

Attitudes towards on-land and offshore wind power development in Denmark; choice of development strategy

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Abstract

Wind power generation is expected to increase significantly in the near future. Owing to the increasingly limited possibilities for using on-land turbines, offshore wind generation is a potential alternative. However, wind turbines located offshore are still associated with visual disamenities potentially making offshore location a less attractive alternative to on-land wind power generation. The present paper analyses attitudes towards both on-land and offshore wind power development using a probit model. It also discusses the elicited determinants of attitude in relation to developing wind power on-land or offshore. Compared to other papers on attitude, the paper is unique in the sense that the Danish population has considerable experience with the different impacts associated with wind turbines compared to most of the other countries investing in wind power generation. This is particularly evident with regards to offshore development. The paper establishes that whilst offshore wind farms are preferred to on-land development, the results also imply that on-land development is still a feasible alternative. In that relation, differences in wind power generation costs and the substitution of smaller on-land turbines with fewer but larger turbines might make on-land development even more attractive. On a more detailed level, younger respondents are more positive towards wind power than older respondents. Interestingly, respondents living close to either on-land or offshore wind turbines did not display a more negative attitude towards wind power generation when compared to respondents who were not living close to wind turbines.

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1. Introduction

In the past decade, on-land wind power generation has grown significantly and several countries have considerable plans for future expansion. However, on-land turbines are associated with visual impacts on the landscape, noise impacts, impacts on birdlife and other types of impacts on the ecological environment. These impacts make it increasingly difficult to find suitable and acceptable sites for future development. Energy planners have consequently shifted their focus to the vast off-shore wind resources. However, even though the off-shore location of wind turbines eliminates noise nuisances, visual disamenity is still an issue.

The energy planner's choice to develop on-land or off-shore is, among other things, dependent on the public's acceptance of off-shore compared to on-land wind power generation. Though discussions concerning the impacts of wind power have taken place simultaneously with its development, attitudes towards on-land and off-shore wind power have not been jointly and systematically analysed. Energy planners may therefore have insufficient information regarding attitudes in order to efficiently determine the extent to which future wind development should be located on-land or off-shore. There is therefore a real need for more scientific information concerning attitudes towards wind power development.

In the present paper, the Danish population's attitude towards future on-land and off-shore wind power development is analysed. Based on elicited determinants of attitude, the policy relevant choice of developing on-land or off-shore

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is discussed. Given the high density of wind turbines in Denmark, the Danish population has unique experiences with the different impacts associated with wind turbines when compared to most of the other countries investing in wind power generation. This is particularly evident with regard to off-shore development. The present study is thus expected to yield essential information regarding the public's acceptance of wind power and the grounds for opposing on-land and off-shore wind power development. Furthermore, this paper aims to improve information levels in order to facilitate the development of more efficient energy policy with regards to the choice of whether wind power should be developed on-land or off-shore.

The paper begins with a short introduction to the study, followed by a description of the method used, a presentation of the results, a discussion of the possible substitution possibilities between on-land and off-shore wind power development and finally a conclusion, which comments on the usage of the results in a wind power policy context.

2. The study

The analysis of preferences for future wind power development in the present paper is based on a study of the attitudes of Danish individuals towards wind power. The study was conducted in the period 2003–2004 and entailed a national sample of 700 randomly selected persons, which was drawn from the Central Person Register (CPR) in Denmark. The sample is representative of the Danish population. Information on attitudes was collected by mailing a questionnaire, which the respondents completed and returned. In total, 375 questionnaires were returned. Of these, 354 questionnaires could be used to analyse attitudes towards more on-land wind turbines whilst 369 questionnaires could be used to analyse attitudes towards more off-shore wind farms. This is equal to an effective response rate above 50%, which is quite good.

In the questionnaire, the respondents were asked a series of questions regarding their attitudes and perceptions of wind power generation and wind power development in general. Among the questions, the respondents were asked to express their attitude towards more on-land and off-shore wind farms on a discrete scale, which is presented below.

