Measuring preferences for low-carbon energy technologies in South-East England: the case of electricity generation

Abstract

This paper reports on a mail survey that investigated public preferences in South-East England for the use of low-carbon energy technologies in electricity production, namely *on-shore wind, biomass and nuclear power*. Using a labelled choice experiment the perceived importance and value to the public of distance and the impacts of these energy options on biodiversity, carbon emissions, land occupation and household cost was explored. Results suggest that the attributes, the name of technology, respondents' demographic characteristics, general attitudes towards the environment and energy, previous knowledge and experience with the technologies were significant choice determinants. Considering the current debate about the further development of low-carbon technologies and in particular of nuclear power and biomass in the UK and worldwide, this survey aims to provide an insight into the factors that could potentially influence their public acceptability.

1. Introduction

Ongoing scientific research about climate change suggests that anthropogenic contributions are one of its most significant causes, with most of the observed warming over the last 50 years likely being due to the increase in anthropogenic greenhouse gas concentrations (IPCC 2007). As climate change impacts can potentially affect the environmental, economic and social functions of the planet, with developing countries bearing most of the burden, there seems to be an ever increasing need for urgent national and international action, in order to mitigate its serious future impacts. The energy supply sector is responsible for the largest growth in global GHG emissions between 1970 and 2004 (increase of 145%) with the transport sector being responsible for an increase of 120% in the same period (IPCC 2001).

According to governmental estimations, it is likely that the UK will need around 30-35GW of new electricity generation capacity over the next two decades and around two thirds of this capacity by 2020[1] (DTI 2007). In view of the challenges caused by climate change, the UK has set as target to cut its carbon dioxide (CO_2) emissions, the main contributor to global warming, by some 60% by 2050 (DTI 2007) and to achieve a 26-32% reduction by 2020, against a 1990 baseline (DEFRA 2007). This reduction calls for a movement to low-carbon technologies across the economy and in particular in the electricity generation and transportation sectors (DTI 2007). In the case of *electricity generation* renewable energy sources are viewed as the key to climate change mitigation and a national target of having 10% of total electricity produced from renewable energy sources by 2010 (with a further goal to double this level by 2020) has been set. In addition, the further development of nuclear power is also being considered, since it is considered a low-carbon energy option which can contribute to energy supplies' security and diversity (DTI 2007).

The successful development of low-carbon energy technologies depends, among other things, on costs of development compared to the benefits by the development (the reduction of CO_2 emissions) and on the involvement of all agents in the market of these energy sources, namely suppliers and consumers. In the case of electricity

[1] This is due to expected increase in electricity consumption and to the fact that a number of coal and the majority of existing nuclear power stations are set to close.

generation, the public acts as the 'host' of energy projects in its area of living and as a consumer that is willing to pay a premium to buy 'green electricity'. Experience so far, has shown that public acceptability of low-carbon energy technologies is a complex issue (Devine-Wright 2005; Upreti & Van der Horst 2004, Batley et al. 2001; Krohn & Damborg 1999), while public preferences for low-carbon energy technologies should be taken into consideration in order to increase the chances of a successful development of these technologies (Walker 1995, Nakarado 1995).

This paper reports on a mail survey that investigated public preferences in South-East England for the use of low-carbon energy technologies in electricity production and in particular for the use of *on-shore wind power, biomass and nuclear power* as alternative energy sources. A labelled choice experiment was employed to explore peoples' preferences for large-scale wind farms, biomass power stations and nuclear power stations that could be located at different distances from their place of residence. The perceived importance and value to the public of distance and of the impacts of these energy options on biodiversity, carbon emissions, land occupation and household cost was investigated.

To our knowledge, this survey is one of the very few UK-based valuation studies on preferences for different energy technologies, the first survey to explicitly present nuclear power as an alternative option and only the second to measure preferences for biomass in the UK. Taking into consideration the current debate about the further development of nuclear power and the use of biomass in the UK and worldwide, this survey aims to provide an insight into how the public perceives these low-carbon energy technologies and the factors that could potentially influence their public acceptability.

The remainder of the paper is organized as follows: the next section reviews previous literature on preferences for energy sources. Section 3 briefly describes the choice experiment method and section 4 introduces the choice experiment design and survey implementation. Section 5 presents the estimated models and the discussion of the results, while section 6 provides a summary of our main findings.

2. Previous literature

Empirical work within the environmental valuation literature consists of two streams of surveys, namely surveys measuring individuals' WTP for the development of particular energy technologies, such as wind farms, and for particular attributes of these technologies, and surveys measuring individuals' willingness to pay (WTP) a premium for green electricity. This section reviews only the first stream of surveys, as the second stream is beyond the scope of this paper.

