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Perceptions and attitudes of residents living near a wind turbine compared with those living near a coal power plant

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ABSTRACT

This study addresses resident attitudes and visual and auditory impacts from nearby electricity generation. Unlike most prior studies, questions allowing bidirectional answers are used, allowing positive or negative responses, and matched questions are applied in paired communities, one community proximate to utility-scale wind generation and the second proximate to fossil generation. At least a few individuals had negative attitudes and reported negative visual and auditory impact regardless of which type of generation-but residents near the wind turbine predominately had positive attitudes toward the facility, and reported more positive than negative visual and auditory impacts. Conversely, residents near coal generation reported substantially more negative attitudes, visual impacts, and auditory impacts from the coal plant. When asked about willingness-to-pay to keep or remove the nearby facility, residents near the wind turbine would, on average, say they would pay $2.56 a month to keep it in place, whereas residents near the coal plant were, on average, willing to pay $1.82 a month to remove that facility. Demographics did not have significant effect on the results.

1. Introduction

Visual and auditory impacts of wind turbines, and attitudes toward wind turbines, have been increasingly studied as the wind industry grows into new landscapes and new countries [1–7]. However, few studies have attempted to quantify this effect in dollars, making it impossible to use resident perceptions and attitudes in cost/benefit analyses. Moreover, apart from a few studies on the visual impacts of smoke plumes [1], no studies have been conducted of the separate visual or auditory impacts of entire fossil generation facilities. Thus there is no data even to ask the basic question of whether residents perceive any visual or auditory impacts of fossil generation, or to compare impacts with wind generation.

Previous studies [2,3] found a correlation between reported noise impacts and visual impacts of wind power, so both will be examined in this study. Wind turbines produce mechanical noise from the gearbox and also create a characteristic whooshing noise as the blades rotate, which has been shown to annoy some local residents [3]. As with visual impacts, wind has been studied but no comparable studies of perceived noise from fossil facilities have been published.

In addition to attitude and perception questions, this study uses contingent valuation methods, which elicit dollar estimates of a resident's value for and against a utility-scale wind turbine and a coal-fired power plant. This method answers questions like, Are residents living near either a wind turbine or a coal plant willing to spend money to have the facility removed? Or conversely, willing to spend money to keep it in its current location? And, in each case, how much money?

Another gap in the existing literature is that typically impacts are considered to only be negative. Our method deliberately allows respondents to give either a negative or a positive answer, for both wind generation and fossil generation. Finally, this study surveys communities where the respective facilities have already been operating for at least 4 years, so respondents are speaking from daily living experience and actual perceptions over time, whereas some studies ask only prospectively about their hopes and fears about some proposed new facility.

The 1000 residents closest to the respective facilities were surveyed on their perceptions of living near each facility. The turbine

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Abbreviations

MW	Megawatt
WTA	Willingness to Accept
WTP	Willingness to Pay

analyzed is a 2 MW G90 turbine located in Lewes, DE, a small coastal town. The coal plant analyzed is the 400 MW Indian River Power Plant, located approximately 15 miles away in Millsboro, DE. Focusing on specific facilities allowed an in-depth survey informed by specifics of housing locations, proximity, and generation facility characteristics. Furthermore, both were essentially on the outskirts of towns, so both locations create a population of many residents with at least 4 years immediate experience with the visual and auditory characteristics of the facility. One could argue that it would be more comparable in MW power for the wind example to be a multi-turbine wind farm, not a single turbine—on the other hand, the turbine studied here is literally in the town limits, much closer, to more homes, than a typical wind farm would be. With those provisos, the facilities and communities in this study are not unusual or atypical in such a way that would lead one to expect that the results are specific to these communities.

2. Background

2.1. Previous studies

While no previous research has been done on the visual impact of coal plants, some has been done with regard to social (visual and auditory) impacts of wind turbines. A recent review by Knapp and Ladenburg [4] found at least fourteen studies looking at both offshore and onshore wind power. However the prior work has either conflated variables or made problematic measurements—for example, some prior work [5–8] used change in property values as a metric, which is a concrete measure of all concerns combined, but does not distinguish visual from auditory impacts, nor other attitudinal variables. Hoen et al. [7] used hedonic pricing to examine the impacts of wind turbines on housing prices. They found that there was no evidence of either area, scenic, or nuisance stigmas in residential property values. Though they acknowledged the stigmas might have existed for individuals, the effects were either too small or uncommon enough that there was no statistical impact. Jensen et al. [9] were able to separate the visual and auditory perceptions of wind turbines using a hedonic method, finding that visual impacts reduced housing prices by 3% and noise by 3–7%.

Stated preference methods have been used as well. Krueger et al. [10] examined the visual disamenity of putting wind turbines off the coast of Delaware. They found that for siting distances of 0.9, 3.6, 6, and 9 miles offshore, inland residents have external costs of $19, $9, $1, and $0, respectively, while ocean residents have much higher costs of $80, $69, $35, and $27, respectively. In another choice experiment, Meyerhoff, Ohl, and Hartje (2009) looked at the disamenity from new onshore turbines in Germany. Their questions sought the effects of turbine height, impact on the red knot (a migratory shorebird) population, minimum distance to nearby residences, and a monthly power bill surcharge. They found mixed results between different populations, although all respondents were concerned with the effects on the red knot, and all preferred turbines to be farther away from residential areas.

The distance from the facility to the respondent's home is an often-used [7,10,11] variable expected to affect disamenity. The effect on the visual landscape has also been studied by some researchers [5,7,12], though only Wolsink [12] found a statistically significant relationship between landscape and attitudes about wind power. While Hoen et al. [7] found that a positive preexisting scenic vista improved home prices, adding turbines did not reduce that relationship. Therefore, for this study we did not expect the underlying scenic vista to greatly affect disamenity for turbines and asked only about visual impact, not about the scenic vista in particular.

