Visual Disamenities from Off-Shore Wind Farms in Denmark

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Abstract

Expansion of the off-shore wind power plays a significant role in the energy policies of many EU countries. However, off-shore wind farms create visual disamenities. These disamenities can be reduced by locating wind farms at larger distances from the coast – and accepting higher costs per kWh produced. Base on the choices among alternative wind farm outlays, the preferences for reducing visual disamenities of off-shore wind farms were elicited using the Choice Experiment Method. The results show a clear picture; the respondents in three independent samples are willing to pay for mowing future off-shore wind farms away from the shore to reduce the wind farms visibility. However, the results also denote that the preferences vary with regards to the experiences with visual disamenities of off-shore wind farms. The respondents Horns Revs sample, where the off-shore wind farm is located at large distance from the shore, have the lowest WTP. The respondents in Nysted, who have the wind farm located close to the shore, have on the other hand by far the highest WTP. In between is the WTP from the national sample. The results thus point towards locating wind farms at large distances from the shore, to minimise the external cost. The results also denote that preference preferences structures between the three samples are significantly different and possibly explained by different experience with off-shore wind farms . Finally the results illustrate that the marginal benefits off-locating wind farms at very large distance from the coast might be small.

Keywords: Off-shore wind power, visual externalities/disamenities, economic valuation, choice experiments, willingness to pay, heterogeneity in preference and experience.

1 Introduction

During the last few years off-shore wind power generation has grown significantly and several countries have extensive plans for future expansion. Wind power is a clean technology but it is not without negative environmental impacts. The most significant externalities are visual disamenities and noise nuisances. Off-shore location of wind turbines eliminates noise nuisances but visual disamenities prevail. The visual disamenities can be reduced – and even eliminated – by moving wind farms to larger distances from the coast. However, the costs per kWh produced increase as the distance is augmented. Hence, the social planner is confronted with a trade-off between minimizing the disamenities, on one hand, and accepting higher costs of power generation on the other. Welfare economic appraisal of alternative wind farm locations requires monetisation of the un-priced externalities.

Using the economic valuation method *Choice Experiments* the study presented in this paper has estimated willingness to pay (WTP) for reducing visual disamenities from *future* off-shore wind farms in Denmark. To the best of the authors' knowledge this is the first attempt to investigate preferences and WTP for reducing the externalities from *off-shore* wind farms. In Denmark wind power has had a prominent position in energy policies for the past couple of decades and Denmark was one of the first countries to establish large off-shore wind farms. This provides a good basis for investigating preferences regarding the externalities from these constructions.

The valuation scenario comprised the location alternatives 12 km, 18 km and 50 km from the shore relative to an 8 km baseline. The effect of extending the distance was visualized using computer simulations. There was a fairly high positive WTP for having future wind farms located at greater distances from the shore. However, there were significant differences in WTP between age groups with younger people showing virtually no WTP for having wind farms located further away from the cost. The paper describes the results of the valuation scenarios with particular emphasis on differences in attitudes and WTP between demographic groups. We start with an overview of previous valuation studies in the field of power generation.

2 Previous Studies on External Costs of Electricity Generation

Assessing the cost of the external effects from energy production initially came to the centre of attention in the beginning of the 1980's [Schuman *et. al* 1982]. The number of studies increased during the 1990s as a consequence of European policy makers growing concern about external costs [European Commission 1995, European Commission 1999].

The external effects of *wind* power generation have also been investigated and various methods have been used to elicit the monetary values of the externalities. *Non-preference* based methods - primarily *Abatement Cost* and *Damage Cost* techniques - are the main approaches used in the studies conducted by the [European Commission 1995, European Commission 1999]. These techniques are also used in other studies such as [Friedrich *et. al* 1993] and [El-Kordy *et. al* 2002].

However, *revealed preference* methods have also been applied [Jordal-Jørgensen 1995, Sterzinger *et. al* 2003] as well as *stated preference* methods [Alvarez-Farizo *et. al* 2002, Bergmann *et. al* , Ek 2002, Navrud 2004]. The revealed preference studies used the *hedonic price method* to examine the relationship between property prices and wind turbines in the adjacent area. These investigations did not reveal any statistically significant effects on house prices from adjacent wind turbines [Sterzinger *et. al* 2003].

In contrast, the results from the stated preference studies indicate that there are significant external costs associated with wind turbines. The studies and their results are not directly comparable. However, they jointly verify that people have preferences for reducing different types of external effects from wind turbines such as visual disamenities, reductions in wild life etc. These studies also show that benefits - such as pollution reduction and the employment effects - add to the acceptance of wind turbines. The studies, the valuated attributes of the wind turbines, and the associated WTPs are presented in Table 1.

