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Attitude towards and Disamenity Costs of Off-Shore Wind Farms

Jacob Ladenburg, Alex Dubgaard, Louise Martinsen, and Jesper Tranberg

Background

CO_2 reduction: Under the Kyoto Protocol Denmark has an obligation to reduce its CO_2 emissions by 21 per cent. Expansion of wind power is one of the relevant measures to realize this target.

Obstacles: Visual disamenities and noise nuisances make it difficult to find new areas suitable for land-based wind turbines.

Off-shore wind power: The evaluation scenario used in the *Discrete Choice Experiment* scenario, described in the right side column stipulates the construction of new off-shore wind farms with a total capacity of 3600 MW.

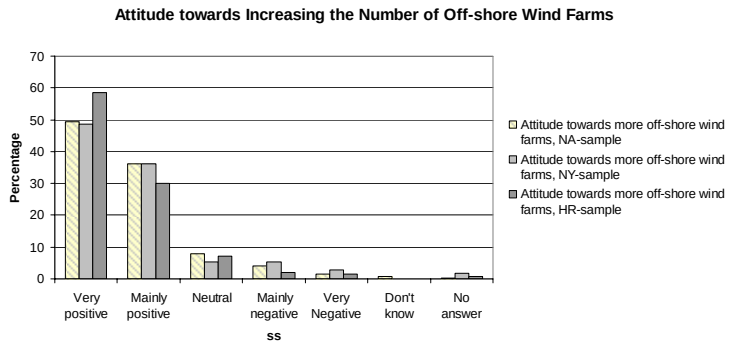
Trade-off: Off-shore location of wind turbines eliminates noise nuisances.Visual disamenities can be reduced by extending the distance to the shore. However, the costs per kWh pro-duced increase as the distance is augmented.

Finding an optimal solution: The social planner is confronted with a trade-off between minimizing the disamenities on the one hand and accepting higher costs of power generation on the other. To find an optimal solution, the disamenities must be measured in monetary terms. This is the objective of the present study.

Main Results:

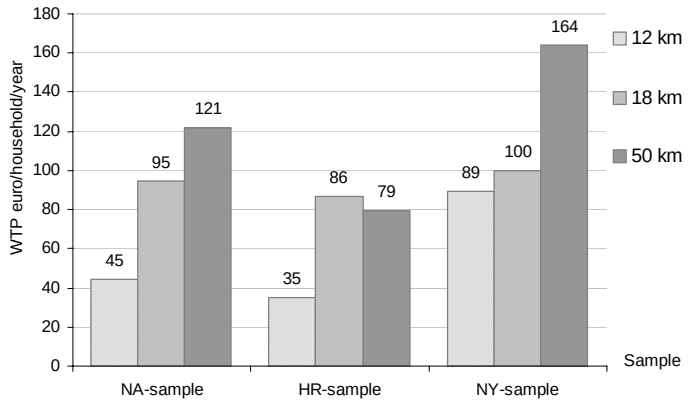
Attitude Towards Wind Power

In general, the respondents expressed positive attitudes towards the *existing* and more off-shore wind farms in Denmark. Only one out of ten respondents expressed a negative attitude towards the establishment of more off-shore wind farms. Interestingly, respondents in the Horns Rev and Nysted areas do express less and more negative attitudes towards off-shore wind power development respectively than the Danish population in general.



WTP for Reducing Visual Disamenities

The survey showed that people are willing to pay extra for electricity to reduce the nuisances from off-shore power generation. On average Danish households were willing to pay an additional annual electricity premium of € 45 for extending the distance to 12 km, € 95 for 18 km, and € 121 for 50 km. These results can be used in cost-benefit analyses of the optimal location and design of future off-shore wind farms in Denmark – and possibly elsewhere in the world.



Willingness to pay in euro/household/year for locating future off-shore wind farms at specified distances from the shore – relative to an 8 km baseline. NA: National, HR: Horns Rev, NY: Nysted.

