

# Visual Disamenity Costs of Off-shore Wind Farms in the Coastal Zone

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## The Influence of Prior Information:

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### Abstract

*There are numerous stakeholders in the coastal zone. However, many of their uses of the zone are rival and/or associated with externalities. In this relation, off-shore wind power generation is a new important stakeholder with a large potential for future resource extraction. However, a view of the wind farms from the shore can cause visual disamenities in the coastal zone. Based on the choices among alternative wind farm outlays, the preferences for reducing visual disamenities from off-shore wind farms were elicited from three samples with different levels of prior information regarding the reduction in resource quality caused by wind farms. The results show a clear picture; the respondents in all three samples are willing to pay for future off-shore wind farms to be moved further from the shore to reduce their visibility. Yet the results also denote that the preferences vary with regards to the level of prior information. On average, the preferences are not significantly different from each other in the three samples. However, in a sub-group analysis of preferences of different user groups, preferences were found to be significantly different in the three samples. Respondents in a local sample, where the off-shore wind farms are located at a large distance from the shore, or a national sample, have significantly lower WTPs compared to another local sample in Nysted, where the wind farms are located close to the shore. From a policy point of view, these results are noteworthy, as they indicate that the level of prior information affects preferences for reducing visual disamenities. More specifically, the results indicate that initially locating off-shore wind farms relatively close to the shore might induce stronger preferences for reducing visual disamenities from future off-shore wind farms compared to the preferences that may have been induced if off-shore wind farms were initially located at larger distances.*

Keywords: Visual disamenities, off-shore wind farms, willingness to pay, prior information, choice experiments.

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## 1 Introduction

The coastal zone provides extraction and use of various types of goods and services. However, many of these uses are rivalrous in use and/or are associated with externalities. Off-shore wind power generation is a new type of resource extraction and vast opportunities for large scale exploration are expected. However, off-shore wind farms are strongly associated with visual externalities. The visual externalities in the coastal zone can be reduced – and even eliminated – by placing wind farms at greater distances from the coast. However, the costs per kWh produced increase as the distance and depth of the water is augmented. Focusing on the visual disamenities, the welfare economics choice of location of off-shore wind farms becomes a trade-off between the minimization of the visual disamenities/externalities, on the one hand, and the acceptance of higher costs of power generation on the other. A welfare economics appraisal of alternative wind farm locations requires the elicitation of preferences and the monetisation of the un-priced externalities.

The visual disamenities of offshore wind farms have previously been analysed in a study by Ladenburg and Dubgaard (2006). Using a sample representing the general population in Denmark, they find that Danish households hold significant preferences for reducing the visual disamenities of off-shore wind farms. Presently, only a few off-shore wind farms are operating world wide. Few people therefore have prior information about/experience with the decrease in the resources quality caused by visual disamenities from off-shore wind. Therefore, the elicited preferences of such a good might not be representative of the preferences in the long run, as more off-shore wind farms are raised and the level of prior information increases.

In the present paper, the relation between preferences for reducing visual disamenities of off-shore wind farms and prior information is explored. This is possible as Denmark was the first country to establish large commercial off-shore wind farms. The different levels of prior information are obtained by pooling the sample from Ladenburg and Dubgaard (2006) with two samples consisting of people living in the vicinity of the two existing off-shore wind farms in Denmark; Nysted and Horns Rev. From a marine resource point of view, this information is essential as it concerns the perceptions of communities in the

coastal zone located in the vicinity of off-shore wind farms regarding visual disamenities and the potential long run perceptions of the population in general.

## **2 Visual externalities of off-shore wind farms**

The numbers of off-shore wind farms are small worldwide. Indeed, to date there are only two large scale wind farms in operation, both of which are in Danish waters. However, a significant number of off-shore projects are under construction, in tender or under planning. This indicates that an increase in visual disamenities in the coastal zone might be evident in the near future.

Visual disamenity can be categorised as being an external effect of wind power generation, a cost which is borne by society at large. Assessing the cost of the external effects of energy production has been the focus of research since the beginning of the 1980's (Schuman and Cavanagh, 1982). The number of studies increased during the 1990s as a consequence of growing concern amongst European policy makers over external costs (European Commission, 1995; European Commission, 1999).

In the previous years, the external effects of *wind* power generation have been investigated using different environmental valuation methods to elicit the monetary values of the externalities, see Sundqvist and Söderholm (2002). The estimated costs are not uniformly defined. Studies using the house price method to examine the relationship between property prices and wind turbines in the adjacent area do not, generally speaking, reveal any statistically significant effects on house prices from adjacent wind turbines (Sterzinger et al., 2003).

In contrast, the results from stated preference studies denote that the external effects of wind power are significant. The studies have different approaches to analyse wind power generated externalities. However, they jointly verify that people have preferences for reducing different types of external effects from wind turbines such as visual disamenities, reductions in wildlife etc, see Ladenburg & Dubgaard (2006) for a more detailed description. To the best of the author's knowledge, Ladenburg & Dubgaard (2006) is the only study to date, which elaborates on the visual disamenities associated with locating off-shore wind farms at different distances from the shore.

### 3 Method

The elicitation of preferences for reducing visual disamenities of off-shore wind farms in the coastal zone is performed by applying the stated preferences method, Choice Experiments (Louviere and Woodworth, 1983). Thereby it became possible to include the different characteristics of off-shore wind farms, which have an influence on the individual's perception of their visual disamenities, such as distance from the shore, size of the turbines, size of wind farms and number of wind farms.

Choice Experiments is also known as a Choice Modelling Method, CMM (Hanley et al., 2001). The theoretical core of CMM is research performed by Lancaster on *characteristics theory of value*, which describes a good as being a bundle of characteristics having certain levels (Lancaster, 1966). The focus of the theory is on how preferences for goods or services are organised with the goal to identify the utility that individuals derive from the attributes, which compose the good or service in question (Bennett and Adamowicz, 2001) - for example the different attributes defining the visual disamenities of off-shore wind farms.