Table 1: Previous stated preference studies on environmental costs of wind power

Study	Method	Capacity specified in scenario	Scenario/Attributes	Significant WTP	WTP Euro/year/ household
Navrud (2004)	Contingent Valuation	1.5-6.7 TWh	Substituting wind power by improving existing hydropower	+	110-130
Ek (2002)	Choice Experiments	-	Location of turbines:		
			-Mountainous	+	0
			-On-shore	+	12
			-Off-shore	+	29
			Noise impacts	-	-
			Size of turbine	-	-
			Grouping of turbines:		
			-individual	+	10

			<10	+	20
			10-50	+	0
Alvarez-Farizo & Hanley (2002)	Contingent Rating & Choice Experiment	-	Protection of:		
			Cliffs	+	22
			Habitat & Flora	+	38
			Landscape	+	37
Bergmann *et. al* (In press)	Choice Experiment	-	Landscape impacts	-	12
			Wildlife impacts	+	6
			Air pollution	+	20
			Employment benefits	- (+)	

The studies in table 1 have different focal points in the description of wind power development and the associated external costs. Navrud [2004] takes a holistic approach in estimating the overall external cost of wind power development in Norway. In the study the external costs of 1.5-6.7 TWh of wind power development are estimated by identifying the WTP for substituting wind power with hydro power by improving efficiency of existing hydro power facilities. The WTP is estimated to 110-130 Euro/year/household for eliminating the environmental cost associated with an increase in Norwegian wind power capacity by 1.5-6.7 TWh respectively[i]. Ek [2002], Alvarez-Farizo and Hanley [2002] and Bergmann *et. al* decompose the external costs of wind power development into attributes representing potential impacts of wind power development. Ek [2002] finds that Swedish households are willing to pay 29 Euro/year for locating wind turbines off-shore and 12 Euro/year for locating them in the low land as opposed to locating them in the mountains. The environmental costs of off-shore location and location in the low land are therefore perceived as smaller than development in the mountains. The same survey also finds preferences for medium size wind farms (<10 turbine) as opposed to individual turbines or large wind farms (10-50 turbines). The size of the turbines and the noise levels did not have a significant impact on the choice by the respondents.

Alvarez-Farizo and Hanley [2002] analysed the environmental cost of wind power development in an important natural heritage area in Spain. The results show that the environmental cost expressed through WTP is 21-38 Euros/year/household. WTP was elicited for protection of the attributes of the natural heritage such as cliffs, flora and fauna, and the landscape.

Bergmann *et. al* (in press) include a potential increase in new local, permanent jobs in the valuation scenario. In addition to expressing positive preferences for new jobs, the respondents were willing to pay 20 Euros/year for reducing air pollution, 12 Euros for reducing landscape impacts and 6 euros for reducing impacts on wild life.

The three studies above verify that wind turbine development is associated with environmental costs and that the costs depend strongly on the location of the wind turbines. Thus, the environmental costs of wind power development can be reduced by selecting appropriate sites for this development.

Of the above mentioned investigations Ek (2002) is the only study addressing off-shore location of wind turbines. It was established that the external costs of wind power generation can be reduced by locating wind turbines off-shore. However, Ek's valuation scenarios did not consider alternative locations of off-shore wind farms with respect to the distance from the shore. To the best of our knowledge the present study of *distance-dependent* disamenities from Danish off-shore wind farms is the first to address the distance aspect explicitly.

3 Method

The size of the individual wind turbine, distance from the shore, size of the wind farms and the number of wind farms are all characteristics, which have an influence on the individual perception of the visual disamenities of off-shore wind farms. From a policy point of view the different disamenity characteristics are very interesting, as they entail important information on welfare economic impacts of locating off-shore wind farms within sight from the shore. To be able to estimate the preferences for reducing the visual disamenities associated with the different characteristics of off-shore wind farms the Choice Experiment valuation method was viewed as ideal for the purpose compared to CVM, which is more holistic in its approach.

Choice Experiments is also known as a Choice Modelling Method, CMM [Hanley *et. al* 2001], which is based on the paper on *conjoint measurement* by Luce & Turkey [1964] who established the theoretical foundation of the CMM used today. During the 1970s, the first attempts to model consumer preferences with CMM, at that time known as *conjoint analysis*, were carried out within the fields of marketing and transportation economics. The aims were to understand the structure of - and to elicit people's preferences for various goods [Green *et. al* 1978]. CMM build on Lancaster's *characteristics theory of value*, which describes a good as a bundle of characteristics having certain levels [Lancaster 1966]. The focus is on how preferences for goods or services are constructed with the goal to identify the utility that individuals derive from the attributes, which compose the good or service in question [Bennett *et. al* 2001] - such as example the different attributes defining visual disamenities of off-shore wind farms.

The revelation of preference is accomplished by presenting respondents with a set of alternatives. The alternatives define the good or service in terms of the key attributes, and different alternatives are described by varying levels of the attributes. CE has a high degree of resemblance to real market situations, where consumers are used to evaluating several products simultaneously, and subsequently to choose between them [Rolfe *et. al* 2001]. By examining the trade-offs between attributes/attribute levels, that are implicit in the choices made by respondents, it is possible to derive an estimate of the utility associated with the different attributes [Garrod *et. al* 1999]. If one of the attributes is measured in monetary units (i.e. price), it is possible to derive estimates of respondents' WTP for the other attributes from the marginal rate of substitution between the monetary attribute and the other attributes [Louviere *et. al* 2000].

