



Assessing acceptability of two onshore wind power development schemes: A test of viewshed effects and the cumulative effects of wind turbines



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ABSTRACT

Presently, onshore wind turbine densities are increasing in many countries. The “crowding” of wind turbines in especially the urban fringe and in more densely populated rural areas is expected to meet resistance. However, few studies have to date analysed the cumulative effects of wind power on the social acceptance of wind power. We shed light on this issue and find that the attitude towards increasing the onshore wind power capacity in Denmark is significantly influenced by the number of turbines people see on a daily basis. However, we find that this effect is conditional on having a wind turbine in the viewshed from the permanent or summer residence. Accordingly, if people cannot see an onshore wind turbine from their permanent or summer residence we do not find significant evidence of cumulative effects on attitude. Furthermore, if we hypothesise that an increase in the wind power capacity is implemented by replacing smaller wind turbines with larger ones, we find that the cumulative effects are reduced also among respondents having onshore wind turbines in the viewshed. This suggests that alternative strategies for increasing the onshore wind power capacity can have significant impact on social acceptance.

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1. Introduction

Worldwide, countries are striving to reach higher levels of renewable energy. Focussing on Denmark, Lund & Mathiesen [1] suggest that obtaining a 100% target in 2050, wind power capacity should be increased to 10,000 MW, from a capacity of approximately 3952 MW in 2011 [2]. The vast majority of the wind power development is expected to take place offshore [3], but new onshore turbines are also expected [4]. The strong emphasis on wind power development in the Danish renewable energy strategy is in line with a long tradition of having a relatively large wind power capacity, which is generally supported by the public [5–9]. However, the acceptance might be challenged by new onshore wind power development, which is expected to use relatively large wind turbines. Compared to the existing (and smaller) wind turbines, the new and larger turbines will most likely cause higher levels of visual and noise related impacts [10]. The success of

increasing the onshore wind power capacity may therefore be conditional on the continuous acceptance of wind power in Denmark. Or as put forward in Ref. [5].

“The sensitivity of those sites with regard to visual and noise impacts by the turbines as well as natural and cultural concerns requires careful evaluation. Finding appropriate sites for wind turbine development, therefore appears to be one of the main challenges with regard to developing the renewable energy system in Denmark.”

We know from the literature that many factors influence acceptance, such as respondents’ demographics [11], Not-In-My-Back-Yard motives [12], degree of public involvement and engagement [13], trust and fairness perceptions [14,15], place-related identity [16], co-ownership [6,17], experience with turbines [18] and location [7]. However, with reference to the paper by Raven et al. [19], which presents a general approach to handle societal acceptance of new energy projects including wind energy, little is known regarding how attitudes are related to the onshore wind turbine landscape people live in, i.e. the past context [19] in a spatial dimension. One example is whether people who live in a crowded wind turbine landscape are equally positive/negative towards wind

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turbines as people who rarely see a wind turbine. Or stated differently, are attitudes spatially correlated with the location of wind turbines? Analysing the spatial dimensions of attitudes/acceptance is particularly motivated by the significant spatial technical and economic characteristics of energy development [20–23], wind power development [24–27] and demand for energy [11–13].

Most attitude studies address the spatial dependence by estimating the relationship between attitude and the distance to the nearest wind turbine. In the attitude/acceptance literature, Warren et al. [28] find that attitudes towards wind turbines become more negative the further people live from two onshore wind farms. In contrast [29,30] find the opposite effects—acceptance of wind power increases with distance to the nearest wind turbine. Interestingly, Ladenburg & Möller [18] find the most negative attitude for people living both close and far from offshore wind farms, and the most positive at intermediate distances. The findings reported in the literature are unfortunately varied, and thus gives little guidance in how to handle the spatial properties of wind power acceptance [6,11–26]. However, the study by Ladenburg & Dahlgaard [31] points out that it might not be the distance to the nearest turbine alone that drives the attitude. The effect on attitude may also be a function of the location of other turbines and how these turbines are distributed relative to the daily travelling patterns of people, i.e. the cumulative number of turbines experienced. Their study confirms this hypothesis by showing that the more wind turbines people see, the higher is the propensity to have a negative attitude towards existing wind turbines.

Referring to Ref. [5], this suggests that the cumulative effects from wind turbines should be included in the identification sites appropriate for wind power development. The present paper aims at complementing [31] by extending the analysis to include *ex ante* attitudes towards new wind power development and test the cumulative effects from existing onshore turbines. We analyse the cumulative effects of existing wind turbines on attitudes towards two different hypothetical wind power development schemes. The first scheme addresses an increase in the number of wind turbines, whereas the second scheme addresses a replacement of smaller turbines with larger ones.

The paper is structured as follows. First we give a brief review on the existing literature. We then describe the survey design and the analytical framework for the analysis. This is followed by the results. Finally, we discuss the results and draw conclusions from the study.

2. Review

The attitude and perception literature related to wind power has many different dimensions, which have been analysed thoroughly in the literature. Examples are papers that analyse perception in general [6,32–34] but also papers that assess the acceptability of different wind power development sites, such as onshore and offshore [7,35–38] and specific wind projects [39,40], prior, during and after the wind farm has been developed and started operating [15,41]. Some studies focus on the influence of implementation processes on attitudes in specific wind turbine development projects [42–44] and among that the effect of co-ownership [17]. Other studies examine the potential impact from wind turbines on tourism [45–50], the perception of the visual impacts from wind turbines [51–53] and the perceived maximum wind power capacity in an area [54]. Finally, in relation to the cumulative effects from wind turbines, several studies analyse how experience and familiarity with wind turbines influence and shape attitudes, see Ref. [18] for a detailed review. However, in relation to wind power planning, one important area has been given very little attention in the literature, namely the cumulative effects of wind power on the acceptance of wind power. More specifically, except from a handful of papers [6,18,31,35,55], no other studies have analysed how the number of turbines in the landscape influences the attitude towards an increase in the onshore wind power capacity.

