An Exploratory Investigation of the Experience of Visible Wind Turbines

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Abstract: Wind turbines are normally the largest structures in the landscape, yet little is known about how they are experienced. Most studies of wind turbines focus on their scenic impact and represent them using visualizations. However, scenic judgments of wind turbines by different viewers can be highly variable and require higher-order cognition. In addition, recent research has called into question the validity of using visualizations to assess very large structures, such as wind turbines. This study explores the more intuitive perceptions of wind turbines, specifically the sense of looming and visual prominence of 35 individual turbines and the sense of looming and the feeling of being surrounded by wind farm turbines at nine viewpoints. Changes in scenic quality and fit with the landscape prior to the wind farms are also rated. The results show that the more intuitive perceptions have higher reliability. These perceptions are affected by turbine exposure, proximity, and extent, which can be represented by physical measures such as distance and the arc of the project around a viewpoint.

Keywords: Visual impact, visual prominence, sense of looming, feeling surrounded, exposure, proximity, extent

1 Introduction

Wind turbines are often the tallest structures and wind farms the most extensive developments in a county or state. Such large projects have the potential for several major environmental impacts, yet the one most mentioned by the public is their visual or aesthetic impact (MATTMANN et al. 2016, RAND & HOEN 2017, TSANI et al. 2024). Studies of how wind energy development affects residential property values have found both positive (HOEN, BRUNNER & SCHWEGMAN 2025) and negative (PARSONS & HEINTZELMAN 2022) results. Economic impacts have typically been accounted for in these analyses as either the distance to the nearest turbine whether visible or not (SCHÜTT 2024) or the nearest potentially visible turbine (DONG, LANG & PARENT 2024). The Lawrence Berkeley National Laboratory (LBNL) is investigating the ways wind projects affect home values (BRUNNER et al. 2024) and sought to develop a more sophisticated way of accounting for visual impacts.

Aesthetic impact is a higher-order cognitive assessment and may not be the most reliable explanation of our experience when seeing wind turbines. Many people find wind development in the landscape to be acceptable and even interesting and beautiful, while others find it to be unacceptable. KIRCHHOFF et al. (2022) have even proposed that many people respond to questions about wind turbines' visual impact as a moral judgment rather than as an aesthetic one as traditionally defined. With such divided judgments among the public, using a mean value may not be a satisfying way to gauge the public's reaction. It seems desirable to identify ways to describing experiences of wind turbines and wind farms that are more widely shared.

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A further problem has been how wind turbines have been represented to research participants, where the quality of simulations is often poor and the representations of turbines are abstract or unrealistic (HEVIA-KOCH & LADENBURG 2019). Research has found that even photorealistic simulations of large structures do not adequately capture the experience compared to viewing them in situ (PALMER & SULLIVAN 2020, TAKACS & GOULDEN 2019). For instance, simulations in VIAs are normally static and determine the viewer's focus with a limited angle of view, while viewers in situ choose their point of focus, looking around at turbines and other elements that are moving in the landscape. However, only a very few studies have been conducted in the field because of the difficulty of transporting many viewers to many diverse viewpoints. The major exception is a study by SULLIVAN et al. (2012), but they only evaluated turbines when they were fully visible.

It was in this spirit that LBNL conducted an exploratory study to determine how we experience views of wind turbines and wind farms. It investigated the experience of wind turbine *visual prominence* and *sense of looming*, and wind farm *sense of looming* and *feeling of being surrounded,* as well as more traditional ratings of *change in scenic quality* and *fit with prior landscape character*. The reliability of these ratings is tested, and their relationships to common metrics describing the views of specific turbines and farms calculated.

2 Methods

A diverse team of 3 men and 4 women representing each decade from their 20s through 70s conducted the observations in the field. Their professions included a biologist, two landscape architects, a mathematician, an economist, and two artists. They were given a 2-hour training session that included an illustrated training manual and worksheets for recording observations in the field. The wind farms they observed were located in the Tug Hill (43.79, -75.58) and Central (42.99, -75.76) regions in New York State, as shown in the Appendix B maps. Data about wind turbines and wind farms was obtained from the U.S. Wind Turbine Database (USWTDB) (HOEN et al. 2018). The identification of visible turbines in the USWTDB was accomplished using a procedure described by PALMER (2025).

Observations were conducted at 9 viewpoints, an average of 2 km apart, on July 20 and 21, 2023, during good visibility conditions. The two types of observations were made: 35 individual turbines and the wind farms surrounding the viewpoint. Photographs from four of the locations showing turbines at different distances and landscape settings are shown in in the Appendix B maps. Three new experiential variables, thought to be more instinctive than scenic judgements, are evaluated.