4 The Survey

The Choice Experiments valuation survey was based on a sample consisting of three samples of randomly selected persons drawn from the Danish Civil Registration Systems database. A national sample (NA-sample) of 700 respondents represents the Danish population. Two samples of 350 respondents each represent the population living close to the two existing commercial off-shore wind farms at Horn Rev (HR-sample) and Nysted (NY-sample). Information on the attitudes was collected by mail delivered questionnaires, which the respondents completed and returned. In total 375, 141 and 178 questionnaires were returned from the Na, HR and NY samples respectively, whereof 13, 1 and 8 were not completed satisfactorily leaving an effective sample of 362, 140 and 170 respondents. This is equal to an effective response rate of between 40.0 and 51.7%, which can be considered as acceptable [Bateman *et. al* 2002]. In the questionnaire each respondent was asked to evaluate three choice set consisting of two alternative off-shore wind farm layouts. For more information on the study see Ladenburg *et. al* [2005].

4.1 The Scenario

The scenario setting up the choice experiments was based on an off-shore wind power development plan from 1996. In this plan it was stipulated that 35% of the Danish electricity consumption should come from wind power by 2030 [Danish Energy Authority 1996]. 4000 MW was expected to be developed off-shore, which is equivalent to nearly 75% of the total wind power expansion planned in the period. Given the present off-shore capacity of about 400 MW the scenario entails a 3600 MW off-shore expansion. Taking the rapid development in wind turbine technology into account 5 MW turbines (100 m high and 120 m wing span) were used in the valuation scenario to give a realistic description of future development. Consequently, the scenario entails the establishment of 720 (720*5=3600 MW) turbines off-shore. To minimise potential value biases in the survey it was emphasised that the location of future off-shore wind farms would be chosen in such a way that the impact on biodiversity and landscapes would be minimised.

Different payment vehicles were tested in a focus group, i.e. a lump sum payment per household versus a payment depending on electricity consumption. The focus group considered a consumption dependent payment (higher price per kWh) as most fair. However, the focus group acknowledged the difficulties respondents would have remembering the annual household electricity bill. The payment mode was therefore defined as a uniform annual surcharge (lump sum) on all households' electricity bill. Respondents were urged to be absolutely sure that their household would in fact be willing to pay the amount specified in the chosen alternative. In addition a *cheap talk* reminder was included stating that in previous surveys respondents have had a tendency to overstate their WTP – such as recommended in the literature [Cummings *et. al* 1999, List 2002]. Finally a *budget reminder* asked the respondents to consider their budget limitations when making their choices [Arrow *et. al* 1993].

The attributes in the choice sets are presented in Table 2 below.

Table 2: List of attributes defining the visual externalities of off-shore wind farms

Attributes	Description/levels
Distance from the shore	8 km, 12 km, 18 km and 50 km
Number of turbines per wind farm	49, 100 and 144
Number of off-shore wind farms in Denmark[ii]	5, 7 and 14
Annual cost (Euro)/household/year	0, 12.5, 23, 40, 80 and 175

4.1.1 Distance

The distances in Table 2 were set to illustrate possible future locations of wind farms relative to the shore. 8 km from the shore is considered to be the minimum distances for futures wind farms [Gaarde 2003]. 12 and 18 km from the shore are perceived as realistic distances and 50 km is the distance where a wind farm consisting of 5 MW turbines cannot be seen from the shore [Nielsen 2003].

4.1.2 Number of Turbines per Wind Farm and Number of Wind Farms

The number of turbines (49, 100 and 144) represents possible wind farm sizes. 49 turbines per farm is less than the number of turbines in the existing off-shore wind farms at Horns Rev (80 turbines) and Nysted (72 turbines). 100 and 144 turbines pr wind farm must therefore be considered relatively large wind farms, but within the expected range of future wind farms [Madsen 2005]. After counselling with wind farm developers, ELSAM and ENERGY E2, it was decided to work with quadratic shaped wind farms in the visualisations. The number of turbines per wind farms is therefore 7^2, 10^2 and 12^2. In the scenario the total number of turbines must sum up to 720 turbines. Accordingly, the number of turbines per wind farm and the total number of farms are perfectly (negatively) correlated.

4.1.3 Payment Vehicle

The costs/prices were set between 0 and 175 Euros/year assumed to be paid over the electricity bill. The plausibility of levels and payment mode was tested during the focus group interview.

4.1.4 Design of Attributes and Choice Sets

The number of possible combinations given the attributes and the attribute levels are 3*4*6 =72. It was decided to implement a fractional design of 36 alternatives. It would have been possible to do a smaller main effect design, which would increase the representation of each alternative in the data. However, it was believed that the visual impacts associated with the size and distance attributes could be casually correlated. Therefore, it was important to control for to possible interaction effects in the elicited choice model. The alternatives were generated in the SAS system by using the macros and the design efficiency recommendations in Kuhfeld [2004]. The initially generated alternatives were afterwards blocked in choice sets of two and combined in groups of three choice sets. To minimise both the number of dominating alternatives and non causal alternatives the swapping procedure presented in Huber *et. al* [1996] was used to construct the final choice sets. Based on discussions with the focus group – and taking into account the policy frame of the scenario describing the future wind power development in Denmark – it was decided not to include a status quo option in the generated choice sets.

The visual impacts of the generated alternatives were illustrated by a visualisation of each of the alternatives. The visualisations were made by a consulting company specialised in computer based visualisations, see appendix A. It must be emphasised that the generated illustrations represent a view to the wind farms under almost perfectly clear weather conditions. On many days during a year the view to off-shore wind farms will be more blurred due to changing weather conditions. Consequently, the chosen presentation may have resulted in a tendency for respondents to overrate the actual disamenities from off-shore wind farms.