An overview of the few published studies analysing cumulative effects of wind turbines seen daily or located in close proximity to the respondents is summarised in Table 1. The table also includes studies that analyse the effect on attitude from the distance to wind turbines. The table is inspired by Refs. [18,31].

2.1. Distance and attitude

Based on the results from a Danish report by Andersen et al. [56], Ladenburg & Dahlgaard [31] find evidence of that acceptance declines with increasing distance to the nearest wind turbines. In contrast, Krohn & Damborg [6] take their point of departure in some of the other questions in the same data but do not find any significant relations between distance to the nearest wind turbine and the *ex ante* attitude towards wind power in general.

Warren et al. [28] conducted two surveys on attitude towards existing and planned onshore turbines in two locations in Scotland and Ireland. In the Irish part of the survey, the *ex post* attitudes

Table 1
Review of studies.

Study	Distance to/number of turbines of existing or proposed wind turbines	Type of attitude	Effect of turbines	No. of respondents in the survey
<i>Distance to wind turbine</i>				
Andersen et al. [56]	Existing on-land	Proposed on-land turbine at neighbour	Distance reduces acceptance	690
Krohn and Damborg [6]	Existing on-land	Wind power in general	No effect of distance	690
Warren et al. [28]	Existing on-land	The existing on-land wind farms	Distance reduces acceptance	240
Johansson and Laike [57]	Existing on-land	Opposition towards the existing on-land turbines	No effect of distance	1150
AMR-interactive [29]	Existing on-land	Proposed on-land wind farm	Distance increases acceptance	683
Ladenburg and Möller [18]	Existing offshore	Existing offshore wind turbines	Mixed effects	1082
Swofford & Slattery [30]	Existing on-land	Wind energy in general	Distance increases acceptance	382
<i>Number of turbine/frequency in turbine encounters</i>				
Thayer and Freeman [55]	Existing on-land	Multiple attitude questions	Multiple results, see text	212
Krohn and Damborg [6]	Existing on-land	Wind power in general	Mixed effects of number of turbines	690
Ladenburg [35]	Existing on-land	Existing offshore wind turbines	No effect of number of turbines ^a	1082
Ladenburg and Dahlgaard [31]	Existing onshore	Existing on-land turbines	Negative effects of number of turbines	1086
Ladenburg and Möller [18]	Existing offshore and on-land	Existing offshore wind turbines	Positive effects of the number of turbines offshore	1082
Warren and McFadyen [17]	Existing on-land	Existing and new on-land	No specific test, see text	136

^a Specific subgroup, see text.

towards two existing wind farms in both Cork and Kerry were found to become more negative, the further away the respondents lived from the wind farms. The results are thus in line with Ref. [56]. Interestingly, the intention to oppose local turbines was not found to be significantly influenced by the distance to the local turbines in a Swedish study [57]. Based on the results from an Australian study [29] and in opposition to Warren et al. [28], Ladenburg & Dahlgaard [31] find evidence of that acceptance appears to be higher among a group of respondents who live far from existing or planned wind farms based on the results from an Australian study [29]. In the support of these results, Swofford & Slattery [30] find that acceptance of wind power in general declines with proximity to an existing wind farm consisting of 80 1.5 MW turbines. Framing the question as an attitude towards a hypothetical wind farm at different locations (on the respondents' property, within sight of the property, within the community, within Texas and within the US) gives similar results. However, the proximity effect only seems to be present with regard to the first three categories. When asked about a location in Texas and the US the effect of living close to the 80-turbine large wind farm no longer seems to be present.

The above-mentioned studies all analyse distance relation using onshore wind turbines as the case. As the apparently only study, Ladenburg & Möller [18] test the relation between the distance to existing offshore wind farms and the attitude towards the offshore wind farms. The results are mixed in the sense that people, who live within 30 min of travelling time to the nearest offshore wind farm are found to be significantly more negative towards the offshore wind farms. However, the results also suggest that the further away respondents live from one of the six offshore wind farms, the more negative they are towards existing offshore wind farms, though at a decreasing rate.

2.2. Number of turbines/frequency of turbine encounters and attitude

Thayer & Freeman [55] test how the number of turbines encountered influences the attitude towards wind turbines. In their setup, respondents seeing a wind turbine at least once a week are defined as being familiar with wind turbines. Respondents who only see turbines once every couple of weeks or less were categorised as unfamiliar. In general, familiar respondents tend to state more negative attitudes, such as seeing wind turbines as “a tax shelter”, “inefficient use of the land” and “less attractive”. The unfamiliar, on the other hand, perceived wind turbines to be more “efficient” “organised”, “new and interesting” and generally stated a more positive attitude.

Krohn & Damborg [6] analyse the effect from the number of turbines in the area on the *ex ante* attitude towards wind power in general. The paper does not report any significant results, though it is put forward that respondents who can see between 20 and 29 turbines from their home and who are living within 500 m from the nearest wind turbine tend to be more positive towards wind power in general. In the paper, which analyses the heterogeneity in attitude formation processes towards offshore wind farms, Ladenburg [35] tests whether the number of onshore turbines in the local area influences the attitude towards existing offshore wind farms. At an average level he finds no significant effects of the number of turbines. However, among respondents visiting the beach on a frequent basis, he finds that people who see more than 20 turbines daily are more negative towards existing offshore wind farms. In another offshore wind power study, Ladenburg & Möller [18] find that the number of wind turbines in the nearest offshore wind farms significantly influences the attitudes. The higher is the number of turbines the nearest wind farm has, the higher the acceptance of existing offshore wind farms. Interestingly, these results are in contrast to Ladenburg & Dahlgaard [31], who estimate

the cumulative effect on the acceptance of existing wind turbines. The study finds that people who see more than five turbines daily are significantly more negative towards the existing onshore wind turbines. Accordingly, the results suggest that the cumulative effects from onshore and offshore wind turbines might be different.