The Study

Objective of study: To measure peoples' willingness to pay for re ducing the visual disamenities of off-shore wind farms.

Method: Willingness to pay for different levels of visual disamenity reductions has been elicited using the economic valuation method *Discrete Choice Experiments*. The valuation scenarios comprised the location alternatives 12 km, 18 km and 50 km from the shore, relative to an 8 km baseline for future wind farms.

Sample: The analysis was based on a questionnaire mailed to 700 randomly selected households in Denmark and 2*350 randomly selected households in the areas close to Horns Rev and Nysted wind farms.

Choice Set: Each respondent was presented with three pair-wise choice sets of off-shore wind power development schemes. The respondent was asked to choose the scheme he/she preferred from each pair. The development schemes varied with regard to the following four characteristics:

- Distance from the coast: 8 km, 12 km, 18 km or 50 km
- Number of turbines per farm: 49, 100 or 144
- Number of off-shore farms in Denmark: 15, 7 or 5 (depending on the number of turbines per farm)
- Cost per household in terms of higher electricity bills (€/year): 0, 10, 23, 40, 80 or 173.

Example of Choice set used in the survey

Distance: 8 km. Turbines: 144. Windfarms: 5. Cost pr household: 10 €.

Distance: 18 km. Turbines: 48. Windfarms: 15. Cost pr household: 40 €.

For more information, contact Ph.D. Student Jacob Ladenburg jala@kvl.dk

Disamenities of Off-shore Wind Farms[1]

Ladenburg[a,2], J; Dubgaard[a], A.; Martinsen[b], L. and J. Tranberg[a].
[a]Food and Resource Economic Institute,
[b] National Environmental Research Institute

Abstract:
Nuisances in terms of visual and noise externalities mean that it is increasingly difficult to find new areas suitable for land-based wind turbines in Denmark. Off-shore location offers opportunities of reducing visual and noise externalities by increasing the distance to the shore. However, the costs per kWh produced increase as the distance from shore is augmented. The present study is seeking to identify the economic trade-off relations between different levels of visual externalities and the costs of power generation. Willingness to pay for different levels of reductions in externalities has been elicited using the economic valuation method Discrete Choice Experiments. The survey 's development scenario is an increase in the Danish off-shore wind power capacity by 720 (5 MW) turbines (3600 MW totally). The valuation scenarios comprised the alternatives 12 km, 18 km and 50 km from the shore relative to an 8 km baseline. On average Danish households were willing to pay an annual premium on the electricity bill equal to 44.2 € for extending the distance to 12 km, 94.2 € for 18 km and 120.5 € for 50 km.

1 Introduction

Wind power is an important element of the Danish greenhouse gas reduction strategy. At present there are land-based turbines in practically all parts of the country. Nuisances in terms of visual and noise externalities mean that it is increasingly difficult to find new areas suitable for land-based turbines. This has brought the costal zone into focus as a resource offering seemingly unlimited opportunities for the expansion of wind power. In addition to off-shore wind power generation the costal zone is a resource base for fisheries, tourism, and housing including summer cottages. There are potential conflicts between these uses and wind power generation. In fact, wind farm projects have meet opposition at the local as well as the national level. The main objections are due to the visual externalities created by off-shore wind farms. This calls for investigations of peoples' attitudes towards off-shore wind power and the requirements with respect the location of future off-shore wind farms.

The present paper outlines the results of an economic valuation survey of the visual disamenities of off-shore wind farms. A detailed description is found in Ladenburg et al. (2005). The study is part of the *Danish monitoring programme for off-shore wind farms* comprising several studies of the environmental impact of off-shore wind farms. The programme is coordinated by the *Environmental Group* with representatives from Elsam Engineering, Energy E2, the Danish Forest and Nature Agency, and the Danish Energy Authority.