- **Visual prominence** of turbines was studied in the field by SULLIVAN et al. (2012).
- **Sense of looming** for turbines and wind farms was studied by BLAU et al. (2009). It can refer to the instinctive reaction to the vertical, 'over-the-shoulder' presence of a physical object, suggesting an impending threatening feeling (RISKIND et al. 2012) and often triggered by rapid motion toward the observer (THIEU et al. 2024).
- **Feeling of being surrounded** horizontally by wind turbines is identified in interview studies (DUNLAP 2017, LADENBURG et al. 2013), and is noted as a cumulative impact concern (NATURESCOT 2021). However, it has not been the focus of empirical investigations.

These variables are measured from low to high using 7-point rating scales, as shown in Appendix A. Two ratings of visual impact, from −7 to +7, are also obtained. The analyses used the mean rating from the 7 observers.

- **Change in scenic quality** perceived by the public and how to assess its severity has been studied at sites of proposed wind farms by PALMER (2015). The single scale approach is typical of public surveys (LADENBURG & DAHLGAARD 2012).
- **Fit with prior landscape character** can change a landscape's sense of place (GOUDRIAAN et al. 2023). BUTLER & WÄRNBÄCK (2019) review how these enormous structures can change the landscape.

Fig. 1: Photographs from different observation locations with turbines in the immediate, near, mid and far distances that also represent the range of landscape settings

In addition, several physical characteristics were recorded. For individual turbines this included exposure (Fig. 2) and perceptually defined distance zones (US FOREST SERVICE 1995). The USWTDB provided data on turbine dimensions and location so the distance to the viewer could be calculated. Observations of wind farms included counting the number of turbines by distance zone and exposure within eight 45° wedges beginning at magnetic north. The observation ended by rating the importance of 10 perceptions describing their experience of the turbines in the landscape. All ratings and observations were done independently.

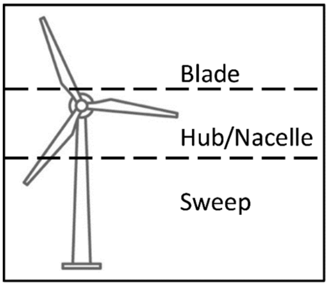

Fig. 2:
Turbine exposure

3 Results

3.1 Reliability

Reliability is measured using the intraclass correlation coefficient (ICC (2, k)) (PALMER & HOFFMAN 2001). The reliability of the three instinctive variables for both wind turbines and farms is excellent, whereas it is only fair for the two wind farm impact variables that require a higher-order cognitive judgment. The reliability of counting visible turbines and wedges with turbines is excellent.

Table 1: Intraclass correlation for the group's rating reliability

		95% C.I.	
Wind Turbine Rating Scales	**ICC (2, k)**	**Lower**	**Upper**
Visual Prominence	0.935	0.881	0.966
Sense of Looming	0.913	0.843	0.953
Wind Farm Rating Scales			
Sense of Looming	0.886	0.722	0.970
Feeling Being Surrounded	0.808	0.534	0.948
Scenic Quality Change	0.409	0.082	0.811
Wind Farm Fit with Landscape Character	0.562	0.086	0.873
Wind Farm Observation			
Count of Visible Turbines	0.998	0.994	0.999
Wedges with Visible Turbines	0.975	0.957	0.987

3.2 Wind Turbines

There is a modest relationship between distance and mean visual prominence (r = -0.471). However, the effect of distance on visual prominence is strongly influenced by the turbine's exposure: sweep (r = -0.749), nacelle (r = -0.333) and blade (r = -0.526). The relationship between distance and sense of looming is also modest (r = -0.419) and the turbine's exposure strongly influences this relationship as well: sweep (r = -0.438), nacelle (r = -0.701) and blade (r = -0.604). These relationships are as shown in Figure 3.

Visual prominence and sense of looming are highly correlated (r = 0.820), and the correlation remains high for different exposures (r values of -0.842, -0.652, and -0.919). This suggests that they may be slightly different expressions of the same fundamental experience.

