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Visual preferences for wind turbines: Location, numbers and respondent characteristics

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A B S T R A C T

There is a dichotomy in the view of wind farms among members of the public: on one hand, there is a desire for renewable energy sources, and on the other hand, there is a major concern about the visual impact of wind turbines used for power production. This concern for visual impact is a major factor in the reaction of the public to the development of new wind farms. Our study aims to objectify this influence and to establish the factors that determine how people evaluate these structures. We tested the visual quality of landscapes in which these structures are to be placed, the number of structures and their distance from the viewer, and various characteristics of our respondents. We found that the physical attributes of the landscape and wind turbines influenced the respondents' reactions far more than socio-demographic and attitudinal factors. One of the most important results of our study is the sensitivity of respondents to the placement of wind turbines in landscapes of high aesthetic quality, and, on the other hand, a relatively high level of acceptance of these structures in unattractive landscapes. Wind turbines also receive better acceptance if the number of turbines in a landscape is limited, and if the structures are kept away from observation points, such as settlements, transportation infrastructure and viewpoints. The most important characteristic of the respondents that influenced their evaluation was their attitude to wind power. On the basis of these results, recommendations are presented for placing wind turbines and for protecting the character of the landscape within the planning and policy making processes.

1. Introduction

The view of wind farms among members of the public is ambivalent: on one hand, there is a desire for renewable energy sources that do not add carbon to the atmosphere [1]. On the other hand, there are many environmental concerns about the siting of wind turbines, the most serious and most widespread of which these concerns is the visual impact of these structures [2–5]. Moreover, while modern technologies can more or less successfully mitigate other environmental impacts, such as noise and danger to bird populations [6,7], this is not the case with the visual impact. To compound the problem, the visual impact of turbines increases as the structures become progressively taller [8]. This problem has become more pressing as the numbers of wind turbines have increased. After European Community Directive 2001/77/EC [9] on the promotion of electricity produced from renewable energy sources in the internal electricity market came into force, many European Union states have accepted policies to promote renewable energy [10] and offered financial incentives to promote the construction of wind turbines. Subsequently, applications to build these structures have grown significantly, exposing the landscape to increased pressure from their impacts. While many wind turbines have already been built since 2001, many more are still awaiting planning permission.

While the number and locations of wind turbines are proliferating, there is a lack of comprehensive research on the visual preferences of the public with respect to wind turbines, and on the factors influencing these preferences. A review of the literature found 18 studies that analysed acceptance of, and preferences for, wind turbines. Most existing studies (Table 1) focus on the level of acceptance of wind turbines and on the influence of respondent characteristics e.g. [5,11]. In order to determine respondents' preferences for wind turbines, most studies e.g. [12–14] used

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Table 1
Focus and methods of previous studies focusing on visual preferences for wind turbines. Methods of assessment of the impact of wind turbines on landscape quality were: verbal questionnaires (*V*), photo-based questionnaires (*P*), questionnaires based on computer simulation (CS) and questionnaires filled in while viewing actual landscape (AL). Assessment evaluators varied between experts, non-expert members of the public and the evaluation of pre-existing data (PE).

Study	Variables								Assessment	
	Acceptance level	Turbine characteristics				Landscape quality/type	Respondent characteristics		Evaluator	Instrument
		Height	Number	Color	Distance from viewer		Socio-demographic	Experience and attitude		
Alvarez-Farizo and Hanley (2001)	X						X	X	Public	V
Bishop (2002)	X	X		X	X				Expert, public	CS
Bishop and Miller (2005)	X				X		X	X	Public	CS
Devine-Wright (2005)	X						X	X	Public	V
Ek (2006)	X	X	X			X	X	X	Public	V
Eltham et al.	X						X	X	Public	AL
Frantal and Kunc (2010)	X					X	X	X	Public	AL, V
Johansson and Laike (2007)	X						X	X	Public	AL
Kaldellis (2005)	X						X	X	Public	V
Kaldellis (2006)	X	X	X			X			Expert, PE	–
Krohn and Damborg (1999)	X	X						X	PE	–
Ladenburg (2009)	X						X	X	Public	V
Lothian (2008)	X			X	X	X			Public	P
Meyerhoff et al. (2010)	X	X	X			X	X	X	Public	V
Tsoutsos et al. (2009)	X	X	X			X	X	X	Expert	P
Warren et al. (2005)	X							X	Pubic	V
Wolsink (2007)	X	X	X			X		X	PE	–
Zoellner et al. (2008)	X							X	Public	V

verbal descriptions of the evaluated landscapes and impacts. However, in evaluation of landscape preferences, verbal measures do not always correlate with visual assessments [15,16]. While three studies were based on views of the actual landscape, only two of the studies reviewed used photographs, and two used computer simulations.

The validity of assessing visual preferences for landscape qualities using photographic assessment has been well established in other areas of landscape research by Kaplan et al. [17], Ryan [18], and Shuttleworth [19], among others. In addition, many studies e.g. [20–22] have focused on the use of computer-generated images in landscape evaluation. This technique has been found valid where highly realistic images are used. However, increasing levels of abstraction in the images reduce the correlation between the evaluation of these images and the evaluation of landscapes in situ or actual landscape photographs [20].

Previous studies have found that in addition to the general level of acceptance of wind turbines by members of the public, there are many specific factors that affect their visual perception: the characteristics of the structures [23–27], landscape qualities [24–28], and distance factors [29]. While a number of studies have evaluated the characteristics of the structures, including perceived size, the impact of moving or stationary blades, height and overall numbers; these have not all been consistently evaluated in a single study.