Finally, Warren & McFadyen [17] compare attitudes in a Scottish study between respondents living on a small island (Gigha) with three smaller turbines (total capacity 0.7 MW) and respondents living on an adjacent peninsula (Kintyre) with nearly 70 turbines in operation and 26 under construction. The capacity on Kintyre is just above 100 MW. The main aim of the study is to test the effect of co-ownership on attitude, but the study also discusses the cumulative effects from several wind farms on the attitude. The results suggest that the respondents on Gigha generally expressed less concern related to different categories of negative impacts, such as visual interference, birdstrikes and habitat disruption. In addition to these attitude-based studies, a number of studies have attempted to estimate the potential relationship between property prices and the distance to wind turbines [58–62] and the stated preferences for different wind power onshore and offshore configurations [63–66]. However, although the studies give some insight in the preferences for the composition of wind turbines in the landscape, they give no information on, how the preferences are spatially correlated with the wind turbines' density in the area where people live.

In this perspective, except from Ref. [31], no other studies have to the authors' knowledge tested the cumulative effects in terms of number of turbines seen from existing onshore turbines on the attitude towards onshore wind power development. In a planning context this is, however, an important issue, especially regarding the identification of favourable wind development sites.

3. Survey

The analysis of the cumulative effects from existing wind turbines on the acceptance of wind energy focuses on the stated attitudes towards two wind power development scenarios; increasing the number of onshore turbines and the replacement of smaller turbines, respectively. The cumulative effects are thus tested in a general setting in which the respondents are asked to express their level of acceptance for a general policy programme and not a specific wind farm. This can naturally have an influence on the level of the acceptance that we based the analysis on. As highlighted in the wind power literature, people tend to be positive towards wind power, but less towards local projects [33,67–69], also described as the social gap [70]. The focus in the present paper is, however, not at the level of acceptance per se, but on the relative influence of the daily number of wind turbine encounters and the effect on attitude. A similar approach has been used in the Swofford & Slattery study [30]. Interestingly, the study finds proximity effects when the respondents state their perception towards a hypothetical wind farm on the respondents' property, within sight from the property, within the community, but not when asked about a wind farm within Texas and within the US. Accordingly, the effect from living close to a wind farm seems to be present in the development scenarios in the local area, but not on the more general state or US level.

It is difficult to generalise from the Swofford & Slattery study to the present one. However, if we find cumulative effects with regard to the two general wind power development scenarios, we could argue that similar effects in a local development context could be present. On the other hand, if we do not find such effects, the identified spatial relations in Swofford & Slattery on a local but not state level suggest that we cannot rule out that cumulative effects might be present in a local development context.

Going back to the two wind power development schemes subject for investigation, the first wind power development scheme

represents a joined increase in the number of wind turbines and a change in distribution of the size of the wind turbines. Generally, new wind turbines are larger than the present ones. Consequently, the number of turbines increase, the distribution of the size of the wind turbines is pushed towards larger turbines and the average size of wind turbines increases. On the other hand, the replacement scheme represents a wind power development, in which the number of wind turbines are reduced and the size of the wind turbines on average increases. Accordingly, a choice between the two types of wind power development is a trade-off between the number of wind turbines and the size distribution of the wind turbines. The two types of wind power development schemes are chosen as they represent two policy relevant designs.

The first scheme represents the type of development carried out in newer wind power countries, the replacement scheme reflects the energy planning situation in older wind power nations, which have a significant share of older and smaller turbines in operation. The replacement scheme is thus inspired by an existing replacement programme in Denmark, where the wind power developers are given direct economic incentives through an increase of the tariff per kWh produced if new and larger turbines replace smaller turbines (450 kW or less). In total, the target for replacement is 175 MW smaller turbines [71,72].

The analyses are based on the sample used in Ladenburg and Dahlgaard [31]. This is a randomised sample of respondents from a nationwide Internet panel consisting of approximately 17,000 people. In total, the effective sample was set to 1050 answers. To obtain this sample, invitations to answer the questionnaire were emailed to the 1860 panel members in July 2006. Of those 1088 filled in the questionnaire, 1082 and 1076 respondents stated an attitude towards the more onshore turbines and towards replacing smaller

wind turbines with larger turbines, respectively. The characteristics of the two subsamples are presented in the sample below (Table 2). As the differences in the sample characteristics are very small, we will only comment on the characteristics of the 1082 respondents, who stated an attitude towards more onshore wind turbines.

Overall, the distribution of males, females and the age categories is representative of the Danish population. The respondents in the sample generally come from households with a higher income level, when compared to the Danish population. Likewise, the educational level is higher in the sample. With regard to the wind turbine related demographics, 5% and 14% of the respondents have stated that they can see an offshore wind turbine/wind farm or an onshore turbine/wind farm from their permanent or summer residence, respectively. Apparently, it has been difficult for the respondents to recollect how many turbines they see on a daily basis. As much as 49.3% have stated that they do not recall how many turbines they see daily. As presented in the next section, these respondents will be controlled for in the analyses. Focussing on respondents recalling the number of turbines seen daily, 23.6% of the respondents see 5 or fewer turbines daily. 13.9, 7.8 and 5.5% see between 6 and 10, 11–20 or more than 20 turbines daily, respectively. The analysis of the cumulative effects will be carried out for the subsamples of respondents reporting to have a turbine in their viewshed or not (see later). For this subsample, the probabilities of seeing 0–5, 6–10, 11–20 or more than 20 turbines daily are 5.2, 5.0, 4.3 and 3.7%, respectively.