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[2] Corresponding author: Ph.D. stud. Jacob Ladenburg, jala@kvl.dk

2 Background

Negative externalities in terms of visual disamenities and noise nuisances make it difficult to find new areas suitable for land-based wind turbines (Danish Energy Authority, 1996). Off-shore location of wind farms eliminates noise nuisances. However, off-shore wind farms may still generate visual disamenities and have different types of impacts on the environment (EWEA, 2002; Manwell et al. 2002). People in general care about the environment, the potential negative impacts on the environment might therefore cause the preferences for off-shore wind power in a more negative direction (Ladenburg, 2005). From a societal point of view this could make off-shore wind power development a less attractive alternative.

The perhaps largest impact, visual intrusion/disamenities, can be reduced by extending the distance of off-shore wind farms to the shore. However, the costs per kWh produced increase as the distance is augmented (Morthost, 1998), Hence, the social planner is confronted with a trade-off between minimizing the disamenities, on the one hand, and accepting higher costs of power generation, on the other. To find an optimal solution, the disamenities must be measured in monetary terms. optimal solution, the disamenities must be measured in monetary terms.

3 The study

The present survey stipulates a development scenario comprising the construction of 720 (5 MW) off-shore wind turbines with a total capacity of 3600 MW. The study and analysis of attitudes and preferences are based on a mail survey including 700 households in a national sample (NA-sample), and 2x350 households in two subsamples representing areas where off-shore wind farms have already been constructed. The two subsamples are from the Horns Rev (HR-sample) and Nysted (NY-sample) areas. The wind farm at Horns Rev is located at a distance of 14-20 km from the coast line and consists of 80 wind turbines, each of 2 MW. At Nysted the wind farm is located at a distance of 9-10 km form the shore line and consists of 72 wind turbines of each 2.3 MW. Thus, the respondent in the HR- and NY-sample have more experience with off-shore wind farms than the respondents in the NA-sample.

Of the 1400 randomly selected households in the three samples close to 50 percent returned the questionnaires. Only 3 percent were discarded because of lack of information, leaving 48 percent or 672 respondents in the three samples. The number of respondents was 362 for the NA-sample, and 140 and 170 for the HR- and NY-samples respectively.

3.1 Attitudes towards Off-shore Wind Farms

Respondents were asked to assert their attitude towards existing off-shore wind farms, additional off-shore wind farms, and impacts on the landscape from off-shore wind farms on a 5 (+1) point scale as specified below.

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

3.2 Preferences for Reducing the Visual Disamenities of Off-shore Wind Farms

The preferences – expressed as Willingness To Pay (WTP) – for reducing the visual disamenities of off-shore wind farms were elicited using the *Discrete Choice Experiment* valuation method (CE). It is the assumption that the value individuals attribute to goods can be derived from observations of individuals' choices between different characteristics of similar goods[3] (Louviere & Woodworth, 1983). In practise the valuation is accomplished by presenting respondents with a number of alternative goods characteristics, also called choice sets. In this case the choice sets comprised potential off-shore wind farm development schemes. The alternatives define the good or service in terms of their key attributes. By varying the levels of the attributes the alternatives in the choice set become different. The respondents are then asked to choose from the choice set the alternative they prefer. 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. The calculation of WTP is based on the marginal rate of substitution between the monetary attribute and the other attributes (Louviere *et al.*, 2000).

The applied choice experiment was designed to estimate the visual disamenities (the "good") as a function of the size of wind farms, number of wind farms, and their distance from the coast. These attributes are described below.

Size attribute

The size attribute is defined as the in terms of the number of turbines per farm: 49 turbines, 100 turbines and 144 turbines. The odd numbers are due to the fact that all farm sizes need to fit a quadratic farm-layout in order to ensure similar appearance of the farms. The three farm sizes have been chosen to reflect the interval that is of primary relevance in relation to the desired capacity of future farms. Due to the fact that the overall scenario assumes a total expansion equel to 3,600 MW, the different farm sizes are tantamount to different numbers of farms. If it is chosen to operate with farm sizes of 49 turbines it will be necessary to establish around 15 farms in order to attain the overall objective of 3,600 MW. For 100 and 144 turbines per farm the corresponding numbers of required farms are around 7 and 5 respectively.