3. Methods

3.1. Survey design

This study surveyed residents of Lewes DE, location of a 2 MW wind turbine, and nearby Millsboro, DE, location of a coal fired power plant. A mail survey was sent in early 2014 to the 1000 closest (as-the-crow-flies) residents to each facility; this was not a sample but literally a list of 100% of the 1000 closest addresses, created by Survey Sampling International. To maximize the response rate, follow up postcards were sent to non-respondents, followed by a second copy of the survey mailed a few weeks later [13]. Most responses were received between March and June 2014. Basic characteristics of the two generation facilities and the two towns are shown in Table 1. Although we did not ask about voting or political party, in the 2016 U.S. Presidential election, the Election Districts around Millsboro voted Trump over Clinton by 3:2, whereas the Election Districts in Lewes were closely divided, about 1:1; both towns are in the County of Sussex, which went 1.6:1 for Trump [14].

Respondents were asked their overall attitude (like/dislike/neutral) about the facility nearest them (coal or wind), as well as their reported ability to see and hear it. Specific details about their perception of the facility, such as number of days it is visible, how much is visible, and the cardinal direction it is from the front of the house were also measured. Next, respondents were asked to provide multiple monetary estimates of the facility's value using a contingent valuation methodology, discussed in the next section. Then, respondents' attitudes toward wind, coal, and natural gas generally (not a specific facility) were ascertained, as well as their

Table 1
Characteristics of Surveyed Populations (from U.S. Census) and the Electricity Generating Facilities (from owner information).

	Lewes (Turbine) Residents	Millsboro (Coal Plant) Residents
Total Population	2808	3931
Male	1289	1783
Female	1519	2148
Median household income (dollars)	58,493	49,856
Mean household income (dollars)	78,291	53,423
Facility Constructed	2010	1957
Current Capacity	2 MW	400 MW

beliefs about impacts on human health and the environment. Finally, basic demographic data were collected.

3.2. Contingent valuation measurments

The WTP was determined by Contingent Valuation questions on the survey. As all facilities were already constructed, residents were asked if there were hypothetical plans to remove the facility, how much would they be willing to pay to either keep the respective facility in their town if they were in favor of it, or facilitate the removal if they were opposed. The payment vehicle was described as a charge or a credit on the respondent's monthly electricity bill, as that is an easily recognizable way of paying for electricity. The payment was described as being made monthly over a 10 year period because ongoing payments are easier for respondents to evaluate than a big one-time payment [15]. See the sample in Fig. 1 of the first question to elicit overall WTP, and see the full survey in the appendix. Subsequent questions' wording is slightly different to request only visual WTP, auditory WTP, and WTP to switch between wind and coal plants.

In preliminary discussions with residents, we found that some people enjoy viewing wind turbines or coal plants and others do not. Thus we designed the survey questions, as shown in Fig. 1, to elicit both positive and negative WTP values using a method of symmetric WTPs [16–19]. Symmetric WTP questions were intended to lessen the probability of a zero response, though results will show there was still a significant number with a WTP of $0.

One alternative to our use of WTP is "Willingness to Accept" (WTA) values, in which the survey questions offer compensation to accept a perceived negative attribute rather than requesting payment for a perceived positive attribute. We did not use WTA because WTA and WTP values are often substantially different from each other, making them difficult to compare [20]. All WTP values were determined using a modified payment card question with payment figures like that in Fig. 1, with values listed from low to high [21]. (Note: "card" refers to the block of questions and the matrix of numerical answers; it is printed on the paper survey not a separate physical card.) Although Smith [21] found similar results if payment options were randomized in in-person interviews, payment options and the order of the WTP questions were the same for all respondents so as to achieve simplicity in the mail survey design. This allowed respondents the freedom to indicate support or opposition to the facility with enough context to provide a viable answer, unlike an open-ended question [22,23], and without the researcher having to predetermine which direction the respondent would choose (as with a dichotomous choice). The survey instrument is found in the Appendix.

Suppose there was a proposal to remove the nearby [wind turbine] [coal plant] from its current location. Considering **all** the effects of the facility (positive and negative, such as visual, health, pollution, greenhouse gases), you might like or not like this, or might be neutral. If you want or don't want it to be removed, this question asks if you would be willing to pay a bit on your utility bill to achieve your preference.

CIRCLE JUST ONE NUMBER IN THIS TABLE OF NUMBERS

I would want the facility to be removed and would be willing to spend $_____ each month to make sure it is removed	$0.01	$2.50	$20.00
	$0.25	$5.00	$25.00
	$0.50	$7.50	$50.00
	$1.00	$10.00	$75.00
	$1.50	$15.00	$100.00
I am neutral towards this change and so I'm not willing to spend money to influence it	$0		
I would want the facility to stay, and if it was going to be removed, I would be willing to pay $_____ each month to keep it here	$0.01	$2.50	$20.00
	$0.25	$5.00	$25.00
	$0.50	$7.50	$50.00
	$1.00	$10.00	$75.00
	$1.50	$15.00	$100.00

Fig. 1. Sample of WTP question on survey.

To further tease out visual impacts, respondents were also asked to assume that the facility had no environmental impact whatsoever, good or bad, and that it produced no noise, so that only its appearance was considered, and then asked the same WTP question. Because noise and visual impacts are sometimes correlated [2,3] respondents were also asked to consider only the sound of the facility and ignore the visual and environmental impacts. Finally, respondents were told to assume that the facility near them was going to be replaced by the other type of facility and again asked their WTP to make or to prevent this shift.

One difficulty with asking these WTP questions is that evidence from the economic literature suggests that respondents may be uncertain of their estimates of WTP [24–26]. Thus, asking follow up questions about how certain the respondent is about his or her answer and weighting WTP based on the individual's certainty has become standard practice in contingent valuation experiments [27–29]. In this survey, each WTP question was followed by the question "How certain are you about your answer to the previous question?" with answers on a 7-point Likert scale, 1 meaning 'Not at all certain' and 7 meaning 'Very Certain.' In our analysis, the WTP variable is weighted by the percent certainty of the respondent, measured as the ratio of the Likert scale value to 7, the highest value (for example, a value with a certainty of 6 was multiplied by 85.7% = 6/7), following Li and Mattsson [26].

