towards the project.
- The modeling found that an individual’s noise annoyance was most strongly influenced by whether they liked the look of a wind project, followed by their noise sensitivity and prior attitude towards the project (see Figure 9). Rotor diameter and sound level were also significant in the model but had lower influence than the subjective variables did.

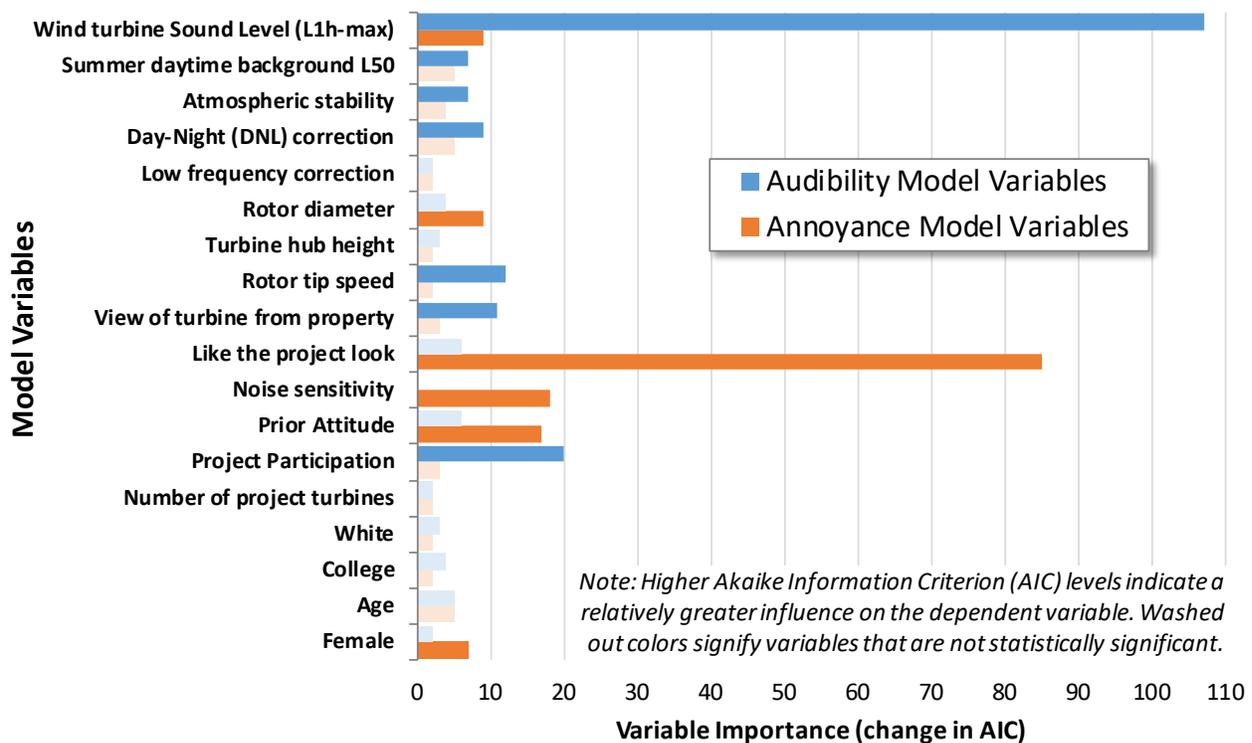


Figure 9 Variable importance, shown as change in Akaike Information Criterion (AIC) score for the sound annoyance and audibility models.

A metric that is widely used in the international community to compare community acceptance of common noise sources is the Community Tolerance Level (CTL). The CTL is defined as the long-term day-night sound level (“DNL”⁷, or in the case of our survey the modeled annual average DNL*⁸) at which 50% of the population is considered “Highly Annoyed” by a noise source.⁹ Respondents are grouped into ranges or “bins” (we use 5-dB bins) of sound levels and the percentage of Highly Annoyed is assessed in each bin. The CTL has been used to propose that wind turbine noise elicits higher levels of annoyance at equivalent sound levels compared to railway, aircraft, and road traffic sources.

Figure 10 plots the mean and +/- 1 standard deviation of international CTL studies calculated by Michaud et al. (2016) (shown as dashed lines) vs. the results of this study, which are grouped either as all respondents (black circles) or just non-participants (orange triangles). Project “participants” are defined as those respondents that are monetarily compensated. For example, they receive a lease payment for hosting a turbine, or a payment as an abutting landowner. Non-participants, alternatively, receive no compensation. Figure 10 shows that non-participating U.S. survey respondents are nearly identical to the average international respondent; their CTLs (i.e., 50% “Highly Annoyed”) are both approximately 61.9 dBA. When participating respondents are included the CTL increases to 70.5 dBA. This reinforces the finding noted above that participants are less aware of turbines sounds than non-participants at the same

⁷ DNL is the annual average sound level, weighted by +10 during nighttime hours.

