Landscape externalities from onshore wind power

1. Introduction

The Global Status Report on renewables (REN21) reports that Germany had in 2006 with more than 20,000 megawatt worldwide the highest capacity of wind power followed by Spain and the US. For the German Federal Government further expansion of renewable energy is a central element of its climate conservation and energy policy. The target for 2020 is to produce 30% of the electricity from renewable energies, for example. In 2007 already 14.2% of the gross electricity consumption was generated by renewables. The most significant sources were wind power (45%) and hydropower (24%). To meet the target set for 2020 wind power will be crucial. The Lead Study (2008) projects that electricity generation from onshore wind turbines will increase by 14 TWh/yr between 2007 and 2020 to 53.5 TWh/yr. That would correspond to an installed capacity of 28,000 MW for onshore wind power in 2020.

However, even magic bullets can hurt and both building new onshore turbines and replacing old by modern turbines (so called repowering) are not universally accepted. Several surveys show that in general wind power is supported by the German population (e.g., Kuckartz and Rheingans-Heintze, 2006; Zoellner et al., 2008) but in many regions residents disapprove building new turbines or replacing older ones with modern turbines. For example, in the state of Brandenburg a citizens' initiative collected in autumn 2008 in a very short time period 15.000 signatures against a further expansion of wind power (Der Tagesspiegel, 16. September 2008). Particularly impacts on the landscape or on biodiversity as well as shadowing and noise caused by the turbines are raised as negative effects.

From an economic point of view the negative effects of wind power are externalities that are not covered by markets because they do not have a price. Thus, to get information about whether these impacts are meaningful, and if so, how large they are, non-market valuation techniques can be used (Pearce, 2006; Menegaki, 2008). In general, these techniques try to infer how individuals value changes in their environment from observable behaviour (e.g., travel expenses) or by establishing hypothetical markets through surveys. A technique that has recently been used more frequently is choice experiments. Belonging to the survey based techniques the underlying assumption is that the utility to consumers of any good depends on its characteristics or attributes. Thus, choice experiments enable to value multidimensional changes and are therefore of particular interest for valuing externalities from wind power.

In the present paper the results from choice experiments in two study regions in Germany determining landscape externalities from onshore wind power are reported. In both regions – Westsachsen and Nordhessen – wind power generation currently takes place at a rather modest level. However, meeting the objective of 30 per cent electricity generation from renewables may require that also in regions such as Westsachsen and Nordhessen wind power has to be expanded. Knowing whether further expansion will cause externalities and to what extend is therefore crucial for environmental and energy policy.

2. Method and econometric model

2.1 The choice experiment method

Choice experiments (CE)[1] belong to the group of stated preference methods, i.e., they establish hypothetical markets through using surveys for valuing environmental changes. Based on the foundations laid down by Lancaster (1966) that the utility to consumers of any good (i.e., also public goods such as a landscape) is derived from the attributes or characteristics of the good, CE ask respondents to make comparisons among environmental alternatives characterised by a variety of attributes and the levels of these. Typically, respondents are offered multiple choices during the survey with each choice consisting of alternative designs of the environmental change in question, e.g., programme A and B, and the option to choose neither. Often the latter is represented by the status quo, i.e., a situation without additional environmental management. The record of choices is then used to estimate the respondents' willingness to pay (WTP) by modelling the probability of an alternative being chosen. CE are particularly useful for valuing multidimensional changes because they provide a wide range of information on trade-offs among the attributes of the environmental change in question (Holmes and Adamowicz, 2003). Varying the level of the attributes of each of the alternatives makes it possible to measure the individual's willingness to substitute one attribute for another. Given that one of the attributes is the monetary cost, it is possible to estimate how much people are willing to pay to achieve more of an attribute, i.e., the marginal WTP, as well as the WTP to move away from the status quo to a bundle of attributes that correspond to the policy outcomes that are of interest.

2.2 The latent class model of choice

Responding to the limitation of the conditional logit model (Train, 2003) to recognise preference heterogeneity the literature has presented two broad avenues of modelling, the random parameter logit (RPL) and latent class models (LCM) (Swait, 2007). In the former individuality of preferences is reflected in individual-specific departures from the mean values of utility parameters. In contrast, latent class models assume that a number of a priori unknown segments exist in a population, each with a different preference structure. In this study we apply LC models investigating whether preference heterogeneity with respect to the use of wind power is present.

In a random utility framework the probability of respondent *n* choosing alternative *i* amongst a set of *J* alternatives $(i \in J)$, conditional on belonging to a given segment *s*, is

$$P_{(ni|s)} = \frac{exp(\beta_s X_{in})}{\sum_{j=1}^{J} exp(\beta_s X_{jn})}. \quad (1)$$

The probability that a respondent *n* with covariats z_n belongs to segment s out of segments is

[1] For a detailed description of choice experiments see Louviere et al. (2000), Bennett and Blamey (2001) or Hensher et al. 2005. For a compact introduction see Amaya-Amaya et al. (2008).

$$Pr(s) = \frac{exp(\theta_s z_n)}{\sum_{s=1}^{S} exp(\theta_s z_n)}. \tag{2}$$

If there are no covariates the only element in z_n would be a constant term ‘1’, and the latent class probabilities would be constants which sum to one (Greene and Hensher, 2003). Both θ_s and β_s are segment specific vectors of estimable parameters associated with the individual covariates and the attributes. When respondents are provided a sequence of choices the unconditional joint probability of a set of T(n) choices for respondent *n* is

$$Pr(T(n)) = \sum_{s=1}^{S}\left[\left(\frac{exp(\theta_s z_n)}{\sum_{s=1}^{S} exp(\theta_s z_i)}\right) x \left(\prod_{t(n)}^{T(n)} \frac{exp(\beta_s X_{int})}{\sum_{j=1}^{J} exp(\beta_s X_{jnt})}\right)\right]. \tag{3}$$

The determination of the number of segments is not part of the maximization procedure from which the parameter estimates are derived. Thus, the standard procedure is to sequentially estimate models with an increasing number of segments S (S = 1, 2, 3, 4, …) and to use information theoretic criteria such as the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC) as a guide to determine the appropriate number of segments (Swait, 2007).