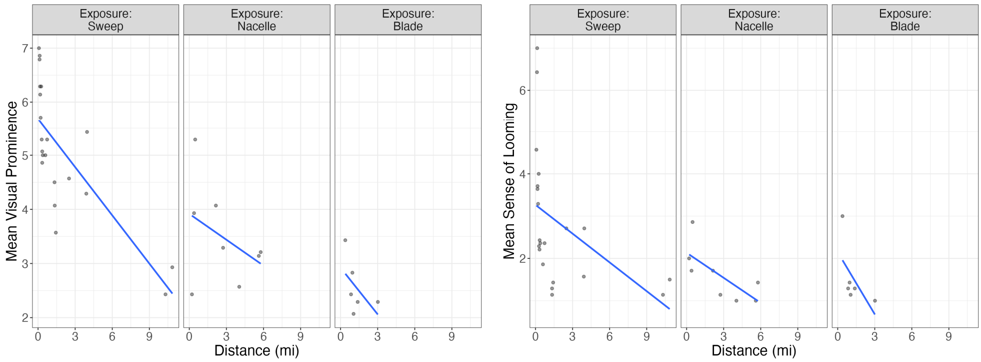

Fig. 3: The relationship between distance and mean visual prominence on the left and mean sense of looming on the right for three turbine exposures

3.3 Wind Farms

The relationship between feeling surrounded and sense of looming associated with the wind farm is weak (r = -0.189), suggesting they are largely independent.

The correlations between the four wind farm experience rating scales and number of turbines and wedges, across all distances and in just the immediate and near perceived distance zones, are reported in Table 2. The relationship with sense of looming is trivial, except between the number of turbines in the immediate and near distance zones where it is still small. On the other hand, the relationship with the feeling of being surrounded is strong, particularly for the number of wedges, and this becomes stronger if only the turbines in the immediate and near distance zones are considered. There is also a strong negative relationship between scenic quality change and the number of turbines, and a moderate positive relationship between the wind farm's fit with landscape character and the number of wedges.

Table 2: Correlation of wind farm ratings with number of turbines or wedges by distance

	All Distances		Immediate & Near	
Wind Farm Mean Rating	**Turbines**	**Wedges**	**Turbines**	**Wedges**
Sense of Looming	-0.070	0.700	0.233	-0.131
Feeling Being Surrounded	0.729	0.874	0.625	0.920
Scenic Quality Change	-0.625	-0.006	-0.266	-0.314
Wind Farm Fit with Landscape Character	-0.187	0.416	0.058	0.166

3.4 Factors Affecting Experience

After completing the turbine and farm observations at a viewpoint, the observers reflected on their overall experience of the wind turbines and landscape and indicated the importance of 10 factors describing their experience at that location. Table 3 lists these factors and the percentage of time their rated importance was low, medium, or high. Perhaps most important is that there is substantial variation in their rated importance, and all factors were judged important at least some of the time.

Table 3: Importance of factors influencing wind farm experience at nine viewpoints

Factors Affecting Experience	Times Rated (%) Low	Medium	High
Distance to nearest visible turbine nacelle	10.1	27.5	62.3
Closeness to some turbines	14.5	27.5	58.0
Shape contrasts with existing character	14.5	29.0	56.5
Wind turbines become the focus of attention	6.0	43.3	50.7
Size of turbines is out of scale with landscape	24.6	31.9	43.5
Density of turbines in the far view	36.4	24.2	39.4
Sense of being surrounded by turbines	25.0	36.8	38.2
Sense that a turbine is looming over me	37.7	26.1	36.2
Landscape changed to more industrial character	23.2	50.7	26.1
Turbines get in the way of the view	56.5	29.0	14.5

Note: There are 63 ratings for each factor (i. e., 7 observers at 9 sites).

Table 4: Varimax rotated principal component loadings of factors affecting wind farm experience

Factors Affecting Experience	Principal Components Proximity	Appearance	Extent	Uniqueness
Distance to nearest visible turbine nacelle	0.870			0.217
Closeness to some turbines	0.839			0.223
Sense that a turbine is looming over me	0.834			0.295
Wind turbines become the focus of attention	0.461	0.536		0.384
Turbine size is out of scale with landscape		0.876		0.202
Shape contrasts with existing character		0.766		0.341
Turbines get in the way of the view		0.702		0.432
Landscape change to more industrial character		0.408	0.604	0.465
Sense of being surrounded by turbines			0.922	0.128
Density of turbines in the far view			0.864	0.214
Percent of variance explained	24.7	24.2	22.1	

Note: KMO MSA = 0.525, Bartlett's Test χ^2= 353.9 df = 45, p < .001.

A polychoric correlation matrix from the importance ratings is used for the varimax rotated ordinal principal component analysis (PCA) reported in Table 4 (JASP Team 2025). There appear to be three different principal components that explain 71% of the variance. Proximity refers to how close the viewer is to the wind turbines, the sense of looming, and the turbines becoming the focus of attention. Appearance also concerns the turbines becoming the focus of attention as well as their contrast with the landscape. Extent relates to turbine density and the sense of being surrounded. The uniqueness is a measure of the variance for a perception not explained by these three principal components; the lower the value the greater the factor's variance is explained by these three factors.

