Preferences for Energy Futures in Scotland

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Abstract

In the next two decades Scotland is facing tough greenhouse gas emissions reduction targets as well as the upcoming shutdown of a number of existing thermal plants. Given the limited timeframe it would seem imperative that Scotland's energy policy is developed with public preferences in mind, as political unpopularity and public objections, with the associated need for lengthy public enquires, are likely to mean that targets are more likely to be missed. As such, appraisal of any potential energy option should not be limited to consideration of financial viability but should also take full account of environmental and social costs. The primary aim of our study was to determine public preferences and willingness to pay for alternative energy options, such as wind, nuclear and biomass against the current generation mix, all of which may form an integral part of the future generation portfolio for Scotland.

One method of determining social costs is through stated preference techniques, one of which is choice experiments – the method applied in the current study. Our analysis is based on a postal survey sent out to a random sample of 1000 households across Scotland. People were asked to choose between four energy options: wind, biomass, nuclear and current energy mix, depending on which energy option and associated mix of attributes they prefer. Attributes were: distance from respondent's home, carbon emissions reduction, local biodiversity impacts, land requirements (a fixed attribute) and an annual electricity bill increase (the cost attribute). Our results suggest that carbon-neutral energy options tend to have a positive willingness to pay associated with them and be more favoured by the population over the current energy mix with distance from the respondent's home, increases in biodiversity and increases in energy bill all having a significant impact on preferences. We also found variation in preferences according to socio-economic groupings, for example respondents with children tend to have a higher preference towards renewable technologies than those without.

In addition to the overall sample, we also investigated divergence in preferences between three areas of Scotland (Highlands and Islands; Central; and South). The results indicate that, depending on the geographical location, people's preferences for energy generation technologies vary. Our results suggest that Scottish energy policy need not only be planned accounting for public preferences for different energy options but also regional divergence of preferences within the country.

1. Introduction

Energy policy is one of the central issues of the global political agenda. A widely accepted need for greenhouse gas reduction in combination with security of supply concerns and ever increasing fuel costs means that the development of a cost-effective low-carbon energy portfolio has become a vital challenge for most countries worldwide, to which Scotland is no exception.

This paper attempts to identify public preferences towards energy generating options in Scotland. We investigate public attitudes towards three energy-generating options (energy from wind, nuclear power and biomass) and compare them with the current generation mix. All of these options have the potential to become a major part of Scotland's future low-carbon generation portfolio, so it is important that public preferences and social costs associated with them are considered and properly understood.

This study uses a stated preference approach, namely a choice experiment to achieve the above objective. A number of choice experiment studies have been carried out worldwide looking at public preferences towards various energy-generating options, e.g. Ek (2005) for Sweden, Fimereli et al. (2008) for South-East England, Kataria (2009) for Sweden, Alverez-Farizo (2002) for Spain, Meyerhoff et al. (2009) for Germany, Navrud (2007) for Norway and Krueger et al. (2010) for the US. Much less, however, has been published to date with regard to public attitudes towards energy-generating options in Scotland. Perhaps the most relevant recent publications on this topic are the papers by Bergmann et al. (2005) investigating renewable energy investments in Scotland and a follow up paper published in 2008 by the same author looking at rural versus urban preferences for renewable energy in Scotland.

Our study specifies the energy options as part of a labelled choice experiment, to capture public preferences between the technologies and includes a nuclear option as part of a low-carbon generation mix. This is something that to our knowledge hasn't been carried out in Scotland before.

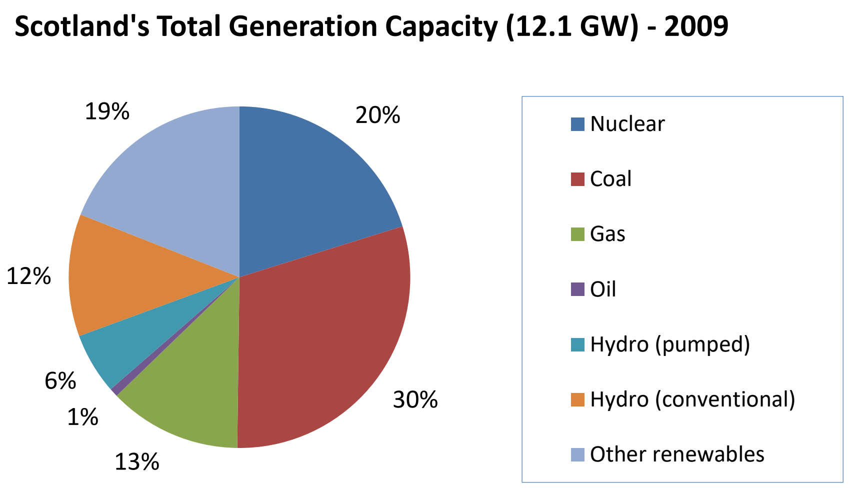
The remainder of the paper is organised as follows: Section 2 gives a brief summary of Scotland's energy policy and current generation mix. Section 3 outlines the methodology and theoretical framework, Section 4 describes the design of the current study and discusses attributes and levels in more details. Section 5 presents the results and findings and, finally, Section 6 concludes the paper with a final summary of the research and a discussion of further research and potential policy implications.