During the 1970s, the CMM<sup>2</sup> was initially used to model consumer preferences for various market goods. The aims were to understand the structure of, and to elicit people's preferences for, various goods (Green and Srinivasan, 1978).

The revelation of preference is realised 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. 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. 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).

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<sup>2</sup> CMM what at that time known as *conjoint analysis*

## 4 The Survey

The Choice Experiments valuation survey was based on a sample consisting of three samples of randomly selected individuals 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 Horns Rev (Hr-sample) and Nysted (Ny-sample). Information on the preferences for the visual disamenities 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, of these 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%. Given the low familiarity with the good in question and to keep the cognitive burden at a minimum, each respondent was asked to evaluate three choice sets consisting of two alternative off-shore wind farm layouts.

### *4.1 The Scenario, choice of attributes and attributes levels*

Development of the questionnaire, choice of attributes, attribute levels etc. are presented in details in Ladenburg and Dubgaard (forthcoming). In the present section of the scenario, choice of attributes and attributes levels are shortly presented.

The setting up the valuation experiments was based on an offshore wind power development plan from 1996. The plan stipulated that 35% of Danish electricity consumption should come from wind power by 2030 (Danish Energy Authority, 1996). 4000 MW was expected to be developed offshore, which was equivalent to nearly 75% of the total wind power expansion planned in the period. Given the present offshore capacity of about 400 MW, the scenario entailed an offshore expansion of 3600 MW. 5 MW turbines (100 m high and with a 120 m wing span) were used in the valuation scenario to give a realistic description of future development (at present the largest offshore wind

turbines in Denmark are between 2 and 2.3 MW). Consequently, the scenario entails the establishment of 720 ( $720 \times 5 = 3600$  MW) turbines offshore.

To represent the visual disamenities, the distance from the coast, size of the wind farm and number of wind farms were chosen as attributes, see table 1. In Denmark, 8 km is the minimum accepted distance from the shore for future large scale wind farms (Environmental Steering Group, 2004)<sup>3</sup> and is used as the bench mark distance in the survey. Distances of 12 and 18 km from the shore are considered as being realistic whilst 50 km is the technical distance from which a wind farm consisting of turbines as large as 5 MW cannot be seen from the shore due to the curvature of the earth (Nielsen, 2003). The number of turbines (49, 100 and 144) represents possible wind farm sizes. The total number of turbines in the scenario must sum to approximately 720 turbines. Accordingly, the number of turbines per wind farm and the total number of farms are almost perfectly (negatively) correlated ( $14 \times 49 = 686$ ,  $7 \times 100 = 700$  and  $5 \times 144 = 720$ ). The visual impacts of the associated with the different combinations of attributes were illustrated by a computer based visualisation, which was prepared by a specialist consultancy company.

The payment mode applied was defined as a uniform annual surcharge (lump sum) on all the households' electricity bills. In the scenario, the respondents were urged to be absolutely sure that their household would in fact be willing to pay the amount specified in

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<sup>3</sup> The *Environmental Steering Group* is a panel of experts from Elsam Engineering, Energy E2, the Danish Forest and Nature Agency and the Danish Energy Authority. The Steering Group coordinates the *Danish Monitoring Programme for Off-Shore Wind Farms*, which comprises several studies of the environmental impact of off-shore wind farms, including the study behind the present paper (Dong Energy et al., 2006)

the chosen alternative and a “cheap talk” reminder was included. (Cummings and Taylor, 1999; List, 2002).

**Table 1: 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 <sup>4</sup>	5, 7 and 14
Annual cost (Euro)/household/year	0, 12.5, 23, 40, 80 and 175

#### **4.2 The choice set design**

A fractional design of 36 alternatives was implemented (a full factorial design encompass 72 alternative). It would have been possible to do a smaller main effect design, however it was believed that the visual impacts associated with the size and distance attributes could be causally correlated. Therefore, it was important to control for the possible interaction effects, size\*distance, in the elicited choice model. The alternatives were generated in the SAS system using the macros and the design efficiency recommendations found in Kuhfeld (2004). The initially generated alternatives were 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 and Zwerina (1996) was used to construct the final choice sets.

The decision to develop offshore wind power has already been taken by politicians.

Consequently, an opt-out alternative was not included.

<sup>4</sup> The number of wind farms is almost 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.

## 5 The sample

Table 2 below displays the distribution of the socio-demographic characteristics of the respondents in the three samples. The distributions of the samples are compared in the two outermost columns to the right.

**Table 2: Distribution of socio-demographics in the samples**

Socio economic characteristics	National Sample (%)	Horns Rev Sample (%)	Nysted Sample (%)	NA	HR
<b>Age</b>					
20-29	15.83	17.65	7.60	NS <sub>HR</sub> , ** <sub>NY</sub>	** <sub>NY</sub>
30-39	20.00	19.85	16.37		
40-49	27.22	20.59	26.90		
50-59	25.00	28.68	25.00		
60-65	11.94	13.85	24.12		
<b>Gender</b>					
Male	53.13	46.81	46.81	NS <sub>HR</sub> , * <sub>NY</sub>	NS <sub>NY</sub>
Female	46.87	53.19	53.19		
<b>Income</b>					
>300,000 DKK	74.31	80.00	68.64	NS <sub>HR</sub> , NS <sub>NY</sub>	** <sub>NY</sub>
150-299,999 DKK	19.06	13.57	23.67		
<150,000 DKK	6.63	6.43	7.69		
<b>Education after high school</b>					
High (>4 years)	13.92	3.55	2.34	** <sub>HR</sub> , *** <sub>NY</sub>	* <sub>NY</sub>
Middle(2-4 years)	27.27	29.08	20.47		
Low (<2 years)	58.81	67.38	77.19		
<b>Visit the beach in wintertime</b>					
At least one visit/week	10.66	14.29	35.26	NS <sub>HR</sub> , *** <sub>NY</sub>	*** <sub>NY</sub>
Fewer visits	89.34	85.71	64.74		

In all, the distributions of the different socio-demographics of the respondents in the samples are significant different from each other. This denotes, with regards to the presented socio-demographics, that the samples are different from each other overall. However, the differences in distribution between the samples are not strictly uniform. Except for education, the distributions in the Hr-sample are not significantly different from

the distributions in the Na-sample. In the estimated models for preferences for reducing visual disamenities, potential differences in preferences between the three samples for reducing the visual disamenities of off-shore wind farms might be caused by differences in the socio-demographics. To account for these differences, the socio-demographic variables will be included in the analysis of preferences.