- *Very positive*
- *Mainly positive*
- *Neutral*
- *Mainly negative*
- *Very negative*
- *Don't know*

3. The methodology

Attitudes towards wind power are individually determined. The attitude is thus expected to be a function of the characteristics of the individual, for example, gender, age,

income, education, etc. To identify possible systematic relations between attitude and the socioeconomic characteristics of the respondents, the individual attitude can be regressed on the characteristics of the respondents. As mentioned, the attitudes of the respondents are stated on a discrete scale. Consequently, a Probit model is used as a measurement of the scale of attitude towards wind power development [1,2].¹ The scale of the stated attitude is converted into two categories, illustrating whether the respondent has a positive/neutral ($Y = 1$), or a negative attitude ($Y = 0$) towards wind power; see below:

- *Very positive* ($Y = 1$)
- *Mainly positive* ($Y = 1$)
- *Neutral* ($Y = 1$)
- *Mainly negative* ($Y = 0$)
- *Very negative* ($Y = 0$)

In the Probit model, the category value (Y) is replaced with a continuous latent variable y^* . An interpretation of y^* is given in the following. If the perceived utility of (individual i) for increasing the number of on-land wind turbines is zero or larger, then the individual has a positive or neutral attitude towards existing wind turbine and vice versa. However, y^* is not observed by the analyst. The latent variable y^* is therefore assumed to be a function of a number of independent variables reflecting the attitude of the respondents. The independent variables can be divided into different categories such as:

- Socioeconomic variables (gender, age, income, education, etc.)
- Geographical variables (zip code, region, size of the city, living close to a wind turbine, etc.)
- Perception and belief orientated variables (attitude to global warming, perception of impacts caused by wind turbines, etc.)

Representing these variable with the common vector x_i , y_i^* can be defined by

$$y_i^* = x_i\beta + \varepsilon_i, N(0, \sigma^2) \quad (1)$$

where y_i^* denotes the individual latent variables, x_i is the characteristics of individual i and ε_i is the individual specific error term, which is assumed to have a normal distribution with a zero mean and a variance of σ^2 .

The presented Probit model estimates the impact of the independent variables (x_i) of the respondents on the probability of having a positive–neutral attitude or a negative attitude towards existing on-land wind turbines [1]. A more detailed presentation of the Probit model is put forward in Appendix A.

It is recognised that the x 's, which represent the perception and belief oriented characteristics of the respondents might

¹A binary logit, ordered logit/probit could alternatively have been applied, see Ref. Maddala, [1].

Variables	Model I		Model II	
	Parameter	Significance	Parameter	Significance
Age 50 +	−0.6507	(0.001)	−0.6205	(0.010)
Gender_age50 +	0.4175	(0.085)	0.3613	(0.210)
Age_missing	−0.7155	(0.048)	−0.7684	(0.111)
Large_cities_west	0.7789	(0.035)	0.8349	(0.074)
Large_cities_east	0.5909	(0.003)	0.4383	(0.067)
View_turbines_land	0.0459	(0.810)	−0.1408	(0.553)
View_turbines_land_sea	−0.8608	(0.079)	−0.5986	(0.286)
Constant	0.8900	(< 0.0001)	5.1793	(< 0.0001)
PImp_land ^a	—	—	−1.1879	(< 0.0001)
	$P^2 = 0.0930, N = 354$		$P^2 = 0.4167, N = 354$	

²The joint probability ($\beta_{Age50++\beta_{Gender_Age50+}$) for a positive attitude for a female respondent older than 49 years is not significantly different from 0zero.

Table 2
Probit model for attitude towards more offshore turbines

Variables	Model I		Model II	
	Parameter	Significance	Parameter	Significance
Age55 +	−0.4574	(0,037)	−0.9747	(0.013)
Age_missing	−0.8472	(0,121)	−1.3279	(0.052)
View_turbines_sea	0.1430	(0.780)	0.7664	(0.401)
View_turbines_sea-miss	−1.3390	(0.023)	−1.3599	(0.124)
View_turbines_land	−0.2605	(0.307)	−0.1096	(0.780)
Beach_user	−0.5484	(0.020)	−0.4202	(0.223)
Constant	2.1379	(0.001)	7.7647	(<0.001)
Visual_imp_offshore ^a	—	—	−1.1050	(<0.001)
Birds_sealife_imp_offshore ^b	—	—	−0.1158	(<0.001)
Impacts_birds-miss	—	—	1.8430	(0.068)
Impacts_sealife-miss	—	—	1.1743	(0.211)
		$N = 369, \rho^2 = 0.1182$		
			$N = 369, \rho^2 = 0.5565$	

^aThe variable is a discrete variable taking distinct levels 1–5, where 1 represents very positive and 5 very negative, the β represents the change in the latent variable moving one level in the discrete variable. The “semi continuous” approach gives the best fit compared to a log and similar transformations.