Bishop [23] emphasized that the perceived size of the wind turbines is slightly (10–20%) larger in rotating wind turbines than it would be if these structures were stationary. Similarly, Sklenicka [30] pointed out that rotating blades are much more conspicuous than a stationary structure of a similar size. However, a study by Bishop and Miller [29] found that the negative visual effects of turbine blades were less when moving than when stationary, and this difference increased as the turbines became more prominent (due to proximity or higher contrast), a response that was related to people's preference for working, useful structures.

It is generally presumed that the height of turbines is a significant negative factor influencing the perception of these structures. However, Ek [31] and Wolsink [27] found that increasing height had no negative effect on preferences for wind turbines. In a study by Meyerhoff et al. [25], turbine height was found to significantly influence the preferences of only one group of respondents. This group, who were given information on the relationship between turbine height and electricity production, preferred taller turbines. While Krohn and Damborg [32] found no evidence that increasing the size and number of wind turbines has a significant impact on public acceptance of the structures, Möller [3] points out that the phenomenon of "landscape loading" may impose limits on wind power development and suggests that this phenomenon could be expressed as a visibility index calculated for the entire region.

Visual thresholds, i.e., the maximum distances at which wind turbines are still perceived to have a significant impact were examined by Bishop [23]. For a wind turbine with a 50 m tower and a 3-blade rotor with 26 m long blades, Bishop found the distance to be 10 km in "ideal" conditions (clear visibility and stormy sky) and 6 km in prevailing conditions (slightly hazy, sky other than stormy). This distance was therefore much less than the detectable visibility of the turbines (more than 30 km in ideal conditions and 20 km in prevailing conditions). A similar approach to landscape thresholds was used in a methodology developed for assessing the suitability of wind turbine siting from the standpoint of landscape character [33]. This method combined empirically determined visual thresholds and visual barriers to determine the so-called Affected Landscape Area.

Most studies concerned with the visual impact of wind turbines [27,34,35] state that the type of landscape in which they are sited is an important factor in public acceptance of these structures. However, there has been little specific research to verify this statement. In a study undertaken in South Australia, Lothian [36] found that wind farms generally had a negative effect on landscapes of higher scenic quality, but a positive effect on landscapes of lower scenic quality. A survey performed among the members of Wadden Vereniging, an environmental organization, cited by Wolsink [27] recorded ratings of the acceptability of wind turbines in various types of landscape on a 5-point scale. Landscape types with high acceptability for wind turbine siting included industrial and harbour areas, military areas and agricultural landscapes. The most sensitive landscape areas were the sea, nature areas and dunes on islands. Several other studies on the visual impact of wind turbines also incorporated the factor of landscape quality into their questions [24,25,27], but did not focus on this factor specifically.

Unlike other research on landscape perception [37,38], most studies concerned specifically with wind turbines report little influence [11,39] or no influence [5] of the socio-demographic characteristics of the respondents on their preferences for the structures. However, these studies do not consider possible effects of respondent characteristics in interactions with turbine characteristics, landscape factors and/or characteristics of the wind park or farm.

The lack of multi-dimensional research of landscape preferences for wind turbines, based on visual evaluation of these structures, has been addressed by [26]. This study used a photo-based survey focusing on both groups of factors as a complementary method to the expert evaluation of the visual impact of wind farms on Greek islands. However, there is a need to apply this approach in a specific study with larger numbers of respondents and more comprehensive statistical analyses.

In order to fill some of the gaps in understanding of the public's reaction to the visual impacts of wind turbines on the landscape, this study uses a visual preference survey to assess a series of turbine characteristics, landscape characteristics and demographic variables of the respondents. The main goals of the study are: (1) to determine the influence of the visual quality of a landscape on the perception of wind turbines placed in that landscape, (2) to establish whether the perception of wind turbines is significantly determined by the distance between the viewer and the turbine, (3) to study the effect of the numbers of turbines in a group, and (4) to evaluate differences in these perceptions between various groups of respondents.

2. Methodology

2.1. Study design

The study focused on three different landscape types of varying aesthetic value in the central region of the Czech Republic. A printed questionnaire was developed with an attached set of 18 photographs that included landscapes with and without wind turbines. Photographs of three different landscapes of varying aesthetic value were used in the questionnaire (Fig. 1a–c). Landscape type A, in the České Středohoří Protected Landscape Area, is characterized by the distinctive morphology of the terrain, its relatively small scale, a high proportion of natural elements and minimal negative human influences. Landscape type B, around Želiv, Central Bohemia, is an agricultural and forest landscape with an indistinctive morphology, intermediate scale and an average proportion of natural elements. Landscape type C, around Neratovice, Central Bohemia, is an intensively exploited lowland landscape with a low proportion of natural elements; the landscape is negatively dominated by a factory chimney.

The landscapes and the images representing them were chosen by the authors to reflect landscapes of varying aesthetic value (A – above average, B – average and C – below average). This rating was

Fig. 1. Photograph types used in the survey. Figures a–c are unedited photographs of the three landscape types evaluated. Figures d–i, have been computer enhanced to add wind turbines. (a. a landscape in the České Středohoří Mountains with high aesthetic value (Type A); b. a landscape around Želiv with average aesthetic value (Type B); c. a landscape around Neratovice with low aesthetic value (Type C); d. a Type A landscape with one digitally added turbine at a distance of 1.5 km.; e. a Type A landscape with four wind turbines at a distance of 1.5 km; f. a Type A landscape with one turbine at a distance of 4.5 km; g. a Type A landscape with four turbines at a distance of 4.5 km; h. a Type A landscape with one turbine at a distance of 8 km; i. a Type A landscape with four turbines at a distance of 8 km).