Scotland's energy policy and current generation mix study design

By 2020 the European Union is committed to reduce its carbon emissions by 20% compared to 1990 levels and to generate 20% of energy from renewables. Strict targets were also put forward by the recently published 'UK Low Carbon Transition Plan – National strategy for climate and energy', which sets out a plan for the UK to reduce its carbon emissions by 34% by 2020 on 1990 levels (White Paper, 2009). The Climate Change Bill passed by the Scottish Parliament in 2009 adopted even more ambitious targets to reduce greenhouse gas emissions by 80% by 2050 with an interim target of 42% by 2020.

The power generation sector is the largest producer of carbon dioxide emissions in Scotland accounting for around 50% of total emissions (Wood Mackenzie, 2009). As can be seen in Figure 1, Scotland currently has 12.1 GW of generating capacity, consisting of 3.6 GW of coal generation (Longannet and Cockenzie), 1.5 GW of gas (Peterhead), 2.4 GW of nuclear power (Torness and Hunterston B) and about 3.7 GW of renewable generation (source: Scottish Renewables, 2010).

Figure 1:



Source: Wood Mackenzie, Scottish renewables, Scottish Government.

Major changes, however, are scheduled to happen to the Scottish generating portfolio in the next two decades. One of the two remaining Scottish nuclear plants, Hunterston B is due to be decommissioned by 2015 at the latest, followed by Torness (due to be retired in 2023) (Scottish Energy Study, 2006). Additionally, Scotland's major coal-fired power station Cockenzie has opted out of Large Combustion Plant Directive (LCPD)[1] and will be shut down by the end of 2015 (BERR, 2007). As can be seen from Table 1, assuming no new-built and no further developments and consents to extend stations life, all existing Scottish thermal plant could be phased out by 2030.

All of the above has lead to an urgent need for development of the country's energy policy to fill the upcoming energy gap. Given the limited timeframe available to achieve the Scottish Government's targets it would seem to be imperative that policy is not politically unpalatable to the public, since this would result in the need for extensive public consultation, objection and enquiries. Thus appraisal should not be limited to consideration of financial viability but should also take full account of environmental and social costs. Therefore the current research aims to identify social preference for different future energy options.

3. Methodology and theoretical framework

There are two branches of non-market goods valuation: revealed and stated preferences methods. Revealed preference methods estimate value of a non-market good by studying actual (revealed) preferences. The two most commonly used examples of revealed preference methods are travel cost method and hedonic price method (see Braden and Kolstad, 1991). This branch of methods has been quite popular in non-market goods valuation, but also has a number of drawbacks, amongst which is impossibility of estimation of non-use values (Alpizar et al, 2001), more specifically social costs associated with a particular energy option in our case. Equally there are issues with using revealed preference for future policy analysis in that what you want to value does not yet exist so there is nothing against which to "reveal preferences". The other branch of non-market goods valuation methods, and the one which is appropriate to the current research, is stated preference approaches. This technique assesses individuals' stated

Table 1: Major Scottish power plants, 2009

Station	Type	Capacity, GW	Assumed Closure Date
Cockenzie	Coal	1.2	2015
Longannet	Coal	2.4	2020
Peterhead	Gas	1.5	2025
Torness	Nuclear	1.25	2023
Hunterston B	Nuclear	1.19	2011
Cruachan	Pump storage	0.4	-
Foyers	Pump storage	0.3	-
Several	Hydro	1.4	-
Several	Wind	2.1	-
Several	Other renewables	0.2	-

Source: Scottish Energy Study, 2006

behaviour in a hypothetical setting (Alpizar et al, 2001). Some examples of stated preference techniques are conjoint analysis, contingent valuation and choice experiments (for a review see Hanley, Mourato and Wright, 2001).

Choice Experiment techniques (CE) draw their roots from traditional microeconomic theory whereby consumers are asked to maximise their utility subject to their budget constraint (Eck, 2005). CEs are based upon the characteristics theory of value (Lancaster, 1966), and the random utility theory (McFadden, 1974; Manski, 1977). The theory behind choice modelling is well described and reviewed by many authors, such as (Adamowicz et al. 1995, Hanley et al. 2001, Louviere et al, 2000, Eck, 2005, Birol et al., 2006), and the remainder of this section draws heavily upon this literature.