⁸ The asterisk (*) in DNL* denotes that the sound level metric is not a true DNL, in that it does not account for conditions when atmospheric stability and wind direction are less favorable for sound propagation, or any noise reduced operations at the modeled projects. As a result, the DNL* is the upper bound of the *actual* DNL for long-term outdoor wind turbine sound.

⁹ Respondents classified as “Highly Annoyed” for the CTL analysis answered that they were “Very Annoyed” by wind turbine noise, which was the highest response level on a 5-point Likert scale in the survey.

sound levels. Not surprisingly, participating respondents experience higher sound levels (47% above 45 dBA DNL*) than non-participants (10%) and tend to live closer to wind turbines.

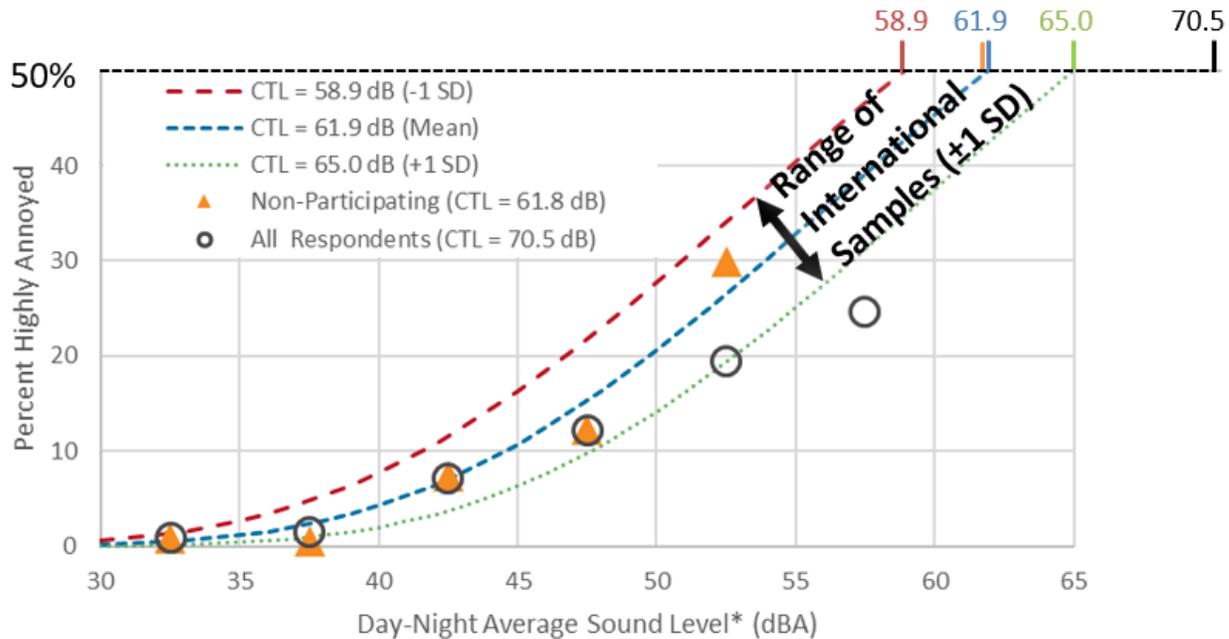


Figure 10: Dose-response relationship between wind-turbine sound level (DNL*) and high noise annoyance. Lines indicate the distribution of international averages in similar studies; the shapes represent the results of this study.