5 The Econometric Model

The respondents' preferences were described formally by use of a random utility function [Manski 1977, Marschak 1960, Thurstone 1927] in which the individual *i*'s, utility from reducing the visual disamenities of the *j* off-shore wind farm outlay (U_{ij}) is described as a function of a deterministic part (V) and a stochastic element (ε) as follows:

$$U_{ij} = V(Z_{ij}, S_i) + \varepsilon$$

where Z represents characteristics of the wind farm outlay, i.e. distance from the coast, number of turbines per wind farm, the total number of wind farms and the cost per household; S characterise the individual, e.g. gender, income etc; i denote the individual respondent; and j the alternative, see Maddala [1983].

The preferences from the chosen alternatives were elicited by use of a conditional logit model based on the utility function described above [McFadden 1974]. If the error terms ε are independently and identically distributed (IID) and follows the Gumbel distribution, the probability that alternative k is selected out of K alternatives is calculated as:

$$\Pr ob(respondent \;\; i \;\; chooses \;\; k) = \frac{\exp(V_{ik})}{\sum_{j=1}^{K} \exp(V_{ij})}$$

where V is the vector comprising both attributes of the alternative and characteristics of the respondent.

The Z in the utility functions represents the attributes of the alternatives evaluated by the respondents. It is with regards to the levels of these attributes that the respondents are assumed to make their choices between the different alternatives. Based on the choices, the relative weight/utility, which the respondents attach to each attribute, can be estimated. These weights are represented by the coefficients of the variables representing the attribute/attribute level, see Hensher and Johnson [1981] for further details. Based on the observed weights, the marginal rates of substitution[iii] between attributes can be estimated, as illustrated in the following general example.

Let Z be defined by a price attribute $\boldsymbol{P}$ and a vector $\boldsymbol{T}$ representing other attributes of the alternatives. The indirect utility function can now be expressed by:

$$V_{nj} = P'\beta_P + T'\beta_T$$

where β_P represents the marginal utility of the price and β_T represents a vector of marginal utilities of the other attributes. Total differentiation of the indirect utility function, holding utility constant (dV/dx_{nj}=0), gives:

$\mathrm{d}V = \beta_P \cdot dP + \beta_T \cdot dT = 0$ and rearranging

$$\frac{dT}{dP} = -\frac{\beta_T}{\beta_P}$$

The above expression is the marginal rate of the substitution between the price attribute and the other attributes of the alternatives. Given that a price attribute is contained in the design, the marginal rate of substitution can be interpreted as the maximum amount the individual is willing to pay to achieve/avoid a change in one of the other attributes.

6 Elicited models and hypothesis:

As presented in section 4, a set attributes (distance to the shore, number of turbines/wind farm and number of wind farms) have been identified to represent the visual disamenities of off-shore wind farms.

However, the perception of the visual disamenities is assumed to be individual. The choice between the presented alternatives is therefore not expected to be homogeneous among the respondents. In theis relation, the perception of the visual impacts of off-shore wind farms and the attitudes towards them are fairly correlated [Ladenburg 2006a]. The analysis of heterogeneity in preferences will therefore take departure in the variables determinant of attitude and the attitude it self. In Ladenburg [2006b] and subsequent analysis the attitudes towards increasing the number of off-shore wind farms was found to covariate with the age of the respondents and the number of visits to the beach. In table 3 below the different variables used in the model are presented together with the associated hypothesis regarding the impact on preferences.

Table 3: Tested variables and hypothesis

Variables	Coding	Interaction	Hypothesis
DIST12*	dummy=1 if distance from the coast=12 km, else=0	-	δU/δDIST12>0
DIST18*	dummy=1 if distance from the coast=18 km, else=0	-	δU/δDIST18>0
DIST50*	dummy=1 if distance from the coast=50 km, else=0	-	δU/δDIST50>0
SIZEL**	dummy=1 if number of turbines =144 km, else=0	-	δU/δSIZEL><0
SIZEM**	dummy=1 if number of turbines =100 km, else=0	-	δU/δSIZEM><0
PRICE	Continuous variable	-	δU/δPRICE<0
Age <30 (A29)	dummy=1 if age<30, else=0	A29*DISTXX	δU/δage29*DISTXX<0
Visits to beach*** (VB)	dummy=1 if visits >6/year, else =0	VB*DISTXX	δU/δVB*DISTXX>0
Attitude towards more off-shore wind farms (AT)	dummy=1 if attitude is negative, else =0	AT*DISTXX	δU/δAT*DISTXX>0

*The distance variable measure in the increase in utility associated with moving wind farms from 8 km (baseline) to 12, 18 and 50 km respectively.

** The size variables measures the difference in utility associated with wind farms with 144 and 100 wind turbines opposed to 49 turbines.

*** The variable is based on the visit to the beach during the winter, as the variation in the visits during the summer is too small.

Besides the presented interactions, other interactions are also tested, see Ladenburg *et. al* [2005].

For each sample two conditional logit models are elicited.