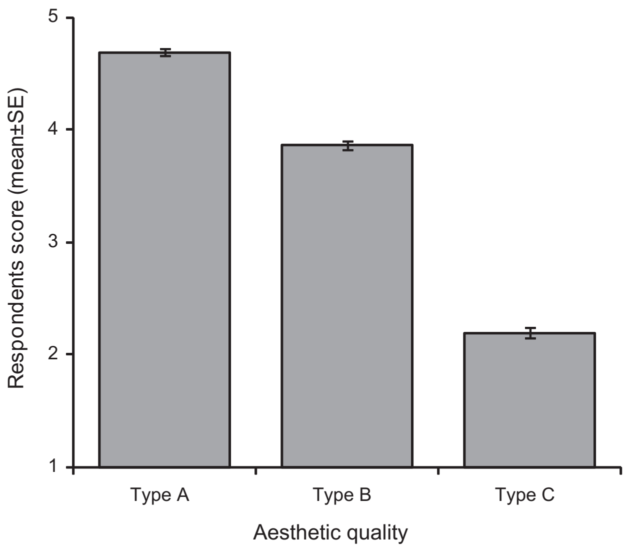

Fig. 2. Verification of the authors' ratings of the aesthetic quality of the landscapes used in the survey. The mean rating of the aesthetic quality of the landscapes by the respondents was consistent with the rating by the authors (*A* = high quality, *B* = average quality, *C* = low quality). The mean differences between each two categories of aesthetic quality (high × medium, high × low, medium × low) were highly significant (Tukey multiple comparisons, all $z > 18.0$, $P < 0.0001$).

Table 2
Evaluated variables.

Landscape characteristics	*Categories and scoring scheme (where applicable)*
Landscape type	High aesthetic value = *A*; average aesthetic value = *B*, low aesthetic value = *C*.
Number of turbines in photograph	One turbine; four turbines
Distance of turbines in photograph from the observer	1.5 km; 4.5 km; 8 km
Characteristics of the respondents	*Categories and scoring scheme*
Gender	Male; female
Age	18–39 years; 40 years and over
Level of education	Elementary; high school; university degree
Attitude to wind power	Rejection = negative; conditional acceptance = tolerant; acceptance with support = positive; no interest in wind power = indifferent
Occurrence of wind turbines in the area where the respondent has a home or a holiday home (referred to in the tables as "occurrence of turbines near home")	No existing or planned turbines in the area = none; turbines planned = planned; existing turbines = existing
Distance of wind turbines from the respondent's home/holiday home	Less than 3 km; 3–6 km; more than 6 km

verified by the respondents, who were asked to evaluate the aesthetic value of the landscapes without wind turbines on a 5-point Likert scale, with scores closer to 5 representing higher aesthetic value (Fig. 2). Photographs of the landscapes were taken using a digital camera with a basic focal length of 50 mm. Using the Adobe Photoshop program, Vestas 90 wind turbines with a hub height of 105 m were added into each landscape, at three different distances from the observer (1.5, 4.5 and 8 km), as a single turbine and as a group of four turbines 300 m apart from each other (Fig. 1d–i). The resulting 18 pairs of photographs of landscapes with and without wind turbines were printed in colour, at a size of 280 × 190 mm. To keep response times under 10 min, each respondent was asked to evaluate 9 randomly assigned pairs of photographs, again using the 5-point Likert scale with the points verbally represented as: 5 – significant improvement, 4 – slight improvement, 3 – no significant change, 2 – slight deterioration, 1 – significant deterioration.

The questionnaire also recorded basic characteristics of the respondents – their gender, age, education, attitude to wind power (rejection, conditional acceptance, acceptance with support, or no interest), whether the respondent lived or had a second home in a place with wind turbines and, if yes, how far from a turbine they lived (0–3, 3–6 or above 6 km). All studied landscape and respondent characteristics are listed in Table 2.

The survey was undertaken in 2007–2009, in areas with existing or planned wind turbines and also in areas currently unaffected by these structures. Study respondents were composed of two groups: a quasi-expert group of students of landscape studies at the Czech University of Life Sciences in Prague and at the Czech Technical University in Prague, and randomly identified individuals throughout Northern and Central Bohemia. Non-student respondents were selected using the roaming method [40], driving and walking through areas affected by wind turbines and asking people to fill in a questionnaire. There were a total of 337 respondents with a close gender split: 165 men and 172 women. The majority of the respondents (297) were below 40 years of age. Approximately two thirds (218) of the respondents were university graduates, with the remaining third completing only high school education. One respondent completed only elementary education, this category was therefore omitted from the analyses.

Of the total respondents, 7.7% (26) expressed a negative attitude to wind power in general, 51% (172) expressed a tolerant attitude, 35% (118) expressed a positive attitude, and 6.2% (21) an indifferent attitude. 12.4% (42) respondents lived in an area where wind turbines were planned, 23.7% (80) respondents lived in areas with existing wind turbines, and 63.8% (215) lived in areas unaffected by wind turbines.

The results of previous studies point to differences in the landscape preferences of residents of areas affected by the evaluated phenomenon and residents of other areas [41] as well as variations in the perception of landscape changes according to whether the respondent's professional or study focus is connected to landscape [42,43]. On the basis of this knowledge and the fact that our sample of respondents was not balanced, we divided our respondents *a priori* into four groups: two quasi-expert groups composed of students either living in close proximity to wind turbines or living in areas without wind turbines; and two non-expert groups, either living in areas with or without wind turbines. The four groups were analysed in separate models.