4. Setup of the analyses

We estimate the cumulative effects of existing onshore turbines on the attitude towards two types of wind power development schemes, i.e.

Table 2
Sample characteristics and variable coding.

Variable	Variable name	% ^a	Coding of variable
Male	Male	53.4 53.6	=1 if male, else = 0
Age	Age		Continuous
16–24 years		14.0 13.9	
25–34 years		16.5 16.6	
35–44 years		16.9 16.9	
45–54 years		23.2 23.0	
55–64 years		18.9 18.9	
≥65 years		10.5 10.6	
Annual household income (DKK)	H. Income		Continuous
<200,000		13.4 13.5	
200,000–399,999		27.0 26.8	
400,000–599,999		23.5 23.5	
600,000–799,999		18.7 18.7	
≥800,000		8.8 8.8	
Income not available	H. Income N.A.	8.7 8.7	=1 if income not stated, else = 0
Education			
Maximum seven years in elementary school	Max 7 yrs. Elem. Sch.	4.0 4.0	=1 if max seven years in elementary school, else = 0
Secondary education	Sec. education	88.4 88.2	=1 if secondary education completed, else = 0
Master degree	Master	18.2 18.3	=1 if master degree obtained, else = 0
View turbines off-shore from residence	View offshore	4.9 4.9	=1 if view from residence or summer house, else = 0
View turbines on-land from residence	View on-land	24.0 24.2	=1 if view from residence or summer house, else = 0
Number of turbines seen daily			
0–5 turbines	No. turb. 0–5	23.6 23.6	=1 if 0–5 turbines daily, else = 0
6–10 turbines	No. turb. 6–10	13.9 13.8	=1 if 6–10 turbines daily, else = 0
11–20 turbines	No. turb. 11–20	7.8 7.8	=1 if 11–20 turbines daily, else = 0
>20 turbines	No. turb. >20	5.5 5.5	=1 if >20 turbines daily, else = 0
Don't recall the number of turbines	No. turb. D. R.	49.3 49.3	=1 if don't recall the number of turbines, else = 0
View turbines on-land from residence × number of turbines seen daily			
0–5 turbines		5.2 5.2	=1 if no. turb. 0–5 = 1 and view on-land = 1, else = 0
6–10 turbines		5.0 5.1	=1 if no. turb. 0.6–10 = 1 and view on-land = 1, else = 0
11–20 turbines		4.3 4.4	=1 if no. turb. 11–20 = 1 and view on-land = 1, else = 0
>20 turbines		3.7 3.6	=1 if no. turb. >20 = 1 and view on-land = 1, else = 0

^a The numbers on the right are representative of the 1072 respondents stating an attitude towards the replacement scheme. For all variables, it cannot be rejected that the distributions of the demographics for respondent stating an attitude towards more on-land wind turbines and an attitude towards the replacement scheme origins from the same distributions.

1. Attitude towards more onshore wind power development
2. Attitude towards replacing smaller wind turbines with larger ones.

The analysis of the cumulative effects from the number of wind turbines people see daily is based on whether or not the respondents oppose (have a negative attitude towards) the two wind power development schemes,¹ see Appendix A for the exact wording of the questions. The outcome variable is thus binary and coded as 1 if the respondent holds a positive or neutral attitude and coded as 0 if the respondent holds a negative attitude. As only the respondent know why he/she has this specific attitude, we replace the individually stated attitude of each individual, q_i with a latent attitude q_i^* in the analysis. The determinants of the latent attitude are analysed by including individual demographics, X_i , such as gender, age, education, income etc., which have been found to influence attitude towards wind power significantly [11,18,34,40,51,54]. We also include a set of variables θ_i , which controls for experience with wind turbines. i.e. $q_i^* = X_i\beta + \theta_i\phi + \varepsilon_i$, where ε_i is the individual specific error term, which is assumed to have a logistic distribution with a zero mean and a variance of σ^2 .² One of these variables is the cumulative effects from the number of turbines seen daily (*No. turbines*). This effect is estimated using a set of dummy variables controlling for whether the respondents see between 6 and 10 turbines, 11–20 turbines or more than 20 turbines on a daily basis. The effect is estimated relative to respondents who only see between 0 and 5 turbines daily. As presented in Table 2, nearly 50% of the respondents do not recall the number of turbines seen daily. The potential effect from not being able to recall the number of turbines daily on the attitude and thereby the measure of the cumulative effects is controlled for with a specific dummy variable for these respondents. This will ensure that the estimated cumulative effects are not confounded with whether or not the respondents recall the number of turbines seen daily. Again, the reference category is the respondents, who see between 0 and 5 turbines daily. In addition to this, we control for a viewshed to onshore (*View onshore*) and offshore (*View offshore*) wind turbines. Unfortunately, we do not have information on how many turbines the respondents have in the viewshed from their permanent or summer residence. The data only entails information on a binary scale. Either there is minimum one wind turbine in the viewshed or not. Accordingly, it is not possible to infer if having many turbines in the viewshed relative to the number of turbines seen on a daily basis influence the acceptance significantly. As found in Ladenburg [35], the influence of the experience variables on attitude could be conditional on the level of other variables. We therefore test if the cumulative effects are dependant on whether or not respondents have a viewshed to onshore wind turbines from their residence.³ Accordingly:

$$\theta_i = \gamma_i \text{ no. turbines} + \delta_i \text{ view onshore} + \vartheta_i \text{ view offshore} + \alpha_i \text{ no. turbines} \times \text{view onshore}$$

The potential effect of the number of turbines seen daily on attitude is tested using three models for the attitude towards more onshore wind turbines and the replacement of smaller turbines with larger ones, respectively. For both attitude questions, the first model is the Main Model, which includes all respondents from the survey. The two other models are run for each attitude question on samples, which are conditional on whether or not the respondents can see onshore turbines from their residence. These models are named the View Onshore Model and No View Onshore Model. In total, six models are estimated.