^bThe variable is a combined measurement of the joint discrete perception of the impacts on birds and life in the sea. The variable is log transformed.

The constant in the model is positive and is a strong determinant of attitude, implying a systematic tendency to have a positive or neutral attitude towards increasing the number of on-land wind turbines given the other variables in the model.

4.1.2. Model II

As previously presented, the attitude towards increasing the number of on-land turbines is expected to be closely related to the perception of the impacts of on-land turbines on the landscape. This information is taken into account in model II, where the variable Imp_land (impact on the landscape) is included. The Imp_land variable is included in order to control for if attitude towards more land-based turbine solely is determined by perception of the visual impacts on the landscape. As it appears from the model, the perception of the impact on the landscape is a very strong determinant of the attitude. As the perception of the visual impacts on the landscape amongst respondents moves from being very positive, to neutral and to very negative, the attitude towards more on-land turbines also becomes gradually more negative.

The explanatory power of the model increases drastically to 0.4167 (compared to 0.0930⁵), which is very good. The large increase in the fit implies the endogenous characteristics of the Imp_land variable, whilst the model should be interpreted with care. Nevertheless, the model indicates that the resistance towards increasing the number of on-land turbines to a large extent is based on the perception of

the impacts on the landscape. However, some of the respondents, who perceive the wind turbines to have a negative impact on the landscape, have a positive/neutral attitude towards more land-based turbines and vice versa.

It is worth noting that the other variables in model II are in general weaker determinants of attitude compared to model I. The conclusions with regards to the other variables in model I are though still applicable.

4.2. Attitudes towards additional off-shore wind farms

As presented, some of the potential impacts associated with wind power generation can be reduced by locating developments off-shore instead of on-land. By situating off-shore wind farms at a relatively large distance from the coast, the noise and visual impacts experienced from the coast can be significantly reduced or completely removed. Given that the number of turbines installed off-shore is relatively small compared to on-land and taking into account the potential for reducing noise impacts in particular, this indicates that the attitude towards increasing the off-shore wind power capacity, a priori, is expected to be more positive than the attitude towards increasing the number of on-land turbines. These expectations are confirmed in the stated attitudes in this survey. Of the 369 valid responses, only 5% of the respondents have stated a negative attitude towards more off-shore wind farms.

In Table 2, a Probit model for a positive attitude towards more off-shore wind farms is presented.

4.2.1. Model I

The determinants of attitude towards more off-shore wind farms are presented by nine variables. The first variable is Age55 +, which represents the respondents older than 54 years. As in the model for on-land turbines, older

(footnote continued)

turbines compared to respondents who stated that there were too few. However, this variable cannot be included in Model I without imposing endogeneity and invalidating the model. In Model II, the variable is insignificant.

⁵Given the relatively small variance in the independent variable, 0.0930 is perceived as being an acceptable fit of the model.

respondents have a higher probability for a negative attitude. Age_missing is jointly significant with the Age55+ and the coefficient is negative. A view over existing on-land turbines or off-shore wind farms is expected to have an influence on the attitude towards more off-shore wind farms. These hypotheses are tested by three variables. View_turbines_sea, represents respondents who can see off-shore wind farms from their residence or summer house. Surprisingly, the variable is insignificant and thus experience with off-shore wind farms has not had a negative influence on the attitude towards more off-shore wind farms. Interestingly, respondents who have neglected to answer whether they can see off-shore wind farms are more negative towards the development of more off-shore wind farms. The last view variable is View_turbines_land, which is insignificant. Thus, respondents who can see on-land turbines consequently do not have a different attitude towards the development of more off-shore wind farms than respondents who cannot see on-land turbines. The final variable in the model, Beach_user, represents respondents who visit the beach at least once per week. These respondents have a more negative attitude than respondents who visit the beach less often. This indicates that these respondents consider the visual impact of off-shore wind farms as being a potential visual intrusion. The constant is positive, which indicates the overall positive attitude towards more off-shore wind farms.