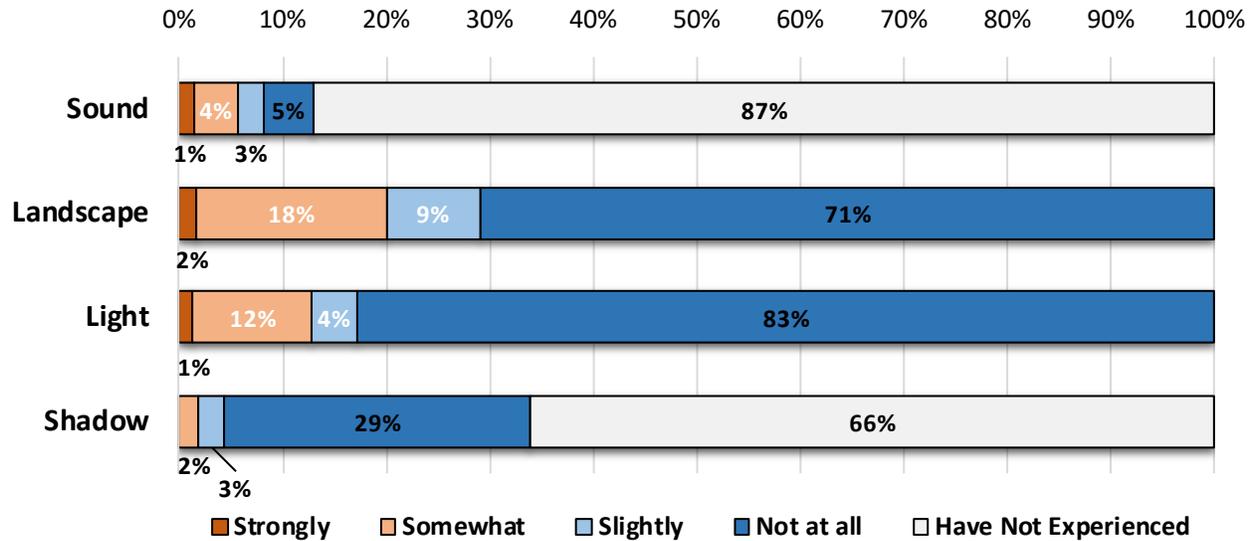
Strongly annoyed individuals

Individuals who reported being very, moderately, or somewhat annoyed and reported regular (at least monthly) health-related symptoms, which they attributed to turbines, were classified as “strongly annoyed” on an annoyance stress-scale (AS-scale). Symptoms include “being in a bad mood,” “anger,” “lack of concentration,” “difficulty falling asleep,” and “otherwise not sleeping well.” Individuals on the AS-scale that are characterized as “somewhat annoyed” are those that reported being very, moderately, or somewhat annoyed but did not report health-related symptoms, while “slightly annoyed” individuals are those that report being slightly annoyed and also do not report symptoms.

*Note: For the statistics below, the 5-mile analysis survey sample, as is often noted above, was limited to those within 3 miles (4.8 kilometers) of a turbine, to conform to samples drawn from Europe, to which these data were compared.*¹⁰

- Of respondents living within 3 miles of a turbine, 2.3% qualified as “strongly annoyed” on the AS-scale. When the results are broken down by reported source(s) of annoyance, 1.1% of respondents living within 3 miles of a turbine were strongly annoyed because of sound, 1.5% because of landscape change, 1.2% because of lighting, and 0.2% because of shadow flicker—see Figure 10.

¹⁰ The three European samples (Pohl et al., 2012; Pohl et al., 2018; Hübner and Löffler, 2013) were concentrated within 3 miles (4.8 kilometers), thus limiting the U.S. sample to that distance is appropriate. Although the designs of the European studies differ from the design of the LBNL U.S. study in some respects, the international comparison of the results patterns is valid (see Hübner et al., 2019).



Note: Responses are weighted by age, sex, education, and sampling cohort to represent the underlying population, and only include respondents within 3 miles of a turbine.

Figure 10: Annoyance Stress Scale: Percentage of respondents who reported being annoyed with associated stress symptoms, by reason

- Compared with respondents who were not strongly annoyed, strongly annoyed respondents reported more negative attitudes toward wind projects and greater annoyance with project planning processes, and they evaluated the planning process as less fair.
- Distance to the nearest turbine, A-weighted sound levels (dBA), and stated noise sensitivity are not found to be correlated with the noise annoyance stress-scale.

Comparison between U.S. and European studies

Limiting U.S. respondents to those living within 3 miles (4.8 kilometers) of a turbine enables comparison between our U.S. study and three different European studies that included several identical questions.

- Similarly small mean levels of sound-related annoyance were found in U.S. and European studies.
- Compared with the European samples, the U.S. sample had slightly lower mean levels of annoyance to lighting, shadow flicker, and landscape change.
- Average annoyance due to local traffic noise was relatively low in both samples and, more importantly, comparable to wind turbine noise annoyance.
- The similarity between the U.S. and European results indicates similar reactions to turbines in different contexts.

Conclusion

This survey represents the first country-level representative sample of wind power project neighbors, and also one of the largest surveys in the wind public-acceptance literature. It provides a first-hand and intimate look at how those living among wind turbines in the U.S. are reacting to them. As such, it provides evidence of costs and benefits of those projects, and therefore provides ample opportunities to further improve development practices for projects installed in the future.