A review of previous studies shows that landscape and environmental impacts were the most important factors influencing public preferences. For example, Alvarez-Farizo & Hanley (2002) elicited public preferences, using both a choice experiment and a contingent rating exercise, for the environmental impacts of a wind farm to be developed in the area of La Plana, Spain. The proposed area of development had a rich fauna and flora and a unique cliff formation, hence the estimation of the landscape and environmental impacts to the public could be significant. Their analysis shows that respondents valued impacts on fauna and flora more highly than landscape or cliff impacts, indicating thus a strong preference for biodiversity protection. In another choice experiment survey by Bergmann & Hanley (2006) respondents were presented with generic renewable energy alternatives (i.e. no specific sources were presented) described in terms of wildlife, air pollution, landscape and employment impacts. The results showed that respondents valued highly the avoidance of wildlife impacts, almost as high as the avoidance of landscape impacts with "the implicit price to maintain a neutral wildlife being 75% of the price households would pay to reduce landscape impacts from high to none" (p. 14).

Ladenbourg & Dubgaard (2007) focused on the estimation of landscape impacts (visual impacts) to the public from the development of off-shore wind farms in Denmark. In particular, WTP to reduce landscape impacts was measured in relation to distance, i.e. how WTP changed as wind farms were located further away from the shore. Results showed that respondents were willing to pay more as distance from the shore increased, however for wind farms located further than 18km from the shore WTP decreased. Hence, respondents had a strong preference for reducing visual disamenities, however it was weakened as the distance increased, probably because respondents did not think that wind farms would be visible at distances greater than

18km (indeed the authors suggest that most wind turbines would not be visible at distance greater than 18km due to weather conditions). In another study on public preferences for wind farms in Sweden, Ek (2005) investigated the effect of noise, location, height and grouping of wind turbines. The results from the mail survey showed that respondents considered the location of wind farms a very significant factor, with respondents' utility increasing with turbines being located off-shore and decreasing with mountainous locations. Moreover, the grouping of turbines affected preferences significantly with respondents preferring smaller groupings of turbines. Noise impacts were significant (at the 10% significance level) indicating that respondents regarded noise reductions as an environmental improvement.

Hanley & Nevin (1999) measured public preferences for different renewable energy sources using the contingent valuation method, where WTP and WTA for wind power, hydro power and biomass projects in remote communities in Scotland was elicited. Respondents were more supportive of wind power and hydro power (78% and 87% respectively), while only 42% of them supported the biomass project. Within the valuation scenario, respondents who said that they were supportive of each source were asked for their WTP to a community managed fund for the development of the project, while respondents who opposed each source, were asked how much compensation they would be willing to-accept (WTA) in the form of reduced electricity bills or local job creation. Mean annual WTP for wind and hydro power was similar (£52.25 and £54.93) and mean WTP for biomass was £25.54. In addition, location was the most important reason for opposing biomass and wind power which emphasizes the importance of location in public preferences (as also emphasised in Ek 2005).

Finally, one study has investigated the risk characteristics of electricity generating sources. Itaoka et al. (2006) estimated WTP of Japanese households to reduce mortality risks by fossil fuel and nuclear power electricity generation, measured in lives lost every year in each sector. Their results show that WTP for mortality reduction in the nuclear sector is approximately 60 times higher than WTP for mortality reduction in the fossil fuel sector, with this disparity being possibly the result of respondents overstating the low risk probabilities of nuclear power disasters because of risk perceptions associated with the technology.

Reviewing previous literature on public preferences for energy sources for electricity generation, it becomes evident that the focus on renewable energy sources is overwhelming. Recently governments worldwide, including the UK government, have started reconsidering the extension of nuclear power as a way to tackle climate change (DTI 2007, Ansolabehere 2007). Public support or opposition for nuclear power is diverse with two-thirds of Australians and 40% of US residents opposing the use of nuclear power (Macintosh & Hamilton 2007, Ansolabehere 2007), whereas 50% of Canadians support the use of nuclear power (Focus Canada Omnibus 2003). In the UK, a national survey found that 42% of UK residents support the construction of nuclear power stations to replace the ones that will be shutdown by 2020, while 29% of the public supports the increase of nuclear power stations in the UK (Ipsos MORI 2005). This research seeks to investigate public preferences for both renewable energy sources, namely on-shore wind power and biomass, and for nuclear power as possible alternatives for electricity generation and thus aims to enrich previous literature which has mainly focused on wind power. To our knowledge it is the first study to explicitly present nuclear power as an alternative energy option in a choice experiment exercise[2] since the study by Itaoka et al. (2006) focused on risk characteristics of nuclear power. Moreover, our study will add to the very few existing UK studies on public preferences for electricity generation and will be the second study measuring preferences for biomass (the other study being by Hanley & Nevin 1999).