Finally, in addition to comparing average WTP across facilities and questions, a linear regression was calculated to determine if specific attributes of the facility or demographics of the respondents affected the WTP valuation. Both the distance the respondent lived from the facility and its visibility from the home were analyzed to see if they affect a respondent's overall attitude towards generation methods, since both of these variables are often compared when measuring WTP for a specific facility [7,10,30]. To investigate potential Tiebout sorting, the time that the respondent lived in the address was included. (Tiebout sorting is the effect that, over time, people move closer to areas with goods or facilities they most value, and away from those they do not [31,32]. Tiebout sorting could complicate the current study, because the coal plant has been in place much longer than the wind turbine. Thus, even if both had equally negative impact, more people would have moved away from the coal plant and, because fewer of those with negative perceptions would remain near the coal plant, a local survey would show less negative perceptions than near the newer facility. This will be discussed with results.)

In addition, basic demographics, including income, age, and gender, were examined as previous studies have shown these can affect WTP for a variety of concerns [20,33,34], including wind power [35,36]. These variables are explained in Table 2.

4. Results and discussion

4.1. Response rate

Of the 1000 surveys mailed to Lewes, 219 were not delivered by the post office, and 355 completed surveys were returned, leading to a response rate of 45.5%. Of the 1000 mailed to Millsboro, 211 were undelivered and 179 completed surveys were returned, so the

Table 2
Variable descriptions for regressions.

Variable Name	Description of Variable
Distance	As-the-crow-flies distance from house to facility (in miles)
See	Can respondent see facility from home (1 = Yes, 0 = No)
Hear	Can respondent hear facility from home (1 = Yes, 0 = No)
Gender	Respondent's gender (1 = Male, 0 = Female)
Age	Respondent's age
Lived here	How long have you lived in current zip code
Overall like/dislike	Overall attitude toward facility (1 = Like, 0 = Feel neutral, −1 = Dislike)
Income	Household income (Binned into <$25,000; $25,000 − $49,999; $50,000 − $99,999; ≥$100,000)
[Wind/Coal] Health 1	Response to Statement "[Wind turbines/Coal plants] have a large impact on human health and shouldn't be used" (1 = Yes, 0 = No)
[Wind/Coal] Health 2	Response to Statement "[Wind turbines/Coal plants] have a large impact on human health but it is still worthwhile to use them" (1 = Yes, 0 = No)
[Wind/Coal] Health 3	Response to Statement "[Wind turbines/Coal plants] have minimal impact on human health but shouldn't be used" (1 = Yes, 0 = No)
[Wind/Coal] Health 4	Response to Statement "[Wind turbines/Coal plants] have minimal impact on human health so it is a good idea to use them" (1 = Yes, 0 = No)
[Wind/Coal] Health 5	Response to Statement "[Wind turbines/Coal plants] have no impact on human health so it doesn't matter if they are used" (1 = Yes, 0 = No)
[Wind/Coal] Envir 1	Response to Statement "[Wind turbines/Coal plants] have a large impact on the environment and shouldn't be used" (1 = Yes, 0 = No)
[Wind/Coal] Envir 2	Response to Statement "[Wind turbines/Coal plants] have a large impact on the environment but it is still worthwhile to use them" (1 = Yes, 0 = No)
[Wind/Coal] Envir 3	Response to Statement "[Wind turbines/Coal plants] have minimal impact on the environment but shouldn't be used" (1 = Yes, 0 = No)
[Wind/Coal] Envir 4	Response to Statement "[Wind turbines/Coal plants] have minimal impact on the environment so it is a good idea to use them" (1 = Yes, 0 = No)
[Wind/Coal] Envir 5	Response to Statement "[Wind turbines/Coal plants] have no impact on the environment" (1 = Yes, 0 = No)

response rate was 22.7%. This led to an overall response rate of 34.1%. Additional surveys were returned partially completed, but those are not tabulated here as completed to ensure the same cohort is represented across questions.

4.2. Demographics of respondents

Table 3 shows the demographics of respondents as compared to the overall demographics of town residents reported in Table 1. For both towns (and thus generating facilities) the respondents are somewhat more often male and higher income that the respective populations. This is not unexpected given typical self-selection bias, and given this topic. Further demographics for the respondents are shown in the Appendix.

4.3. Overall results

Table 4 shows respondents' attitudes toward the respective facility in general (that is, incorporating all aspects of the facility) and self-reported effects. The first three rows in Table 4 are responses to the question "Overall, do you like, dislike, or feel neutral toward this [plant] [turbine]?" The second group of three rows are responses to the question "Some people feel that living near a [coal plant] [wind turbine] has a positive effect on their life while others feel it has a negative effect and others feel it has no effect. What impact do you feel overall?" The third and fourth groups of rows are answers to the question "Does ***[seeing] [hearing]*** the [coal plant] [wind turbine] have an effect on your everyday activities and enjoyment of your property? The effect could be positive or negative." The seeing/hearing questions were only asked of those who reported they could see or hear the facility from their residences, so the total number of respondents is less than for the first two questions. As a hypothesis, because the coal generator has been in place longer, and because many in the local community rely on the coal generator for jobs but few did for the turbine, we might expect more local support for the coal plant. This was not the case.

People living near the wind turbine had a more positive reaction to their local generator than did those living near the coal plant, by multiple metrics. 61% of turbine residents liked the turbine, only 12% of coal plant residents liked the coal plant. Only 6% of turbine residents disliked the turbine, while 35% of coal residents disliked the coal plant. Regarding reported "effects on my life," 43% reported the turbine had positive effects, while only 9% said the coal plant did. As for negative effects on life, only 6% of turbine residents

Table 3
Demographics of respondents compared to residents.

	Lewes (Turbine) Residents	Lewes (Turbine) Respondents	Millsboro (Coal Plant) Residents	Millsboro (Coal Plant) Respondents
Total Population	2808	348	3931	177
Male	1289 (46%)	199 (57%)	1783 (45%)	117 (66%)
Female	1519 (54%)	149 (43%)	2148 (55%)	60 (34%)
Median household income (dollars)	58,493	87,500	49,856	62,500
Mean household income (dollars)	78,291	117,784	53,423	64,071
Facility Constructed	2010		1957	
Current Capacity	2 MW		400 MW	

Table 4
Results of Survey Respondents to "What is your overall opinion of the [facility]" (Rows 4–6), "What effect does the [facility] have on your everyday life" (Rows 8–10), and "What is the effect of [seeing/hearing] the [facility] on your everyday life?" (Rows 12–17 and 20–25, respectively). The categories in the first column correspond to map points colors in Fig. 2.