## 6 Prior information and willingness to pay

The aim of the present paper is to analyse whether differences in prior information between respondents in three independent data sets have an influence on their preferences for reducing the visual disamenities of future off-shore wind farms. In the following a prior information WTP model is presented, followed by a discussion of the differences in prior information in the three samples. Finally the econometric model applied is presented.

### 6.1 Prior information

The influence on preferences as a function of the level of the enclosed information was initially analysed in a number of studies using the contingent valuation method in the 1980's, see Blomquist and Whitehead (1998). Recently, in the paper by Blomquist and Whitehead (1998) the difference in perceived and objective quality of the resource was investigated. In their paper, the willingness to pay in stated preferences studies is modelled as a function of the perceived quality of the environmental good,  $q^5$ . Following Blomquist and Whitehead (1998), the information effect on perception of the environmental change can be expressed by:

$$q[\theta, I] = \beta\theta + \delta I \quad (1)$$

Where  $\beta$  and  $\delta$  are “learning parameters”, which are related to the level of prior information ( $\theta$ ) and the level of enclosed information in the survey ( $I$ ). In this relation, it is important to highlight that the focus in the present study is differences in prior information ( $\theta$ ) and not enclosed information ( $I$ ). The enclosed information in the present paper is thus kept identical across the three samples analysed<sup>6</sup>.

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<sup>5</sup> In the present study the perceived quality of the environmental good should be interpreted as the perceived reduction in the quality of the environmental good.

<sup>6</sup> The set of for testing prior information thus resembles the study by Tkac (1998).

Referring to (2), the perceived quality of the environmental good is formulated a function (positive, as  $\beta > 0$ ) of the objective perception of the quality and the information level. According to (2), if the enclosed information is identical between respondents in the survey, but prior information varies between respondents, the perceived information and consequently stated preferences will, everything else being equal, also vary.

## **6.2 Prior information in the three samples**

In the present study the prior information is assumed to be different between the three samples. In the two local samples (Horns Rev and Nysted) the respondents have personal experience with the visual disamenities of the off-shore wind farms and consequently a higher level of prior information regarding the reduction in the resource quality caused by off-shore wind farms. This level of prior information is assumed to be absent from the national sample. Between the two local samples, the prior information is also expected to be different. This is particularly evident with regards to the location of the Nysted and Horns Rev off-shore wind farms in relation to urban areas. The off-shore wind at Nysted is located approximately 10 km from the coastline. The wind farm can be seen from a considerably large number of permanent residences and summerhouses compared to the wind farm at Horns Rev, which is sited 14 km from the coastline. Furthermore, the wind farm at Nysted is visible from the town harbour, which is an important meeting place for the local people of Nysted town (Ladenburg *et. al*, 2006a; 2006b). These differences create dissimilar visual interferences, which are assumed to give rise to different levels of prior information between the two local samples. As such, the prior information in the NY-sample seems to entail a higher degree of visual disamenity and supports a more negatively orientated attitude towards visual disamenities compared to the prior information level in the HR-sample.

## **6.3 Econometric model**

The respondents' preferences for reducing visual disamenities from off-shore wind farms 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 ( $\varepsilon$ ) as follows:

$$U_{ij} = V(Z_{ij}, S_i) + \varepsilon_{ij} \quad (2)$$

where  $Z$  represents characteristics of the wind farm layout, i.e. distance from the coast, number of turbines per wind farm, the total number of wind farms and the cost per household;  $S$  characterises the individual, e.g. gender, income etc;  $i$  denotes the individual respondent; and  $j$  the alternative, see Maddala (1983).

Inserting (1) in (2), the indirect utility function can be expressed by:

$$V_{ij} = Z_{ij}(q_i[\theta, I]) + Z_{ij}(S_i) \quad (3)$$

The utility associated with the different characteristics affecting the visual disamenities of the off-shore wind farms is divided into two components, a component  $Z_{ij}(q_i[\theta, I])$ , relating to differences in prior and perceived information, and a component relating to the characteristics of the individual  $Z_{ij}(S_i)$ . The decomposition of the utility function makes it possible to take into account the fact that otherwise identical individuals express different preferences for reducing the visual disamenities of off-shore wind farms based on differences in prior, and thereby perceived, information about the quality of the resource.

The probability that an individual chooses alternative  $j$  from a choice set  $C_n$  is given by:

$$\Pr(j|C_i) = \Pr(V_{ji} + \varepsilon_{ji} > V_{ni} + \varepsilon_{ni}, \text{ all } n \in C_i) = \Pr(Z_{ij}(q_i[\theta, I]) + Z_{ij}(S_i) + \varepsilon_{ji} > Z_{ni}(q_i[\theta, I]) + Z_{ni}(S_i) + \varepsilon_{ni}) \quad (4)$$

The preferences from the chosen alternatives are elicited by use of a conditional logit model based on the utility function described above (McFadden, 1974). If the error terms  $\varepsilon$

are independently and identically distributed (IID) and follow the Gumbel distribution, the probability that alternative  $j$  is selected out of  $N$  alternatives is calculated as:

$$\text{Prob}(\text{respondent } i \text{ chooses } j) = \frac{\exp(Z_{ij}(q_i[\theta, I]) + Z_{ij}(S_i))}{\sum_{n=1}^N \exp(Z_{ni}(q_i[\theta, I]) + Z_{ni}(S_i))} \quad (5)$$

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 using maximum likelihood estimation.