3. The choice experiment valuation method

The theoretical basis for the choice experiment method lies in the characteristics theory of value by Lancaster which assumes that it is the characteristics of goods that give rise to the utility derived by individuals (Lancaster 1966) and in random utility theory. Within the Random Utility framework the ith individual is faced with j alternatives and the utility for the k alternative is $U_{ik} = V_{ik} (X_{ik}) + e_{ik}$ where $V_{ik} (X_{ik})$ is the deterministic component as a linear function of the attributes X of the alternatives and e_{ik} is the stochastic component which captures any unobservable to the researcher influences on individual choices. When the individual chooses

[2] Two conjoint analysis studies by Roe (2001) and Menges (2005) that elicited consumers' willingness to pay a premium for green electricity, presented nuclear power as a level of the attribute 'fuel mix' and are therefore not reviewed in this paper.

alternative k it is assumed that the utility derived from alternative k is the maximum among the j utilities and thus the probability that an individual chooses alternative k over all other alternatives is expressed as Prob($U_{ik} > U_{ij}$) for all other $k \neq j$. If (and only if) the error terms are independent and identically distributed with Weibull distribution, then the above probability of choice can be formally expressed with the Conditional Logit model, namely Prob($U_{ik} > U_{ij}$) = exp(μV_{ik}) / Σ_j exp (μV_{ij}), where μ is a scale parameter, inversely related to the standard deviation of the error term.

The conditional indirect utility function $V_k = asc_k + \beta_{1k} (X_{1k}) + \beta_{2k} (X_{2k}) + \ldots + \boldsymbol{\beta}$ (Socio-economic characteristics) for an alternative k represents a linear relationship between the attributes (X_{1k}), (X_{2k}) …etc. of the alternative and the socio-economic characteristics and the utility associated with the alternative. The asc is the alternative specific constant which accounts for variations in choices that are not explained by the attributes or the socio-economic variables. The estimated coefficients are linear parameters and can be used to measure individuals' willingness to pay to obtain a specific attribute level by calculating the ratio of the non-monetary attribute estimate and the cost attribute ceteris paribus. This monetary value is called the 'implicit price' for the specific attribute level and is calculated as *implicit price* = - (β_{1k} / β_{cost}).

Within a choice experiment respondents are presented with a number of choice cards that include two or more alternatives, which describe different environmental states and the existing status quo, and are asked to choose their preferred alternative. This exercise is repeated several times, with respondents choosing each time their preferred alternative, thus enabling the researcher to collect a significant amount of information on each respondent's preferences for the alternatives and the environmental good/policy in question. Each alternative is described by several attributes, which are relevant to the problem/policy analysed, realistic and easily understood by the sample population. Each attribute takes different levels, which describe best the range of possible values. The inclusion of a price attribute is essential for the estimation of respondents' implicit willingness to pay for the environmental good/policy in question. In particular, choice experiments offer the opportunity to estimate respondents' implicit willingness to pay (or consumer surplus) for changes in attribute levels and for increasing all attribute levels simultaneously (Hanley et al. 2001). Moreover, they indicate which attributes determine the values respondents place on the environmental good/policy and the implied ranking of these attributes (Bateman et al. 2002) In addition, through the observed choices of respondents, one can also estimate the probability of a particular alternative being chosen, as a function of its attributes and to estimate the percentage of the population that would prefer a particular alternative (or the 'market share') (Bennett and Blamey 2001). The latter is important from a policy point of view, as it can offer an indication of the level of support for each alternative among the relevant population.

4. Study design and implementation

4.1 Choice experiment design

The design of a choice experiment involves different stages, such as defining and refining the policy problem, the choice alternatives, the attributes and attributes' levels and selecting and generating the experimental design (Hensher et al. 2006). After having defined our policy question as 'what aspects of low-carbon energy technologies affect public acceptability of and preferences for low-carbon energy technologies' and identified on-shore wind power, biomass and nuclear power as the energy technologies of interest, the next stage of the choice experiment design involved the identification and refinement of the attributes and their levels that describe the alternatives. To this end, consultation with experts, two focus groups with members of the general public, pilot interviews and a small-scale pilot survey were conducted.

The choice of attributes describing the alternative energy options is a combination of all attributes previously used in other relevant surveys. The objective of this choice was to measure the influence of these attributes on public preferences *simultaneously*, since previous surveys focused on the effect of some of these attributes. Moreover, the use of a labelled choice experiment was considered to be the most appropriate since labelled alternatives (i) are considered to approach better the real context in which respondents' choices will be made, thus increasing the predictive validity of choice experiments (Blamey et al. 2000), (iii) they would enable us to use alternative-specific attributes' levels which would capture better the impacts of each energy option, (iii) can capture any prior beliefs of respondents about the alternatives (together with any other systematic unobserved effects) through the inclusion of alternative specific constants in the estimation function (Blamey et al. 2000).