2.2. Data processing

Prior to the analyses, the respondents' responses were log-transformed to achieve normally distributed data. First, we compared the average ratings awarded by the four groups of respondents, using analysis of variance (one-way ANOVA). We also verified the agreement between the scores awarded by the authors and by the respondents for the aesthetic qualities of the proposed photographs, which represented three categories of landscapes; multiple comparisons among the three groups were performed using the Tukey test. Mixed-effect models with chi-square testing were applied to assess the statistical significance of particular variables, including the landscape characteristics and attributes of the wind farm (objectified aesthetic value of the landscape, number of turbines and distance of turbines in the photograph) and respondent characteristics (gender, age, education, attitude to wind power, and distance of the respondent's home from the nearest wind turbines) (Table 2) in explaining variations in respondent responses. In addition to the fixed effects, we also treated the effects of first-order interactions between characteristics of the landscape and wind farm on the one hand and respondent characteristics on the other. As individual respondents might cause pseudoreplications of respondent characteristics, we assigned a respondent individuality random factor in the models. In a manual stepwise backward selection procedure we eliminated all non-significant ($p > 0.05$) terms from the fully saturated models; minimum adequate models were constructed following the model simplification procedure according to Crawley [44]. All statistical procedures were performed using R version 2.12.0.

3. Results

Across all of the landscape types and variations on the number and location of turbines, the addition of wind turbines into a landscape was, on an average, perceived as a slight deterioration of the aesthetic value of the landscape (mean = 2.45). In 22% of the evaluated pairs of photographs, the addition of a wind turbine was perceived as a ''significant deterioration'', whereas it was perceived as a ''significant improvement'' in fewer than 3% of responses. The average rating awarded by the four groups of respondents was not significantly different (ANOVA: $F_{3,3027} = 1.074$, $p = 0.368$). The respondents' visual preferences were significantly influenced by the visual quality of the landscape in which the turbines were located, the number of turbines in the photograph and the distance of the turbines in the photograph. The characteristic of the respondents that most significantly influenced their visual preferences in this study was their attitude to wind power (Table 3). In addition to these factors, the visual preferences of each group of respondents were influenced by the interactions among factors listed in Table 4.

3.1. Attributes of landscapes and wind turbines

3.1.1. Landscape type according to the initial visual quality of the landscape

All studied groups of respondents expressed significantly higher preferences ($p < 0.00001$, Table 3) for wind turbines in landscape scenes of low visual quality (mean = 2.90) than for those in average landscapes (mean = 2.36) or in visually attractive landscapes (mean = 2.10) (Fig. 3). In the most attractive landscapes, only 1% of respondents perceived the addition of wind turbines as a significant improvement, whereas 35% perceived it as a significant deterioration. In the least attractive landscapes, 8% of respondents evaluated wind turbines as a significant improvement, 5% as a significant deterioration. In this type of landscape, the addition of wind turbines was evaluated as a nearly non-significant change by both groups of non-expert respondents: those living in close proximity to wind turbines (mean = 2.97) and those not living close to wind turbines (mean = 2.99).

The difference in the perception of wind turbines along the gradient of landscape attractiveness was more pronounced in respondents who do not live in landscapes with wind turbines (Table 3). In the quasi-expert group, respondents who live closer to wind turbines are less sensitive to the visual quality of landscapes in which wind turbines are placed. For respondents living up to three kilometres from a wind turbine, the difference in the evaluation of wind turbines in the most attractive and least attractive landscapes was 0.14, while for respondents living 6 km or more from wind turbines this difference was 0.82 (Table 4). Among the quasi-experts who do not live close to wind turbines, landscape attractiveness is significant in interaction with attitude toward wind power, with gender and with level of education. Supporters of wind power see the placement of wind turbines in the least attractive landscapes as slightly positive (mean = 3.26). Men are more sensitive than women toward the quality of landscapes where wind turbines are placed. They award lower scores than women to wind turbines in visually attractive landscapes, and higher scores to wind turbines in unattractive landscapes. Respondents with a university degree are more critical toward wind turbines in attractive and average landscapes than respondents with a lower level education. In unattractive landscapes, there are no differences between the preferences of these two groups.

3.1.2. Numbers of turbines in the photograph

All groups of respondents except non-experts living close to wind turbines significantly preferred photographs containing one wind turbine (mean = 2.62) to those containing four turbines (mean = 2.28). Landscapes with a single turbine received 2% of the highest scores and 14% of the lowest scores. Landscapes with four turbines received 3% of the highest scores, but as many as 30% of the lowest scores. The difference between the perception of landscapes with one turbine or with four turbines was more

Table 3
Variables that significantly influenced the visual preferences of the respondents (p < 0.05).