Changes in welfare due to a marginal change in a given attribute can be calculated using the marginal WTP (MWTP) measure. It is defined as the maximum amount of income an individual is willing to pay in exchange for an improvement in the level of a given attribute provided. In a LCM the MWTP is calculated separately for each segment *s* by

$$MWTP = -\frac{\beta_{s\_attribute}}{\beta_{s\_money}} \tag{4}$$

where $\beta_{s\_attribute}$ is the coefficient of the attribute of interest and β_{s_price} is the coefficient of the price attribute representing the marginal utility of income.

3. Choice experiments concerning wind power externalities

Both positive and negative externalities of renewables have been subject to non-market valuation studies. Primarily the direct valuation methods, contingent valuation and choice experiments are used. Examples for the former method are Hanley and Nevin (1999) who appraised three renewable energy options for a remote community in Scotland and, more recently, Groothius et al. (2008) who investigated the compensation required for siting wind turbines in a viewshed. As the present survey uses CE the overview is confined to applications of this method. Three kinds of valuation objects are differentiated: impacts from onshore wind farms at certain locations, impacts from offshore wind farms at certain locations, and externalities from renewables including wind power at a regional or national level.

Álvarez-Farizo and Hanley (2002) were among the first who used a CE investigating the environmental impacts of a wind farm. With respect to a wind farm development in the north of Spain, La Plana, they used the attributes *protection of cliffs*, *protection of habitat and flora*, *protection of the landscape* and *costs*. All the environmental attributes were strongly significant indicating considerable social costs in the form of environmental impacts. Impacts on flora and fauna were valued more highly than impacts on the landscape or on the geologically-rare cliff sites. Dimitropoulos and Kontoleon (2008) examined the local acceptance of wind farm investments in the small Greek Aegean islands. Attributes are *number of turbines*, *their heights*, the *conservation status* of the site where the turbines will be located, whether *planning will be carried out in cooperation* with municipal authorities and local representatives or not, and, in contrast to other studies, an *annual subsidy* received per household as a compensation for negative externalities (i.e., a willingness to accept format). The results show that respondents value the conservation status of the potential location and a cooperative planning procedure more than the number of turbines or their height. With respect to the latter two attributes, however, the authors find significant differences between the study sites. Reducing the number of turbines and their height significantly affected the required compensation in only one location showing different degrees of local acceptance at both study sites.

Ladenburg and Dubgaard (2007) and Krueger (2007) investigated the disamenities from offshore wind farms. The former elicited preferences for moving future wind farms in Denmark further away from the shore line reducing disamenities. Their valuation scenario comprised future wind farms totalling 720 turbines at distances of 12, 18 or 50 km from the shore, relative to an 8 km baseline. The results of the mail survey indicate that overall social benefits will arise from diminishing the visual disamenities from future offshore wind farms. Ladenburg and Dubgaard also find that the marginal benefits from increasing the distance to the coast decrease with distance. Locating wind farms at distances greater than 18 km from the coast are said to be fairly small. Also using a mail survey Krueger (2007) investigated preferences for different variants of offshore wind farms in Delaware, U.S. Among the five attributes used in this study are *location of the wind farms* and *distance from the shore*. The results show strong support for offshore wind power development. However, distance from the shore is one of the most important attributes. Respondents were willing to pay significant amounts for moving wind farms further away from the shore with inland residents having a much lower willingness to pay than those living closer to shore display.

Belonging to the third group of studies Ek (2006) asked in a national mail survey Swedish households' about their valuation of environmental attributes associated with wind power generation. The focus of the investigation is not on whether and how much wind power capacity should be installed but how the expansion should be carried out to maximise the net social benefits associated with wind power. Ek uses five attributes: *noise*, *location of turbines*, *height of turbines*, their *grouping*, and a *price* as a surcharge to the power bill. The study finds that the visual impact in general and the locations of the turbines in particular significantly influence respondents' utility. Wind power offshore is considered as an environmental improvement compared to onshore locations and placing turbines in mountainous areas is considered an environmental deterioration. Moreover, reduced noise levels would affect utility positively and small wind farms were found to be an improvement to separately located turbines. In contrast, large farms affected utility negatively compared to separately located turbines.

Using as well a mail survey Bergmann et al. (2006) investigated the environmental impacts of renewable energy resources in Scotland. Thus, subject was not a particular renewable energy source but various impacts of renewables. In addition to attributes such as *landscape impact* and *wildlife impact* they also included the *number of jobs* renewable energy projects would create. A particular focus of this study was on any differences between the preferences of rural and urban residents. Among other things, for the whole sample they found that the most important attribute is reduction in air pollution. Also reducing impacts on wildlife was important. The WTP to change the visual impacts on the landscape is only significant if the project in question causes a high impact on the landscape. The results also indicate that preferences among urban and rural residents are different. For example, the authors find some evidence that negative landscape impacts from the development of a project are more acceptable to the rural population. Respondents from rural areas at the same time significantly positively value the creation of jobs. In an extended analysis of their data Bergmann et al. (2008) calculate the welfare effects of various renewable energy projects substituting a 200 MW expansion of natural gas power station. The whole sample, i.e., regardless whether respondents live in a rural or urban area, places the highest value on large offshore wind farms followed by small wind farm projects. For large onshore wind farms and biomass power plants the WTP was not statistically different from zero.