A detailed description of each attribute and of its levels is presented below:

Table 1: Choice experiment attributes and levels

Attribute	***Description***	***Levels***
Distance	How far/close the energy option will be located from your home.	0.25 miles, 1 mile, 6 miles, 10 miles
Local Biodiversity	The impact on the local diversity of species in the area surrounding the energy option.	*Wind*: No change, Less *Biomass*, More, Less *Nuclear*: No change, Less
Carbon Emissions' Reduction	Reduction in CO_2 emissions that relates only to the 20% of electricity generation. The reduction does not refer to overall CO_2 emissions' reduction in the economy, which will require other measures.	*Wind*: 99%, 97% *Biomass*: 90%, 50% *Nuclear*: 99%, 95%
Total Land	How much land the energy option will have to occupy all over the UK in order to generate 20% of total electricity by 2020.	*Wind*: 5,832 ha *Biomass*: 816,000 ha *Nuclear*: 568 ha
Cost	How much your electricity bill will increase every year.	£20, £40, £67, £90, £143
Asc wind	Takes value 1 for alternative wind, 0 for all other alternatives	
Asc biomass	Takes value 1 for alternative biomass, 0 for all other alternatives	
Asc nuclear	Takes value 1 for alternative nuclear, 0 for all other alternatives	

Distance from respondents' home was selected to capture the visual impacts of the energy options, but at the same time to capture any perceived health impacts and safety issues with the options. Visual, health and safety perceptions are particularly relevant to energy options (Ladenburg & Dubgaard 2007; Itaoka, et al. 2006) and have been the focus of both proponents and opponents to different energy options. Four attribute levels, common for all alternatives were employed and presented in miles and kilometres. *Biodiversity impacts* were found to significantly influence public preferences in previous surveys (e.g. Alvarez-Farizo & Hanley 2002) and were thus considered an important attribute. This attribute was selected to describe the impacts on local biodiversity (i.e. on the area surrounding the energy option and for biomass it also included biodiversity impacts from the cultivation of energy crops and woody biomass) and it referred to impacts on fauna and flora. In order to ensure homogeneity in the description of attributes' levels across alternatives, ordinal qualitative levels were employed, namely 'No change' in biodiversity and 'Less' and 'More' biodiversity. The attribute *'Carbon emissions' reduction'* describes how much

CO_2 reduction each option can achieve for the 20% of electricity it will produce. This CO_2 reduction would contribute to the UK national target of reducing CO_2 emissions by 2020. The attribute levels' differed for each energy option, in order to capture better the contribution of each option to CO_2 reduction, and each option had two attribute levels measured in percentage reduction of CO_2 emissions.

The *cost* attribute is a key attribute in the choice experiment exercise as it allows the estimation of trade-off changes in attribute levels against the cost of making these changes and the compensating (or equivalent) surplus (Bateman et al. 2002). The cost attribute was described as the annual lump-sum increase in the household electricity bill. The choice of the particular payment vehicle (electricity bill) was based on a review of previous literature which indicated that participants tend to comprehend better lump-sum increases than increases as a function of their actual electricity consumption. The final attribute selected was *total land*, which described the land required by each energy option all over the UK in order to produce 20% of total electricity by 2020. This attribute was a fixed attribute, i.e. it only had one fixed level, which differed for each option and was described in hectares and in football fields equivalent, in order to provide respondents' with an easy-to-comprehend equivalent. The inclusion of the total land attribute followed suggestions by focus group participants that felt that it would enable their choices and was thus considered an important attribute. Furthermore, our study is the first study to investigate the importance of providing information on total land requirements for the development of energy sources on public preferences.

Given the three labelled alternatives, the four attributes and their associated levels, the full factorial design of the experiment would involve a large number of possible choice profiles. Using SPSS 14.0, instead of the full factorial design, fractional main effects designs for each alternative were produced and thirty-two choice profiles for each alternative were produced in the fractional design, which subsequently were reduced to thirty by elimination of duplicates. Thirty choice cards were generated by randomly selecting a choice profile from each alternative without replacement and assigning it to the previously selected choice profiles of the other two alternatives. Presenting each respondent with thirty choice cards can pose great cognitive burden and taking into consideration the complexity of the attributes, it was decided to block the thirty choice cards into six blocks of five choice cards. The order of the attributes between the blocks was alternated to minimize any possible ordering bias.

Each respondent in the survey was thus presented with five only choice cards, which consisted of the alternative energy options ‘Electricity from wind, biomass and nuclear’ and the status-quo option ‘Electricity from current energy mix’ which described the current UK energy mix that includes mainly the use of coal and natural gas and some renewable energy. Before completing the choice cards, respondents were presented with a description of the policy change in question, namely that the *‘UK government has set as target the reduction of its* CO_2 *emissions by 2020 and one way towards this reduction (along with other measures) would be to produce 20% of total electricity from low-carbon energy sources by 2020’*. In order to facilitate their understanding of the energy options, they were provided with a brief description of each technology and with a photo of a typical wind farm, biomass plant and energy crop, nuclear power station and coal power station. Respondents were also informed that each choice card was different as a result of different technological possibilities, were advised to treat each choice card independently and were reminded to consider their household budget constraint and all other things they would like to spend their money on (Bennett & Blamey 2001). Figure 1 presents an example of a choice card:

Figure 1: Example of a choice card

Card 1				
Characteristics	**Option 1** Electricity from WIND	**Option 2** Electricity from BIOMASS	**Option 3** Electricity from NUCLEAR	**Option 4** Electricity from Current Energy Mix
Distance from Home	6 miles *[10km]*	0.25 miles *[400m]*	1 mile *[1.6km]*	18 miles *[29km]*
Local Biodiversity	Less	More	No change	Less
Carbon Emissions	Reduction by 99%	Reduction by 50%	Reduction by 95%	Reduction by 0%
Total Land for producing 20% of electricity	5,832 ha *Or 7,930 football fields*	816,000 ha *Or 1,190,750 football fields*	568 ha *Or 772 football fields*	1,594 ha *Or 2167 football fields*
Increase in electricity bill per year	£143	£40	£67	£0

I would choose Option […1….]