Distance attribute

In terms of the distance between the farms and the adjacent shore it was chosen to operate with 4 different distances: 8 km, 12 km, 18 km, and 50 km. At 50 km a wind farm is virtually out of sight from the shore - implying that there are no visual externalities from the farm.

[3] CE is based on the theory by Lancaster (1966) and Rosen (1974), stipulating that individuals' preferences for goods are derived from their preferences for the attributes comprising the goods.

Cost attribute

The cost attribute is specified in terms of an annual “renewable” (lump sum) energy fee to be paid by each household over the electricity bill. It has 6 different levels: 0, 10, 23, 40, 80, and 173 €.

Visualization of alternatives

The visualization of wind farms at 12, 18 and 50 km is an essential part of the CE set up. The visualisations were made by Elsam-Engineering and the height/size of the wind turbines is scaled to fit the exact distance making the different views as realistic as possible. The different visualisations are based on the same original photo to ensure the same appearance (foreground, background, light, etc.). This is important as the choice between different attributes must not be disturbed by other irrelevant parameters.

An example of a choice set is presented Figure 1 below.

Alternative A

Distance: 8 km. Turbines: 144. Wind farms: 5. Cost pr household: 10 €

I choose A [ ]

Alternative B

Distance: 18 km. Turbines: 48. Wind farms: 15. Cost pr household: 40 €.

I choose B [ ]

Figure 1: Example of a choice set

4 Results

The present section outlines the results from the analysis of attitudes towards off-shore wind farms and preferences for reducing the visual disamenities. For a more detailed presentation and discussion of the results see Ladenburg et al. (2005).

4.1 Attitudes towards Existing Off-shore Wind Farms

In the questionnaire the respondents were asked about their general attitudes towards existing off-shore wind farms. In Figure 2, the respondents' attitudes are presented.

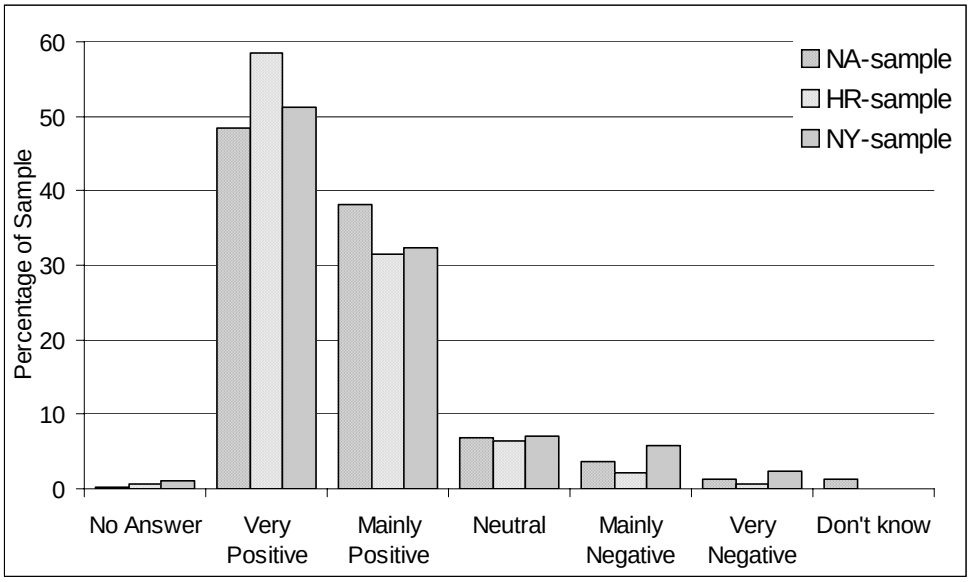

Figure 2: Attitudes towards existing off-shore wind farms, NA: National, HR: Horns Rev and NY: Nysted.