1. Main effect model
2. Trimmed interaction model including significant and causal interaction variables.

7 Results

In the following section the results of the conditional logit regression on preferences for reducing the visual disamenities are presented for the three samples.

7.1 Main effect models

The main effect model refers to a model, which only entails the average preferences of the sample associated with the attributes of the alternatives, see table 4 below.

Table 4: Main effect models

	National		Hornsrev		Nysted	
Variables	β	P<t	β	P<t	β	P<t
DIST12	0.5118	>0.0001	0.5233	0.0093	0.5125	0.0028
DIST18	1.1105	>0.0001	1.2914	>0.0001	0.6277	0.0003
DIST50	1.4254	>0.0001	1.1912	>0.0001	0.9941	>0.0001
SIZEL	-0.1822	0.0615	0.1570	0.3789	0.1209	0.3844
SIZEM	-0.0252	0.8103	0.1898	0.2585	0.0947	0.5158
PRICE	-0.0016	>0.0001	-0.0020	>0.0001	-0.0009	>0.0001
LRchi2	359.30 (6)		146.16 (6)		73.40 (6)	
McFadden R^2	0.2301		0.2534		0.1091	

Overall the coefficient of the different variables in table 4 have the expected sign (DISTXX>0 and PRICE<0) and are strongly significant. The coefficient of the distance variables furthermore appears to more or less be increasing with the distance from the coast. The results consequently fit the hypothesis, as the visual disamenities are reduced with increased distance to the shore. The respondents are thus expected to express stronger preferences for wind farms located at 12, 18 and 50km respectively. The variables representing the size of the wind farms are in general not significant, which is not that surprising. The size variables are perfectly correlated with the total number of wind farms in Denmark. The variables consequently represent a two dimensional problem (number of turbines/wind farms and number of wind farms), which is expected to have diluted the preferences for the size variables.

Looking at the ratios between coefficients in the three models the preferences across samples seem to be relative distinct. This is particular evident when comparing the preferences between the NY-sample and the HR-sample. In spite of this, using the likelihood ratio test (LL-test) for joining data [Swait *et. al* 1993], reveals that the data from three sample can be joined, when accounting for scale differences, see appendix B. This indicates that the preferences across the three samples are not significantly different from each others. However, dummy-coding the attributes for one of the samples in the joint data reveals, that the respondents in the HR-sample have significant weaker preferences for reducing the visual disamenities than respondents in the NY-sample, see Appendix C.

In table 5 below the marginal rates between the price coefficient and the other attributes are presented for the three samples. As presented previously this measure is equivalent with the willingness to pay.

Table 5: Willingness to pay (Euro)/household/year

	National	Hornsrev	Nysted
Variables	WTP	WTP	WTP
DIST12	43	35	76
DIST18	93	86	93
DIST50	119	79	147
SIZEL	*-15*[*]	*10*	*18*
SIZEM	*-2*	*13*	*14*

[*] Numbers in italic denote that the non-price attribute in the main model is insignificant

Even though the LL-test denotes insignificant different preference between samples, the WTPs in table 5 for reducing the visual disamenities across the three samples appear to be heterogeneous. Respondents from the NY-sample have the highest WTPs for moving the off-shore wind farms from the coast. The respondents are wiling to pay 76, 93 and 147 euros/household/year from moving the off-shore wind farms from 8 km to distances 12, 18 and 50 km respectively. These WTPs exceed the WTPs for the NA- and HR samples with regards to moving wind farms to 12 and 50 km. Interestingly the respondents in the HR-sample have the smallest WTP for reducing the visual disamenities and the respondents in the NY-sample the highest. The off-shore wind farm at Nysted is located much closer to the coast then at Horns Rev. It therefore seems like the preferences for reducing the visual disamenities is a function of the experience with and exposure to visual effects from existing off-shore wind farms[iv].

7.2 Trimmed interaction model

The preferences for reducing the visual disamenities are as mentioned expected to be heterogeneous. The heterogeneity is tested by including the presented interaction variables to the main effect model. In table 6 the trimmed interaction models are presented. The trimmed models include the significant and causal interactions. For the full (un-trimmed) interaction models see Appendix D.

Table 6: Trimmed interaction models

	National		Hornsrev		Nysted	
Variables	Β	P<t-value	Β	P<t-value	β	P<t-value
DIST12	0.4141	0.0112	1.2564	0.0001	0.4759	0.0081
DIST18	1.0932	<0.0001	2.2638	<0.0001	0.4262	0.0169
DIST50	1.3284	<0.0001	2.2904	<0.0001	0.8184	<0.0001
SIZEL	-0.1976	0.0478	0.1777	0.3473	0.1239	0.3844
SIZEM	0.0013	0.9920	0.1484	0.4180	0.1168	0.4414
PRICE	-0.0013	<0.0001	-0.0022	<0.0001	-0.0007	0.0002
P_SEX	-0.0006	0.0081	-	-	-0.0006	0.0602
EO_SL	-	-	1.0596	0.0265	-	-
AT_DIST12	-	-	-	-	1.9662	0.0803
AT_DIST18	-	-	-	-	4.6945	0.0030
AT_DIST50	-	-	-	-	4.7251	0.0023
VB_DIST12	0.4599	0.0704	-0.8879	0.0341	-	-
VB_DIST18	0.5266	0.0501	-0.9414	0.0341	-	-
VB_DIST50	0.6272	0.0265	-1.3131	0.0108	-	-
A29_DIST12	-0.5084	0.2042	-1.1949	0.0367	-	-
A29_DIST18	-1.4141	0.0002	-1.8179	0.0008	-	-
A29_DIST50	-0.9274	0.0156	-1.6441	0.0091	-	-
LRchi2	388.33		169.79		104.03	
McFadden R^2	0.2487		0.2944		0.1546	