4.1. Limitations of the study and the data

In addition to the general framing of the attitude questions, which have been addressed in the beginning of the article, we will elaborate on the other limitations of the data and the implications for the study. Starting with the central variable, the number of turbines seen daily, the respondents were asked to state the number of turbines based on five predefined categories; 0–5 turbines, 6–10 turbines, 11–20 turbines, more than 20 turbines and a “Do not recall the number of turbines” option. Unfortunately, this makes it impossible to identify respondents who do not see any wind turbines on a daily basis. Clearly, it would have been appropriate to have added a “no turbine” category, so that the cumulative effects of seeing turbines daily on the attitude could be measured relative to the attitude of people who do not see any wind turbines.

There is another limitation that we would also like to highlight. We use self-reported levels of daily wind turbine encounters.⁴ A more objective measure based on a GIS assessment of the number of turbines would have been preferable as done in Möller [10]. This would also make it possible to account for the more technical characteristics of the wind turbines, such as height and grouping of the turbines [53,75,76]. However, this has not been possible within the frame of the project behind this paper.

5. Results

5.1. General attitude

The general attitude towards increasing the number of turbines on land and replacing smaller turbines with larger ones is positive. In the Main Model 86.5% and 89.2% have a neutral or positive attitude towards increasing the number of onshore turbines and replacing the smaller turbines, respectively.

Of those who have a viewshed to onshore turbines from their residence (“View Onshore Model”) 84.4% have a positive/neutral attitude towards more onshore turbines, whilst 86.9% of those who do not have a turbine in the viewshed from their residence have a positive/neutral attitude. A χ^2 test shows that the difference is insignificant. In the case of the attitude towards the replacement scheme, the numbers are 88.5% and 89.5%, respectively. The difference is insignificant.

In Table 3 we present the results from the binary logit models, there among the cumulative effects.

¹ The information on attitude stems from the respondents' statements on a five-point scale ranging from *very positive*, *mainly positive*, *neutral*, *mainly negative* to *very negative* towards more onshore wind turbines and the replacement scheme. In order to take advantage of the ordinal characteristics of the data, several ordinal models have been tested, including test of whether parameter estimates are stable across the ordinal levels (parallel regression assumption) [73,74]. The tests signify that the parallel regression assumption is violated for a number of variables, including variables related to the cumulative effects and having a viewshed to onshore wind turbines. The results are available upon request.

² Given the nature of the binary attitude data, a positive parameter estimates denote that the variable influences the attitude positively.

³ Another approach that has been tested is to estimate a joined model, which captures the conditional viewshed effects by including dummy variables for the cumulative effects, which are interacted with the viewshed dummy. The models give the same results, but are less straightforward to infer from the estimated parameters, as they require additional tests including combinations of the estimated parameters. To make the paper more accessible to the reader, we have therefore chosen the present approach.

⁴ A similar approach has been used in Firestone & Kempton [40] in relation to attitude towards the proposed Cape Cod offshore wind power project. In the paper, respondents perceiving that the offshore wind farms would be visible from the daily routine, whilst controlling for viewsheds from the residence, were found to be more negative towards the project.

5.2. Attitude and respondents' demographics

In all six models, age of the respondents seems to influence the attitude negatively. This is in line with the results from a large number of studies, in which older respondents appear to be more negative compared to the younger respondents ($\beta_{\text{Age}} < 0$),⁵ see Refs. [11,65] for a review. Except in the “No View Onshore Model” for the replacement attitude (see also note^b in Table 3), the education of the respondents also appears to influence the attitude significantly. Respondents who have only completed seven years of elementary school are significantly more positive towards the wind power development ($\beta_{\text{Max 7 yrs. Elem. Sch.}} > 0$). In the “More Wind Turbines” attitude models, respondents with a secondary education are more positive compared to respondents who do not have a secondary education ($\beta_{\text{Sec. Education}} > 0$). However, those with a master's degree are significantly more negative ($\beta_{\text{Master}} < 0$) in the “Main” and “No View Onshore” models. None of the variables related to the level of secondary education are significant in the replacement models. To conclude the traditional socio-demographics, there are no effects on attitude from variation in the gender of the respondents or household income levels.

Generally, the attitude towards increasing the number of onshore turbines and the replacement scheme seems to be unaffected by having a viewshed to onshore or offshore wind turbines from the residence or summer house. Apparently, a viewshed to an onshore wind turbine alone does not influence attitudes towards onshore wind power development.

5.3. Cumulative effects

If we start with the attitude towards more onshore wind turbines, we find that people, who see more than 20 turbines on a daily basis, are significantly more negative towards more onshore wind turbines ($\beta_{\text{No. turb. } > 20} < 0$). The $\beta_{\text{No. turb. 6–10}}$ and $\beta_{\text{No. turb. 11–20}}$ parameter estimates are both negative, but not significant. To verify if they are jointly significant, we have tested (not reported in the table) a dummy variable grouping respondents who see between 6 and 20 turbines daily or not. The variable is not significant. Accordingly, on a sample level, the cumulative effect of seeing 20 or less turbines on a daily basis on the attitude seems not to be present.