Borchers et al. (2007) investigated whether Delaware residents WTP for green energy differs by source. As specific energy sources the CE covers solar, wind, farm methane and biomass. The results suggest that a positive WTP exists for green energy and that interviewees prefer some sources more than other. Biomass and farm methane were found to provide less utility than solar and wind. However, the authors do not examine why respondents prefer some sources, i.e., which attributes of the energy sources are positively or negatively valued. In a mail survey in South-East England Fimereli et al. (2008) asked respondents about their preferences for the use of low-carbon technologies in electricity production. The three sources in their labelled choice experiment are onshore wind power, biomass and nuclear power. The status quo alternative was described by the current electricity mix in the UK. Attributes are *distance to place of residence*, *impacts on biodiversity*, the *carbon emissions reductions* achieved by each source, and *land occupation* in addition to *household costs* (annual electricity bill increase). The analysis shows that both the attributes describing the energy technologies as well as the name of technology (the labels onshore wind, biomass and nuclear power) have a significant effect on individual's choices. In particular, respondents express strong preferences for onshore wind power and biomass options over the 2008 current energy mix. With respect to nuclear power they express aversion. Furthermore, energy options that would increase local biodiversity and lead to higher reductions in carbon emissions were preferred. Also a larger distance to locations of the energy option increase utility.

Overall, present CE demonstrate that wind power can cause substantial negative externalities. Particularly impacts on nature or biodiversity protection are valued negatively. Individuals also seem to prefer larger distances to the turbines in both offshore and onshore projects. The econometric analysis of previous studies mainly relies on the conditional logit models while more recent studies employed random parameter logit models investigating preference heterogeneity. So far no study has used the latent class approach to investigate preference heterogeneity.

4. Study regions and survey

Westsachsen lies in the east of Germany and belongs to the state of Saxony. The regions surface area comprises 3964 square kilometres and the population was around 0.99 million inhabitants in December 2007. Nordhessen lies in central Germany and belongs to the state of Hesse. The regions surface area comprises 6909 square kilometres and the population was around 1.02 million inhabitants in December 2007. In both regions wind power generation with regard to installed capacity takes place at a rather modest level compared to regions in the states Lower Saxony, Brandenburg or Saxony-Anhalt. In Westsachsen 221 turbines are installed (2007: 235 MW capacity; approx. 345 GWh electricity production; approx. 295000 t CO_2 avoided) and in Nordhessen 263 turbines (2005: 152 MW capacity; approx. 270 GWh electricity production; approx. 231000 t CO_2 avoided).

The interviews in both regions were conducted in May and June 2008 via telephone, i.e., interviewees were contacted by random digit dialling and asked whether they are willing to participate in the survey. If they agreed, a date for the main interview was arranged and they were mailed the information about the objective of the survey, detailed descriptions of the attributes and the choice sets. Overall, 708 interviews were conducted, 353 in Westsachsen and 355 in Nordhessen. In the course of the interview respondents were first presented the choice sets (Figure 1) and subsequently a couple of questions concerning their experience with and attitudes toward wind power. Finally, socio-demographics were requested.

Figure 1: Example of a choice card

Wind power in Nordhessen until 2020			
	Programme A	**Programme B**	**Programme C**
Size of wind farms	large farms	small farms	large farms
Maximum height of turbines	200 meter	110 meter	110 meter
Effect on red kite population	10%	5%	10%
Minimum distance to settlements	750 meter	1.100 meter	1.500 meter
Monthly surcharge to power bill	€ 0	€ 6,-	€ 1,-
I choose	□	□	□

Each choice set comprises three generic alternatives for wind power development in Westsachsen or Nordhessen until 2020. To define the three alternatives four attributes describing different impacts of wind power plus a price attribute were used. The first four attributes are *size of wind farms*, *maximum height of turbine*, *effect on the red kite population*, and the *minimum distance* to settlements. All attributes, their levels and the description given to respondents are presented in Table 1. Particularly height of the turbines and the minimum distance to settlements are highly debated aspects of wind power in Germany (Klinski et al., 2007). Both strongly influence the opportunities to build new turbines and repower old ones. As modern turbines are in general larger than old ones (e.g., the turbine itself is higher, blades are longer), they have to be built further away from settlements due to the current regulation in many states of Germany. In a country as densely populated as Germany this raises the problem of land scarcity i.e., suitable locations for wind power development are rarely found at large distances to settlement areas. Attributes such as noise or shading were not included in the CE as these impacts are generally treated within the Federal Immission Control Act (Bundes-Immissionsschutzgesetzt). Thus, respondents were informed that standards set in the Federal Immission Control Act will be fulfilled in any case, even at a distance of 750 metres. Moreover, the amount of electricity production by wind power was set to be constant in order to focus on the landscape externalities.