4 Discussion and Conclusions

This study proposed three new variables to describe the more intuitive experience of wind turbines. Ratings of all three proved highly reliable, more so than ratings of traditional measures of scenic impact and fit with the landscape. The sense of looming and visual prominence of turbines are highly correlated, suggesting they may be different aspects of the same experience. They are both moderately correlated with distance, and this relationship is strengthened by consideration of turbine exposure. The feeling of being surrounded by a wind farm's turbines is strongly correlated with the number of turbines, and particularly with the number of wedges containing turbines. In contrast, the relationship of number of turbines or wedges to sense of looming is poor. It may have been a poor choice to evaluate the sense of looming in relation to the whole wind farm, and a wind farm's dominance in the landscape may be a better way to describe the potential experience.

The field observations at each wind farm concluded with reflective ratings of how important ten possible factors affected the experience. A PCA analysis identified three factors – Proximity, Appearance, and Extent – each explaining over 20% of the variance. These factors would appear to relate the physical dimensions of distance between the viewer and the turbines, turbine exposure, and wind farm extent which were found to be effective in explaining the three intuitive experiences investigated here.

This study was a preliminary exploration to test whether it was possible to reliably measure these more basic intuitive experiences of wind turbines. It has been successful in that objective. However, additional variables describing the experience of wind turbines could also be explored, such as the circumstances that explain wind farm dominance in a landscape or how they change the sense of tranquility (WARTMANN et al. 2019).

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Appendix A: Description of the Rating Scales

Sense of Looming. Rate the extent of your sense that one or more wind turbines is looming or towering over you. It may be related to the need to tip your head back to see all the turbine or it may be its movement in your peripheral vision. It may be a feeling of being in the presence of the turbine rather than it "being out there." It may be accompanied by an uncomfortable feeling, even if you are not looking at the turbine – e. g., it "feels" like something is looking over your shoulder.

Rating	Sense of Looming Description
1	No looming – the turbine is just a spatial element.
3	Weak looming – may need to look up to see the whole turbine.
5	Looming – may need to look up to see the nacelle.
7	Strong looming – perhaps a visceral feeling of the turbine's presence.

Feel Being Surrounded. Rate the extent of your feeling that you are surrounded by wind turbines. This may result from a feeling of being enclosed by turbines. Or maybe it is a feeling that they are blocking or interfering with all the views. It is particularly important that you try and describe why you feel this way, since there is no narrative description for this scale. What contributes to different levels of feeling surrounded?

Rating	Being Surrounded Description
1	Not surrounded.
3	Weakly surrounded.
5	Surrounded.
7	Strongly surrounded.

Visual Prominence. How noticeable is the turbine to the observer? The following table describes different levels of a turbine's visual prominence. Even though there may be a line-of-sight to part of the turbine (i. e., it is in the viewshed), if you are not able to see it, then the evaluation would be Level 1 Not visible. Turbines that are difficult to see are at visual prominence Levels 2 or 3. Turbines are easily seen at Levels 4 or 5. Turbines that draw the viewer's attention are Levels 6 or 7.