These weights are represented by the coefficients of the variables representing the attribute/attribute level, see Louviere *et al.* (2000) for further details. Based on the observed weights, the marginal rates of substitution<sup>7</sup> between attributes can be estimated. If the denominator is the parameter of the cost attribute used in the study,  $\beta_{\text{cost}}$  the marginal rate of substitution between the denominator and numerator can be interpreted as the willingness to pay for the associated change in the numerator variable,  $\beta_{xi}$ :

$$\text{WTP} = \frac{\beta_{xi}}{-\beta_{\text{cost}}} \quad (6)$$

## 7 Results

In the following section the results of the conditional logit regression on preferences for reducing the visual disamenities are presented for each of the three samples. As presented in section 4, a set of attributes (distance to the shore, number of turbines/wind farm and number of wind farms) have been identified as representing various aspects of the visual disamenities of off-shore wind farms.

However, according to (2) and (3), the perception of the visual disamenities might be heterogeneous in the samples. In Ladenburg and Dubgaard (2006), the preferences for

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<sup>7</sup> 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.

reducing the visual disamenities covariate with the age of the respondents and whether or not the respondents have a view of off-shore wind farms from their residence or summer house.

As the present paper includes the dataset from Ladenburg and Dubgaard (2006), it is natural to analyse the co-variance of the same variables in the HR and NY data sets. However, in the analysis of preferences, it turned out that the visit rate of the respondents to the beach was a much better indicator of the direct use values represented by the view from residence variable used in Ladenburg and Dubgaard (2006). Beside the age of the respondents and the visit rate to the beach, the present analysis of preferences will incorporate a large number of socio-demographic variables, which are presented in table 3 below.

**Table 3: Variables tested in the econometric models**

Variables	Coding
Attributes of off-shore wind farms	
DIST12	dummy=1 if distance from the coast=12 km, else=0
DIST18	dummy=1 if distance from the coast=18 km, else=0
DIST50	dummy=1 if distance from the coast=50 km, else=0
SIZEL	dummy=1 if number of turbines =144 km, else=0
SIZEM	dummy=1 if number of turbines =100 km, else=0
SIZEM	Continuous variable
Socio-demographic	
Age <30 (A29)	dummy=1 if age<30, else=0
Medium level of education (ME)	dummy=1 if respondents has 2-4 years of education after high school, else =0
High level of education (HE)	dummy=1 if respondents has more than 4 years of education after high school, else =0
Income 300.000 (INC3)	dummy=1 if respondents has a household income> 300,000 per year, else =0
Income 150-299,999 (INC2)	dummy=1 if respondents has a household between 150,000-299,999 per year, else =0
Visits to beach* (VB)	dummy=1 if visits >6/year, else =0
Recreational boater (RB)	dummy=1 if respondents is a recreational boater, else =0
Angler (AN)	dummy=1 if respondent is a angler, else =0

For each sample two models are elicited.

1. Main effect model, which only includes the attributes of the off-shore wind farms
2. Interaction model.

## 7.1 Main effect models

The main effect model refers to a model, which can be characterized as a sample average preference model. In table 4 below the main effect models for the three samples are presented.

**Table 4: Main effect models for the three samples**

Variables	National		Horns Rev		Nysted	
	B	P<t	B	P<t	B	P<t
DIST12	0.5321	<0.0001	0.4899	0.0180	0.5094	0.0030
DIST18	1.1788	<0.0001	1.3379	<0.0001	0.6089	0.0004
DIST50	1.4680	<0.0001	1.2369	<0.0001	0.9934	<0.0001
SIZEL	-0.2055	0.0386	0.1476	0.4239	0.0989	0.4700
SIZEM	-0.0274	0.7949	0.1896	0.2717	0.0844	0.5590
PRICE	-0.0122	<0.0001	-0.01648	<0.0001	-0.0066	<0.0001
LL(0)	-758.996		-283.497		-336.176	
LL( $\beta$ )	-577.136		-210.399		-301.016	
No. obs	1095		409		485	
McFadden R <sup>2</sup>	0.2388		0.2738		0.1036	

Overall, the coefficient of the different variables in table 4 have the expected sign ( $DIST_i > 0$  and  $PRICE < 0$ ) and are strongly significant. Furthermore, the coefficient of the distance variables appears to be increasing with the distance from the coast as represented by the variables. The results are theoretical as expected, as the visual disamenities are reduced as the distance from the shore is increased. The respondents thus express stronger preferences for wind farms located at 50 km compared to 18 km, 18 km compared to 12 km and 12 km compared to 8 km, respectively.

As mentioned previously, the wind farm size variables (number of turbines per farm) are almost perfectly (negatively) correlated with the attribute controlling for the total number of off-shore wind farms in Denmark. Some respondents may prefer larger but fewer wind farms whilst other respondents may prefer many smaller wind farms so that the visual externality per wind farm is minimised. Except for  $\beta_{SIZEL\_Na-sample}$ , the size variables (SIZEM and SIZEL) are both negative but are not statistically significant. It was not possible to identify any systematic differences between the respondents regarding whether they preferred relatively large numbers of small wind farms or relatively few large wind farms.

Comparing the parameter estimates across the three models, the estimates seem to be rather different. However, given potentially different scale parameters in the two models, the parameter estimates cannot be directly compared across the models (Swait and Louviere, 1993). However, a direct comparison *can* be made with regards to the WTP estimates, as the scale parameter cancels out.