	Turbine Residents		Coal Plant Residents	
	Number	Percent	Number	Percent
Overall like/dislike attitude				
Dislike	22	6%	63	35%
Feel Neutral	115	33%	94	53%
Like	215	61%	21	12%
Effect on your life				
Negative Effect	21	6%	79	46%
No Effect	180	51%	79	46%
Positive Effect	149	43%	15	9%
Effect of Seeing				
Strongly Negative	3	2%	5	8%
Somewhat Negative	18	10%	13	22%
No Effect	86	49%	35	59%
Somewhat Positive	42	24%	5	8%
Strongly Positive	27	15%	1	2%
Cannot See	181		118	
Effect of Hearing				
Strongly Negative	4	7%	2	11%
Somewhat Negative	7	12%	7	37%
No Effect	36	62%	6	32%
Somewhat Positive	7	12%	1	5%
Strongly Positive	4	7%	3	16%
Cannot Hear	294		159	

reported negative effects, while 46% of coal residents reported that the plant had negative effects on their lives. Again, given that the coal plant employs many people in the local community, we found this surprising.

When the survey asks about the specific perceptual aspects of seeing and hearing the local facility, results are parallel. Per Table 4, turbine residents reported fewer negative and more positive perceptions of both sight and sound of the turbine, whereas the residents near the coal plant reported more negative and fewer positive responses to both visual and sound of the plant. Fig. 2 demonstrates the sight and sound results graphically and appears to show that there is no geographic correlation among more positive versus more negative responses.

We reflect briefly on these results. There is considerable literature reviewing both physical evidence [42] and surveys of the visual and auditory impact of wind turbines. The balance of the literature suggests that is an issue of wind power not fossil power. But when nearby residents of each type of facility were surveyed, with equal questions for each facility, we find very substantial differences in that nearby residents report that the wind generation has less visual and less auditory impacts, that they have a more positive attitude towards their local generation for wind, and that more people feel the generator's presence "improves their everyday lives."

There were reasons not to expect this result. Far more people in the coal plant community work at the plant, and the coal plant has been in place 60 years, so that Tiebout sorting had more time to operate. Conversely, Tiebout sorting would not have had time to

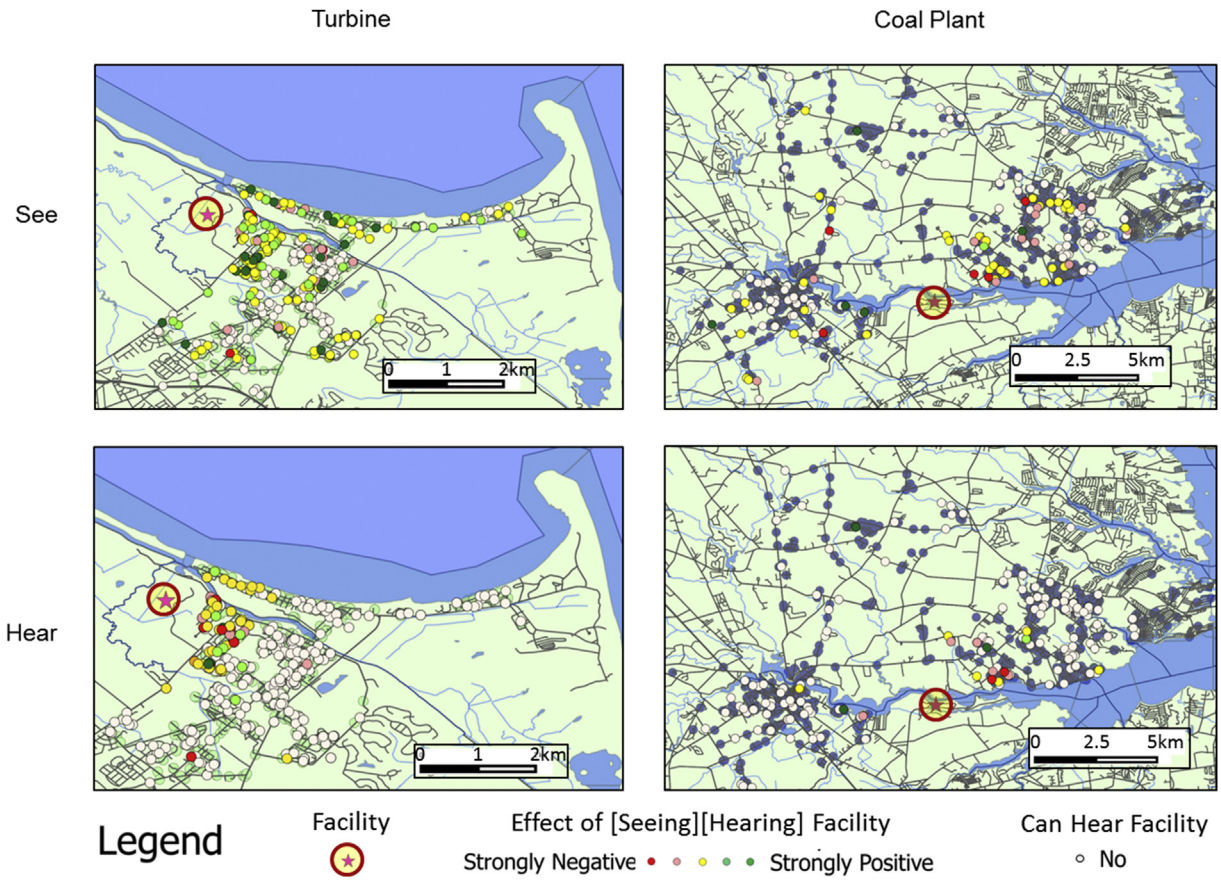

Fig. 2. Overall Survey Results to the question "Does *[seeing] [hearing]* the [coal plant] [wind turbine] have an effect on your everyday activities and enjoyment of your property? The effect could be positive or negative." Table 4 gives these results numerically. Circle with asterisk locates the power generation facility.

operate fully for the much newer wind turbine, so we would expect more residents with negative views of wind to still be in place and answer the survey. None of these effects were sufficient to overcome the more positive visual, auditory, and overall attitudes toward the wind generation in relation to coal.