Before going to the interacted variables associated with the distance parameters, two other significant interaction variables will shortly be commented on. P_SEX, which is a dummy variable for female respondents, represents the difference in utility of the price attribute between male and females. The variable is significant in the NA- and Nysted sample. The coefficient is below zero, which denotes that female respondents are more sensitive towards the price attribute than male respondents. The other interaction variable is EO_SL. The variable is also a dummy variable and represents the difference in preferences between respondent who are members of an environmental organisation and not. $B_{EO\_SL}>0$, meaning, that respondents, who are members of an environmental organisation, have stronger preferences for large wind farms compared to non-members.

In table 6 the different distance interacted variables (AT-, VB- and A29_DISTXX) are included in the models. Looking at the different models, it is apparent, that the models of the samples are quite different both with regard to significant variables and the sign of the significant variables.

The interaction variables between a negative attitude towards more off-shore wind farms and the distances dummies; AT_DIST12, AT_DIST18 and AT_DIST50 (AT_DISTXX) were only found to be significantly different from zero in the NY-sample[v]. In the NY-sample, the coefficients of the AT_DISTXX variables are very high. This denotes that the respondents who have a negative attitude towards more off-shore wind farms also have very strong preference for reducing the visual disamenities of future off-shore wind farms. However, this is apparently only in the case in the NY-sample. A possible explanation could be that the covariance between the attitude towards more off-shore wind farms and perception of the visual impacts is larger in the NY-sample compared to the NA- and HR-sample [Ladenburg 2006b].

The other interacted variable is the interaction between frequency of visit to the beach and the distance dummies; VB_DIST12, VB_DIST18 and VB_DIST50 (VB_DISTXX). VB_DISTXX is significant in both the NA- and HR-samples, but the sign of the variables are different from each other; $\beta_{VB\_DISTXX,\ HR\text{-}sample}$ (negative) $<\beta_{VB\_DISTXX,\ NA\text{-}sample}$ (positive). These results are quite surprising. In table 3 it was hypothesised that $\delta U/\delta VB*DISTXX>0$, which does not correspond uniquely with the models. However, when interpreting the results it is important to take into account the difference in experiences with off-shore wind farms between the NA- and the HR-sample. The respondents in the NA-sample have relatively little or even no experience with the visual disamenities of off-shore wind farms. The respondents from the HR-sample on the other hand are expected to have substantial more experience due the location of an off-shore wind farms in the sample area. The differences in experienced might induce the differences in preferences, meaning that preferences for reducing visual disamenities are reduced when people gets hands on experience with off-shore wind farms.

In this relation it is worth mentioning that the interaction term in the NY-sample is insignificant. With regard to experience with visual disamenities, this might indicate, that the relatively close location to the shore of Nysted off-shore wind farm, could have made the frequent visitors, though more experienced, perceive the visual impacts as more severe, than the same respondents in the HR-sample. These results thus strongly denote the effect of experience with regard to preferences revelation.

With regard to the interaction variable between age and distance, it was expected that that $\delta U/\delta age29*DISTXX<0$[vi]. This means, that younger respondents have weaker preferences for reducing the visual disamenities. Looking at the three individual models, the hypothesis seems to be supported in the NA –and HR-samples, but not in the NY-sample[vii].These results point towards a structural difference in respondents' preferences around the age of 30[viii]. From a policy point of view the observed relationship between the age of respondents and the perception of the disamenities is interesting. It indicates that coming generations might be much less sensitive to visual disamenities from off-shore wind farms than the present older generations. If so, the disamenity costs will tend to decline over time, everything else equal. Again, this is an issue which calls for further investigations.

Overall, the three trimmed interaction models denote that, though average preferences between the three samples appear to be insignificant different, the preferences are rather heterogeneous. This is especially particularly evident with regard significant interaction variables and the sign of the variables[ix].

7.3 Marginal WTP

In the survey, the reductions of visual disamenities are defined on a discrete scale (wind farms can be located on 8, 12, 18 and 50 km). The decision criteria for determining the locations of future wind farms are based on a more continuous scale. It would therefore be relevant to have the preferences for reducing the visual disamenities of off-shore wind farm defined on a more useful scale. The marginal properties of the preferences (WTP/km/household/year) can be explored by estimating the difference in WTP between mowing the wind farms from 8 to 12, 12 to18 and 18 to 50 km from the coast divided with the difference in km. The constructed marginal WTPs are presented in figure 1 below.