If we move on to the models, in which the data is separated according to whether the respondents have an onshore turbine in the viewshed or not, the most interesting results are the heterogeneity in the effects from the number of wind turbines in the local area. In the “View Onshore Model” both respondents who daily see between 6 and 20 turbines (see note^a in Table 3) and respondents who see more than 20 turbines tend to have a significantly more negative attitude than those who have five or less turbines in their local area ($\beta_{\text{No. turb. 6–10}}$, $\beta_{\text{No. turb. 11–20}}$ and $\beta_{\text{No. turb. } > 20} < 0$). The effect is strongest for respondents who see more than 20 turbines. To put it in another way, the more wind turbines a respondent, who also has a viewshed to an onshore turbine from the residence, sees every day, the more negative the respondent is towards additional wind turbines.

In the “No View Onshore Model” we do not find sufficient evidence of that the number of turbines seen daily influence the attitude significantly.⁶ The negative effect of having many turbines

in the area thus appears to be conditional on having a viewshed to turbines from the residence. Consequently, if respondents cannot see any turbines from their residence, the cumulative effects of the number of turbines seen daily on the attitude are insignificant. On the other hand, if the respondents have one or more onshore wind turbines in their viewshed from their residence, their attitude towards more onshore turbines is sensitive towards and negatively correlated with the number of turbines they see daily, i.e. a cumulative effect.

If we move on to the attitude towards replacing smaller turbines with larger ones, we see that the parameter estimates in the “Main Model” for the number of turbines seen daily are insignificant and not uniformly negative. Again, controlling for whether the respondent sees between more than 5 or 10 wind turbines daily does not change these conclusions. Accordingly, the cumulative effects found in the “Main Model” in relation to the attitude towards more onshore wind turbines seem to be reduced by the replacement programme. These observations are supported by the results from the “View Onshore Model” and “No View Onshore Model”. In the “View Onshore Model”, we find that the parameter estimates for the number of turbines seen daily are negative ($\beta_{\text{No. turb. 6–10}}$, $\beta_{\text{No. turb. 11–20}}$ and $\beta_{\text{No. turb. } > 20} < 0$) and have the similar relative size as in the model for more wind farms. Though this could point towards a cumulative effect, they are all insignificant. This is also the case, when we control for whether the respondent sees between more than 5 or 10 wind turbines daily (not reported in the table). In the “No View Onshore Model”, the parameters for the number of turbines seen daily seem to have both positive and negative effects on the attitude ($\beta_{\text{No. turb. 6–10}}$ and $\beta_{\text{No. turb. 11–20}} > 0$ and $\beta_{\text{No. turb. } > 20} < 0$) and are insignificant.

In Fig. 1 we have illustrated these results. The numbers in the figure are based on the estimated marginal effects from the number of turbines seen daily.

In the figure, we display the average sample probabilities for having a positive attitude towards more wind farms and the replacement programme, respectively. The horizontal axis is the number of turbines seen on a daily basis. For each attitude question related to the two development schemes, we have conditioned the average sample probability on whether the respondents can see onshore wind turbines from their residence or not. If we start with the attitude towards more onshore wind turbines, we can see that the respondents who do not have a wind turbine in the viewshed are not significantly influenced by the cumulative effects from existing wind turbines. Though the probability of a positive attitude declines from 89% for respondents seeing between 0 and 5 wind turbines daily to 83% for respondents who see more than 20 wind turbines daily, the change is not significant. However, conditional on having a wind turbine in the viewshed, the cumulative effects are more apparent. Respondents seeing between 0 and 5 wind turbines have an average probability to have a positive attitude of 87%. This probability is reduced the more wind turbines the respondents see daily. More specifically, the probability is 73%, 73% and 63% for respondents, who see 6–10, 11–20 or more than 20 turbines daily, respectively. As mentioned, the difference in the probability between respondents seeing 0–5 and jointly respondents seeing 6–10 and 11–20 turbines is significant at a 90% level. Respondents seeing more than 20 turbines daily are also significantly more negative at a 90% level of confidence. These results change in the model for the attitude towards the replacement programme. First of all, the respondents who do not have a wind turbine in the viewshed were not found to be significantly sensitive to the number of turbines seen daily. The probability of a positive attitude lays constantly around 91%. With regard to the respondents who have a turbine in the viewshed, we observe a decline in the acceptance, from 91% to 76% for the respondents who

⁵ A log and quadratic specification of the age have been tested, but the model at convergence had a numerically higher loglikelihood compared to a model with a linear specification.

⁶ We have also tested two dummy variables (not reported in the table) controlling for whether the respondent sees between more than five ($\beta_{\text{No. turb. 6+}}$) or more than 10 wind turbines daily ($\beta_{\text{No. turb. 10+}}$). None of the variables were significant.

Table 3
Attitude towards onshore wind power development, binary logit models.