Variables	Mean perceived influence of wind turbines on landscape scenes						
Landscape type	$\chi 2$	*df*	*P*	A	B	C	
Quasi-expert – resident	61.78	1.8	<0.00001	2.14	2.34	2.84	
Quasi-expert – nonresident	202.24	1.0	<0.00001	2.10	2.34	2.88	
Non-expert– resident	26.45	1.7	<0.00001	2.21	2.53	2.97	
Non-expert – nonresident	60.43	1.7	<0.00001	2.00	2.30	2.99	
Number of turbines in photograph	$\chi 2$	df	P	One	Four		
Quasi-expert – resident	10.22	1.8	0.00139	2.61	2.26		
Quasi-expert – nonresident	18.36	1.0	<0.00002	2.62	2.25		
Non-expert – nonresident	10.65	1.7	0.0011	2.54	2.31		
Distance of turbines in photograph	$\chi 2$	df	P	1.5 km	4.5 km	8 km	
Quasi-expert – resident	31.94	1.8	<0.00001	2.11	2.50	2.71	
Quasi-expert – nonresident	89.48	1.0	<0.00001	2.9	2.54	2.69	
Non-expert – resident	4.26	1.7	0.0389	2.31	2.73	2.67	
Non-expert – nonresident	8.52	1.7	0.0035	2.20	2.47	2.61	
Attitude to wind power	$\chi 2$	df	P	Negative	Tolerant	Positive	Indifferent
Quasi-expert – resident	43.63	3.6	<0.00001	1.71	2.30	2.95	2.11
Quasi-expert – nonresident	30.11	3.0	<0.00001	1.74	2.32	2.78	2.43
Non-expert – resident	114.72	3.5	0.0021	1.26	2.57	2.96	2.30
Non-expert – nonresident	11.61	2.6	0.003	1.78	2.19	2.81	X[a]

[a] This category could not be evaluated due to lack of data.

Table 4
Interactions among the variables that significantly influenced the visual preferences of the respondents ($p < 0.05$).

Interactions among variables	Mean perceived influence of wind turbines on landscape scenes		
	$\chi 2$	*df*	*P*
Distance of turbines from home × landscape type	A	B	C
Quasi-expert – resident	6.66	1.16	0.0099
Less than 3 km	2.67	2.81	2.81
3–6 km	2.26	2.38	2.79
More than 6 km	2.3	2.25	2.85
Attitude to wind power × landscape type	A	B	C
Quasi-expert – nonresident	19.94	3.00	0.00017
Negative	1.45	1.55	2.23
Tolerant	2.1	2.20	2.76
Positive	2.37	2.72	3.26
Indifferent	2.18	2.46	2.63
Gender × Landscape type	A	B	C
Quasi-expert – nonresident	14.82	1.00	0.000118
Male	2.3	2.31	2.96
Female	2.16	2.38	2.80
Level of education × Landscape type	A	B	C
Quasi-expert – nonresident	4.53	1.00	0.033
Elementary	X[a]	X	X
High school	2.18	2.44	2.87
University degree	2.6	2.30	2.89
Age × Number of turbines in photograph	One	Four	
Quasi-expert – resident	6.80	1.16	0.0091
18–39 years	2.61	2.32	
40 years and over	2.65	1.81	
Occurrence of turbines near home × Number of turbines in photograph	One	Four	
Non-expert – resident	9.51	1.18	0.0021
None	X	X	
Planned	2.85	2.90	
Existing	2.57	2.33	
Attitude to wind power × Number of turbines in photograph	One	Four	
Non-expert – resident	8.19	3.16	0.0423
Negative	1.36	1.15	
Tolerant	2.60	2.54	
Positive	3.20	2.75	
Indifferent	2.80	2.47	
Level of education × Number of turbines in photograph	One	Four	
Non-expert – resident	4.51	1.18	0.0337
Primary	2.80	3.00	
Secondary	2.70	2.49	
University	2.29	2.37	
Age × Distance of turbines from home	Under 3 km	3–6 km	Above 6 km
Quasi-expert – resident	4.15	1.16	0.0417
18–39 years	2.77	2.56	2.39
40 years and more	X	2.22	2.27
Non-expert – resident	8.19	3.16	0.0423
Negative	1.36	1.15	
Tolerant	2.60	2.54	
Positive	3.20	2.75	
Indifferent	2.80	2.47	
Level of education × Number of turbines in photograph	One	Four	
Non-expert – resident	4.51	1.18	0.0337
Primary	2.80	3.00	
Secondary	2.70	2.49	
University	2.29	2.37	
Age × Distance of turbines from home	Under 3 km	3–6 km	Above 6 km
Quasi-expert – resident	4.15	1.16	0.0417
18–39 years	2.77	2.56	2.39
40 years and more	X	2.22	2.27

[a] Categories marked X could not be evaluated due to lack of data.

marked in the quasi-expert group than in other respondents (Fig. 4, Table 3).

The number of turbines in the photograph also proved to be significant in interaction with respondent characteristics (Table 4). In the quasi-experts living close to wind turbines, respondents below the age of 40 and over 40 expressed similar preferences for photographs containing one turbine, but older respondents expressed significantly less preference than younger respondents for photographs with four turbines.

In the non-experts living close to wind turbines, the number of turbines in the photograph was significant in interaction with the factor "turbines near home", which describes whether turbines are planned or are in existence near the respondent's home/vacation home, in interaction with attitude towards wind power, and

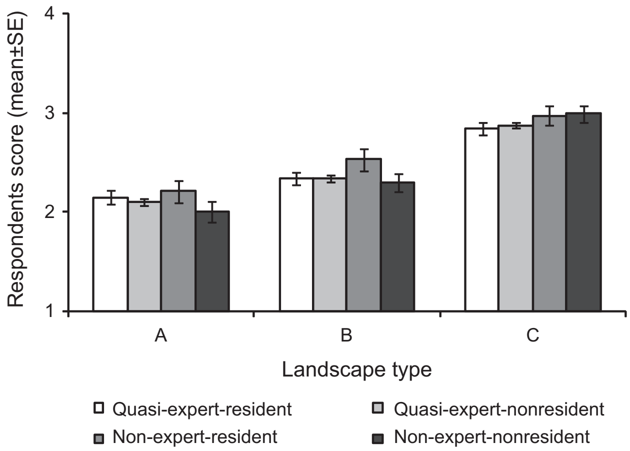

Fig. 3. Effect of landscape visual quality on respondents' assessment of the visual impact of wind turbines.