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 (€)/household/year

Variables	Na- sample	Hr- sample	Ny- sample	$\Delta WTP_{Na-Ho}$ ( $CI_{NaVsCI_{Ho}}$ )	$\Delta WTP_{Na-Ny}$ ( $CI_{NaVsCI_{Ny}}$ )	$\Delta WTP_{Ho-Ny}$ ( $CI_{HoVsCI_{Ny}}$ )
	WTP [95% CI]	WTP [95% CI]	WTP [95% CI]			
	44	30	75	14	-31	-45
DIST12	[23-65]	[5-55]	[20-130]	(NS)	(NS)	(*)
	98	81	90	17	8	-9
DIST18	[75-121]	[54-108]	[33-147]	(NS)	(NS)	(NS)
	122	75	147	47	-23	-72
DIST50	[98-146]	[44-106]	[82-212]	(*)	(NS)	(NS)
	-17	9	15	-26	-32	-6
SIZEL	[-33- -1]	[-13-31]	[-29-59]	(NS)	(NS)	(NS)
	-2	11	13	-13	-15	-2
SIZEM	[-19-15]	[-9-31]	[-28-54]	(NS)	(NS)	(NS)

Note: 95% confidence intervals [-] are estimated using the Delta Method in accordance with Greene (2003) and Hanemann and Kanninen (1999).  $CI_XVsCI_Y$  denotes a t-test of overlap between the two confidence intervals of sample y and x. (\*) indicates no significant overlap at the 95.0% level. (NS) indicates a significant overlap, i.e. no significant difference in WTP.

From table 5 the estimates of WTP indicate that preferences for the  $DIST_i$  are different between the three samples. In the Na-sample, the respondents are annually willing to pay 44, 98 and 122 euros per household for locating off-shore wind farms at 12, 18 or 50 km from the shore respectively. With reference to the estimated confidence intervals of WTP, this means that on average the location of off-shore wind farms at 50 km is significantly preferred to 18 km, which is significantly preferred to 12 km and so forth. Accordingly, the respondents in the Na-sample have unambiguous preferences for locating off-shore wind farms at larger distances.

The WTPs in the Hr-sample are generally smaller than in the Na-sample. The respondents are thus willing to pay 30, 81 and 75 euros per household per year to locate off-shore wind farms at 12, 18 or 50 km respectively. Nevertheless, it is only with regards to the WTP for locating the wind farms at 50 km that the difference in WTP is significant. Interestingly, the respondents in the Hr-sample do not hold unambiguous preferences for situating off-shore wind farms at larger distances.  $WTP_{DIST18}$  is thus not significantly different than  $WTP_{DIST50}$ . So in this relation the preferences in the Hr-sample seem to be different than those in the Na-sample.

Compared to the other samples, the WTPs in the Ny-sample exceed the WTPs in the two other samples with the exception of  $WTP_{DIST18\_Na-sample}$ . On an annual basis, the respondents are willing to pay 75, 90 and 147 euros per household. However, due to the large variance of the estimated WTP in the Ny-sample, the WTPs are only significantly different when compared to  $WTP_{DIST12}$  in the Hr-sample. Interestingly,  $\Delta WTP_{DIST12\_DIST18}$  and  $\Delta WTP_{DIST18\_DIST50}$  are not significantly different from zero. The respondents are thus indifferent regarding whether off-shore wind farms are located at 12 or 18 km and 18 or 50 km from the coastline ( $\Delta WTP_{DIST12\_DIST50}$ ). These properties indicate that the preference structure in the Ny-sample might be different from the preference structure in the Na- and Hr-samples.

An alternative way to examine the preference differences between the three samples is to consider differences in overall preferences. To formally test the hypothesis of identical *preferences* in the two splits, a likelihood ratio test (LR) for nested models is conducted. The test statistic:

$$LR = -2(LL_{pooled\ model} - (LL_{splitA} + LL_{splitB})) \quad (9)$$

is asymptotically  $\chi^2$ -distributed with  $(K+1)$  degrees of freedom, where  $K$  is the number of variables in the models (Swait and Louviere 1993). The test results are displayed in table 6.

Table 6: LR test for equality of model parameters, main effect models

$LL_{SampleX} + LL_{SampleY}$	$LL_{pooled\ model}$	LR-test (DF)	P-value
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Na- vs. Hr-sample	-579.570-205.885=-785.455	-791.453 ( $\mu = 1.1^{NS}$ )	11.72 (6)	0.069
Na- vs. Ny-sample	-579.570-303.883=-883.453	-886.103 ( $\mu = 0.55^{***}$ )	5.30 (7)	0.623
Ny- vs. Hr-sample	-303.883-205.885=-509.768	-513.75566 ( $\mu = 0.45^{***}$ )	7.97 (7)	0.335

Using a grid search procedure, the ratio between scale parameters,  $\mu$ , in the three samples is estimated. Starting with the test for equality of parameters in the Na- and Hr-sample, the LR-test statistics is 11.72, which with 6 degrees of freedom (scale parameter insignificant) gives a P-value 0.069. Consequently, the test for equality of model parameters in the Na- and Hr-sample can not be rejected on a 5% level, but is rejected on a 10% level. The tests for equality of parameters in the Na- and Ny-sample and Ny- and Hr-samples are also insignificant.

Accordingly, the LR-test denotes that the preferences in the three splits are not significantly different from each other when testing on the main effect models.

## 7.2 Interaction models

In addition to variables representing the attributes of the wind farm alternatives the interaction models also incorporate the main socioeconomic characteristics of respondents presented in table 7. The interaction models are presented for each sample in the table below.