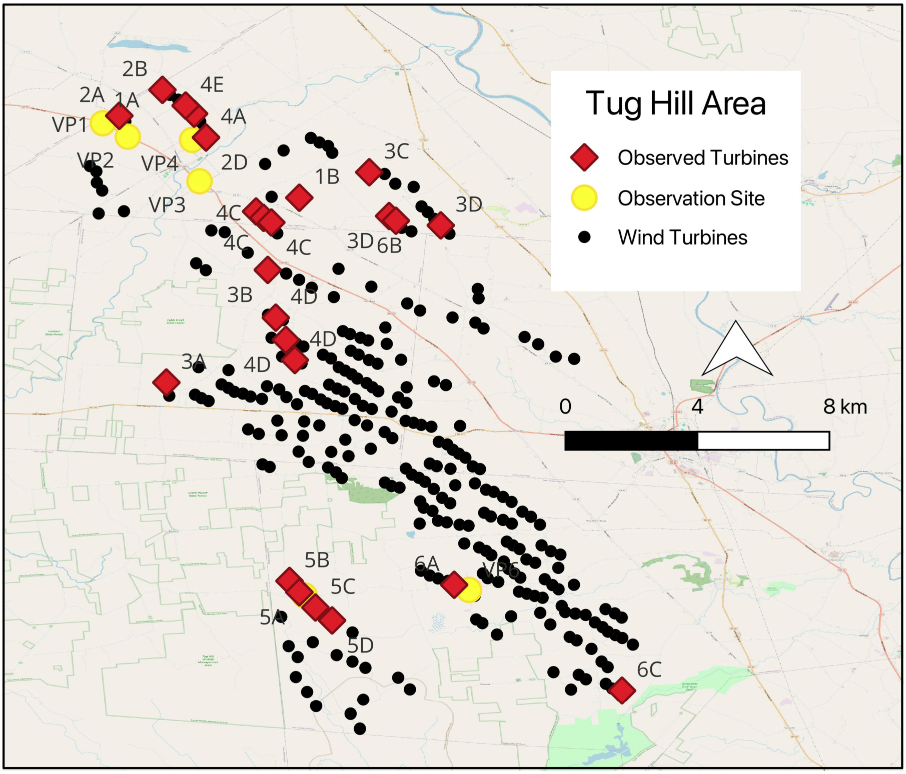
Rating	Visual Prominence Description
1	Not visible, even though there may be a line-of-sight to some part of the turbine.
2	Near the extreme limit of visibility. Would not be seen unless a person was looking for it. Can only be seen after looking at it closely for an extended period of time.
3	Very small and/or faint, but when the observer is scanning the horizon or looking more closely at an area, can be detected without extended viewing. It could sometimes be noticed by a casual observer; however, most people would not notice it without some active looking.
4	Can be easily detected after a brief look and would be visible to most casual observers, but without sufficient size or contrast to compete with major landscape/seascape elements.
5	Is obvious and with sufficient size or contrast to compete with other features, but insufficient to strongly attract visual attention and insufficient size to occupy most of the observer's visual field.
6	Not of large size, but contrasts with the surrounding features so strongly that it draws and holds viewer attention immediately. It interferes noticeably with views of nearby features.
7	Strong visual contrasts. Large apparent size dominates most of the visual field, and views of it cannot be avoided except by turning the head more than 45 degrees from a direct view. Major focal point that detracts noticeably from views of other Features.

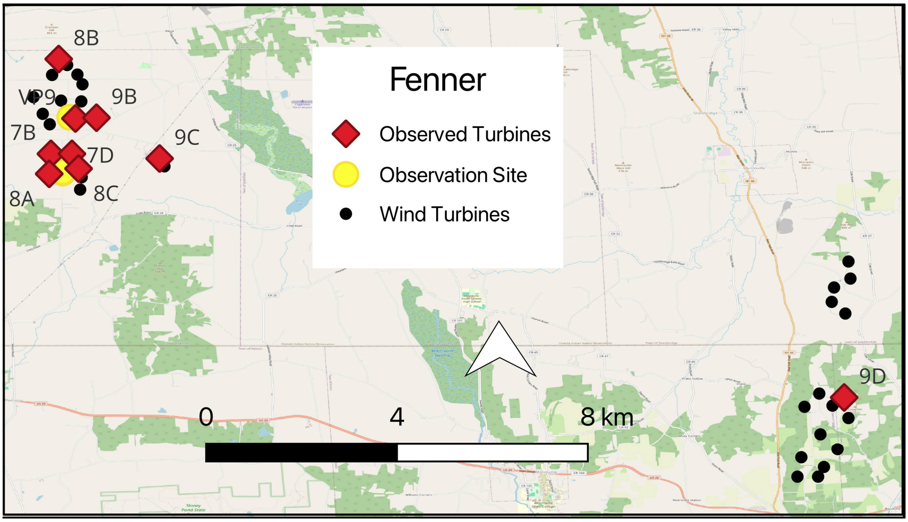
Wind Farm Fit with Prior Landscape. All landscapes have character – it is neither good nor bad, it just is. However, landscapes are also constantly changing, sometimes due to natural causes and other times human causes. If a change between the landscape prior and after introducing wind turbines is Not Apparent, rate it 0. If the change fits Very Well and enhances the prior landscape character it would be rated +7 with other positive fit changes between +1 and +7. If the change fits Very Poorly and changes the landscape character beyond recognition, it would be rated –7 other negative changes in the fit between –1 and –7.

Scenic Quality Change. Consider the scenic quality of the prior and existing landscape views. How would you rate the change in scenic quality attributable to the wind turbines as experienced from this location?

Appendix B: Study Area Maps

These maps are of the study area wind farms. Observation sites are numbered VP1, VP2, etc. and individually observed turbines by their observation number and order 1A, 1B, etc.




Fenner
Observed Turbines
Observation Site
Wind Turbines
8B
VP9
9B
7B
9C
7D
8A
8C
9D
0
4
8 km