The rest of the survey instrument included a series of questions on respondents’ previous knowledge of wind power, biomass and nuclear power, on the type of information they had access too (negative, neutral, positive), on their attitudes towards environmental and energy issues in general, on their direct experience with low-carbon energy sources and on their socio-economic characteristics. Moreover, taking into consideration the current debate in the UK about the use of off-shore wind farms, a question exploring respondents' attitudes towards this energy technology was also included. Finally, two identical questions asking respondents to name which energy technologies the UK is likely to use in the next fifteen years were employed. These questions were asked before and after the choice experiment exercise. The aim of these questions was to investigate whether choice experiments, and the survey instrument as a whole, can act as information sources to respondents and can thus have an effect on respondents' attitudes towards and perceptions of energy technologies. The results of the above investigation are presented in the section 5.4.

4.2 Sample selection and survey implementation

The target population of our survey were residents in South-East England. Given, however, the geographical dispersion of the population, a cluster sampling technique was employed where every town in South-East England with over 100,000 inhabitants was identified as a cluster and three towns were randomly selected, namely Guildford, Reading and Luton. Using the drop-off/mail back method, one thousand and two hundred questionnaires were randomly distributed to residents in all three towns and after approximately one week a reminder card was mailed in order to increase the response rate. In total three hundred and ninety-two questionnaires were mailed back of which three hundred and seventy-six questionnaires were usable resulting in a response rate of 31% which is acceptable for mail surveys (Bateman et al. 2002).

5. Results

5.1 Descriptive statistics

Our sample consisted of 55% female and 45% male respondents with an average age of 41.6 years. When compared to the South-East England population (ONS 2006), our sample is biased towards respondents who are higher educated (69.71% of our sample had a college/university or higher degree or a professional qualification compared to only 38.2% of SE England population) and have higher income (mean income of

£37,030 versus £28,430). As our sample's socio-economic characteristics were significantly different from the SE England population at the 5% level, different weights were tested in model estimation to account for the differences between sample and population characteristics. Weights based on sex, median income, above average income, education and combined sex and above average income were tested with the most accurate representation being provided when controlling for median income. The results of the unweighted and weighted models are presented in the following section.

Table 2: Summary of respondents' socio-economic characteristics

Variable	***Sample***	***S-E England***[a]
Sex		
Males (%)	45.33%	48.89%
Age[b] *(mean)*	41.61yrs	46.31yrs
Education		
College degree or above and professional qualifications	69.71%	38.2%
Employment		
Self or full time employed	69.51%	77.90%
Gross annual income[c] *(mean)*	£37,030	£28,430

[a] Data for 2006-2007, Source: NOMIS/ONS (2006)
[b] Age taken as mid-point of category
[c] Income taken as mid-point of category

With respect to knowledge of the various low-carbon energy technologies, over 85% of respondents stated having some knowledge or a lot of knowledge of wind power, a pattern that also holds for respondents' knowledge of nuclear power with 90% of respondents having knowledge of nuclear power. On the other hand, respondents were less familiar with biomass as an energy source with 60% of the sample having no knowledge of biomass and with only 5% of respondents having a lot of knowledge. With respect to the type of information (negative, neutral, positive) that respondents had access to, almost three quarters of respondents had access to positive or neutral information on wind power and biomass. On the other hand, over 60% of respondents had access to negative information on nuclear power. Finally, 35% and 14% of respondents in our sample had made a donation to an environmental organization and were members of an environmental organization respectively.

5.2 Model estimation

This section presents the analysis of the determinants of preferences for electricity generation from on-shore wind, biomass and nuclear power, using a Conditional Logit model. Using STATA Version 10, four models were estimated in order investigate the influence of different factors on the probability that any respondent prefers one of the four energy options in the choice set over the other three available energy options.

The factors, whose influence was investigated, were:
Model 1: Simple unweighted model with attributes-only specification;
Model 2: Simple weighted model with attributes-only specification;
Model 3: Extended unweighted model that includes also socio-economic variables, knowledge of and experience with the energy options and environmental attitudes
Model 4: Extended weighted model that includes also socio-economic variables, knowledge of and experience with the energy options and environmental attitudes

As mentioned in section 5.1 different weights were tested in model estimation to account for the differences between sample and population characteristics, such as weights based on sex, median income, above average income, education and combined sex and above average income. The weighted models presented here are controlling for differences in median income. Tables 3 and 4 show the results of the Conditional Logit analysis.