The fundamental assumption of choice experiments is closely related to hedonic analysis in that consumers derive utility from the different characteristics of a good rather than from the good itself (Lancaster, 1966). The utility function can be specified as:

$$U_{ij} = V_{ij}(X_{ij}) + e_{ij} = bX_{ij} + e_{ij}.$$

Where Uij – is the utility to the individual i, derived from alternative j. In accordance with the random utility framework the utility function is decomposed in two parts: a deterministic part (V), which represents observed influences and a stochastic part (e), representing unobservable impacts on individual choice. X is the linear index of observable attributes and socio-economic and policy characteristics interacting with these attributes while b is a vector of utility parameters to be estimated.
The probability that a respondent prefers alternative “g” in the choice set to an alternative “h”, can be expressed as follows:

$$P[(U_{ig} > U_{ih})\forall h \neq g] = P[(V_{ig} - V_{ih}) > (e_{ih} - e_{ig})].$$

To calculate this probability, distributions of the error terms (eij) should be assessed. It is generally assumed that error terms are independently and identically distributed and therefore the probability of an alternative g being preferred over an alternative h can be expressed in terms of a logistic distribution (McFadden 1973, Hanley 2001):

$$P(U_{ig} > U_{ih},\ \forall h \neq g) = \frac{\exp(\mu V_{ig})}{\sum_j \exp(\mu V_{ij})}$$

Once the model has been estimated and if a cost attribute is present in the model, implicit prices or marginal willingness to pay (WTP) for a change in attribute can then be calculated. This is simply done by dividing a non-monetary attribute (for example % reduction in carbon emissions) by the monetary (cost) attribute with a negative sign (see for example Alpizar et al. 2001 for more details).

One of the difficulties with using the standard conditional logit model is the existence of ‘independence from irrelevant alternatives’ (IIA) property, stating that relative probabilities of two options being selected must be unaffected by the introduction or removal of other alternatives (see Luce 1959). If a violation of the IIA hypothesis is observed, then alternative statistical mixed logit models need to be explored, such as the random parameters logit model (Train, 1998, Hanley et al. 2001), nested logit model or error component model.

Study design

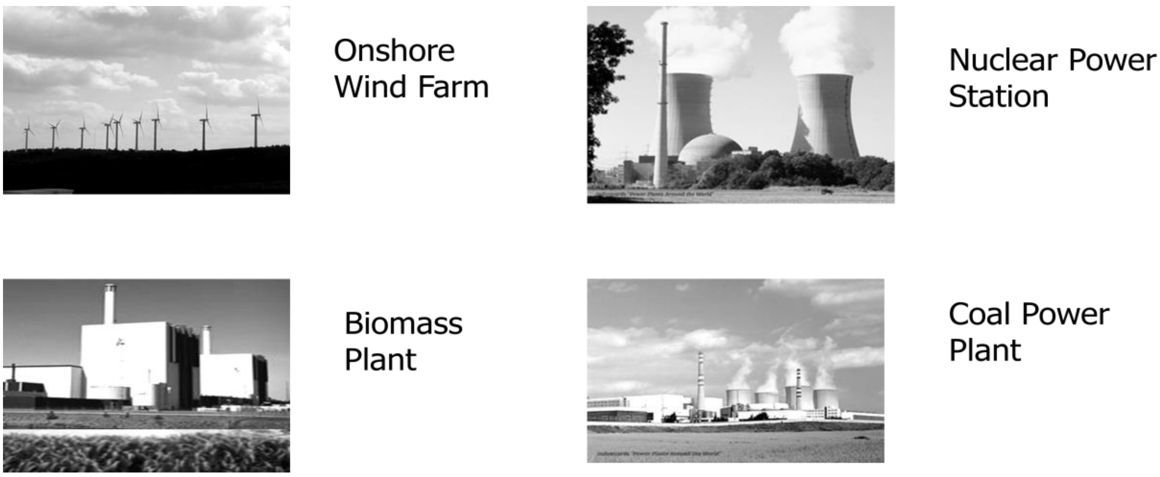
Our study attempts to estimate public preferences and willingness to pay for alternative energy options, such as wind, nuclear, biomass and the current generation mix (status quo option), all of which may form an integral part of future generation portfolio in Scotland. It is a collaborative effort between colleagues from Imperial College London and The University of Stirling and as such the piloting of the survey and two focus groups interviews were carried by Imperial College London (Fimereli et al, 2008). The next section describes in more detail the study design and implementation stages: i) survey structure; ii) defining levels and attributes; iii) choice scenario; and iv) sample selection, strategy and questionnaire logistics.