The result that more nearby residents have positive than negative experience living with nearby wind generation is consistent with some other studies of wind turbines. Firestone [37] found that 78% of residents had positive feelings toward the turbine, and 82% liked it visually. 15% of those surveyed were disturbed by the sound.

More generally, there seems to be both in research literature and in the press, a sense that there is considerable opposition to new wind generation. Physically, yes, if homes are too close to turbines there can be problems with shadow flicker or noise. And, even if opposition is only 2%–7%, tens of opposed residents speaking at siting hearings can seem like a large opposition movement. The bigger picture, we feel, is that if siting guidelines are followed, as in the turbine studied here, the experience of actual residents living close to power generation reveals some negative reactions for any type of generation, but by every measure taken (from sight and sound to "effect on my life") there is much more positive than negative for wind, and much more negative than positive for fossil generation.

After the question on what effect seeing the turbine had on their everyday life, respondents were also given the opportunity to explain their answers, via an open ended "Why?" question. Some responses were: "it says that someone in our neighborhood is environmentally concerned" "I like that the University use alternative energy" "It signifies progress to me" "It reminds me that we care about our environment" "Appears Lewes is keeping up with the times" "Landmark!" "I am a fan of wind energy and I do not find the turbine itself to be unattractive" and "Feel pride that community is using alternative source - saving the environment." Talking with other residents outside the survey, we were told that the slow sweep of the rotor blades was "beautiful" and the soft swoosh was "relaxing." This set of responses illustrate reasons that local residents might give positive evaluation for a new sound and visage in their community, although most incorporate other aspects than just the immediate perceptual.

4.4. Average WTP to keep or remove each type of generation

Each respondent was asked to answer four WTP questions (See the Appendix for complete wording of questions) relating to the overall keep/leave (no specific factors identified), the visual effects, the auditory effects, and the desire to have the nearby facility switch to the contrasting facility. Results are shown in Table 5 for residents living near the turbine and in Table 6 for residents living near the coal plant. The average value is the arithmetic mean for all respondents, treating those willing to pay to get rid of the facility as a negative WTP.

No post-hoc weighting was done to make the survey demographics match the population demographics because t-tests and Kruskal-Wallis tests found that survey responses did not vary significantly across demographic groups tested, including gender, age, home ownership, education, and income. Because groups must have different means in order for post hoc weighting to improve outcomes, we determined that weighting was not called for [38].

Table 5
Turbine Residents' WTP to keep (+) or remove (−) the generator, certainty weighted. Overall WTP was unspecified/all reasons to keep or remove, Visual WTP asks about just the visual impacts, Auditory WTP asks about just the auditory impacts, and WTP if Facility Switched asks about the WTP to keep or remove the facility if it would be replaced with a coal plant.

	Overall WTP	Visual WTP	Auditory WTP	WTP if Facility Switched
Average WTP	2.56	1.65	1.33	10.05
Total Respondents	335	333	330	324

Table 6
Coal Plant Residents' WTP to keep (+) or remove (−) the generator, certainty weighted. Overall WTP was unspecified/all reasons to keep or remove, Visual WTP asks about just the visual impacts, Auditory WTP asks about just the auditory impacts, and WTP if Facility Switched asks about the WTP to keep or remove the facility if it would be replaced with a turbine.

	Overall WTP	Visual WTP	Auditory WTP	WTP if Facility Switched
Average WTP	−1.82	−0.86	0.10	−1.91
Total Respondents	170	168	163	165

Respondents living near the wind turbine were willing to pay an average of $2.56 a month to keep the turbine in its current location. When only considering visual impacts they were willing to spend $1.65 and only considering auditory $1.33. Notably, turbine residents were willing to spend a substantial $10.05 a month to prevent the turbine from being replaced with a coal plant.

Conversely, respondents living near the coal plant were willing to pay $1.82 per month to have it removed (negative value in Table 6). Near-coal residents would pay to have it removed for all categories except when considering only its auditory impacts for which payment was near zero (a slightly positive $0.10). When only considering visual impacts, they were willing to spend $0.86 a month to have the coal plant removed. And they were willing to spend slightly more, $1.91 per month, to replace the coal plant with a wind turbine.

For near-turbine residents, the WTP to keep the turbine for visual plus WTP for auditory reasons was approximately equal to the WTP for all reasons combined ($1.65 + $1.33 ≈ $2.56). Specifically, although a few (5%–7%) would pay something to remove the turbine, a much larger 24%–38% would pay to keep it (percentages of plus and minus are not shown in table, only the resulting positive for average WTP). Furthermore wind turbine residents on average would pay to keep the visual and the auditory aspects. However the WTP to NOT swap their wind turbine for a coal plant was much higher ($10.05). This high WTP to avoid swapping suggests a strong negative for coal by near-wind residents, adding to a positive but smaller WTP to keep the turbine. As noted, most of the literature concentrates on the negative visual and sound aspects of wind power, so how do we explain that residents living near a wind turbine would actually pay to keep it, for all reasons, and also keep it for visual and auditory reasons? An answer is suggested by the resident quotations above acknowledge multiple positive aspects of the turbine, not only the physical plant but also how it makes them feel about environmental progress and leadership by their community. For respondents living near the coal plant, the overall opposition was larger than the sum of the visual and auditory opposition, suggesting the opposition is to some attribute other than those two.

4.5. Attitudes toward different fuels in general

Some survey questions were general attitude, knowledge, or belief about power plant fuels, not requiring direct experience with a local facility. These questions, near the end of the survey, compared electricity generation by coal, natural gas, and wind. This set of questions makes no reference to the local generation facility, but we tabulate the answers by respondents' local generation to examine effects of their experience on their general attitudes.

Table 7
Responses to the question "Do you approve or disapprove of the [burning of coal] [burning of natural gas] [use of wind turbines] to generate electricity?"