Table 3: Estimation of attributes-only unweighted and weighted models

	Model 1		***Model 2***	
			Weighted for median income	
Variable	**coefficient**	**z-stat**	**Coefficient**	**z-stat**
Asc wind	1.4469***	3.64	1.3698***	3.24
Asc biomass	0.1637	0.46	0.1791	0.46
Asc nuclear	0.2164	0.56	0.2186	0.53
Distance	0.0643***	6.86	0.0563***	5.77
Biodiversity – No change	0.0492	0.68	0.0324	0.42
Biodiversity – More	0.4115***	2.63	0.3775**	2.23
Emissions' reductions	0.0203***	5.65	0.0190***	4.97
Household cost	-0.0151***	-13.65	-0.0154***	-12.94
Pseudo R^2	0.2271		0.2068	
Prob>chi2	0		0	
No. of observations	376		376	

*** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level

Table 4: Estimation of extended unweighted and weighted models

	Model 3		*Model 4*	
			Weighted for median income	
Variable	**coefficient**	**z-stat**	**coefficient**	**z-stat**
Asc wind	3.2337***	6.16	3.1654***	5.72
Asc biomass	1.9358***	3.68	1.9188***	3.42
Asc nuclear	-1.6492***	-2.95	-1.7116***	-2.95
Distance	0.0692***	6.84	0.0571***	5.39
Biodiversity – No change	0.0395	0.49	-0.0008	-0.01
Biodiversity – More	0.4101**	2.54	0.3729**	2.15
Emissions' reductions	0.0195***	5.28	0.0190***	4.86
Household cost	-0.0161***	-13.45	-0.0163***	-13.13
*Income*ascwind*	0.0007**	2.15	0.0009**	2.51
*Income*ascbiomass*	-0.0002	-0.68	-0.0001	-0.28
*Income*ascnuclear*	0.00009	0.25	0.0001	0.3
*Sex*ascwind*	-0.5008***	-2.88	-0.4199**	-2.28
*Sex*ascbiomass*	-0.5528***	-2.6	-0.4105*	-1.8
*Sex*ascnuclear*	-0.4689**	-2.35	-0.3145	-1.46
*No Knowledge*ascwind*	-0.6144***	-3.15	-0.6767***	-3.49
*No Knowledge*ascbiomass*	-0.5745***	-3.76	-0.4610***	-2.9
*No Knowledge*ascnuclear*	-0.7428***	-2.6	-0.7406**	-2.29
*SeeCoal*ascwind*	0.6271***	3.68	0.6070***	3.27
*SeeCoal*ascbiomass*	0.6508***	3.1	0.5555**	2.48
*SeeCoal*ascnuclear*	0.4938**	2.52	0.5268**	2.45
*Climatechange*ascwind*	-0.5549***	-7.87	-0.5181***	-6.56
*Climatechange*ascbiomass*	-0.3734***	-4.36	-0.3546***	-3.78
*Climatechange*ascnuclear*	-0.2372***	-2.98	-0.2068**	-2.4
*MoreNuclear*ascwind*	-0.1731**	-2.03	-0.2745***	-2.83
*MoreNuclear*ascbiomass*	-0.0910	-0.89	-0.1911	-1.64
*MoreNuclear*ascnuclear*	0.8561***	8.31	0.7736***	6.83
Pseudo R^2	0.3012		0.2819	
Prob>chi2	0		0	
No. of observations	376		376	

*** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level

All four models are statistically significant overall and achieve a reasonably high for choice experiments pseudo R^2 between 0.20 and 0.30 (Bennett & Blamey 2001) which can be translated as an R^2 of approximately between 0.40 and 0.60 for the linear model equivalent (Hensher et al. 2006). Moreover, the statistical significance of the attributes and the other socio-economic and attitudinal variables remains unchanged for the majority of variables when both controlling and not controlling for median income, suggesting that our estimated models are sufficiently robust in capturing respondents' preferences.

Looking at the *simple models (Models 1 and 2)* all attributes, except for the 'No change' biodiversity level are statistically significant and have the expected sign. In particular the results indicate that the further away an energy option is located from a respondent's' home the more likely it is for a respondent to choose the energy option, while energy options that will lead to increases in local biodiversity (compared to energy options that will lead to decreases in local biodiversity) are more likely to be chosen. Furthermore, higher carbon emissions' reductions affect positively the choice probability while further increases in the annual household cost affect negatively the choice probability, a finding that conforms to consumer theory. As mentioned previously, the alternative-specific constants for each energy technology capture other unobserved sources affecting utility from this energy source. In our case, the ASCs capture, among other things, the effect of the technology name and indicate a strong preference for on-shore wind power (in the simple models) as an energy technology for electricity generation compared to the other three alternative energy options, while it also captures the effect of total land required for each energy option in order to generate 20% of total electricity by 2020.