4.1 Survey structure

Respondents were presented with a mailed questionnaire survey and a letter stating the reasons behind the survey. It was also explained that the survey was entirely confidential and voluntary. The questionnaire consisted of three main parts:

- Part A: "Energy and Environment" contained questions on the levels of knowledge about different energy options and general attitudes towards environmental and energy issues in the UK;
- Part B: "Energy Options" contained a choice experiment section containing 5 choice cards where respondents were asked to choose between four energy options: wind, biomass, nuclear and the current energy mix, depending on which mix of attributes they prefer. This section explained the UK Government's aim to reduce carbon emissions by 2020 and to generate 20% of the UK's electricity from low-carbon energy sources. Participants were given a short description of each of the energy options (Wind, Biomass, Nuclear and the Current Energy Mix) as well as being supplied with a picture for each of the power plant technologies (see Figure 2).

Figure 2:



After completing the choice cards respondents were asked to answer some follow up questions testing the reasons behind the choices they made and also some additional questions aimed at finding out more about public attitudes towards off-shore and micro-generation. This was done to test public attitudes towards alternative generation and provide a platform for further research.

- Part C: "Respondents / Household Profile" a final section containing socio-economic questions about respondents' age, education, work status, number of children and income. In this section respondents were reminded that the survey was strictly confidential, voluntary and information provided would only be used for statistical purposes.

4.2 Levels and attributes

Each of the power generating options in the experiment was described in terms of the following attributes: distance from respondent's home (distance), carbon emissions reduction (carbon emissions), local biodiversity impacts (biodiversity), land requirements (fixed attribute) and an annual electricity bill increase (cost attribute).

- *Distance from respondents' home* – is the distance from the respondent's home to newly built generation sites.
- *Carbon Emissions Reduction* - is the reduction in emissions that future energy options can provide in relation to 20% of the UK's electricity generation.
- *Local biodiversity* – the impacts on local number of species of birds, mammals, insects or plants.
- *Total land* – is the amount of land occupied by the energy option all over the UK in order to produce 20% of total UK's electricity.
- Annual Increase in Electricity Bill – the amount by which each household's annual energy bill will increase.

Table 2: Attributes, corresponding variables, levels and coding

Attribute's name	Variable Name	Description	Levels	Coding
Distance from respondents' home	Distance	How far/close the energy option will be located from your home.	0.25 miles, 1 mile, 6 miles, 10 miles	0.25, 1, 6, 10
Local Biodiversity	Biodiversity - more	Impact of the local biodiversity of species in the area surrounding the energy option	Wind: no change, less	1 - if more, 0 -
	Biodiversity - no change		Biomass: more, less	1 - if no change, 0 - all others
	Biodiversity - less		Nuclear: no change less	1- if less, 0 - all others
Carbon Emssions Reduction	Emissions reductions	Reduction in carbon emissions that relates to the 20% electrcity generation.	Wind: 99%, 97%	99, 97
			Biomass: 90%, 50%	90, 50
			Nuclear: 99%, 95%	99, 95
Total Land	Land	How much land the energy option will have to occupy all ove the UK in order to generate 20% of total electricity by	Wind: 5,832 ha	5,832
			Biomass: 816,000 ha	816,000
			Nuclear: 568 ha	568
Annual Increase in Electrcity Bill	Cost	How much your electricity will increase every year.	£20, £40, £67, £90, £143	20, 40, 67, 90, 143
Alternative specific constant for wind	Asc wind	Constant associated with the 'label' for wind power.	1 for alternative wind, 0 for all other alternatives	
Alternative specific constant for biomass	Asc biomass	Constant associated with the 'label' for biomass power.	1 for alternative biomass, 0 for all other alternatives	
Alternative specific constant for nuclear	Asc nuclear	Constant associated with the 'label' for nuclear power.	1 for alternative nuclear, 0 for all other alternatives	

Table 3: Example choice card

EXAMPLE Card

Characteristics	**Option 1 Electricity from WIND**	**Option 2 Electricity from BIOMASS**	**Option 3 Electricity from NUCLEAR**	**Option 4 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 *for producing 20% of UK electricity*	Reduction by 99%	Reduction by 50%	Reduction by 95%	Reduction by 0%
Total land *for producing 20% of UK 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 2,167 football fields*
Annual increase in electricity bill	**£143**	**£40**	**£67**	**£0**
Please tick your preferred option	☐	☑	☐	☐

Table 2 contains more detailed information on the attributes and its levels and coding.