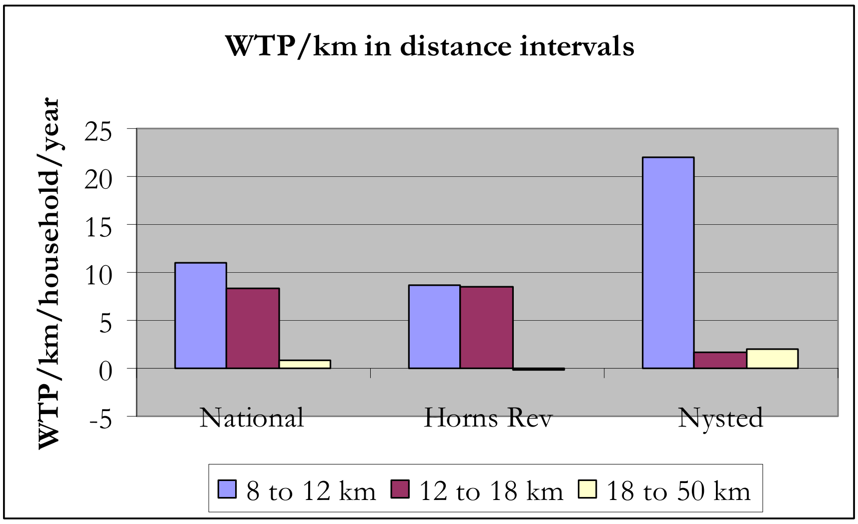

Figure 1: Marginal WTP for reducing the visual disamenities

The marginal WTPs in Figure 1 illustrate the policy relevant aspects of the estimated WTPs in table 5. Overall the distinct intervals defined by the discrete levels of the distance attribute the marginal WTPs drop from between 8-22 euro/km (8-12km) to less than 2 euros/km (18-50 km). The consistency across the three samples, indicate that the relatively small benefits associated with mowing off-shore wind farms very long distances from the shore are rather robust.

These results have interesting policy implications, as the estimated benefits for mowing wind farms to a distance larger than 18 km from the shore apparently are small. This indicates that the welfare economic optimal location of off-shore wind farms hardly can be at a distance where the off-shore wind farm cannot be seen from the shore. Depending on the cost, the optimal location seems to be between 12-18 km from the shore given the size of the turbines (5MW).

8 Conclusions

Off-shore wind farms produce clean energy. However, the off-shore wind farms can cause visual disamenities. From a welfare economic point of view, these disamenities should be taken into account when planning the future off-shore wind power development. Visual disamenities of off-shore wind farms are non-market goods. The associated cost can therefore not be directly observed on the market.

The present study sets up a hypothetical market for visual disamenities of future off-shore wind farms in Denmark using the economic valuation method Choice Experiment. Based on three samples, one national and two local samples, the study analysed peoples' willingness to pay for reducing the visual disamenities of off-shore wind farms - by mowing them to larger distances from the coast. Based on the respondents' choices between alternative off-shore wind farm layouts, varying with regards to the distance from the coast, size of the wind farm, number of wind farms and the increased cost per household, the willingness to pay was estimated. In the national sample, the respondents were on average willing to pay 43, 93 and 119 euros/household/year for mowing 3600 MW off-shore wind farms to 12, 18 and 50 km from the coast compared to locating them at 8 km. The WTPs in the Nysted sample are 76, 93 and 147 euros, whilst the WTPs in the Horns Rev samples are and 35, 86 and 79 euros respectively.

Testing for heterogeneity in preference across the three samples showed that preferences are very heterogeneous between the three samples. However, the heterogeneity is not strictly identical across the samples. In the National - and Horns Rev samples younger respondents have significant weaker preferences for reducing the visual disamenities compared to older respondents, whilst insignificantly different preferences in the Nysted-sample. Similarly, respondents who visit the beach frequently in the National-sample have stronger preferences for reducing visual disamenities compared to less frequently visitors. However, frequent visitors in the Horn Rev - and Nysted-sample have weaker or insignificant different preferences for reducing the visual disamenities, respectively. Finally, respondents with a negative attitude towards more off-shore wind farms only have significant stronger preferences than respondents with a positive attitude for reducing the off-shore wind farms in the Nysted-sample.

Overall the results of the survey demonstrate the importance of incorporating estimates of disamenity costs in the appraisal of future off-shore wind farm projects. More precisely, the results emphasize the need for cautions towards locating off-shore wind farms at short distances from the coast in order to minimize the direct costs of power. However the results also uniformly denote that the marginal benefits associated with mowing off-shore wind farms beyond 18 km from the coast are small. In this relation, the results strongly denote that the welfare economic optimal location of off-shore wind farms only will be at very large distances if the marginal costs of locating an off-shore wind farm one km further away from the coast are small.

Finally, the deviations in preferences (experience, age, attitude and visits to the beach) are worth putting forward, as their policy implications justify further research.

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[i] To estimate the environmental cost of wind power the respondents were asked how much they were willing to pay for increasing the renewable energy capacity by a more efficient use of existing water generating power facilities (no increase in environmental impacts) as opposed to wind power development

[ii] The number of wind farms is perfectly correlated with the number of turbines per wind farm. Consequently, this variable was not included as an attribute in the design of the survey.

[iii] The marginal rate of substitutions is the ratio of marginal utilities of two attributes, and thus expresses how much the individual must be compensated with attribute 1 to forgo attribute 2.

[iv] As discussed in Ladenburg *et. al* [2006] the differences in experience might also relate to differences in newspaper coverage and number of respondents with a view to the wind farms.