	More onshore wind turbines			Replacing smaller turbines with larger turbines		
	Main Model	View Onshore Model	No View Onshore Model	Main Model	View Onshore Model	No View Onshore Model
Male	−0.0548 [0.193]	0.213 [0.379]	−0.123 [0.224]	0.0259 [0.205]	0.249 [0.438]	−0.0244 [0.235]
Age	−0.0334*** [0.00662]	−0.0370* [0.0144]	−0.0342*** [0.00756]	−0.0390*** [0.00692]	−0.0455* [0.0189]	−0.0374*** [0.00757]
H. Income	−0.0821 [0.0849]	−0.0469 [0.161]	−0.0872 [0.101]	−0.0471 [0.0966]	−0.155 [0.167]	0.00132 [0.118]
H. Income N.A.	−0.558 [0.417]	0.0239 [0.895]	−0.683 [0.469]	−0.449 [0.461]	−0.654 [0.996]	−0.345 [0.514]
Max 7 yrs. Elem. Sch.	1.818* [0.746]	1.823+ [0.975]	2.049+ [1.079]	1.471* [0.747]	− ^b	0.966 [0.779]
Sec. education	0.776* [0.305]	1.233+ [0.639]	0.691+ [0.357]	−0.172 [0.415]	−0.331 [0.980]	−0.157 [0.455]
Master	−0.637** [0.219]	−0.259 [0.448]	−0.732** [0.249]	−0.265 [0.239]	−0.485 [0.473]	−0.178 [0.277]
View offshore	−0.0140 [0.382]	0.479 [0.635]	−0.292 [0.433]	−0.0149 [0.444]	0.411 [0.802]	−0.171 [0.541]
View onshore	0.0339 [0.226]	—	—	0.0451 [0.252]	—	—
No. turb. 6–10	−0.358 [0.306]	−0.984 ^a + [0.648]	−0.231 [0.367]	0.0927 [0.345]	−0.596 [0.757]	0.202 [0.400]
No. turb. 11–20	−0.548 [0.345]	−0.988 ^a + [0.647]	−0.478 [0.448]	−0.265 [0.375]	−1.074 [0.729]	0.0112 [0.538]
No. turb. >20	−0.794* [0.391]	−1.435* [0.675]	−0.504 [0.597]	−0.395 [0.435]	−1.218 [0.776]	−0.167 [0.665]
No. turb. D. R.	−0.00177 [0.243]	−0.496 [0.640]	0.0759 [0.264]	−0.0183 [0.262]	−1.143 [0.714]	0.189 [0.278]
Constant	3.305*** [0.513]	3.148*** [0.935]	3.446*** [0.619]	4.356*** [0.647]	5.825*** [1.365]	4.007*** [0.726]
N	1076	260	816	1076	243	816
LL(0)	−425.4	−111.6	−313.2	−367.9	−90.82	−274.8
LL(β)	−398.2	−103.9	−291.8	−346.7	−82.67	−260.4
Chi2	50.64	16.55	36.96	37.90	15.29	28.53

Standard errors in [].

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

^a The variables are jointly significant at a 90% level of confidence.

^b Max 7 yrs. Elem. Sch. Predicts perfectly, all are positive.

see 0–5 and more than 20 turbines, respectively. The differences are though not significant.

6. Discussion

A distinct result from the analysis of attitudes towards more onshore wind turbines is that attitude towards more wind turbines is significantly influenced by the number of turbines people see daily. The results suggest a negative relation between attitude and the number of turbines seen daily. Except for Ladenburg & Dahlgaard [31], these results have not yet been reported in the literature. As Ladenburg & Dahlgaard [31] use the same data in relation to the acceptance of existing onshore wind farms, one of the first questions that seems relevant to discuss is whether people who see many turbines on a daily basis have a higher propensity to be negative towards more wind turbines/the replacement scheme relative to the existing onshore turbines than respondents who see fewer turbines on a daily basis. A theory could be that, although respondents seeing many turbines daily might have learnt to live with

the existing wind turbines, their relative acceptance measures between existing wind turbines, more turbines and/or the replacement of smaller turbines with larger ones might be more sensitive compared to respondents who see fewer turbines. We have therefore estimated a number of models, in which we analyse changes in attitude between existing onshore wind farms and more onshore wind farms and existing wind turbines and the replacement scheme. As in the present paper, Main Models, View Onshore Models and No View Onshore Models have been estimated. All the estimated cumulative effect parameters were insignificant.⁷ This suggests that people who see many turbines daily have an equal probability to change their attitudes towards the two developments schemes relative to their attitude towards the existing onshore wind turbines as people who see fewer turbines daily.

Going back to the results of the paper, an important result is that the cumulative effects are conditional on whether the respondent can see onshore wind turbines from the residence or not. In a policy perspective, these results could have several implications. First of all, the results suggest that wind development would generally be easier to obtain acceptance in areas in which few people have a wind turbine in the viewshed. The results also suggest that if areas with many “viewshed” households are to be developed, the spatial properties (in terms of the number of turbines seen daily) of the attitude are particularly important to take into account in order to minimise the number of households who see many turbines daily. In a more dynamic wind power development scheme, the results also indicate that the location of wind turbines in an initial development phase could have an influence on the acceptance of subsequent development. Accordingly, the location of the initial turbine should be planned carefully and should take into account the number of turbines in the area and the number of households that will get a view to the new turbine. On the positive side, the results also suggest that the cumulative effects can potentially be mitigated if the wind power capacity is increased by replacing smaller turbines with larger one(s), i.e. the replacement scheme. In this scheme, we do not find any significant cumulative effects. The positive attribute of the replacement scheme on the cumulative

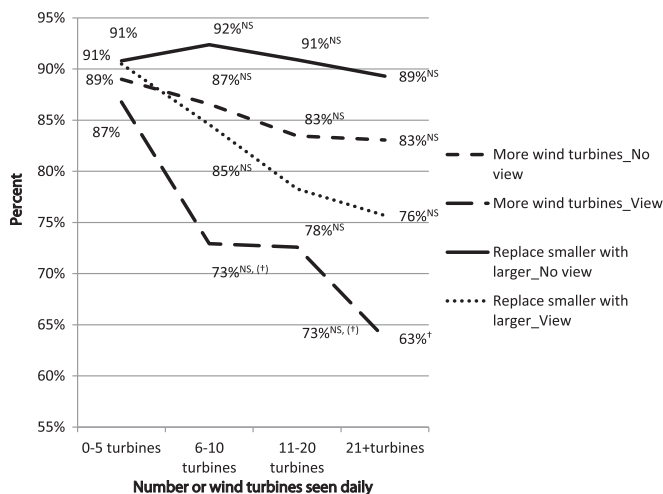


Fig. 1. Average probability for having a positive/neutral attitude.