	Burning Coal		Burning Natural Gas		Wind Turbines	
	Turbine Residents	Coal Plant Residents	Turbine Residents	Coal Plant Residents	Turbine Residents	Coal Plant Residents
Strongly disapprove	33%	17%	5%	3%	2%	6%
Somewhat disapprove	34%	24%	13%	11%	1%	5%
Neither approve nor disapprove	14%	22%	23%	24%	9%	13%
Somewhat approve	13%	19%	36%	32%	22%	22%
Strongly approve	6%	17%	23%	30%	66%	54%

Table 7 shows the result of asking generally if they "approve or disapprove" of generation from coal, natural gas, and wind. Fig. 3 shows the same results graphically. Differences of means were calculated between the turbine residents and the coal plant residents, and the results were different (significant at the 0.05 level) for all fuel types. That is, residents near the coal plant are more approving of both fossil fuels, and a little less approving of wind generation. But despite the differences between communities, the larger differences seen in Table 7 and Fig. 3 are among fuels for electric generation. For example, looking only at percentages who "strongly approve" (Table 7, last row) in each community, 6% and 17% strongly approve burning coal, 23% and 30% do so for natural gas, and 66% and 54% do for wind turbines.

Respondents were also asked about their opinions on the effect of electricity generating facilities on human health and the environment. Table 8 shows the tabulations for health, and Table 9 the same tabulations for environment. Each item is a compound, to test not only one attitude or opinion, but also whether respondents used those beliefs in arguments for or against generation types.

An approximate scale of increasing acceptance, from top to bottom, is shown as "Scale Values" 0 through 5 on the left of Tables 8 and 9. Using a scale to collapse these survey questions collapses the information about size of impact together with judged desirability of use, losing information. However, the "Mean Scale Value" provides an imperfect overall belief-based measure of desirability for each power source, for each group, shown in the bottom row.

For health, the residents of the two towns give very similar mean values for the health impact and desirability of using each source. Residents of the coal plant are more accepting of coal power than turbine residents; the difference is small but statistically different (significant at 0.10). More notable in Table 8 is that both towns' residents find natural gas and wind increasingly less impactful and more desirable to use, with differences across types of generation much larger than differences between towns for each single type of generation. A very similar pattern is seen in Table 9 for environmental damage, with significant but small differences between towns, but much larger differences between generation facilities. The mean values give a summary measure, but an inspection of the answers to each question also shows a consistent pattern.

In short, people who spend more time very close to a generation facility are a little more likely to believe that the health and

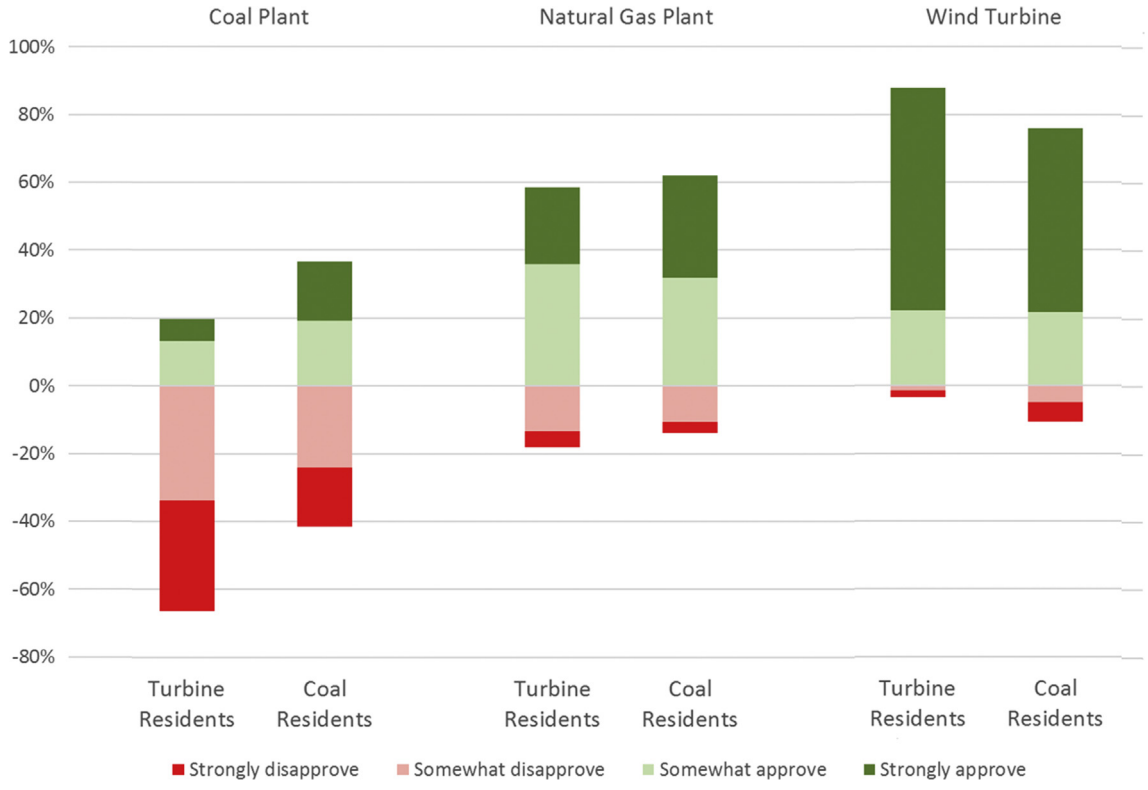

Fig. 3. Responses to the survey question "Do You Approve or Disapprove of the use of _____ to generate electricity?" Approve is above 0%, disapprove is negative. Only approve or disapprove answers are graphed, not the neutral answer.

Table 8
Human Health impacts, question: "What is your opinion on the impact of [coal plants] [natural gas plants] [wind turbines] on human health?" Value in table are percentage agreeing. Scale values on the leftmost are averaged in the last row, as "Mean".