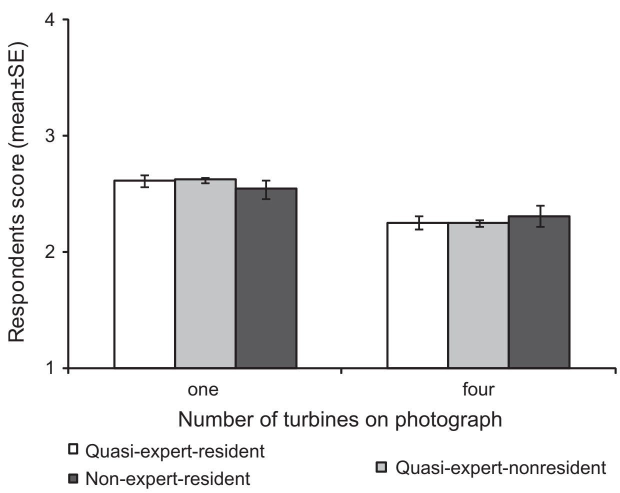

Fig. 4. Effect of number of turbines in the photograph on respondents' assessment of the visual impact of wind turbines.

in interaction with the level of education. Respondents living in areas where wind turbines are planned considered these structures as a very slight deterioration to the landscape, and preferred four turbines to one turbine, whereas respondents living in landscapes already containing wind turbines express significantly less preference for these structures, and consider that four turbines cause greater damage to the visual landscape than one turbine (Table 4).

Respondents with a negative approach to wind power considered that four turbines cause significant deterioration in the visual quality of the landscape (mean = 1.15), while they considered one turbine to be slightly less damaging (mean = 1.36). Respondents with a positive approach to wind power rated one turbine as an improvement (mean = 3.20), but four turbines as a deterioration (mean = 2.75). The only group that rated four turbines as less damaging than one turbine were respondents whose approach to wind power is indifferent (see Table 4).

3.1.3. Distance of turbines in the photograph

All groups of respondents rated photographs with wind turbines at a distance of 1.5 km significantly lower (mean = 2.12) than photographs showing turbines at a distance of 4.5 km (mean = 2.55) and 8 km (mean = 2.68). The closest wind turbines and the most distant wind turbines were both considered "a significant improvement" by 3% of respondents. However, the most distant turbines

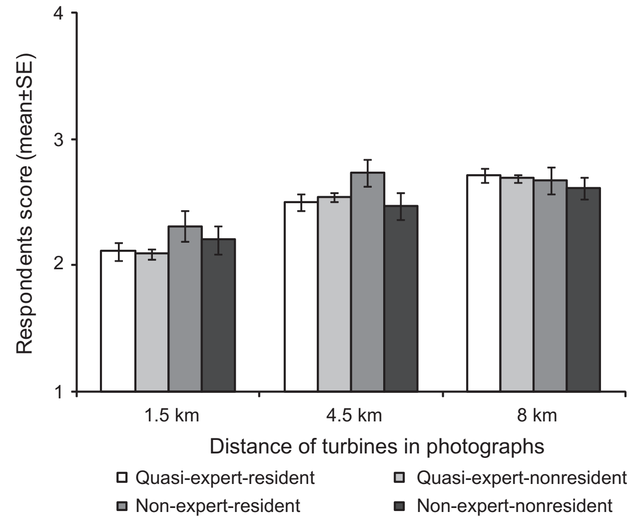

Fig. 5. Effect of the distance of turbines in the photograph on respondents' assessment of the visual impact of wind turbines.

were rated as a "significant deterioration" by 12% of respondents, and the closest turbines were given the lowest rating by 38% of respondents. As with the number of turbines in the picture, the difference between the perception of the closest turbines and the most distant turbines was more marked in the student groups than in the other groups of respondents (Fig. 5, Table 3).

3.2. Characteristics of respondents

Apart from attitude toward wind power, the only other respondent characteristics that proved to be significant were in interaction with landscape attributes and wind turbines.

3.2.1. Attitude toward wind power

Respondents of all groups with a negative opinion of wind power considered landscapes with wind turbines significantly less attractive (mean = 1.69) than respondents who accept wind power conditionally (mean = 2.33), those who support wind power (mean = 2.8), and respondents indifferent to the issue (mean = 2.4) (Fig. 6, Table 3). None of the respondents sceptical toward wind power evaluated wind turbines as a significant improvement to the landscape, while 53% of them rated turbines as a significant deterioration of the

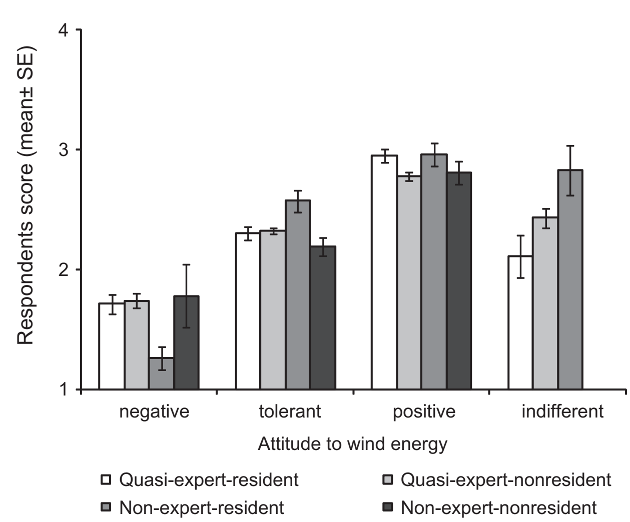

Fig. 6. Effect of respondents' attitude to wind power on their assessment of the visual impact of wind turbines.

landscape. On the other hand, 5% of supporters of wind power gave wind turbines the highest rating and 12% gave wind turbines the lowest rating. The difference in ratings according to attitude toward wind power was more pronounced in residents of landscapes with wind turbines, both in the negative evaluation by the sceptics (mean = 1.71 for quasi-experts, 1.26 for others) and in the almost neutral evaluation by supporters (mean = 2.95 for quasi-experts, 2.96 for others).