4.2.2. Model II

In model II, the Visual_imp_off-shore variable is a strong determinant of attitude. This variable represents the respondents' perception of the visual impacts of off-shore wind farms. The $\beta_{\text{Visual_imp_off-shore}} < 0$, therefore respondents who believe that off-shore wind farms have a negative impact on the coastal landscape, consequently have a more negative attitude towards additional off-shore wind farms. However, just as in the case of on-land turbines, perception of attitude is not a perfect determinant of attitude. Birds_sea_imp_off-shore is also significant and negative. This variable encompasses beliefs concerning the impact on birds and sea life associated with off-shore wind farms.

Respondents who believe that off-shore wind farms have a negative impact on birds and life in the sea consequently have a more negative attitude towards more off-shore wind farms. This negative relation is worth putting forward, as a number of state-of-the-art studies point towards that the impacts on birds and life in the sea might be small and even positive, see for example, Leonhard and Birklund [4] and Fox et al. [5]. If this information is conveyed to the population, the attitude towards more off-shore wind farms might be even more positive.

The two last variables included in model II, Impacts_birds-miss and Impacts_sealife-miss, code for respondents who either have not answered the attitude question or have answered "do not know". Both variables are jointly significant with the Birds_Sealife_Imp_Off-shore. The

positive coefficient denotes that these respondents, in general, have a more positive attitude than respondents who have stated a belief. Except for the two age variables, the other variables are insignificant in model II. As in model II for attitude towards more on-land turbines, the representation of attitude of the model has improved significantly.

5. Substitution possibilities between on-land turbines vs. off-shore wind farms

In the previous sections, the attitude towards more on-land and off-shore wind power development was elicited with regards to the different characteristics of the respondents. Very interestingly, increasing the on-land wind power capacity is still an acceptable solution, even though the density of wind turbines in the Danish rural landscape is the highest in the world. In fact, only 25% of the respondents oppose an increase in the number of turbines on-land. However, a comparison of the attitudes towards on-land and off-shore wind power generation reveals that overall the respondents seem to be more positive towards increasing wind power capacity off-shore, as only 5% of respondents expressed a negative attitude towards more off-shore wind turbines. Whether the attitude towards more on-land turbines is significantly different from the attitude towards more off-shore wind farms is analysed through the use of a Pearson χ^2 test. The test results denote (on a <0.0001 level) that the respondents are more positive towards more off-shore wind farms as opposed to on-land turbines.⁶

Based on the stated attitude, the results from the study advocate locating future wind power development in Denmark off-shore. However, there are a number of aspects to the results which need in-depth elaboration before they can be interpreted in such a general way.

5.1. Cost of development

The questions regarding attitudes towards an increase in on-land and off-shore wind capacities are simple in their formulation. The respondents are therefore not informed about the cost associated with on-land and off-shore development. The attitude stated can therefore be characterised as a "free choice". The respondents might not necessarily consider the differences in power generation costs (and consumer costs) between on-land and off-shore turbines when expressing their attitudes. Had the respondents been informed about the possible costs of on-land and off-shore wind power development, it is expected that the attitudes would have changed in favour of the lowest cost alternative of wind power generation, known as preference reversal [6,7]. Referring to Morthorst [8,9], off-shore wind power generation is more expensive than

⁶The tests results are independent on whether the binary or initial scale of attitude is used.

on-land. The average cost of on-shore production (coastal areas) is 3.4 c€/kWh (1 MW turbine) which is expected to decrease to somewhere within the range of 2.3–3.0 c€/kWh in the period 2009–2011. Off-shore wind generation costs are estimated to be 4.2 c€/kWh (3 MW turbines) [9]. Everything else being equal, this denotes that the respondents might have been more positive towards the development of more on-land wind turbines if they had been informed about the differences in costs.