Table 1: Attributes and levels used in the choice experiment

Attributes	Information given	Levels
Size of wind farms (WF)	Larger wind farms generally lower the costs of electricity production but the bigger they are the bigger could be their influence on the landscape; when farms are larger in total fewer farms are needed to produce the same amount of electricity.	**large (16 to 18 mills)** medium (10 to 12 mills) small (4 to 6 mills)
Maximum height of turbines (HM)	The higher turbines are the more electricity can be generated as winds are stronger and more constant at higher altitudes. Thus, fewer turbines are needed to produce a certain amount of electricity. On the other hand, visibility increases with height.	110 meter 150 meter **200 meter**
Effect on red kite population (RK)	Turbines would not be installed in conservation areas but also outside these areas conflicts may arise. For example, negative impacts on the red kite, a predatory bird that has a main habitat in the region, may lead to a decreasing population.	5% **10%** 15% reduction of red kite population
Minimum distance to settlements (MD)	Due to regulation turbines have to keep a minimum distance to settlements in order to avoid adverse effects through e.g., noise or shading. Programme A with a minimum distance of 750 metres complies with these regulations. Visibility would diminish with higher distances.	**750 meter** 1.100 meter 1.500 meter
Monthly surcharge to power bill (PR)	Programme A presents today's state of technology and thus enables to produce electricity efficiently. Programmes B and C would lead to higher costs e.g., for infrastructure such as longer power cables, and thus require a surcharge to the monthly power bill.	**€0** €1 €2.5 €4 €6
Avoided carbon dioxide emissions	All three programmes would avoid the same amount of CO_2: in Westsachsen 570 000 t and in Nordhessen 550 000 t	Not included in choice sets

Note: bold levels are those of Programme A; information is presented here in a compacted form

Programme A on each choice set describes how wind power would develop until 2020 if respondents would not decide otherwise. Respondents were informed that Programme A would allow producing electricity from wind power at low costs and choosing this alternative would not require any surcharges. Programme A always has the same attribute levels. The Programmes B or C restrict the use of wind power at least with respect to one attribute compared to Programme A. For example, the maximum height of turbines can be restricted to 110 or 150 metres. Respondents were informed that implementation of these programmes would require a monthly surcharge to their power bill because costs for electricity production would rise. Building turbines further away from settlements would, for instance, cause higher costs for infrastructure (e.g., longer power cables). For creating the attribute level combinations on the choice sets a D-optimal fractional factorial design consisting of 40 choice sets was identified using the SAS-macros (Kuhfeld, 2005). The sets were blocked into 8 subgroups with 5 choice sets[2] and each block was presented at least to 44 respondents.

After the sequence of choice sets respondents were presented a couple of questions aiming at their experience with and attitudes toward wind power generation in their region. For example, they were asked how many times they have seen turbines during the last four weeks prior to the interview, whether they have actually heard the noise caused by a turbine, whether turbines are located close to their place of residence, and, if so, whether they are disturbed by them. A first version of the questionnaire and the choice sets were discussed with residents of Westsachsen during three focus group meetings with altogether 25 participants. Before the main survey a pilot study was carried out in both regions.

5. Results

5.1 Disturbed by wind turbines

In both regions around 30 per cent stated that they have seen turbines daily while at the same time 14 per cent said that they have not seen any turbine during the last four weeks. The remaining 56 per cent have seen turbines between several times per week and only once during the last four week prior to the interview. In Westsachsen and Nordhessen 60 respectively 67 per cent reported that they have actually heard the noise of a turbine. Table 2 summarises how many respondents live close to turbines and, if so, whether they feel disturbed by them. Close to the place of residence was defined as a distance of up to three kilometres. If interviewees responded that they live close to turbines, they were asked to detail the distance. In Westsachsen 24 per cent live close to a turbine with a majority living between two and three kilometres away. In Nordhessen roughly 20 per cent of the interviewees live close to turbines with a majority again living between two and three kilometres distance. Within both samples only eight respectively ten households live closer than one kilometre to a turbine. When respondents were asked to state how much they are disturbed by the turbines the majority in both samples said “not at all”. Only a very few stated that they are disturbed very much by the turbines in their neighbourhood.

[2] Additionally, two methodological choice set were presented to each respondent, one presenting a dominated alternative (fifth card in the sequence) and one repeating the second card at the end of the sequence.

Table 2
Closeness of turbines and degree of disturbance

	Westsachsen		Nordhessen	
	%	N	%	N
Wind turbine up to 3 km from place of residence				
Up to 1 Kilometre	9.4	8	14.5	10
1 to 2 Kilometre	21.2	18	14.5	10
2 to 3 Kilometre	69.4	59	71.0	49
Total	100.0	85	20.0	69
Thereof feel disturbed by wind turbines				
very disturbed	83.5	71	70.0	48
rather disturbed	10.6	9	15.0	15
not very disturbed	4.7	4	4.0	4
not at all disturbed	1.2	1	2.0	2
Total	100.0	85	100.0	69

As another indicator of how strongly individuals might feel affected by the turbines we asked all respondents to state how satisfied they are with the present state of the environment in their region. The translated wording is “Finally, we would like to ask you about your satisfaction with the current state of the environment in Westsachsen (Nordhessen). Would you agree that altogether you are very satisfied, quite satisfied, not very happy, or not at all satisfied with the state of the environment in Westsachsen (Nordhessen)?” Table 3 reports the answers in relation to the presence of turbines close to the respondent’s place of residence. Overall, the majority of respondents states that they are “quite satisfied” or “very satisfied” with the environmental quality in their region. The results indicate that the closeness to a turbine does not affect the assessment of environmental quality.[3]

Table 3
Satisfaction with environmental quality in region

	Westsachsen				Nordhessen			
	Turbine close				Turbine close			
	Yes		No		Yes		No	
	N	%	N	%	N	%	N	%
not at all satisfied	4	1.5	3	3.5	1	0.4	1	1.4
not very happy	36	13.6	19	22.4	27	9.5	4	5.7
quite satisfied	200	75.5	56	66.0	199	70.1	48	68.6
very satisfied	25	9.4	7	8.2	57	20.1	17	24.3
Total	265	100.0	85	100.0	284	100.0	70	100.0

Note: Due to missing values the total number of interviews is in Westsachsen 350 and in Nordhessen 354.

[3] Using a chi-square test it was not possible to reject the null hypothesis that assessing environmental quality and closeness to turbines are independent.