4. Discussion

Overall, the results of this study show that landscapes containing wind turbines are perceived as less attractive than the same landscapes without these structures. Thayer [35] notes that wind power is an issue that tends to arouse either extremely positive or extremely negative responses. In our study, while extremely negative responses were relatively frequent, extremely positive responses occurred only occasionally. Though this trend was almost universal throughout the study, the level to which wind turbines were perceived to detract from the landscape scene varied according to a number of landscape and respondent characteristics.

Unlike other studies [15,41,43], which point to differences in the landscape preferences of respondents according to their place of residence and professional focus, the results of our study indicate that the perception of the aesthetic impact of wind turbines may be more universal. The average evaluation by the groups of respondents in our study was not significantly different, and the preferences of these groups showed influences by the same landscape factors. While we anticipated a difference in responses between students in environmental-related fields, and therefore a learned awareness of visual quality, these differences were much smaller than expected. This suggests a high degree of awareness of visual quality already in the general public.

However, these groups varied in some of the combined factors behind their landscape preferences.

4.1. Attributes of landscapes and wind turbines

The initial visual quality of a landscape proved to be a very strong factor determining the preferences for wind turbines in the landscape. Wind turbines placed in the least attractive landscapes were still perceived as a negative phenomenon, but they received the highest ratings throughout. Non-experts, especially, considered them to create almost no significant change in the landscape. Very few respondents perceived the wind turbines as a significant deterioration. On the other hand, scenes with wind turbines placed in the most attractive landscapes received significantly lower scores than the same scenes without turbines, and the turbines were considered a significant deterioration by more than one third of the respondents.

Our results support the opinion of most authors e.g. [34,35] that the type of landscape in which wind turbines are sited is an important factor in public acceptance of these structures. Both the highest average ratings and the lowest average ratings recorded in our study are less distinct than those cited by Wolsink [27], which is probably because the study presented by Wolsink used a wider range of landscapes from the standpoint of aesthetic quality, and because its respondents were members of an environmental organization. Another important factor could be the character of the landscape from the standpoint of the level of anthropization, or the continuity of historical development [45,46]. Further research should determine the differences in the impact of wind turbines in natural and human changed landscapes, where both types of landscape are of high aesthetic value.

The number of turbines in the photograph also proved to have a significant influence on the preferences of the respondents. In marginal areas of wind power production, e.g. in large parts of the Czech Republic, single wind turbines or very small wind farms are often built, rather than developments covering large areas. In these circumstances, all groups of respondents except non-experts living close to wind turbines significantly preferred scenes containing one turbine to scenes containing four turbines. This is consistent with the findings of some studies dealing with this phenomenon on a larger scale [47], while other authors are more sceptical toward the effect of the number of turbines on public acceptance of turbines [32].

In our study, the respondents chose between two scenarios: there was either one turbine or four turbines in the same scene. The results would perhaps have been different if the respondents had evaluated four turbines in the same scene versus four single turbines in four different scenes. In this respect, Sklenicka [48] mentions the cumulative effect of negative dominant features, when both landscape experts and the general public often prefer the more intensive negative impact of multiple structures concentrated in a smaller area to the extensive impact of single structures spread over a larger area.

Similarly to the results of Bishop [23], the preferences of all groups of respondents for wind turbines increased significantly with increasing distance of these structures in the photograph. When interpreting the results of this study, it is important to note that the respondents were given static photographs to evaluate, whereas wind turbines in a landscape have a dynamic character. This character accentuates the visual dominancy of wind turbines, and can lead to a more critical evaluation in some respondents [30], whereas others appreciate the fact that these are working structures and evaluate them more positively [29]. However, we have presumed that most respondents are capable of evoking the dynamic character of wind turbines while evaluating the aesthetic impact of these structures.

4.2. Respondent characteristics

The results of our study support the findings of Devine-Wright [11] and Ladenburg [39], and find socio-demographic characteristics to be significant only in interaction with landscape factors. Similarly to Johansson and Laike [5], the only characteristic of the respondents that significantly influenced their preferences for wind turbines in our study was their attitude towards wind power. This factor proved to influence respondents' evaluations quite strongly. The average preference for wind turbines expressed by respondents who reject wind power was the lowest value determined by a single factor throughout the study, whereas the preferences expressed by supporters of wind power were only surpassed by preferences for wind turbines in landscapes with the lowest visual quality. However, even this relatively high score was slightly negative, and more supporters of wind power found wind turbines to be a significant deterioration to the landscape scene than found it a significant improvement.

Although this factor proved to be significant in all groups in our study, the difference in evaluation due to attitude toward wind power was more pronounced in residents of landscapes with wind turbines (both quasi-experts and others). This suggests that attitude to wind power is more relevant to the landscape preferences of people who live close to these structures. However, future research should verify an alternative hypothesis: that in respondents living close to wind turbines, the immediate positive or negative aesthetic impact of wind turbines may influence their overall approach to wind power.