Table 7: Interaction models

	National sample		Hornsrev sample		Nysted sample	
	Parameter estimate	P-value	Parameter estimate	S.E	Parameter estimate	S.E
Main effects variables						
DIST12	0.2393	0.090	1.2877	0.001	0.3559	0.268
DIST18	0.8166	<0.001	2.3418	<0.001	0.4344	0.174
DIST50	0.9801	<0.001	2.5925	<0.001	0.0683	0.838
SIZEL	0.0023	0.976	0.1765	0.415	0.2085	0.201
SIZEM	-0.1344	0.056	0.2392	0.215	0.1185	0.432
PRICE	-0.0024	<0.001	-0.0047	0.023	-0.0006	0.344
DIST <sub>i</sub> interacted variables						
A29*DIST12	-0.1608	0.684	-1.2800	0.047	0.0526	0.957
A29*DIST18	-1.2423	0.001	-1.9016	0.003	-0.6607	0.400
A29*DIST50	-0.8657	0.022	-1.9853	0.005	-0.3234	0.712
ME*DIST12	0.1758	0.574	0.3501	0.487	0.0610	0.901
ME*DIST18	0.0126	0.969	0.7812	0.156	0.3532	0.459
ME*DIST50	-0.0222	0.948	0.6174	0.316	1.9380	0.004
HE*DIST12	0.0059	0.988	-0.3236	0.795	1.5358	0.310
HE*DIST18	-0.1572	0.702	2.4715	0.328	1.0813	0.456

HE*DIST50	0.3344	0.465	1.8005	0.484	3.5928	0.303
A*DIST12	-0.2037	0.495	0.6746	0.268	1.0024	0.032
A*DIST18	-0.4083	0.198	2.6147	0.001	0.0331	0.937
A*DIST50	-0.4097	0.230	1.3732	0.097	0.7655	0.117
HS*DIST12	0.0274	0.941	-1.6088	0.025	-0.1168	0.824
HS*DIST18	-0.1944	0.619	-1.9556	0.008	0.2445	0.617
HS*DIST50	-0.3160	0.453	-2.0164	0.015	0.8234	0.174
VB*DIST12	0.6261	0.023	-0.9018	0.048	-0.1512	0.694
VB*DIST18	0.8609	0.006	-1.6832	0.003	0.1707	0.648
VB*DIST50	0.9742	0.005	-1.7956	0.006	0.5887	0.138
PRICE interacted variables						
INC2*PRICE	0.0015	0.015	0.0028	0.180	0.0001	0.985
INC3*PRICE	0.0021	0.008	0.0017	0.395	-0.0004	0.495
A29*PRICE	0.0009	0.020	-0.0004	0.643	0.0004	0.574
ME*PRICE	-0.0002	0.473	0.0000	0.954	-0.0014	0.012
HE*PRICE	-0.0004	0.233	-0.0015	0.494	-0.0017	0.558
A*PRICE	0.0007	0.013	0.0004	0.577	0.0011	0.008
HS*PRICE	0.0007	0.043	-0.0020	0.052	-0.0006	0.275
VB*PRICE	-0.0004	0.158	0.0011	0.059	-0.0001	0.670
LL(0)	-758.996		-283.497		-336.176	
LL( $\beta$ )	-554.278		-178.357		-279.6229	
No. obs	1095		409		485	
McFadden R <sup>2</sup>	0.2721		0.3709		0.1752	

From table 7, it is obvious that the heterogeneity in preferences across subgroups in the samples is different. The preferences of subgroups, defined by the demographic variables, are presented in the following subsections.

### 7.2.1 Income

In the Na-sample, respondents from middle and high income households have expressed significantly lower marginal utility of income than respondents from low income households ( $\beta_{INC2\_PRICE}$  and  $\beta_{INC3\_PRICE} > 0$ ). In the Hr-sample,  $\beta_{INC2\_PRICE}$  and  $\beta_{INC3\_PRICE}$  are also positive, but they are insignificant on 95% level. The sign of the  $\beta_{INC2\_PRICE}$  and  $\beta_{INC3\_PRICE}$  are mixed and the parameters highly insignificant, which denotes that respondents from middle and high income households have expressed the same level of marginal utility of incomes as respondents from low income households. However, taking into account that the WTPs in general were found to be higher in the Ny-sample compared to in the Na- and Hr-samples, the preferences of respondents from middle and high income households might not be different. These properties will be tested using the LR-test in the subsequent section, see 7.3.

### 7.2.2 Age

Starting with the  $DIST_i$  interacted variables, respondents younger than 30 years ( $AGE29$ )<sup>8</sup> have significantly weaker preferences in the Na- and Hr-samples for sitting off-shore wind farms at 12, 18 or 50 km from the coast compared to the older respondents. The joint utility of reducing the visual disamenities for respondents below 30 years ( $\beta_{DIST_i} + \beta_{AGE29\_DIST_i}$ ) is not significantly different from zero in the Na- and Hr-sample. In other words, respondents younger than 30 years seem to be indifferent as to whether wind farms are situated at 8, 12, 18 or 50 km from the shore in the Na- and Hr-samples. In the Ny-sample, the younger respondents also have weaker preferences but they are not significant. In this relation it should be highlighted that the preferences for reducing visual disamenities in a main effect model, which only includes respondents younger than 30 years, are not significantly different from zero. This indicates that the younger respondents in the Ny-sample are also indifferent as to whether off-shore wind farms are located at 8 km, 12 km, 18 km or 50 km from the coast. However, due a much larger variance on the parameter estimates, the results are less clear compared to the Na- and Hr-samples. Referring to the PRICE interacted variables; the younger respondents in the Na-sample have expressed a significantly lower level of disutility of income compared to older respondents.

The observed non-preferences for reducing the visual disamenities from off-shore wind farms across all three samples are interesting, as they jointly indicate that younger respondents find off-shore wind farms less intrusive compared to older respondents. These findings are unique in relation to estimating WTPs for reducing disamenities from off-shore wind farms, but are supported by the literature relating to attitudes towards wind power generation and wind turbines. In Ek (2005), Firestone and Kempton (2007), Bishop and Miller (2007) and Ladenburg (forthcoming), younger respondents generally have a more positive attitude towards wind turbines (on-land and off-shore). As discussed in Ladenburg and Dubgaard (forthcoming), a possible explanation of the observed age dependent preference relation could be that the “mental landscape” of the respondent, typically referring to a landscape of the past (Short, 2002), is different. The mental

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<sup>8</sup> Various age and distance interactions have been tested. Inclusion of the variables  $\ln(\text{age}) * DIST_i$ ,  $\text{age} * DIST_i$  and  $\text{age}^2 * DIST_i$  improve the model significantly compared to the base model (no interactions). This indicates that the perception of the disamenities of off-shore wind farms depends on the age of respondents. It became evident that a dummy variable coding depicted this heterogeneity in preferences better in the Na. and Hr-samples.

landscape of younger respondents has always included wind turbines, whilst the older respondent recalls a pristine landscape with no wind turbines.