5.2 Latent class analysis

The latent class model (LCM) is used to investigate whether preference heterogeneity with respect to wind power generation is present among respondents. Applying LCM the first task is to determine the number of segments. To make this determination the three statistics BIC, AIC, and CAIC[4] are used. Table 4 reports their value together with the number of parameters and the log-likelihood value for models with one to five segments. The measures in both cases do not allow a clear-cut identification of the optimal number of segments. As would be expected, the greater the number of segments S, the lower the log-likelihood. The other results are mixed. In both regions AIC indicates a five segment solution while the other measures favour models with less segments. CAIC both times suggests a three segment model. The BIC supports this in Westsachsen but is for Nordhessen slightly lower for the four segment model. As it is evident from the literature the AIC tends to overestimate the number of segments and there is consent that parsimony is preferable in modelling, the preferred LCM discussed below has three segments (Table 5). All attributes are effect coded. With regard to the quantitative attributes, such as the minimum distance, this allows to investigate whether threshold affects (non linear parameter values) appear, i.e., whether respondents value an increased distance from 750 to 1100 metres differently than an increase from 750 to 1500 metres.

Table 5
Goodness of fit criteria for 2 to 6 segments

Segments	2	3	4	5
		Westsachsen		
N parameters	21	32	43	54
Log-Likelihood	-1360	-1318	-1294	-1264
BIC	2844	**2825**	2841	2845
AIC	2763	2700	2674	**2636**
CAIC	2865	**2857**	2884	2899
		Nordhessen		
N parameters	21	32	43	54
Log-Likelihood	-1503	-1460	-1426	-1402
BIC	3129	3107	**3104**	3121
AIC	3048	2983	2937	**2912**
CAIC	3149	**3139**	3147	3175

The results of the LCM are each time contrasted with those of a conditional logit (CL) which show a very similar pattern in both regions. The coefficients for the price variables are significant with the expected negative sign. Increasing prices lower the likelihood that a certain alternative is chosen. The positively significant ASC_{ProA} relating to Programme A indicates that ceteris paribus respondents prefer this alternative. Both times the coefficients

[4] Bayesian Information Criterion ($BIC = -2 \log L+(\log N)k$), the Akaike Information Criterion 3 ($AIC = -2\log L + k$), and the Consistent Akaike Information Criterion ($CAIC = -2 \log L+[(\log N) + 1] k$) (Vermunt and Magidson, 2005).

for red kite and minimum distance to settlement areas are significant showing that individuals prefer to reduce the impact of turbines on the red kite population and prefer to move turbines further away from villages compared to the baseline of 750 metres distance. On the other hand, the coefficients for wind farm size and turbine height are not significant. The LCM may show whether this is due to preference heterogeneity, i.e., respondents preferences might be strongly opposed and thus cancel each other out.

The three segment LC models clearly perform better than the CL models. In both regions the log likelihood values decrease significantly and the pseudo R^2 increases accordingly. Thus, the results support the existence of preference heterogeneity in the data. Beginning in Westsachsen, in segment W1 (39 per cent of the respondents) lower the maximum height of turbines from 200 to 150 metre would decrease utility while lowering the impact on the red kite population would increase utility. The ASC_{ProA} is positively significant indicating that respondents in this segment prefer programme A. The other attributes are not significant suggesting that increasing the minimum distance and changing the size of wind farms is not important for respondents in this segment. Segment W2 comprising 35 per cent of the respondents shows different preferences. The ASC_{ProA} is significant but, here, has a negative sign, i.e., moving away from Programme A affects utility of these respondents positively. Also more attributes significantly influence choices. Individuals in this segment prefer smaller wind farms as in Programme A. And, similar as in the CL model, they prefer less negative effects on the red kite population and greater distances of turbines to settlements. Between these two segments is segment W3 (26 per cent of respondents). Utility of respondents in this segment would decrease if, instead of large wind farms as offered in Programme A, small farms would be built. With respect to the red kite population and the minimum distance to settlements they reveal similar preferences as those of segment W2. Only an increase of the minimum distance to settlements to 1500 metres is not significant. The coefficients for price are in all segments significant with a negative sign.

Results for Nordhessen (N) show similar preference segments. Individuals in segment N1 prefer, as in segment W2, small wind farms, prefer less negative impacts on the red kite population and want to move turbines further away from villages. In segment N2 (35 per cent) individuals indicate preferences similar to segment W3. They dislike small wind farms but would prefer medium sized farms, they prefer less impacts on the red kite population, and also want to move turbines further away. Finally, segment N3 in this region is similar to segment W1. Respondents are concerned about the red kite population but are not in favour of other changes compared to Programme A.