4.3. Interactions between respondent characteristics and landscape factors

The most distinct and sometimes unexpected reactions to wind turbines, both positive and negative, occurred under some combinations of landscape factors and respondent characteristics.

In the quasi-expert group who live close to wind turbines, the preferences for wind turbines were significantly influenced by the combination of age and number of turbines in the photograph, and by the combination of landscape type and distance of turbines from home. The preferences of younger respondents (under 40) for a single turbine were similar to their preferences for four turbines. Older people even showed slightly more preference for a single turbine than younger respondents did, but they showed far less preference for four turbines. This may be connected with the fact that traditional man-made landmarks (castles, church towers, etc.) were of a point type, whereas the younger generation has grown up in landscapes where landmarks are multiple features and cover larger areas (e.g. groups of high-rise buildings) and young people are more accustomed to this phenomenon. Respondents who live further from wind turbines were significantly more critical toward the placement of these structures in aesthetically valuable landscapes. This suggests that people who are accustomed to wind turbines have lower sensitivity toward their aesthetic impact.

The preferences of quasi-experts who did not live close to wind turbines were influenced by landscape type in combination with attitude to wind power, gender and education. Respondents with a positive attitude to wind power saw the addition of wind turbines to the landscape with lowest visual quality as an improvement to the landscape scene, though only a very slight improvement. Respondents indifferent to wind power were not as sensitive to the placement of these structures in high visual quality landscapes as were the other groups, perhaps due to their general lack of interest in this issue. Males were more sensitive to the placement of wind turbines in high quality landscapes than females. This is consistent with their generally more critical approach to landscape visual qualities [49,50], which can be explained by evolutionary differences in landscape perception between the genders [49]. People with a university education tended to be more critical toward the placement of wind turbines in the highest quality landscapes and in average landscapes.

The non-experts who live in close proximity to wind turbines was the only group in the study where the number of turbines in the photograph was not significant as a single factor, but it was significant in combination with attitude to wind power, occurrence of wind turbines in the area where the respondent has a home or a holiday home, and education. Respondents in favour of wind power regarded the placement of a single turbine as a positive impact, but, unexpectedly, they regarded four turbines as a negative impact. A possible explanation is that the respondents' positive attitude to wind power could be partly motivated by environmental concerns, and that people sensitive to environmental issues are also sensitive to excessive loading of the landscape (sensu [3]) with technical structures. Respondents indifferent to wind power were the only group which preferred four turbines to one. Respondents from areas where wind turbines were planned expressed a slight preference for four turbines rather than a single turbine, and saw wind turbines as causing almost no significant change to landscape quality. However, respondents from areas with existing wind turbines evaluated these structures more negatively and strongly preferred a single turbine rather than four. This suggests a negative role of the respondents' experience with wind turbines, which exceeds their (already negative) expectations. Bishop and Miller [29] found similar trends, whereas Eltham et al. [52] found that the acceptance of wind turbines and their perceived visual attractivity was significantly higher 14 years after their construction than prior to construction. These differences may be caused by other underlying e.g. economic motives (contributions to the budgets of municipalities and other benefits and compensation for the public). People with different levels of education varied more in their rating four turbines than in their rating of a single turbine.

5. Conclusions and planning implications

In this work we have analysed an evaluation by the public of the effects of wind turbines on the aesthetic quality of landscapes and the influence of several landscape and respondent characteristics on this evaluation. To minimize the distortion which can be caused by verbal representations of visual elements, we incorporated the landscape characteristics and the assessed structures directly into the photographs that were evaluated. The addition of wind turbines was almost universally perceived as a negative impact on the landscape scene. However, the level to which wind turbines were perceived to deteriorate the aesthetic and visual quality of the landscape depended on several factors. Unexpectedly, the respondents' preferences were influenced almost exclusively by landscape attributes and by the siting of the turbines. The influence of respondent characteristics was limited, and was in most cases significant only in interaction with landscape factors.

The results of our study show that in order to achieve public support, placement of wind turbines must above all respect the qualities of the landscape. Wind turbines in landscapes with high aesthetic quality provoked some of the strongest negative reactions from the respondents in this study, whereas turbines placed in the least attractive landscapes did not increase negative responses to those landscapes. This trend became even more marked in interaction with some respondent characteristics – people living close to wind turbines, males, and individuals with higher education tended to be more critical of the placement of wind turbines in landscapes with higher visual quality while people with a positive attitude toward wind power even saw the addition of wind turbines to the landscapes of the lower visual quality as a very slight improvement. The results also show that wind turbines achieve higher acceptance if they are limited in number, and if they are remote from observation points, e.g. settlements, viewpoints and the transportation network. The importance of avoiding valued landscapes and areas close to observation points to minimize adverse reactions to wind turbines has also been confirmed by Bishop [53].

The most important characteristic of respondents that determined their preferences for wind turbines was their attitude toward wind power, both as a single factor and in interaction with landscape factors. Though the relationship may to some extent be circular, this finding provides a further argument for considerate planning of renewable energy schemes and for the use of public participation, factors known to improve public attitudes toward wind power (e.g. [27,51]). Finally, it should be noted that where the supporters of wind power saw a single turbine as an improvement to the landscape scene, four turbines were perceived as a deterioration. It is therefore possible that even supporters of wind power can find wind turbines unattractive when their numbers cross certain thresholds.

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