### 7.2.3 Education

The respondents with either a middle or high level of education systematically (for all  $DIST_i$  variables) do not have significantly different preferences for locating off-shore wind farms at 12, 18 or 50 km compared to respondents with a lower level of education. This is true for all three samples.

### 7.2.4 Anglers

In the Hr- and Ny-sample, anglers express a stronger preference for reducing visual disamenities ( $\beta_{A\_DIST_i} > 0$ ) compared to non-anglers. However, the level of significance is not consistent across all three  $DIST_i$  variables. Anglers in the Na-sample seem to have weaker preferences for reducing visual disamenities than non-anglers, but the preferences are not significantly different. Interestingly  $\beta_{A\_PRICE} > 0$  and is significant in both the Na- and Ny-sample. This denotes a significantly lower marginal utility of income compared to respondents who do not use the sea for sports fishing and a consequently higher WTP. Taking into account the fact that the WTPs in the Hr-sample are the smallest, anglers in the Na- and NY-samples seem to have stronger preferences for reducing visual disamenities than in the Hr-sample.

As found in Ladenburg (forthcoming), the attitude towards increasing the number of off-shore wind farms in Denmark is correlated with the perception of impacts on marine life in the sea around off-shore wind farms. Consequently, a possible explanation for the observed stronger preferences of anglers could be that anglers perceive potential impacts on sealife to be positively correlated with locating off-shore wind farms at larger distances, as this may reduce impacts on fish stocks etc. This is tested by running a model for each sample in which information relating to the perception of impacts on marine life interacts with the  $DIST_i$  and  $PRICE$  variables. By comparing the log likelihood of the interacted model (model A) with the log likelihood of an unrestricted model (model B), a LR-test on nested model can be conducted. The perceptions of impacts are stated on a 6 point scale from 1 (very positive) to 5 (very negative), where 6 is a “do not know” option. In table xx below, the test results are presented for a model in which the information relating to the

perception of impacts is dummy coded; 1 is equal to the perception of a negative impact and 0 is equal to no impacts or do not know.

Table x: LR-test of the influence of perceived impacts on marine on preferences for reducing visual disamenities.

Sample	No. obs	LL <sub>Model A</sub>	LL <sub>Model B</sub>	LR-test (DF)	P-value
Na-sample	271	-157.547	-154.765	5.56 (4)	0.234
Hr-sample	94	-43.155	-40.011	6.29(4)	0.179
Ny-sample	151	-88.730	-85.849	5.76 (4)	0.218

In none of the three samples does the inclusion of information relating to the perception of impacts on marine life significantly improve the models. The results are robust with regards to different specifications of the information on perception variable.

### 7.2.5 Recreational Boaters

Referring to the  $DIST_i$  variables, the hobby sailors in the Hr-sample have significantly different preferences for reducing the visual disamenities of off-shore wind farms than non-hobby sailors.  $\beta_{HB\_DIST_i} < 0$  and, together with  $\beta_{DIST_i}$ , is not significantly different from zero. In other words, hobby sailors in the Hr-sample are indifferent as to whether wind farms are located at 8, 12, 18 or 50 km from the shore. The preferences are also heterogeneous in the Na-sample. Hobby sailors in the Na-sample thus have expressed a significantly lower marginal utility of income compared to respondents who are not hobby sailors. This denotes that the WTP for reducing the visual disamenities for hobby sailors is larger than for non-hobby sailors. Again, it is difficult to verify whether the preferences of the hobby sailors are different in the three samples. However, the results indicate that the hobby sailors in the Hr-sample have different preferences than the hobby sailors in both the Na- and Ny-samples.

### 7.2.6 Frequent Visitors

Frequent visitors to the beach in the three samples have expressed very heterogeneous preferences when compared across samples. In the Na-sample  $\beta_{VB\_DIST_i}$  is significantly larger than zero. Respondents who visit the beach on a frequent basis thus have stronger preferences for reducing the visual disamenities than less frequent visitors. However, in the Hr-sample the conclusion is the opposite. The  $\beta_{VB\_DIST_i}$  is significantly smaller than zero and

is jointly ( $\beta_{\text{DIST}_i} + \beta_{\text{VB\_DIST}_i}$ ) not different from zero. Frequent visitors to the beach in the Hr-sample are therefore indifferent as to whether the off-shore wind farms are located at 8 km, 12 km, 18km or 50 km from the coast. In the Ny-sample frequent visitors do not hold significantly different preferences than less frequent visitors.

### 7.3 Test for equality of preference with subgroup in the samples

As presented in the previous section, the preferences of the different subgroups seem to be different across the three samples. However, as mentioned, it is not possible to infer whether preferences for reducing visual disamenities are identical in the different subgroups across samples. The LR test (LR) is conducted in order to formally test the hypothesis of identical *preferences* in the sample, the results of which are presented in table 8 below.