⁷ The estimated models are available upon request.

effects suggests that reducing the numbers of existing wind turbines, whilst increasing the capacity with new and larger turbines appears to appeal to the respondents in the survey even though larger turbines as put forward in the example above might be seen from more households. The latter has for example been documented in Möller [10] using Northern Jutland in Denmark as the case. Accordingly, this could indicate that there is a flipping point in the cumulative effects with regard to whether the wind power development entails a net increase in the number of turbines. Interestingly, similar results are found in Lee et al. [77] in which the attitude towards few large vs. many small turbines is compared among respondents who live in an area with minimum one turbine (PH2 sample in the paper) and no turbines (PH1 sample in the paper). There are 423 respondents in PH1 and 1286 respondents in PH2. When asked about whether they prefer “Few larger machines” or “Large number of smaller machines” 44 and 47 percentages prefer the former in the PH1 and PH2 sample, respectively. 57 and 49 percentages prefer the latter, respectively. These differences are borderline significant at a 95% confidence level.

However, again it is important to keep in mind that the cumulative effects are based on a general attitude question and that many other factors might influence the preferred wind power deployment scheme and that people might perceive things differently. This is nicely demonstrated in a study on onshore development in two German regions by Meyerhoff et al. [75]. In a stated preference survey for onshore wind power development, the demand for the number of turbines and the height of the turbines were elicited using the economic valuation method Choice Experiments [78]. The estimated demand models indicate large levels of heterogeneity in the preference for these two attributes. Whereas some respondents prefer smaller wind farms other respondents prefer large wind farms. The study also includes a minimum distance to the nearest residential area as an attribute and almost all respondents prefer larger distances. So in perspective of the present paper, the optimal choice of onshore wind power development strategy from a spatial view is a joined function of the height and number of the turbines and the distance to the nearest residential area and not solely on the number of turbines.

Another interesting result in this article is that having a view to a wind turbine(s) from the residence does not in itself induce a more negative attitude towards onshore turbines. Only in combination with the number of turbines seen daily, do we observe an effect of having a view. Similar conditional effects from having a view to an onshore turbine are also found in Ladenburg [7]. In the article, attitudes towards more onshore turbines are elicited in a Danish survey from 2004. The results pointed towards that having an onshore and offshore wind turbine in the viewshed from the permanent or summer residence triggered a negative attitude towards more onshore turbines. If the respondents only had a viewshed to an onshore turbine, a significant effect was not found. Similarly, Johannsson & Laike [57] find no effects of having a view to onshore turbines on the attitudes towards onshore turbines. In their paper they also test for distance effects from the residence to the onshore turbines. They do not find any significant effects. However, it would have been interesting to see the results from having both a wind turbine in the viewshed and for the turbines being close to the residence. Jointly, the results from the different papers point towards that further research might be needed to shed a detailed light on the conditional viewshed effects. As such, it would also be interesting to test if the viewshed effects are conditional on the number of turbines that are visible from the residence!

Finally, the above-mentioned discussion should also be seen in the light of co-ownership of a wind turbine. Unfortunately, we are not able to control for this factor in the analysis. However, the positive effect of ownership on local acceptance has been emphasised in

for example Toke [79] and found to have a positive influence on the acceptance of wind turbines [6,32]. An interesting paper in this relation is [80]. In the paper, the demand for wind farms is elicited in a Choice Experiment survey. In the survey, location of the wind farm, benefits for the local (training and micro credit to local enterprises), local ownership and changes in the electricity bill were used as attributes. The results demonstrated that local ownership could be used to compensate when locating wind farms at less preferred locations. In a cumulative perspective, we might expect that co-ownership to have similar effects on the acceptance. Accordingly, a person with a share in one or several wind turbines in the local area might be less sensitive to the number of turbines seen on a daily basis, compared to a person in the same neighbourhood, who does not have a share in the turbines. From a policy perspective, co-ownership of existing and particularly new turbines might thus mitigate some of the found cumulative effects, particularly among people, who have a wind turbine in the viewshed and see many turbines on a daily basis. This calls for further research.

7. Conclusion

The relations between attitude and onshore wind turbine densities have been given relatively little attention in the literature. Except from a few studies, the cumulative effects from having more than one turbine in the local area are still an open question. In the present article, we focus on this particular issue in a wind power development context. Based on a sample with nearly 1100 respondents we analyse if the number of turbines in the local area has an influence on attitude towards two development schemes; more onshore turbines and replacement of smaller wind turbines with larger ones. The results strongly indicate that the number of turbines does matter and that the more turbines the respondents have in the local area, the more negative they are towards more onshore turbines. However, and most interestingly, a significant relation is conditional on whether the respondent has one or more wind turbines in the viewshed from the residence. If the respondents do not have a view to a turbine, we do not find evidence of that attitude is affected by the number of turbines in the local area. On the other hand, if the respondent has a view to an onshore turbine, attitudes are significantly influenced by the number of turbines in the local area. These results are important in a planning context, as they point towards that having many turbines in the local area as such might not have a negative influence on the acceptance of further development. However, if a large proportion of the households has one or more of the turbines in the viewshed and have many turbines in the local area, further development could pose a problem. However, the results also suggest that the cumulative effects from existing wind turbines can be mitigated or even removed if the wind power capacity is increased by reducing the net numbers of turbines by replacing smaller turbines with larger ones, even though the larger ones might be visible from a higher number of residences.

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Appendix A. The attitude questions

Q.1. What is your attitude towards more onshore wind turbines?

- Very Positive
- Mainly Positive
- Neutral
- Mainly Negative
- Very Negative
- Don't Know

Q2. What is your attitude towards more larger onshore wind turbines, if they replace many smaller wind turbines?

- Very Positive
- Mainly Positive
- Neutral
- Mainly Negative
- Very Negative
- Don't Know

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