4.3 Choice alternatives

As part of the choice experiment respondents were asked to choose between four energy-generating alternatives: electricity from wind, electricity from biomass, electricity from nuclear, electricity form current energy mix. The latter is the 'status quo' option against which the other alternatives were measured. All alternatives that participants were presented with were labelled.

The experimental design of the choice experiment was developed using SPSS 14.0 and followed was a fractional factorial main effects design. Thirty-two choice profiles for each alternative were produced in the design. Thirty choice cards were generated randomly and the cards were blocked into six blocks of five choice cards. To minimise ordering bias, the order of the attributes between blocks was alternated (Fimereli et al, 2008). In summary each respondent was presented with a questionnaire survey containing five choice cards. Each card had four energy generating options described in terms of five attributes. They were asked to choose only one preferred option. An example of a choice card is presented below.

4.4 Sample selection and questionnaire logistics

There are different ways of carrying out public surveys such as postal, internet based, and face-to-face interviews. Each of these methods has its drawbacks and advantages. Face-to-face interviews tend to generate high response rates and tend to be more flexible in its implementation, but they are relatively expensive. Postal surveys tend to be cheaper, allow respondents to complete questionnaires at their own pace and are more easily elicit answers to sensitive questions, but they are often criticised for a high chance of a 'self-selection bias' and low response rates (Bennett and Blamey, 2001, McFadden et al. 2005). Internet-based surveys tend to also be cheaper and can potentially generate high response rates, but they are also subject to a self-selection bias and technical limitations for their development still exist. The current study was administered through a postal survey. This method was predominantly chosen due to its relative cost-efficiency given the scale of the surveyed area.

We have identified areas within Scotland that are representative of most of the country, namely Glasgow, Stirling, Fort William, Perth, Dumfries, Oban, Inverness, Aberdeen, Edinburgh, Isle of Lewis, Isle of Harris and Orkney (these included surrounding rural areas in each case). They were later combined into three distinct groups: 'South', 'Central' and 'Highlands and Islands' according to their geographical characteristics and population density. The number of respondents the survey was sent out to was scaled according to population size within each area. The survey was sent out to a sample of 1000 households across Scotland. Participants were chosen randomly based on the 2008 Electoral Register Database. Three weeks later a reminder containing another copy of a questionnaire was sent out to all non-respondents. After accounting for returned/undelivered questionnaires, 245 usable or partially usable responses were received – a total response rate of 27%, which is considered to be within the common range for mail surveys (e.g. Bateman et al., 2002).

Results

5.1 Sample characteristics

With 46% male, average annual income of £25,000 and 47 years average age, our sample provides a fairly good representation of a typical Scottish householder according to the Scottish Household Survey 2007/08. For more details on the comparison see Table 4 below.

We have also estimated the level of information that our sample had access to and their level of knowledge of low-carbon energy options offered in the current study, i.e. wind, nuclear and biomass. The vast majority of people in our sample had heard of wind power and nuclear power (96% and 88% respectively). Respondents, however, displayed much lower familiarity with biomass technology.

With respect to the type of information that the sample had access to from mass media sources, half of the sample stated to have access to mostly positive information about wind power, whereas 68% of respondents on the contrary stated to have mostly heard negative information about nuclear (see Table 5 for more details).

This perhaps is not surprising given the current Scottish Government's commitment to "no nuclear" in Scotland. At the same time the Scottish Government is backing renewables, such as wind power, which is of course reflected by the mass media coverage and as such the "type of information" that the public has access to.

To gain an insight into the general perceptions of the respondents towards key problems addressed in the study such as climate change and the UK's role in tackling this issue we also asked the respondents to express their views on some of the general statements described in Table 6.

We found that the vast majority of respondents agree that solving environmental problems should be a priority when it comes to public spending in the UK. Most of the respondents also agreed that climate change is a problem that needs to be addressed internationally and that everyone should substantially change our behaviour to tackle it. Public views were not as straightforward, however, with regards to investment in renewable and nuclear energy as a way of tackling climate change. As such only slightly over half of the sample (59% and 56% respectively) agree or strongly agree that the UK should invest more in these technologies.