5.2. *Substitution of small turbines on-land*

In Denmark, the Government has initiated a wind turbine substitution scheme [10]. The substitution scheme promotes an increase in on-land wind power capacity by replacing existing small turbines with fewer but considerably larger turbines. More specifically, the plan is to replace approximately 900 turbines (maximum capacity 450 kW) with 150–200 2 MW turbines. A typical 450 kW turbine is just over 50 m, measured to the tip of the blades whereas a 2 MW turbine is approximately 100 m. A 2 MW turbine is thus approximately twice as high as a 450 kW turbine. By replacing many smaller turbines with fewer and larger turbines, the visual impacts are significantly changed. Therefore, the relevant question concerns the extent to which the impacts related to the size of the turbines substitute the impacts related to the number of turbines. The data in the present survey does not provide information as to whether people prefer a situation with many small turbines as opposed to one with few but larger turbines. However, as briefly discussed in Ladenburg [11], the attitude towards more on-land turbines across three surveys seems weakly to be a function of the number of turbines and not the average size of the turbines in the landscape. These results seem to be somewhat supported by a Swedish study by Ek [12]. Ek [12] elicits preferences for future wind power development in Sweden. She concluded that it was the location and grouping of the turbines rather than their size which triggered preferences for wind power development. Following these results, it could be argued that substituting small turbines with fewer larger turbines would induce a more positive attitude towards the development of more on-land turbines than has been observed in this paper.

5.3. *Age and attitude*

Across the elicited choice models, the age of the respondents has a significant influence on the attitude towards increasing the number of on-land and off-shore wind turbines. Depending on the model, respondents older than 49 or 54 years have a more negative attitude towards on-land and off-shore wind turbines than younger respondents. This denotes a paradigm shift in attitude between generations, which may indicate that young and future generations are more positively inclined towards wind turbines than the present day older generation. The age

dependent attitude towards wind turbines has also been identified in other studies. Ek [13], Bishop and Miller [14], Ladenburg and Dubgaard [15] and Firestone and Kempton [16], find that older respondents seem to have either a more negative attitude towards wind turbines or that they perceive the visual impacts as being more intrusive compared to younger respondents.

The observations on age and attitudes across the different studies are interesting from a policy point of view. The differences in attitude might indicate that future generations will be more positively inclined towards wind power in general compared to the 50+ generation. Using a Pearson χ^2 test, differences in attitude towards more on-land and off-shore wind power development is tested. The test indicates that even though younger respondents are more positively inclined towards wind power generation in general, off-shore locations are strongly preferred to on-land locations (significant on 0.0001 level).

In relation to this, it is worth mentioning that the younger respondents are relatively more positively inclined towards more on-land wind turbines as opposed to off-shore wind farms when compared to older respondents. The difference in the percentage of younger respondents with a positive attitude towards on-land and off-shore turbines is 13 percentage points (83% and 96%, respectively). For older respondents the difference is 19 percentage points (73% and 92%, respectively). This means that, everything else being equal, younger respondents perceive on-land locations as being relatively more acceptable when compared to off-shore locations than do older respondents.

5.4. *NIMBY effects and experience with wind turbines*

A final aspect of the discussion of the future development of wind power development in Denmark concerns whether the stated personal attitude is influenced by the Not-In-My-Back-Yard (NIMBY) effect. The NIMBY concept is based on the idea that people, who oppose a project because it is located close enough to their home to cause them a nuisance, would be in favour of the project if it were located elsewhere [17,18]. The survey data collected in this study does not permit a direct test of the NIMBY hypothesis based on this definition.

However, some of the variables included in the models potentially could give information with regards to if experience with wind turbines is a determinant of attitude and consequently some level of potential NIMBY.