A number of socio-economic and other attitudinal variables were included in the *extended models (Models 3 and 4)* in order to examine a wider range of factors that could potentially influence choice probability. The inclusion of these variables resulted in a higher pseudo R^2 in both the unweighted and weighted models compared to the simple models and also in changes in the significance and signs of the ASCs. Again the ASCs capture, among other things, the effect of the technology name and of the total land fixed attribute. They suggest, on the one hand, a strong preference for on-shore wind power and biomass compared to the status-quo option for electricity generation and on the other hand, respondents' aversion for nuclear power as an energy option. In the case of nuclear power other unobserved factors that affect negatively the choice probability not captured by the attributes could also refer to safety and health considerations associated with nuclear power. From the socio-economic variables income and sex are statistically significant with higher income respondents being more likely to choose wind power, while males are less likely to choose any of the three low-carbon energy technologies over the status-quo.

The inclusion of different attitudinal variables tells an interesting story. Previous knowledge of the energy technologies has a significant effect (at 1% level) on respondents' choices with respondents that reported *no previous knowledge* of wind power, biomass and nuclear power being less likely to choose any of the low-carbon alternatives over the status-quo. In order to measure the effect of *previous experience* with different energy technologies two proxies were employed in the survey, namely whether respondents have ever seen or lived near a number of energy technologies, including an on-shore wind farm, a biomass, a nuclear, a coal and a gas power station. Having seen a coal or gas power station was found to have a significant positive effect on the choice of all three alternative energy options over the status-quo option of current energy mix. Therefore, previous familiarity with energy technologies both in terms of knowledge/ information and of direct experience seems to play an important role in public preferences and acceptability. Taking into consideration the public's low familiarity with some sources, such as biomass (DTI 2003a, 2003b) it becomes evident that more efforts to promote public familiarity and experience with all energy sources are necessary.

Environmental attitudes were measured by respondents' level of disagreement or agreement with two statements, namely with statement '*Environmental problems, such as climate change and air pollution have been exaggerated'* and statement '*The UK should invest more in nuclear power stations as a way to tackle climate change*'. Beliefs about the severity of environmental problems, such as air pollution and climate change, significantly affected respondents' choices (at 1% level), with respondents that believed that environmental problems are exaggerated being less likely to choose the further development of wind power, biomass and nuclear power over the current energy mix. Moreover, the more respondents agreed that the UK should invest more in nuclear power as a way to tackle climate change, the more likely they were to choose the nuclear power option over the status quo and less likely to support the further development of wind power. This finding suggests that those that view nuclear power as the best solution for reducing CO_2 emissions tend to hold strong preferences for it and do not believe in the use of other low-carbon energy options, an attitude that was also observed among some of our focus group participants.

5.3 Economic values

As mentioned in section 3 the estimated coefficients can be used to measure individuals' willingness to pay, as an increase in their annual household electricity bill, to obtain a specific attribute level by calculating the ratio of the non-monetary attribute estimate and the cost attribute ceteris paribus. This monetary value is called the 'implicit price' for the specific attribute level. Table 5 shows the *implicit values* for all four estimated models and their respective 95% confidence intervals which have been calculated using the Delta method.

Table 5: Implicit values and (95% confidence intervals)

	Simple models		*Extended models*	
	Model 1	***Model 2*** *Weighted for median income*	***Model 3***	***Model 4*** *Weighted for median income*
Asc wind	£95.38*** (45.53-145.23)	£88.80*** (36.43-141.18)	£111.69*** (63.06-160.32)	£99.89*** (48.68- 151.10)
Asc biomass	£10.79 (-34.46-56.04)	£11.61 (-37.29-60.52)	£52.84* (-4.25-109.93)	£58.47* (-3.37- 120.32)
Asc nuclear	£14.26 (-35.22-63.75)	£14.17 (-37.50-65.84)	£13.94 (-37.23-65.13)	£14.49 (-39.76- 68.75)
Distance (per mile)	£4.24*** (2.93-5.55)	£3.65*** (2.34-4.95)	£4.28*** (2.95-5.60)	£3.49*** (2.16-4.82)
Biodiversity – No change (from baseline level Less)	£3.24 (-6.14-12.64)	£2.10 (-7.74-11.95)	£2.44 (-7.23-12.12)	£-0.05 (-10.21-10.10)
Biodiversity – More (from baseline level Less)	£27.13*** (6.54-47.71)	£24.47** (2.57-46.37)	£25.36** (5.45-45.26)	£22.80** (1.63-43.97)
Emissions (per % reduction)	£1.34*** (0.82-1.85)	£1.23*** (0.71-1.76)	£1.20*** (0.71-1.69)	£1.16*** (0.65-1.67)

*** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level

From the above table, we can see that respondents are willing to pay (as an annual increase in household electricity bill) on average between £88.80 and £111.69, ceteris paribus, for the development of on-shore wind power projects and between £52.84 and £58.47 for biomass projects for producing electricity. Moreover, they are willing to pay on average between £3.49 and £4.28, ceteris paribus, for *every mile* that wind farms, biomass and nuclear power stations are located further away from their homes, on average between £22.80 and £27.13 for energy options that *increase* local biodiversity as opposed to energy options that would lead to decreases in local biodiversity, and on average between £1.16 and £1.34, ceteris paribus, for *every percentage* of further emissions' reductions by the energy options. In an effort to understand further respondents' strong preferences for on-shore wind power in particular, a follow-up to the choice experiment question was included which asked respondents to explain their motivations behind choosing systematically one particular energy option. An analysis of respondents to the question indicate that some respondents held strong views about the advantages of wind power over other sources, others simply were nuclear-averse and thus preferred wind power as an alternative, while a number of them found wind turbines aesthetically pleasing.