Scale Value	Coal Plants		Natural Gas Plants		Wind Turbines	
	Turbine Residents (N = 343)	Coal Plant Residents (N = 171)	Turbine Residents (N = 345)	Coal Plant Residents (N = 174)	Turbine Residents (N = 345)	Coal Plant Residents (N = 173)
0 I don't know what impact ____ have on human health	18%	22%	35%	41%	15%	23%
1 _____ have a large impact on human health and shouldn't be used	48%	32%	4%	5%	1%	3%
2 _____ have a large impact on human health but it is still worthwhile to use them	18%	20%	12%	6%	1%	1%
3 _____ have minimal impact on human health but shouldn't be used	3%	5%	6%	2%	3%	3%
4 _____ have minimal impact on human health so it is a good idea to use them	13%	16%	40%	34%	43%	28%
5 _____ have no impact on human health so it doesn't matter if they are used	0%	5%	3%	13%	37%	43%
Mean Scale Value	1.48*	1.69*	2.27	2.15	3.69	3.45

***Difference significant at the 0.01 level.
**Difference significant at the 0.05 level.
*Difference significant at the 0.10 level.

Table 9
Environment impacts, question "What is your opinion on the impact of [coal plants] [natural gas plants] [wind turbines] on the natural environment?" Value in table are percentage agreeing. Scale values on the leftmost are averaged in the last row, as "Mean".

Scale Value	Coal Plants		Natural Gas Plants		Wind Turbines	
	Turbine Residents (N = 305)	Coal Plant Residents (N = 170)	Turbine Residents (N = 348)	Coal Plant Residents (N = 234)	Turbine Residents (N = 346)	Coal Plant Residents (N = 175)
0 I don't know what impact _____ have on the environment	14%	16%	35%	39%	10%	24%
1 _____ have a large impact on the environment and shouldn't be used	53%	35%	6%	6%	2%	3%
2 _____ have a large impact on the environment but it is still worthwhile to use them	0%	23%	15%	10%	3%	3%
3 _____ have minimal impact on the environment but shouldn't be used	18%	4%	5%	3%	1%	3%
4 _____ have minimal impact on the environment so it is a good idea to use them	4%	18%	35%	36%	68%	42%
5 _____ have no impact on the environment	0%	2%	3%	6%	15%	24%
Mean Scale Value	1.47**	1.72**	2.13	2.05	3.64***	3.13***

***Difference significant at the 0.01 level.
**Difference significant at the 0.05 level.
*Difference significant at the 0.10 level.

environmental consequences are smaller for that type of facility or to accept such damages as necessary. Nevertheless, both communities agree that the damages to health and environment are reduced as one moves from coal, to natural gas, to wind power.

As noted previously, there were several places that respondents could give open-ended description of the basis of their options. Table 10 lists the more common of those factors, with wording volunteered by respondents then categorized by a coder from the open-ended comment fields. To clarify some of our categories in Table 10, "Private investment" includes those who opposed paying to support or oppose the facility because it was a private investment that they didn't feel they should pay for. "Process" includes those who commented on the community acceptance process involved in putting up the turbine (no one made this comment for the older coal plant). Although an imperfect instrument, Table 10 gives some indication of what factors were reported to have been considered in answering the survey, their relative frequency, and which town was more likely to raise each factor. Table 10 shows that those who lived near the turbine considered environmental concerns and a need for power generation, along with support of a new technology, most often, while also being concerned with birds and costs. Those who live near the coal plant were more concerned with cost and health, not at all considering new technology, and otherwise reported the same factors as turbine residents but at lower frequency.

Several interpretations follow from these data. By multiple measures, those who live closer to each facility are more approving of it, in agreement with previous research on the topic [39]. This could be explained by those living near it having first-hand

Table 10
Self-reported explanations for responses.

	Birds	Bats	Anti-government/regulation	Fracking	Cost	Private Investment	New Technology	Jobs	Health	Environment	Power Need	Process
Turbine residents	24	2	3	7	19	6	27	1	8	128	115	10
Coal Plant residents	12	0	5	3	26	4	0	11	24	71	39	0

experience and realizing the facility isn't as problematic as outsiders might think. A second possible explanation would be that, near the coal plant at least, while most survey respondents weren't directly employed by the plant, many members of the community are employed by either supporting services or the plant, or know people employed by the plant, so they would reduce cognitive dissonance by believing its impact is lower. A third possible explanation for this would be Tiebout sorting, in that those who object to the facility move away over time. But as noted previously, Tiebout sorting can't explain the full differences, as the coal plant has been there 50 years, yet nearby residents still rank it worst in health and pollution, and say they would pay monthly to have it removed.

Results for opinions on the energy facility's effect on human health and the environment are more surprising. The impacts of these can be quantitatively measured, so deviations from these science-derived values are likely a matter of perception and overall risk tolerance. For example, one could know that coal plants have an effect on human health, but still think that damage is worth the benefits of power that the plant produces. However, 5% of near-coal respondents say that coal plants have no impact on human health, and 2% say they have no impact on the environment. Yet, numerous studies [40–43] provide evidence that they do, and as a matter of US law, coal power plants are being shut down or required to control emissions for this reason. Thus we would have to consider this small fraction's belief that they have no impact a misconception. Based on responses to other questions and comments the belief of zero pollution from coal may be driven by ideology rather than direct perceptions (one respondent stated that his job category was “Obama's underemployed”, another said “Coal is a clean source of energy as is natural gas + wind. I am not willing to pay any $ towards the removal of a perfectly functioning coal plant b/c some environmentalist thin[k]s it's [coal] a bad thing for the environment.”). So we might ask, is this a question of pre-existing biases and ideological information sources affecting knowledge [44], or a question of incomplete knowledge?

4.6. Regression to determine factors affecting WTP judgments

A multiple regression was calculated for the Overall WTP to keep or remove the nearby generator. Results are found in Table 11 for turbine residents and Table 12 for coal plant residents. Both regressions did a reasonable job of explaining the dependent variable, overall WTP ($r^2 > 0.2$). The respondents' overall like/dislike attitude towards the facility was significant in both cases, with liking the turbine increasing the willingness to pay by $5.80 and liking the coal plant increasing the willingness to pay by $3.62. Although, arguably the overall like/dislike is a metric overlapping with WTP to keep or remove.

Some infrequent responses had large effects when present. The 1% of near-turbine respondents who agreed that wind turbines “have a large impact on human health but it is still worthwhile to use them” (WindHealth2) would pay a very large $22.03 less to keep the turbine in comparison to those who most agreed with a different statement. Similarly, the 1% of near-turbine respondents who agreed that wind turbines “have minimal impact on the environment but shouldn't be used” (WindEnvir3) would pay $32.11 less to keep the turbine in comparison to those who most agreed with a different statement.