[v] The number of respondents with a negative attitude towards more off-shore wind farms in the HR-sample is only 5, which is not enough to estimate all three AT_DISTXX interaction variables, see Appendix C.

[vi] Various age and distance interactions have been tested, such as interaction between ln(age) or age(linear) and the distance parameter. Inclusion of the variable ln(age)*$DIST_i$ improves the model significantly compared to the base model (no interactions). This indicates that the perception of the disamenities of off-shore wind farms is a increasing function of the age of respondents – the younger the respondent the less negative the perception of the visual impact. It turned out that a dummy variable coding depicted this heterogeneity in preferences better. In the final model a dummy variable (AGE29_$DIST_i$), representing respondents younger than 30 years, was included..

[vii] The number of respondents younger than 30 years is however only 10 in the NY sample giving 3*10 observations. This number might be too small to identify significant difference in preferences between younger and older respondents.

[viii] The data set do entail enough observations to verify if the cut of age is exactly 30 years or if preferences smoothly change in the late twenties.

[ix] The trimmed models are non-nested, why the LL-ratio test cannot be used to test for whether the data sets can be joined or not. Testing on the full models, even though each sample model entails insignificant variables, reveals that the data preferences based on the full models are significantly different between the three samples.

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Appendix A: Choice set

Distance: 8 km, No. Turbines: 144, No. Wind Farms: 5 and Price 80 euro/household/year

Distance: 18 km, No. Turbines: 49, No. Wind Farms: 14 and Price 175 euro/household/year

Appendix B: LL-test for pair wise joining of datasets with full models

	2LL Individuel models	2LL-scaled models	CHI-test (15,16)
National-Horns Rev	523.72	551.28 (μ=1.10)	*
National-Nysted	492.57	458 (μ=0.54)	**
Nysted-Horns Rev	266.11	236,03 (μ=2.10)	*

Appendix C: Scaled pair wise joint models with sample specific dummies

	National* - Nysted		Horns Rev* - National		Horns Rev*-Nysted	
Variables	β	P<t	β	P<t	β	P<t
DIST12	0.5085	<0.0001	0.5078	<0.0001	0.5090	0.0028
DIST18	1.1047	<0.0001	1.1118	<0.0001	0.6224	0.0003
DIST50	1.4170	<0.0001	1.4188	<0.0001	0.9992	<0.0001
SIZEL	-0.1860	0.0562	-0.1902	0.0513	0.0932	0.4966
SIZEM	-0.0276	0.7949	-0.0330	0.7566	0.0723	0.6171
PRICE	-0.0016	0.0001	-0.0016	<0.0001	-0.0009	<0.0001
DIST12_ dummy*	0.3489	0.2586	-0.0477	0.8259	-0.2629	0.1772
DIST18_ dummy*	-0.0808	0.7949	-0.0054	0.9840	-0.0306	0.8808
DIST50_ dummy*	0.2615	0.4296	-0.3861	0.1444	-0.4467	0.0386
SIZEL_ dummy*	0.0001	0.6600	-0.0002	0.5222	-0.0001	0.7566
SIZEM_ dummy*	0.3775	0.1286	0.3668	0.0367	0.0012	0.9920
PRICE_ dummy*	0.1772	0.4966	0.1846	0.3272	0.0088	0.9601
LRchi2	429.09		502.68		215.75	
McFadden R^2	0.1913		0.2355		0.1715	

Appendix D: Full interaction models

	National		Hornsrev		Nysted	
Variables	B	P<t-value	B	P<t-value	β	P<t-value
DIST12	0.4353	0.0086	1.2143	0.0002	0.4860	0.1032
DIST18	1.1215	<0.0001	2.2544	<0.0001	0.4010	0.1937
DIST50	1.3073	<0.0001	2.2800	<0.0001	0.2357	0.4655
SIZEL	-0.2131	0.0341	0.1612	0.4010	0.1124	0.4414
SIZEM	-0.0005	1.0000	0.1374	0.4533	0.0896	0.5620
PRICE	-0.0006	0.0118	-0.0022	<0.0001	-0.0007	0.0003
P_SEX	-0.0014	<0.0001	-	-	-0.0006	0.0563
EO_SL	-	-	1.0580	0.0265	-	-
AT_DIST12	-0.2067	0.6672	1.4179	0.2042	1.9907	0.0769
AT_DIST18	-0.5627	0.2462	0.3874	0.7189	4.6907	0.0021
AT_DIST50	0.8155	0.1772	na	na	4.7910	0.0021
VB_DIST12	0.4680	0.0674	-0.9094	0.0309	-0.0077	0.9840
VB_DIST18	0.5346	0.0478	-0.9464	0.0333	0.0910	0.8026
VB_DIST50	0.6056	0.0341	-1.3013	0.0118	0.8200	0.0333
A29_DIST12	-0.4533	0.2671	-1.1442	0.0456	0.1259	0.8966
A29_DIST18	-1.3579	0.0005	-1.8079	0.0009	-0.7246	0.3272
A29_DIST50	-0.9426	0.0148	-1.6387	0.0091	0.5489	0.4840
LRchi2	395.10		171.55		113.00	
McFadden R^2	0.2530		0.2975		0.1680	