Papers Developed under this Project

- Firestone, J., Hoen, B., Rand, J., Elliott, D., Hübner, G., and Pohl, J. (2018). Reconsidering Barriers to Wind Power Projects: Community Engagement, Developer Transparency and Place. *Journal of Environmental Policy & Planning*, 20(3): 370-385. <https://doi.org/10.1080/1523908X.2017.1418656>
- Haac, T.R., Kaliski, K., Landis, M., Hoen, B., Rand, J., Firestone, J., Elliott, D., Hübner, G., and Pohl, J. (2019). Wind Turbine Audibility and Noise Annoyance in a National U.S. Survey: Individual Perception and Influencing Factors. *Journal of the Acoustical Society of America*, 146(2): 1124-1141. <https://doi.org/10.1121/1.5121309>
- Hoen, B., Firestone, J., Rand, J., Elliot, D., Hübner, G., Pohl, J., Wisner, R., Lantz, E., Haac, T.R., and Kaliski, K. (2019). Attitudes of U.S. Wind Turbine Neighbors: Analysis of a Nationwide Survey. *Energy Policy*, 134: 110981. <https://doi.org/10.1016/j.enpol.2019.110981>
- Hübner, G., Pohl, J., Hoen, B., Firestone, J., Rand, J., Elliott, D., and Haac, R. (2019). Monitoring Annoyance and Stress Effects of Wind Turbines on Nearby Residents: A Comparison of U.S. and European Samples. *Environment International*, 132: 105090. <https://doi.org/10.1016/j.envint.2019.105090>
- Rand, J., and Hoen, B. (2017). Thirty Years of North American Wind Energy Acceptance Research: What Have We Learned? *Energy Research & Social Science*, 29: 135-148. <https://doi.org/10.1016/j.erss.2017.05.019>

Additional Information

An LBNL four-part webinar series, *Understanding Wind Project Neighbors Through a National Survey of Attitudes*, was held in 2018. Dates and subjects are as follows. Recordings of the webinars are available on the website: <https://emp.lbl.gov/projects/wind-neighbor-survey>.

January 30, 2018: “Overall Analysis of Attitudes of 1,700 Wind Power Project Neighbors”

February 13, 2018: “Wind Power Project Planning Process Fairness and Attitudes”

February 27, 2018: “Predicting Audibility of and Annoyance to Wind Power Project Sounds Using Modeled Sound”

March 13, 2018: “Comparing Strongly Annoyed Individuals with Symptoms near U.S. Turbines to Those in Surveyed European Communities”

Survey Data: A fully de-identified version of the survey data collected as part of this effort is available to researchers at the following link: [data request form](#).

Other References

- Hübner, G., and Löffler, E. (2013). *Wirkungen von Windkraftanlagen auf Anwohner in der Schweiz: Einflussfaktoren und Empfehlungen*. Institut für Psychologie der Martin-Luther-Universität Halle-Wittenberg, Halle (Saale).
- Mai, T., Lantz, E., Mowers, M., and Wisner, R.H. (2017). *The Value of Wind Technology Innovation: Implications for the U.S. Power System, Wind Industry, Electricity Consumers, and Environment*. NREL/TP-6A20-70032. Golden, CO: National Renewable Energy Laboratory.
- Michaud, D.S., Keith, S.E., Feder, K., Voicescu, S.A., Marro, L., Than, J., Guay, M., Bower, T., Denning, A., Lavigne, E., Whelan, C., Janssen, S.A., Leroux, T., and van den Berg, F. (2016). Personal and Situational Variables Associated with Wind Turbine Noise Annoyance. *Journal of the Acoustical Society of America*, 139: 1455-1466.
- Pohl, J., Hübner, G., and Mohs, A. (2012). Acceptance and Stress Effects of Aircraft Obstruction Markings of Wind Turbines. *Energy Policy*, 50: 592-600.
- Pohl, J., Gabriel, J., and Hübner, G. (2018). Understanding Stress Effects of Wind Turbine Noise—The Integrated Approach. *Energy Policy*, 112: 119-128.

Wiser, R., and Bolinger, M. (2017). *2016 Wind Technologies Market Report*. DOE/GO-102917-5033. Berkeley, CA: Lawrence Berkeley National Laboratory. Prepared for U.S. Department of Energy.

Wiser, R., Jenni, K., Seel, J., Baker, E., Hand, M., Lantz, E., and Smith, A. (2016). Expert Elicitation Survey on Future Wind Energy Costs. *Nature Energy*, 1: 16135.

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