Table 5: Knowledge of and access to information about discussed energy options

Knowledge of energy options	Wind	biomass	nuclear
% of People that heard about	96%	53%	88%
% of People that stated to have at least some knowledge about	85%	31%	36%
% of People that had access to mostly POSITIVE information about	50%	22%	11%
% of People that had access to mostly NEGATIVE information about	19%	17%	68%

Table 6: Public attitudes towards general statements regarding climate change

% of Total sample	Disagree or Strongly disagree	Unsure	Agree or Strongly agree
Solving environmental problems should be one of the top 3 priorities for public spending in the uk.	16%	11%	70%
Environmental problems such as climate change and air pollution have been exaggerated.	49%	24%	25%
Developed countries are the main contributors to global warming.	20%	15%	62%
The UK should invest more in renewable energy as a way to tackle climate change.	16%	21%	59%
The UK should invest more in nuclear power stations as a way to tackle climate change.	20%	20%	56%
Climate Change is a global problem that needs to be addressed internationally y all countries.	7%	3%	86%
We all have to substantially change our behaviour in order to help tackle climate change.	9%	8%	81%

Note: Based on total respondents, non response to these accounts for difference from 100%

5.2 Results of the choice experiment

This section of the paper reports our findings on two separate estimations. Firstly, we report on attitudes and preferences for the total Scottish sample including preferences according to socio-economic groupings and respondents' willingness to pay for the energy options given the different levels of attributes. Secondly we investigate divergence in preferences between three areas of Scotland (Highlands and Islands; Central; and South).

Random parameters Logit Model

As was mentioned earlier in section 3, one of the key requirements of the conditional logit model is the validity of the IIA assumption. This assumption was tested using Hausman and McFadden chi-square test (1984) and we found that the IIA assumption is rejected. To overcome this we then tested alternative model specifications that can relax the IIA property. The specifications tested were Random Parameters Logit Model (RPL), Nested Logit and Error Component Model . We found that the RPL model, which allowed the investigation of heterogeneity across respondents, also provided us with the best fit and therefore the remainder of the paper will focus on the results estimated using RPL specification.

As with the conditional logit model, in RPL models utility is decomposed into a deterministic part (V) and an error component stochastic term (e). Indirect utility is a function of the choice attributes (Zj), with parameters β, which may vary across individuals by a random parameter ηi, and of the socio-economic and attitudinal characteristics (Si) (Birol et al. 2006).

$$U_{ij} = V(Z_j(\beta + \eta_i), S_i) + e(Z_j, S_i)$$

Table 7: Random parameter logit estimation results

Variable	Comment	Original RPL Model including Socio-Economic Characteristics Mean effect	t-statistic
Random parameters in utility functions			
Distance	*Distance Attribute*	0.035**	2.61
Biodiversity-no change	*No change in biodiversity*	-0.07	-0.7
Biodiversity - more	*Increase in biodiversity*	0.44**	2
Emissions reductions	*Reduction in carbon emissions*	0.01**	2.19
Non-random parameters in utility functions			
Asc Wind	*Alternative specific constants - Wind, Biomass and Nuclear*	2.48***	2.94
Asc Biomass		1.42	1.63
Asc Nuclear		1.92**	2.29
Cost	*Cost attribute (increase in electricity bill)*	-0.01***	-7.12
Sex*Asc wind		-0.66**	-2.16
Sex*Asc biomass	*Gender*	-0.49	-1.52
Sex*Asc nuclear		0.04	0.14
Kids*Asc wind		0.6***	2.65
Kids*Asc biomass	*Households with children*	0.49**	2.13
Kids*Asc nuclear		0.22	0.95
Age*Asc wind		-0.45***	-4.47
Age*Asc biomass	*Age*	-0.32***	-3.16
Age*Asc nuclear		-0.17*	-1.68
BNW*Asc wind	*We should all change our behaviour to tackle climate change*	-0.03	-0.43
BNB*Asc biomass		-0.09	-1.12
BNN*Asc nuclear		-0.29***	-3.65
More nuclear*asc wind	*The UK should invest more in nuclear power stations as a way to tackle climate change*	0.68**	2.03
More nuclear*asc biomass		0.16	0.45
More nuclear*asc nuclear		1.6***	4.49
ENW*Asc wind	*Solving environmental problems should not be one of the top 3 priorities for public spending in the UK*	0.51***	3.4
ENB*Asc biomass		0.44***	2.94
ENN*Asc nuclear		0.48***	3.2
Derived standard deviations of parameter distributions			
Distance		0.08**	2.44
Biodiversity-no change		0.13	0.28
Biodiversity - more		0.23	0.29
Emissions reductions		0.02**	2.38
Number of observations	1162		
Log likelihood value	-1245.6		

Note: ***, **, * = Significance at 1%, 5%, 10% level.

Table 8: Willingness to Pay (WTP) Estimates

Variable	Mean Effect	95% confidence intervals	t-statistic
Distance (per mile)	£3.8**	0.89 - 6.65	2.57
Biodiversity-no change (from baseline 'less')	-£7.69	-29.59 – 14.21	-0.69
Biodiversity – more (from baseline 'less')	£47.51*	-1.82 – 96.83	1.89
Emissions reductions (for % reduction)	£1.13**	0.87 – 2.17	2.12

Note: ***, **, * = Significance at 1%, 5%, 10% level.