Table 5
Conditional logit and latent class model

Attribute	CL	Latent class model		
			Westsachsen	
Segment		W1	W2	W3
Segment size		39%	35%	26%
ASC_{ProA}	0.683 (4.778)	1.595 (2.106)	-1.079 (-5.69)	-0.798 (-3.41)
Wind farm: medium	0.088 (1.525)	-0.528 (-1.047)	0.167 (2.47)	-0.026 (-0.290)
Wind farm small	-0.022 (-0.384)	0.039 (0.095)	0.220 (3.13)	-0.337 (-3.59)
Max. Height turbine: 110	0.023 (0.414)	0.149 (0.291)	0.025 (0.39)	0.106 (1.23)
Max. Height turbine: 150	-0.016 (-0.297)	-1.266 (-1.958)	0.083 (1.38)	-0.048 (-0.53)
Red kite: 5%	0.417 (7.453)	1.834 (3.19)	0.281 (4.63)	1.003 (11.52)
Red kite: 15%	-0.462 (-7.534)	-1.710 (-1.851)	-0.340 (-5.12)	-1.092 (-10.42)
Minimum distance: 1100	0.142 (2.556)	0.209 (0.581)	0.298 (4.72)	0.183 (1.980)
Minimum distance: 1500	0.248 (4.528)	0.413 (0.99)	0.456 (7.75)	0.153 (1.679)
Price	-0.168 (-7.109)	-1.124 (-3.68)	-0.106 (-4.10)	-0.444 (-12.09)
No. of observations	1765	710	625	430
No. of respondents	353	142	125	86
Log-likelihood	-1742.14		-1318.39	
Pseudo R^2	0.03		0.32	
			Nordhessen	
Segment		N1	N2	N3
Segment size		44%	30%	26%
ASC_{ProA}	0.275 (*2.04*)	-1.683 (-8.04)	-0.066 (-0.34)	-1.13 (-1.56)
Wind farm: medium	0.057 (*1.05*)	0.069 (1.16)	0.207 (2.42)	-0.94 (-2.03)
Wind farm small	0.028 (*0.53*)	0.505 (7.90)	-0.756 (-8.27)	-0.321 (-0.86)
Max. Height turbine: 110	-0.048 (*-0.90*)	0.022 (0.38)	0.088 (1.14)	-0.617 (-1.29)
Max. Height turbine: 150	0.035 (*0.69*)	0.016 (0.29)	0.042 (0.53)	-0.064 (-0.17)
Red kite: 5%	0.416 (*7.89*)	0.474 (7.86)	0.598 (7.82)	1.302 (3.63)
Red kite: 15%	-0.372 (*-6.65*)	-0.442 (-6.62)	-0.518 (-6.53)	-1.529 (-2.62)
Minimum distance: 1100	0.194 (*3.77*)	0.315 (5.32)	0.319 (4.12)	-0.027 (-0.07)
Minimum distance: 1500	0.276 (*5.41*)	0.438 (8.19)	0.391 (5.01)	-0.587 (-1.24)
Price	-0.173 (*-7.87*)	-0.149 (-6.14)	-0.289 (-8.78)	-1.085 (-3.87)
No. of observations	1775	790	500	485
No. of respondents	355	156	107	92
Log-likelihood	1849.24		1459.59	
Pseudo R^2	0.05		0.25	

Table 6 reports the marginal WTP (MWTP) estimates for the significant coefficients. The estimates for the red kite at a first glance suggest that respondents who experience lower externalities are willing to pay less for reducing impacts. However, the 95%-confidence intervals strongly overlap indicating that the MWTP is not significantly different across segments. This applies to both regions. In Westsachsen all other estimates are different across segments. The intervals for an increase to 1100 metres do not overlap across segment W2 und W3 indicating a lower MWTP for segment W3. The same is true for a move to small wind farms because respondents in segment W3 would experience negative utility and those in segment W2 would experience positive utility. For the second region results are similar with two major differences. Individuals in segment N2 would experience disutility from small wind farms and seem to prefer medium sized farms. With respect to minimum distance

MWTP values are lower for those in segment N2 but the confidence intervals strongly overlap indicating that differences among both segments are not significant. Finally, the quantitative attribute *minimum distance* was effect coded in order to investigate non-linearity in parameters. In three segments both levels are significant (W2, N1, N2) but the confidence intervals strongly overlap indicating that the MWTP for an increase is the same regardless of whether it is increased to 1100 or 1500 metres.

Table 6
Marginal willingness to pay estimates in € per year

Attribute	CL	Latent class model		
			Westsachsen	
Segment label		Advocates (marginal externalities)	Opponents (strong externalities)	Moderates (medial externalities)
Segment size		39%	35%	26%
Wind farm: medium	n.s.	n.s.	1.58 (0.19 — 2.97)	n.s
Wind farm small	n.s.	n.s.	2.07 (0.45 — 3.7)	-0.76 (-0.34 – -1.17)
Height mill: 110	n.s.	n.s.		n.s.
Height mill: 150	n.s.	-1.13 (-0.06 — -2.19)		n.s.
Red kite: 5%	2.49 (1.59 — 3.39)	1.63 (0.54 — 2.73)	2.65 (1.12 — 4.19)	2.26 (1.79 – 2.72)
Red kite: 15%	-2.76 (-3.79 — -1.74)	n.s.	-3.21 (-5.07 — -1.36)	-2.46 (-1.88 – -3.04)
Minimum distance: 1100	0.85 (0.16 — 1.53)	n.s.	2.82 (1.10 — 4.53)	0.41 (0,00 – 0.82)
Minimum distance: 1500	1.48 (0.75 — 2.22)	n.s.	4.31 (2.06 — 6.55)	n.s.
			Nordhessen	
Segment label		Opponents (strong externalities)	Moderates (medial externalities)	Advocates (marginal externalities)
Segment size		44%	30%	26%
Wind farm: medium	n.s.	n.s.	0.71 (0.13 — 1.30)	n.s.
Wind farm small	n.s.	3.37 (2.05 — 4.69)	-2.61 (-3.42 — -1.79)	n.s.
Height mill: 110	n.s.	n.s.	n.s.	n.s.
Height mill: 150	n.s.	n.s.	n.s.	n.s.
Red kite: 15%	2.41 (1.61 — 3.20)	3.16 (2.10 — 4.23)	2.06 (1.44 — 2.68)	1.20 (0.36 — 2.04)
Red kite: 5%	-2.15 (-1.34 — -2.96)	-2.95 (-1.81 — -4.09)	-1.79 (-1.13 — -2.45)	-1.49 (-0.11 — -2.70)
Minimum distance: 1100	1.12 (1.76 — 0.48)	2.11 (1.13 — 3.08)	1.10 (0.53 — 1.67)	n.s.
Minimum distance: 1500	1.59 (0.93 — 2.27)	2.93 (1.93 — 3.92)	1.35 (0.79 — 1.90)	n.s.