For near-coal residents in Table 12, the substantial 32% who agreed that coal plants “have a large impact on human health and shouldn't be used” (CoalHealth1) were willing to pay $5.85 more to remove the plant (Negative value) in comparison to those who most agreed with a different statement. And the 4% of near-coal residents who agreed that coal plants “have minimal impact on the environment but shouldn't be used” (CoalEnvir3) were willing to pay $7.35 more to remove the plant. So the near-coal community has many more people—although still less than half—whose beliefs lead to high WTP values to remove the plant.

Only a few variables were significant in explaining resident's willingness to pay. The overall like/dislike is one of the most significant for both communities, although perhaps not totally distinct from what WTP measures, so arguably less substantively significant. For each community, there are two belief statements with

Table 11
Turbine Residents: Regressions to explain Overall WTP for keep/remove (Certainty Weighted).

R^2		0.208
n		305
Variable	Coefficient	SE
Distance	7.550	9.448
See	0.552	1.610
Hear	2.990	2.420
Gender	1.290	1.502
Age	−0.042	0.062
Lived here	0.063	0.050
Overall like/dislike	5.797***	1.431
Income	0.564	0.618
Wind Health 1	3.161	8.072
Wind Health 2	−22.034**	8.624
Wind Health 3	1.354	5.966
Wind Health 4	2.267	3.162
Wind Health 5	2.267	3.367
Wind Envir 1	−0.919	7.749
Wind Envir 2	−3.447	6.038
Wind Envir 3	−32.111***	8.765
Wind Envir 4	−3.737	3.596
Wind Envir 5	3.096	4.216
Constant	−2.585	5.551

***Significant at the 0.01 level.
**Significant at the 0.05 level.
*Significant at the 0.10 level.

Table 12
Coal Plant residents: Regressions to explain Overall WTP for keep/remove (Certainty Weighted).

R^2		0.296
n		137
Variable	Coefficient	SE
Distance	6.337	5.399
See	−0.381	1.465
Hear	2.035	2.443
Gender	0.547	1.328
Age	0.024	0.048
Lived here	0.017	0.041
Overall like/dislike	3.620***	1.306
Income	−0.105	0.463
Coal Health 1	−5.846**	2.769
Coal Health 2	−1.500	2.056
Coal Health 3	−3.159	4.193
Coal Health 4	−2.537	2.788
Coal Health 5	−3.911	4.857
Coal Envir 1	1.672	2.948
Coal Envir 2	0.846	2.251
Coal Envir 3	7.346**	3.423
Coal Envir 4	0.448	2.820
Coal Envir 5	1.437	6.698
Constant	−4.364	4.890

***Significant at the 0.01 level.
**Significant at the 0.05 level.
*Significant at the 0.10 level.

high prediction, the one significant for both being the seemingly incomplete or contradictory Coal/WindEvnir3 ("Wind/Coal Plants have minimal impact on the environment but shouldn't be used"). None of the demographic variables collected were significant, nor were time lived nearby nor distance to the facility. The lattermost follows previous research [5–8,45,46] that also found distance from the facility to have no significant impact on WTP. In sum, the regression analysis to explain WTP shows statistically significant explanatory power from the overall like/dislike, which facility one lives near, and some specific beliefs about damage and whether that type of generator consequently should or should not be used—nevertheless, the factors causing variation in WTP are not fully explained (also revealed in the r^2 of 0.208–0.296.)

5. Conclusion

This study is the first to comprehensively compare multiple measures, including visual and auditory experience, beliefs about effects, and general attitudes toward power generation—by people who actually live with such generation in their community. Prior studies have disproportionally focused on wind power, and much of the existing literature is prospective, of what residents expect of new facilities, rather than retrospectively drawing from years of experienced coexistence. The existing literature is incomplete, suggesting that wind has visual and auditory impacts and fossil does not, and giving little thought to the possibility that these perceptions and attitudes are sometimes positive. (If you don't measure it, you can't detect it.)

We find, in fact, that: a) the visual and auditory effects were more negative for fossil than for wind, and b) for wind generation, the positive perceptual effects were stronger than the negative ones, while for coal generation, the negative perceptual effects were stronger than the positive ones.

Those findings describe averages—of course, some local residents object to both visual and noise impact from power plants, whether they are powered by wind or coal. Also, there was a small tendency to be more accepting of whichever form of electric generation is already in one's local community. Nevertheless, both communities perceive greater visual and noise impacts from coal than for wind. This is true even for residents of the near-coal community, a community built around a large coal power plant that employs many people, and that voted Trump by a 3:2 margin in the 2016 election. We find even in this community, a majority recognize the disadvantages of coal with respect to natural gas and wind, on all measures tested, and a majority also seem to acknowledge that a switch away from fossil fuels will have to be made. Another way of describing these results is that, on average, residents in both communities accurately describe the relative environmental and health impacts of coal, natural gas and wind, with only a slight bias based on familiarity, local employment, and possibly also due to community political preferences.

A multiple regression analysis of factors that could affect the overall WTP to keep or remove the local plant was significant but did not seem to capture the strongest factors. A partially synonymous measure of like or dislike, along with four beliefs pro or con, all contributed explanatory power. Contrary to expectation, neither distance from the facility (which would affect visual and auditory disamenity) nor demographic characteristics, had significant effects. The write-in explanations on the survey suggest that positive attitudes toward the wind turbine may relate to pride in the community about using advanced technology, the value of reducing pollution, or appealing visual or sound aspects. Comments by those believing coal had no environmental or health impact attributed coal's decline to environmentalists' misconceptions or "Obama" policies. Tabulation of the write-ins showed the most common write-in factors (combining all communities and technologies) to be: Environmental, power needs, birds, health, cost, and new technology. These qualitative write-in and verbal comments suggest additional questions that could be asked in future surveys, to elicit previously unexpected factors that might explain more of the variance than we have done here.

In addition to any contribution from this study to the literature and to improving methods on this topic, these results may be of some practical value in designing material to discuss with communities facing nearby development of local power generation.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.renene.2017.10.036.

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