In Figure 2 it can be seen that most respondents in the three samples have a positive attitude towards the existing off-shore wind farms in Denmark. In the HR-sample 90 percent of the respondents have a positive (very or mainly positive) attitude. In the NA-sample it is 86 percent and

in the NY-sample 84 percent. The respondents in the HR-sample stand out as more positive than the respondents in the other two samples. Thus, in the HR-sample as many as 59 percent of the respondents have a very positive attitude, whereas the figures for the NA-sample and the NY-sample are 48 percent and 51 percent respectively.

4.2 Attitudes towards Additional Off-shore Wind Farms

The respondents in all three samples are quite positive towards the establishment of new off-shore wind farms. Looking at Figure 3 below the respondents from the HR-sample seem to be more positive (59 percent very and 30 percent mainly positive) than the respondents in the NA- and NY-sample (49 percent very and 37 percent mainly positive).

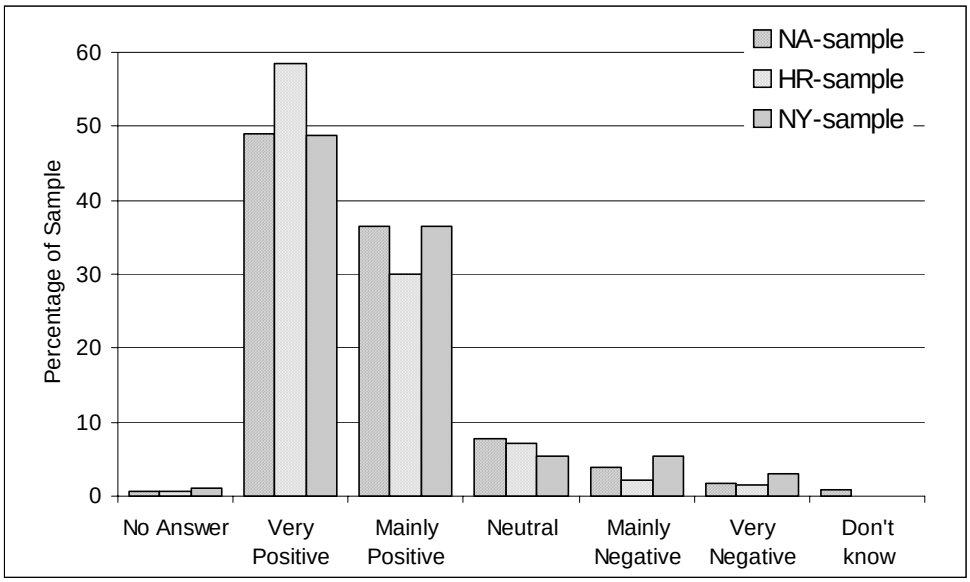

Figure 3: Attitudes towards establishment of additional off-shore wind farms, NA: National, HR: Horns Rev and NY: Nysted.

It is interesting to note that only between 4 percent and 8 percent (HR- and NY-sample respectively) of the respondents express a negative attitude towards new off-shore wind farms. These numbers are significantly smaller than in the case of new land-based wind turbines (see Ladenburg et al., 2005).

As mentioned, the respondents of the HR- and the NY-sample have already experiences with large off-shore wind farms. From this point of view the differences in attitudes between the NY- and HR-samples make sense. As mentioned the off-shore wind farm at HR is located at a considerably larger distance than the off-shore wind farm in NY. Consequently, the visual impacts are larger for the Nysted off-shore wind farm. The difference in the visual impacts may explain why respondents in the NY-sample tend to be slightly less positive towards existing and new off-shore wind farms. The properties of these attitudes are presented in more detail in the following section.