In both the model for on-land turbines and off-shore wind farms, variables denoting whether the respondents can see turbines from their residence or summer house are included. An NIMBY effect could be present if these respondents had a more negative attitude towards more wind turbines (only because they knew that wind turbines would be located in their neighbourhood) than other respondents. In general, these variables were not significant, indirectly rejecting the NIMBY effect. This indicates that even though the respondents are affected by potential

negative effects (primarily visual) this does not mean that they have a more negative attitude towards more on-land and off-shore wind turbines. These results thus support the findings of Krohn and Damborg [19] and Ek [13]. These two studies find that people living close to wind turbines do not have a more negative attitude towards wind power.⁷ Interestingly, the results contradict Firestone and Kempton [16] who, in a survey on attitudes towards a planned off-shore project near Cape Cod in USA, found that respondents who (*hypothetically*) would be able to see the planned off-shore wind power project from their house or daily route strongly opposed the project. The findings in the present survey (involving respondents who can see *actual* off-shore wind farms from their residence or summer house and who are *not* more negative towards more off-shore wind farms) are thus unique.

The neutral experience relations are however strictly not uniform in the attitude models. In the model for on-land turbines, respondents who can see both off-shore and on-land turbines from their residence have a more negative attitude towards the development of more on-land turbines (significant on 0.1 level). In the same model, respondents living in some of the larger urban areas have a more positive attitude towards the development of more on-land turbines.⁸ These results indicate a potential indirect NIMBY effect. However, both examples could be interpreted as somewhat extreme cases.

6. Conclusion

In the present survey, the Danish population's attitudes towards increasing the number of on-land wind turbines and off-shore wind farms were analysed. The results show that in general the Danish population has a positive attitude. On a more specific level, the attitude towards wind power is found to be correlated with the characteristics of the respondents, such as age (negatively), gender, experience with off-shore wind farms and use of the beach. Interestingly, the attitude between respondents who can or cannot see wind turbines from their residence or summer house is not significantly different.

The survey also finds that the respondents in general prefer off-shore wind farms to on-land turbines. Everything else being equal, this indicates that future wind power development should, to a large extent, be located off-shore. However, the results also imply that on-land development is still a feasible alternative. On-land development may become even more attractive thanks to its relative low-cost when compared to off-shore developments and by sub-

stituting smaller on-land turbines with fewer but larger turbines.

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Appendix A. The binary Probit model

The binary Probit model is expressed by

$$y_i^* = x_i\beta + \varepsilon_i, N(0, \sigma^2) \quad (\text{A.1})$$

where y_i^* denotes the individual latent variable of attitude towards wind turbines, x_i is the characteristics of individual i and ε_i is the individual specific error term, which is assumed to have a normal distribution with a zero mean and a variance of σ^2 .

The latent value y_i^* is mapped $\Rightarrow y_i$ by assuming that:

$$y_i = \begin{cases} 1 & \text{if } y_i^* \geq 0, \\ 0 & \text{if } y_i^* < 0. \end{cases} \quad (\text{A.2})$$

Given the model specification of the latent variable:

$$E[y] = Pr(y_i = 1) = Pr(y_i^* \geq 0) = Pr(x_i\beta + \varepsilon_i \geq 0) = Pr(\varepsilon_i \geq -x_i\beta). \quad (\text{A.3})$$

Normalising the final term in (3) with σ_ε and subtracting the mean (= 0), the probability changes to

$$Pr(\varepsilon_i \geq -x_i\beta) = Pr\left(\frac{\varepsilon_i}{\sigma_\varepsilon} \geq \frac{-x_i\beta}{\sigma_\varepsilon}\right) = Pr\left(\frac{\varepsilon_i}{\sigma_\varepsilon} \leq \frac{x_i\beta}{\sigma_\varepsilon}\right) = \Phi(x_i\beta) \quad (\text{A.4})$$

which is a standard normal distribution. Applying maximum likelihood estimation, the log likelihood (LL) becomes

$$LL(\beta) = \sum_{i=1}^n [y_i \ln \Phi(x_i\beta) + (1 - y_i)(1 - \ln \Phi(x_i\beta))]. \quad (\text{A.5})$$

Given the specification of a positive ($y_i = 1$) and a negative ($y_i = 0$) answer and the normal distributed error term, the limited dependent variable model is a Probit model.

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⁷Neither of the two studies specifically addresses the attitude question with regards to both on-land and off-shore wind farms.

⁸These results are somewhat in contradiction with Krohn and Damborg [19]. They find that people living in the city zone (defined by speed limits) tend to be more negative towards wind power. However the two definitions of people living in urban areas/city zone are not directly comparable.

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