Table 8: Test for equality of preference with subgroup in the samples

	No-obs	LL <sub>SampleX</sub> + LL <sub>SampleY</sub>	LL <sub>pooled model</sub>	LR-test (DF)	P-value
<b>Income3</b>					
Na- vs. Hr-sample	1115	-399.024-161.058= -560.082	-564.522 ( $\mu=1.20^{\text{NS}}$ )	8.88 (6)	0.180
Na- vs. Ny-sample	1133	-399.024-214.695= -613.719	-617.068 ( $\mu=0.57^{***}$ )	6.70 (7)	0.461
Ny- vs. Hr-sample	676	-214.695-161.058= -375.753	-379.595 ( $\mu=0.45^{***}$ )	7.68 (7)	0.362
<b>Income2</b>					
Na- vs. Hr-sample	254	-112.435-29.677= -142.112	-145.960 ( $\mu=0.91^{\text{NS}}$ )	7.69 (6)	0.261
Na- vs. Ny-sample	306	-112.435-66.301= -178.736	-182.515 ( $\mu=0.47^*$ )	7.56 (7)	0.373
Ny- vs. Hr-sample	162	-66.301-29.677= -95.978	-99.012 ( $\mu=0.56^{\text{NS}}$ )	6.07 (6)	0.416
<b>Respondent &lt;30 years</b>					
Na- vs. Hr-sample	194	-71.594+-32.938= -104.532	-107.022 ( $\mu=2.65^*$ )	4.98 (7)	0.662
Na- vs. Ny-sample	149	-71.594+-16.372= -87.966	-91.534 ( $\mu=0.62^{\text{NS}}$ )	7.15(6)	0.307
Ny- vs. Hr-sample	105	-16.372-32.938= -49.265	-53.177 ( $\mu=0.1^*$ )	7.82 (7)	0.349
<b>Anglers</b>					
Na- vs. Hr-sample	365	-157.193-42.696= -200.162	-203.834 ( $\mu=2.04^*$ )	7.44 (7)	0.384
Na- vs. Ny-sample	422	-157.193-88.686= -245.879	-252.486 ( $\mu=0.75^{\text{NS}}$ )	13.21 (6)	0.040
Ny- vs. Hr-sample	245	-88.686-42.696= -131.382	-143.515 ( $\mu=0.3^*$ )	24.27 (7)	0.001
<b>Hobby Sailors</b>					
Na- vs. Hr-sample	273	-102.000-35.061= -137.061	-144.430 ( $\mu=2.07^*$ )	14.74 (7)	0.040
Na- vs. Ny-sample	297	-102.000-63.985= -165.985	-169.211 ( $\mu=0.85^{\text{NS}}$ )	6.45 (6)	0.374
Ny- vs. Hr-sample	200	-63.985-35.061= -99.046	-109.119 ( $\mu=0.25^*$ )	20.15 (7)	0.005
<b>Frequent visitors</b>					
Na- vs. Hr-sample	612	-204.775-104.606= -309.381	-317.625 ( $\mu=0.75^{\text{NS}}$ )	16.49 (6)	0.011
Na- vs. Ny-sample	742	-204.775-195.191= -399.966	-404.540 ( $\mu=0.45^{\text{NS}}$ )	9.15 (6)	0.165
Ny- vs. Hr-sample	520	-195.191-104.606= -299.797	-305.569 ( $\mu=0.59^*$ )	11.54 (7)	0.116

The results from the table generally support the previous indication of differences in preference between the subgroups in table 7. Starting with Anglers, the test results reject the hypothesis of an equality of preferences amongst anglers in the Na versus Ny-sample, and the Ny versus Hr-sample, respectively. In both cases, the anglers in the Na and Hr-samples have lower WTPs than those in the Ny-sample.

An identical preference structure amongst the recreational boaters is also rejected. The test results denote that hobby sailors in the Na and Ny-samples have significantly different preferences than hobby sailors in the Hr-sample. The WTPs of the hobby sailors in the Hr-sample are lower than those in the Na and Ny-samples.

Finally, frequent visitors to the beach in the Hr-sample have significantly different preferences than the frequent visitors in the Na-sample. The WTPs of the frequent visitors in the Hr-sample are lower than those in the Na-sample.

An equality of preferences among younger respondents, high and middle income households in the three samples could not be rejected.

## **8 Conclusions**

There are numerous stakeholders in the coastal zone. However, many of their uses of the zone are rival and/or associated with externalities. In this relation, off-shore wind power generation is a new important stakeholder with a large potential for future resource extraction. However, a view of wind farms from the shore can cause visual disamenities in the coastal zone. From a welfare economics point of view, these disamenities should be taken into account when planning the future development of off-shore wind power. Visual disamenities arising from off-shore wind farms are non-market goods, which few respondents are expected to have prior knowledge of, or experience with. The elicitation of preferences based on respondents with a low level of prior information regarding the reduction in resource quality caused by the visual disamenities might therefore not be representative in the longer run, as people accumulate more knowledge and experience. 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, with perceived different levels of prior information the study analysed peoples' willingness to pay for reducing the visual disamenities of off-shore wind farms. The willingness to pay was estimated based on the respondents' choices between alternative off-shore wind farm layouts, which varied with regards to the distance from the coast, size of the wind farm, number of wind farms and the increased cost per household. In the Na-sample, the respondents were willing to pay 45, 95 and 120 euros/household/year for moving a 3600 MW off-shore wind farm to 12, 18 and 50 km from the coast, respectively compared to locating it at 8 km. The WTPs in the Ny and Hr-samples are 90, 100 and 165 and 35, 85 and 80 euros respectively for the same distances from the shore.

Even though the WTPs seem to be quite different between the three samples, an equality of preferences in the three samples could not be rejected on a 95% significance level using a main effect model. However, an equality of preference amongst different users of the coastal zone, such as anglers, hobby sailors and frequent visitors, was rejected. In all cases, the user groups in the Hr or Na-sample had lower levels of WTP for reducing the visual disamenities than those in the Ny-sample. As the off-shore wind farm at Nysted is located closer to the shore (9-10 km) compared to the wind farm at Horns Rev (14-20 km), the results consequently denote that individual experiences with/prior information on the visual disamenities of off-shore wind farms might have an influence on the preferences and WTP for reducing the disamenities. The user groups in the Hr-samples thus generally had the lowest WTP, whilst those in the Ny-sample had the highest.

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 caution towards locating off-shore wind farms at short distances from the coast in order to minimize the direct costs of power.

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