Note: n.s. = not significant; 95%-confidence intervals were calculated using the delta method.

Based on these findings segments are assigned labels in order to characterize the preferences held by respondents in each segment. In Westsachsen segment W1 assembles respondents who mostly agree with Programme A but are in favour of reducing the impact on the red kite population. The segment is labelled “advocates” indicating that they only report marginal externalities agreeing mainly with the shape of a cost efficient wind power development in future. In segment 2 respondents would experience much stronger negative externalities from wind power. Thus, they are labelled “opponents” (substantial externalities). As segment W3 is situated between W1 and W2 it receives the label “moderates” (medial externalities). In the second region, Nordhessen, similar segments with comparable preference structures are present. However, the segment size is significantly different. While the advocates are the biggest group in Westsachsen it is the opposite in Nordhessen.

Table 7
Socio-demographics by classes (mean/ standard deviation)

		Westsachsen		
Class label		Advocates	Opponents	Moderates
Class size	100%	39%	35%	26%
N	353	142	125	86
Age	49.20 (16.89)	51.35 (16.85)	48.45 (14.95)	46.72 (19.20)
Woman	0.49 (0.50)	0.53 (0.50)	0.53 (0.50)	0.37 (0.49)
Income	1907.43 (1024.04)	1781.32 (995.51)	2190.46 (1023.50)	1704.26 (992.16)
People per household	2.27 (1.16)	2.15 (1.05)	2.54 (1.27)	2.09 (1.12)
Urban (1 = yes)	0.38 (0.49)	0.39 (0.49)	0.32 (0.47)	0.45 (0.50)
Turbines close by (1 = yes)	0.24 (0.43)	0.30 (0.46)	0.22 (0.41)	0.19 (0.39)
Member environmental organisation (1 = yes)	0.05 (0.23)	0.06 (0.23)	0.04 (0.20)	0.07 (0.26)
Green power (1 = yes)	0.07 (0.26)	0.08 (0.27)	0.09 (0.28)	0.05 (0.21)
Years at place of residence	26.74 (21-06)	28.81 (21.90)	26.29 (19.57)	23.99 (21.62)
		Nordhessen		
Class label		Opponents	Moderates	Advocates
Class size	100%	44%	30%	26%
N	355	158	100	97
Age	48.21 (15.99)	49.56 (15.60)	46.53 (16.11)	47.74 (16.45)
Woman	0.49 (0.50)	0.49 (0.50)	0.47 (0.50)	0.52 (0.50)
Income	2380.09 (995.27)	2346.15 (1039.81)	2338.96 (918.53)	2477.78 (1000.00)
People per household	2.62 (0.28)	2.50 (1.31)	2.64 (1.27)	2.78 (1.24)
Urban (1 = yes)	0.20 (0.40)	0.22 (0.42)	0.19 (0.39)	0.16 (0.37)
Turbines close by (1 = yes)	0.20 (0.40)	0.21 (0.41)	0.14 (0.35)	0.24 (0.43)
Member environmental organisation (1 = yes)	0.12 (0.32)	0.11 (0.31)	0.11 (0.31)	0.14 (0.35)
Green power (1 = yes)	0.13 (0.34)	0.15 (0.35)	0.13 (0.34)	0.11 (0.32)
Years at place of residence	26.95 (19.62)	27.34 (19.78)	23.40 (18.71)	29.97 (19.90)

Table 7 reports socio-demographics for both samples and according to the three segments. Differences across segments with respect to socio-demographics are modest. This is confirmed by additional latent class models including socio-demographics as covariates determining individual class-membership. These models reveal that none of the covariates has a significant influence on segment membership. Even characteristics such as living close to turbines or living in urban or rural areas does not significantly influence the preferences on wind power use. Thus, beyond the preferences revealed through the attributes we lack information on why individuals belong to a certain segment, i.e., why they have certain preferences for wind power.

6. Discussion and conclusions

The expansion of renewable energy is a central element of the German's Federal Government climate conservation and energy policy. Among other things, it aims at producing 30% of the electricity from renewable energies until 2020. Replacing old wind turbines by modern ones and building new wind turbines will be crucial to meet this objective. However, the expansion of onshore wind power is not universally accepted. In many regions residents disapprove repowering turbines or building new ones because negative impacts are associated with wind power.

The results presented in this paper show that many people in the study regions, Westsachsen and Nordhessen, are familiar with wind power, i.e., they have seen turbines on a weekly or even daily basis in the week prior to the interview, many of them have already heard the noise produced by turbines, and between 20% (Westsachsen) and 25% (Nordhessen) live close to turbines. Among those who live close to turbines only a minority states that they feel disturbed by them. The presence of turbines furthermore does not influence respondents' assessment of the quality of the regional environment. However, the figures in Table 1 and Table 2 only comprise residents. Whether respondents who do not live close to turbines but feel disturbed because of encountering them in the landscape is not reflected by these figures. Thus, the figures may underestimate the overall level of disturbance caused by turbines.

At the same time the results point out that wind power development as described in Programme A results in negative externalities. Particularly impacts on the red kite population and minimum distance to settlements are attributes significantly influencing respondents' choices. The latent class models reveal that preferences vary among subgroups. In each region one subgroup of respondents mainly agrees with programme A that would allow electricity generation at comparably lower costs (Advocates). Individuals in this group are only concerned about the impacts on the red kite population. On the other hand, in each region one subgroup is expected to experience stronger disutility from Programme A (Opponents). In this group, in addition to lowering the impact on the red kite, individuals prefer smaller wind farms and want to move turbines further away from settlements. A third group of respondents lies between advocates and opponents with respect to their externalities and is thus called moderates.