4.3 Visual Impacts of Off-shore Wind Farms on the Coastal Landscape

As specified in the previous section there seems to be some differences in the attitudes between the respondents in the HR- and the NY-sample concerning both existing and new off-shore wind farms. A possible explanation of the nature of these differences is explored in Figure 4 below, where answers regarding the perception of visual impacts are presented.

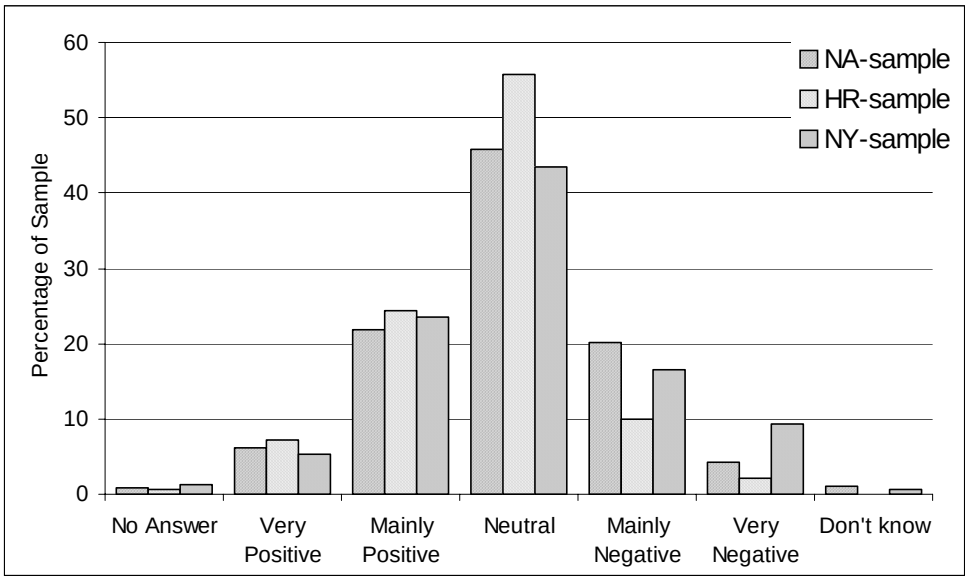

Figure 4: Off-shore wind farms' visual impacts on the coastal landscape, NA: National, HR: Horns Rev and NY: Nysted.

As it can be seen in Figure 4 the perceptions of the visual impacts are more heterogeneous than the attitudes towards existing and new off-shore wind farms. The majority (56 percent) of the respondents in the HR-sample consider the visual impacts to be neutral. In the NA- and NY-sample the percentage of respondents with a neutral perception is significantly smaller, that is 46 percent and 44 percent respectively. The percentage of respondents who considers the visual impacts to be positive (very - and mainly positive) are almost equal across the three samples. Consequently attitudes must differ across samples in relation to whether or not off-shore wind farms have a negative impact on the coastal landscape. In Figure 4 it appears that almost twice as many respondents in the NA- and the NY-sample state that off-shore wind farms have a *negative* impact compared to the respondents in the HR-sample. These differences are even more noticeable in the percentage of respondents who find the visual impacts *very negative*. In the HR-sample this number is 2 percent, whereas the percentage is as high as 4 and 9 for the NA- and NY-samples respectively. This indicates that experiences regarding off-shore wind farms in the HR- and NY-samples influence the attitudes of the respondents. The differences between the HR- and NA-sample also indicate that the experiences with the Horns Rev wind farm have left the respondents in the HR-sample more positive towards off-shore wind farms than the respondents in the NA-sample.

4.4 Willingness to Pay for Reduced Visual Disamenities

A positive attitude towards off-shore wind power development does not necessarily imply that people are satisfied with whatever level of visual disamenities which this might create. The survey investigated if there is a willingness to pay for reducing the visual disamenities associated with future off-shore wind power development. The respondents evaluated three choice sets containing two alternative off-shore development plans. An off-shore development plan is characterised by a set of attributes which define the size, distance, cost (energy fee to be paid by household), and visual impact of a wind farm, see page 3.