To account for unobserved heterogeneity, and by specifying the distributions of the error terms e and η, the equation above can be expressed as:

$$P_{ij} = \frac{\exp(V(Z_j(\beta+\eta_i), S_i))}{\sum_{h\in C}\exp(V(Z_h(\beta+\eta_i), S_i))}$$

This model is not restricted by the IIA assumption hence the correlation of the stochastic part of utility is allowed between the alternatives via the influence of η (Birol et al. 2006).

In our study the RPL model with a non-random cost attribute was employed. The model was estimated using NLOGIT 4.0.4. All random parameters were assigned normal distributions, although triangular distributions were also considered. Distribution simulations were based on 500 draws using Halton's method.

5.2.1 Total Scottish sample

Table 7 reports the results for the Random Parameters Logit model (RPL) with added socio-economic variables, such as age, gender and number of children in the household. The other socio-economic variables were also tested but, since we found no significant impact of those variables, they were excluded from the final model. We also found that certain attitudinal variables had a significant impact on model fit, they are reported below.

For the overall Scottish sample our results suggest that people consistently identify distance, an increase in biodiversity and a reduction in emissions as the most significant attributes. These variables come through as significant at the 5% level and have positive preference associated with them. Standard deviations for distance and reduction in emissions attributes come through as significant at the 5% level, which suggests the presence of heterogeneity in the parameter estimates over the sampled population (Hensher et al., 2005). As expected, people prefer to live further away from power stations, wish to see an increase in biodiversity and have positive preferences towards a reduction in carbon emissions. At the same time they have strong negative preferences towards increases in their annual energy bill, as confirmed by the reported results (the cost attribute is negative and significant at the 1% level).

Interesting results were observed with regards to public attitudes towards alternative specific constants, i.e. respondents in the total sample displayed positive attitudes not only towards wind, but also towards the nuclear energy option compared to the current generation mix (alternative specific constants are positive and significant at 1% and 5% levels respectively). These results may have direct policy implications for Scotland given that the current Scottish Government made it clear that it will not support any new-build nuclear power stations in Scotland. The existing policy in itself may be one possible explanation of such positive preference, i.e. the public "knows" that new nuclear will be built outwith Scotland, hence the positive Scottish attitude towards it (a continuation of the positive willingness to pay for greater distance to a power station). On the other hand this preference may simply be a reflection of the fact that people do indeed prefer to have carbon free nuclear power plants and wind farms over existing coal and gas power stations.

Our analysis of socio-economic characteristics showed that females are more likely to choose the wind energy option, whilst positive preferences towards low-carbon energy (wind, biomass and nuclear) over the current generation mix are decreasing with age. Presence of children in the household is also a significant factor when it comes to choosing low-carbon energy options, specifically biomass and wind over the status quo.

A number of attitudinal variables did have an impact on model fit, as such they were included in the model. More specifically, those respondents who agree with the statement that "We should all significantly change our behaviour in order to tackle climate change" are less likely to choose the nuclear energy option over the current generation mix (negative and significant at 1% level). Perhaps not surprisingly those who agree that "The UK

Table 9: RPL model results of the regional analysis

Variable	Central Perth, Stirling and Aberdeen		South Glasgow, Edinburgh and Dumfries		Highlands and Islands Harris, Lewis, Orkney, Inverness, Fort William, Oban	
	Mean effect	t-statistic	Mean effect	t-statistic	Mean effect	t-statistic
Random parameters in utility functions						
Distance	0.04	1.64	0.07***	2.95	0	0.13
Biodiversity - no change	-0.19	-1.1	0.17	1.01	-0.06	-0.45
Biodiversity – more	0.24	0.34	0	-0.01	0.72**	2.16
Emissions reductions	0.01	1.54	0.02**	2.21	0	-0.11
Non-random parameters in utility functions						
Asc Wind	2.51*	1.76	1.37	1.53	2.51***	3.45
Asc Biomass	1.39	1.03	0.42	0.51	0.6	0.87
Asc Nuclear	2.18	1.56	0.6	0.69	1.74**	2.47
Cost	-0.01***	-3.45	-0.01***	-5.17	-0.01***	-3.52
Derived standard deviations of parameter distributions						
Distance	0.11	1.3	0.07	1.54	0.05	0.99
Biodiversity - no change	0.14	0.18	0.21	0.35	0.08	0.18
Biodiversity – more	0.71	0.41	0.3	0.35	0.21	0.25
Emissions reductions	0.01	0.54	0	0.27	0.01	0.51
Number of Observations		347		355		475
Log Likelihood Value		-413.9		-419.15		-550.73

Note: ***, **, * = Significance at 1%, 5%, 10% level.

should invest more in nuclear power stations to tackle climate change" displayed strong positive preference towards nuclear and wind energy options (positive and significant 1% and 5% respectively). Finally we found that those respondents who think that "Solving Environmental Problems should not be one of the top 3 priorities for public spending in the UK" over the status quo, i.e. respondents are willing to pay for low-carbon energy themselves rather than relying on public funds. This provides additional ground for further research when it comes to the investigation of public preferences towards existing energy policy in Scotland.