A striking result in both regions is that the height of the turbines is not significant except in segment W1 were individuals prefer not to limit the maximum height to 150 metre. Even in the latent class model allowing for preference heterogeneity no strong differences between segments emerge. This is in contrast to the expectations of many proponents of wind power. They are concerned that people generally would tend to opt for smaller turbines. The second obvious result is that even individuals who do not experience externalities from Programme A with respect to the attributes wind *farm size*, *height of turbines*, and *minimum distance* prefer lower impacts on the red kite population.

Overall, the results demonstrate that the use of wind power generates externalities and that due to preference heterogeneity the externalities differ between subgroups of the population. However, with the information available in the survey it was not possible to figure out what influences individual membership in one of the subgroups. None of the individual specific characteristics show a significant influence on group membership. Further research on what influences group membership is thus needed because for decision makers it is not only crucial to know whether and to what extend externalities exist but also what motivates different preferences.

Acknowledgement

Funding for this research, which was part of the project 'Strategies for sustainable land use in the context of wind power generation' (Fkz. 01UN0601A, B), was provided by the Federal Ministry of Education and Research in Germany and is gratefully acknowledged. The views expressed in this paper are the responsibility of the authors alone.

References

Alvarez-Farizo, B., Hanley, N., 2002. Using Conjoint Analysis to Quantify Public Preferences over the Environmental Impacts of Wind Farms. An Example from Spain. Energy Policy 30, 107-116.

Amaya-Amaya, M., Gerad, K., Ryan, M., 2008. Discrete Choice Experiments in a Nutshell. In:

Borchers, A. M., Duke, J. M., Parsons, G. R., 2007. Does Willingness to Pay for Green Energy Differ by Source? Energy Policy 35, 3327-3334.

Bennett, J., Blamey, R. K., (Eds.) 2001. The Choice Modelling Approach To Environmental Evaluation. New Horizons in Environmental Economics series. Cheltenham, Edward Elgar.

Bergmann, A., S. Colombo, Hanley, N., 2008. Rural versus Urban Preferences for Renewable Energy Developments. Ecological Economics 65, 616-625.

Bergmann, A., Hanley, N., Wright, R. E., 2006. Valuing the Attributes of Renewable Energy Investments. Energy Policy 34, 1004-1014.

Dimitropoulos, A., Kontoleon, A., 2008. Assessing the Determinants of Local Acceptability of Wind Farm Investment: A Choice Experiment in the Greek Islands. Cambridge, UK.

Ek, K., 2006. Quantifying the Environmental Impacts of Renewable Energy: The Case of Swedish Wind Power. In: D. Pearce (Ed.), Environmental Valuation in Developed Countries: Case Studies. Edward Elgar, Cheltenham, pp. 181-210.

Fimereli, E., S. Mourato, Pearson, P., 2008. Measuring Preferences for Low-Carbon Energy Technologies in South-East England: the Case of Electricity Generation. ENVECON. London.

German Federal Ministry for the Environment, Nature Conservation and Nuclear (Ed.), 2008. Lead Study 2008. Further development of the "Strategy to increase the use of renewable energies" within the context of the current climate protection goals of Germany and Europe Safety. Berlin.

Greene, W. H., 2007. NLOGIT Version 4.0. Reference Guide. New York.

Hensher, D. A., Rose, J. M., Greene, W. H. 2005. Applied Choice Analysis. A Primer. Cambridge Univercity Press, Cambridge.

Klinski, S, Buchholz, H., Rehfeldt, K., Schulte, M., Nehls, G. (2007). Development of an Ecological Strategy for Onshore and Offshore Wind Power Use. Summary: Results and Recommendations for Action. Berlin.

Krueger, A. D., 2007. Valuing Public Preferences for Offshore Wind Power: A Choice Experiment Approach, University of Delware.

Kuckartz, U., Rheingans-Heintze, A., 2006. Trends im Umweltbewusstsein. Umweltgerechtigkeit, Lebensqualität und persönliches Engagement. Wiesbaden.

Ladenburg, J., Dubgaard, A., 2007. Willingness to Pay for Reduced Visual Disamenities from offshore Wind Farms in Denmark. Energy Policy 35, 4059-4071.

Lancaster, K. J., 1966. A New Approach to Consumer Theory. Journal of Political Economy 74, 132-157.
Louviere, J. J., Hensher, D. A., Swait, J. D., 2000. Stated Choice Methods. Analysis and Application. Cambgridge University Press, Cambridge.
Menegaki, A. 2008. Valuation for Renewable Energy: A Comparative Review. Renewable and Sustainable Energy Reviews 12, 2422-2437.
Pearce, D., 2006. Introduction: Valuing Environments in the Rich World. In: Pearce, D. (Ed.), Environmental Valuation in Developed Countries. Edward Elgar, Cheltenham.
REN21. 2008. Renewables 2007 Global Status Report. Paris, Washington, DC.
Swait, J. D., 2007. Advanced Choice Models. In: Kanninen, B. (ed.), Valuing Environmental Amenities Using Stated Choice Studies. Dordrecht, Springer, pp. 229-293.
Train, K. E., 2003. Discrete Choice Methods with Simulation. Cambgridge University Press, Cambridge.
Vermunt, J.K., Magidson, J., 2005. Technical Guide for Latent GOLD 4.0: Basic and Advanced. Belmont Massachusetts: Statistical Innovations Inc.
Zoellner, J., Schweizer-Ries, P., Wemheuer, C., 2008. Public Acceptance of Renewable Energies: Results from Case Studies in Germany. *Energy Policy* 36, 4136-4141.