The respondents in all three samples hold significant preferences for reducing the visual externalities of the future off-shore wind farms in the valuation scenario – comprising the off-shore

erection of 720 turbines (equal to 3600 MW). The WTPs for reducing the visual externalities of off-shore wind farms in this scenario is presented in Figure 5 for each sample.

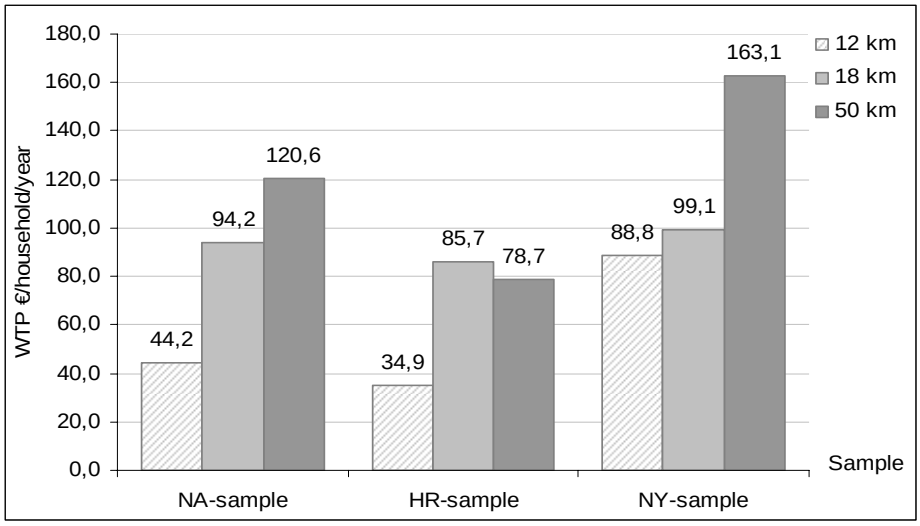

Figure 5: Willingness to pay in Basic Model for locating future off-shore wind farms at the specified distances from the shore – relative to an 8 km baseline. €/household/year.

4.4.1 NA-sample

Starting with the NA-sample the respondents are willing to pay 44.2 €/household/year for having future wind farms located at a distance of 12 km from the coast compared to 8 km. WTP for moving the wind farms to 18 and 50 km is 94.2 and 120.6 €/household/year respectively. WTP can also be expressed in terms of how much the respondents are willing to pay for moving the wind farm one more km away, also known as the *marginal* willingness to pay. The marginal WTP is interesting in the sense that it is an estimation of the benefits (of reducing the visual externalities) associated with mowing the wind farms one more km away from the coast. In the national sample WTP is equal to 44.3 € for the 4 km in the interval 8-12 km. This gives a marginal WTP equal to 10.9 €/household/year/km. The marginal WTP for moving the wind farm from 12 to 18 km and 18 to 50 km can be estimated in a similar way. The marginal WTP in the interval 12 to 18 km ≈ 8.3 €/household/year/km and the marginal WTP in the interval 18 to 50 km ≈ 0.8 € /household/year/km. In other words, the social benefits from reducing the visual disamenities from off-shore wind farms decline sharply for distances beyond the interval 12 to 18 km.

4.4.2 HR-sample

In the HR sample preferences for reducing the visual externalities are weaker than in the NA-sample. As illustrated in Figure 5 the respondents in the HR-sample are willing to pay 34.9, 85.7 and 78.7 € /household/year for mowing the wind farms from 8 km to 12, 18 or 50 km respectively. It seems a paradox, of course, that WTP for moving the wind farms to 18 km is larger than WTP for moving them out to 50 km. However, the difference between the two WTP measures is not statistically significant. The marginal WTP in the interval 8 to12 km is 8.8 €/household/year/km. In the interval 12 to 18 km, marginal WTP is 1.1 €/household/year/km. Given that the respondents are indifferent to having the wind farms at 18 or 50 km the marginal WTP in this interval is = 0.