A direct comparison of the attributes' implicit prices presented above is not feasible as different units have been employed for the attribute levels. However, the above implicit prices can be used in order to estimate the total economic value individuals attach to the development of a particular energy technology under alternative scenarios with different attribute levels. The total economic value can be calculated according to: TEV = Implicit price of ASC+ Implicit Price *Distance+ Implicit price*Biodiversity impact + Implicit price*Emissions' reduction

A scenario for the case of a biomass power station vs. the baseline scenario of the current electricity mix using the implicit prices of Model 4 is considered in Table 6 below. According to this scenario households would be willing to pay £123.05 annually as an increase in their electricity bill for the development of a biomass power station with the indicated attribute levels.

Table 6: Total economic value for alternative energy scenarios

	Current electricity mix	Biomass power station
Distance	18 miles	2 miles
Biodiversity	Less	More
Emissions' reduction	0	30%
TEV	£0	£123.05

5.4 Information effects

As mentioned in section 4.1 two identical questions asking respondents to name which energy technologies the UK is likely to use in the next fifteen years were employed in the survey. These questions were asked before and after the choice experiment exercise. The aim of these questions was to investigate whether choice experiments, and the survey instrument as a whole, can act as information sources to respondents and can thus have an effect on respondents' attitudes towards and perceptions of energy technologies. Using the Chi-square goodness of fit test, we tested whether respondents' answers differed significantly between the two questions. Our test showed that respondents' answers did indeed differ significantly between the two questions. This finding is interesting since it suggests that choice experiments and survey instruments as a whole can act as information sources to participants in a survey. In our case, participants were provided with different types of information throughout the survey, for example a technical description and photos of the energy technologies, detailed information on the environmental and land impacts of the technologies within the choice experiment and finally, information on the characteristics of off-shore wind power during the question on attitudes towards off-shore wind power. Participants in our survey seemed to consider the different types of information provided throughout the survey and to change significantly their views of the different energy technologies at the beginning and end of the survey by taking into consideration technologies they were not previously aware of (e.g. biomass) or by altering their views on some technologies (e.g. wind power).

Table 7: Respondents' answers to question: '*Which energy sources do you think the UK is likely to use in the next years?'*

	Before the CE	*After the CE*
Nuclear power	55.23%	58.76%**
Biomass	15.25%	32.88%**
Off-shore wind power	66.22%	61.19%**
On-shore wind power	57.91%	64.15%**
Same energy mix	40.75%	37.47%**
Other sources (e.g. solar)	15.82%	12.13%**
Do not know	4.56%	3.77%**

** Significantly different at 5% level

6. Conclusions

UK targets to cut its carbon dioxide (CO_2) emissions, the main contributor to global warming, by some 60% by 2050 and to achieve a 26-32% reduction by 2020, against a 1990 baseline, call for a movement to low-carbon technologies across the economy and in particular in the electricity generation sector. However, the successful development of low-carbon energy technologies depends, among other things, on costs of development compared to the benefits by the development (the reduction of CO_2 emissions) and on the involvement of all agents in the market of these energy sources, namely suppliers and consumers, making thus public preferences for low-carbon energy technologies an important part of the development process. This paper reports on a mail survey that investigated public preferences in South-East England for the use of *on-shore wind power, biomass and nuclear power* as alternative energy sources for electricity production using a labelled choice experiment. Analysis of responses to the survey suggests that both the attributes describing the energy technologies and the name of technology had a significant effect on peoples' choices. In particular, respondents held strong preferences for on-shore wind power and biomass options over the current UK energy mix, while they expressed nuclear power aversion. Moreover, energy options that would increase biodiversity and lead to high carbon emissions' reductions were valued higher, while the location of energy technologies was also considered important factor with respondents valuing more energy options that would be located far from their home. Respondents' demographic characteristics, such as income and sex, and their general attitudes towards the environment and energy sources also affected their choices. Finally, respondents' previous knowledge of and experience with the energy technologies were also significant determinants of choice, a result that underlines the potential of information on influencing public acceptability of complex environmental goods. To our knowledge, this survey is one of the very few UK-based valuation studies on preferences for different energy technologies, the first survey to explicitly present nuclear power as an alternative option and only the second to measure preferences for biomass in the UK. Taking into consideration the current debate about the further development of nuclear power and the use of biomass in the UK and worldwide, this survey aims to provide an insight into how the public perceives these low-carbon energy technologies and the factors that could potentially influence their public acceptability.

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