4.4.3 NY-sample

The respondents in the NY-sample hold the strongest preferences for locating wind farms as far from the coast as possible - and preferably out of sight. This is reflected in the fact that WTP for each of the three distances is the highest across the three samples. WTP for locating the off-shore wind farms at 12 km compared to 8 km is 88.8 € /household/year. This is at more than twice as much as in the two other samples. For the distance 18 km WTP is equal to 99.1 €/household/year. This is not much more than in the two other samples. WTP for locating the farms at a distance of 50 km equals 163.1 €/household/year. The marginal WTPs are 22.3 €/km, 1.7 €/km and 2.0 €/km, respectively, for the three intervals.

It lays near at hand to seek the explanation for these WTP patterns in the different experiences with off-shore wind farms, which people in the two areas have. The Horns Rev wind farm is located at a distance of 14 to 20 km from the coast line. That is, at a distance where the visual disamenities are significantly reduced. The Nysted wind farm, on the other hand, is located at a distance of only 9 to 10 km form the shore. This means that the visual disamenities are rather significant. As noted previously, the NY-sample did not have a much greater share of respondents expressing negative attitudes towards wind farms. However, when focussing on respondents expressing preferences for moving wind farms out of sight this subgroup had considerably *stronger* preferences for this alternative in the NY-sample than the similar subgroups in the two other samples. A sociological investigation in the Nysted area shows a similar pattern (see Kuehn, 2005a and 2005b).

5 Conclusions

The respondents across the three samples all appear very positive towards the existing off-shore wind farms. This means that the respondents in the HR- and NY-sample are also positive towards the two off-shore wind farms located in their vicinity. The same positive attitude is observed with regards to the establishment of new off-shore wind farms. Almost 80 percent of the respondents are found to have a positive attitude towards the establishment of new off-shore wind farms. In this context it is worth mentioning that the respondents from the Horns Rev area are even more positive. With regards to the visual impacts associated with off-shore wind farms the majority of the respondents express a neutral attitude.

Still, in all three samples the surveys reveals significant preferences for reducing the visual disamenities of off-shore wind farms. Taking the national sample as the “standard” case Figure 4 shows the following pattern: WTP for extending the distance from 8 to 12 km is 44.2 € /household/year. WTP increases by more than 100 percent for extending the distance from 12 to 18 km, where the visual disamenities are significantly reduced, and by around 30 percent for having the distance extended from 18 to 50 km, i.e. virtually out of sight.

WTP in the two local samples (Horn Rev and Nysted) shows a somewhat different pattern. In the HR-sample respondents are willing to pay (only) 34.9 €/household/year for having the distance extended from 8 to 12 km. WTP increases with approximately 150 percent for having the distance extended from 12 to 18 km, but surprisingly there is no extra WTP for having wind farms moved from 18 to 50 km from the shore. In the NY-sample respondents are willing to pay nearly twice as much as in the national sample for having the distance of wind farms extended from 8 to 12 km from the shore. WTP for extending the distance to 18 km is not much higher than WTP for 12 km, but WTP increases by more than 160 percent for locating wind farms out of sight, i.e. at a distance equal to 50 km from the shore.

Conclusively, the present study point towards that the preferences for off-shore wind farms strongly depend on the visual disamenities associated with off-shore wind farms. The public acceptance of future off-shore wind farm projects might consequently be positively influenced if off-shore developers take into account the visual disamenties. The estimated WTPs for reducing the visual disamenities furthermore show, that the welfare economic gains by locating off-shore wind farms at large distances from the coast are substantial and cannot be neglected in the planning future off-shore wind farms.

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