Implicit prices or marginal 'willingness to pay' (WTP) amounts associated with the CE attributes are reported in the Table 8. These reflect the value that respondents place on the change in a given attribute.

According to the results, the sampled population in Scotland is willing to pay on average £3.8 per mile for living further away from a power generating option. With regards to increase in biodiversity respondents are willing to pay £47.51 for an increase and £1.13 for a 1% reduction in carbon emissions. It is important to note that the values should not be interpreted as a 'precise' monetary figure, but an indication of the magnitude of respondents' willingness to pay. Taking the above into account implicit prices can serve as a valuable policy-making and investment analysis tool.

5.2.2 Regional analysis

Whilst realising limitations with the number of observations in our sample, at the next stage of the analysis we wanted to test whether energy preferences across Scotland were uniform throughout the country, or if there is any divergence depending on regional location. As discussed earlier in section 4.4, we have split our sample into three areas combining all the investigated regions: South, Central and Highlands and Islands according to their geographical characteristics and population density. Just as before the RPL model was used in the estimation, although we have not reported parameter estimates for any socio-economic variables, as we did not find them to be significant for the current section of the study. Regional analysis results are reported in Tables 9 and 10.

Due to the small size of the sample, our results are somewhat lacking statistical significance, but what they do indicate is that depending on the region of Scotland people place different values on different attributes of the study, for example people in the Highlands and Island seem to be

Table 10: Willingness to pay (WTP) estimates - regional analysis

Variable	**Central –** Mean effect	95% conf. interv.	t-stat	**South –** Mean effect	95% conf. interv.	t-stat	**Highlands and Islands** – Mean effect	95% conf. interv.	t-stat
Distance (per mile)	4.64*	-0.73 – 10.01	1.69	5.83***	1.7 – 9.96	2.77	£0.35	-5.16 – 5.86	0.13
Biodiversity-no change (from baseline ‘less’)	-£20.88	-58.7 – 16.97	-1.08	£15.00	-14.15 – 44.14	1.01	-£9.96	-54.5 – 34.63	-0.44
Biodiversity – more (from baseline ‘less’)	£26.54	-132.1 – 185.17	0.33	-£0.27	-67.83 – 67.3	-0.01	113.41*	-9.6 – 236.4	1.81
Emissions reductions (for % reduction)	£1.41	-0.35 – 3.17	1.58	1.51**	0.06 – 2.94	2.05	-0.09	-1.81 – 1.63	-0.11

Note: ***, **, * = Significance at 1%, 5%, 10% level.

more consistent in identifying increased biodiversity as the most valued attribute, whereas distance from respondents home comes through as significant for people in the Central region. For the respondents in the ‘South’ the attributes distance and reduction in emissions come through as highly significant (at 1% and 5% levels respectively). Given that Glasgow and Edinburgh, the two largest and highly populated cities in Scotland, are included in this group, such preference towards these two particular attributes seems logical. That is the population of these cities are likely to experience the highest background levels of air pollution in Scotland and are the most densely populated so proximity to electricity producing plants will be most strongly felt. This is especially true of Edinburgh, with two major coal power plants, Longannet and Cockenzie, located nearby.

Given the above, our results indicate that there is a great need for further research in this area since if confirmed our results will suggest that Scottish energy policy needs to be planned taking account of regional preferences to a much greater extent than is currently done.

5.2.3 Non-compensatory preferences

One aspect of the analysis that is of a particular interest is observed non-compensatory preferences across respondents. The fundamental assumption in random utility models since Lancaster (1966) and McFadden (1974) is that ‘individuals’ decisions respond to compensatory heuristics by which individual attributes are weighed by their contribution to the overall utility in order to evaluate the relative utility of each profile’ (Arana, 2009). This implies that individuals are able to make trade-offs between attributes to identify the most preferred alternative. Previous research, conducted by authors such as Kahneman and Frederick, 2002; Gowda and Fox, 2002; Payne et al., 1993), showed that people often avoid making trade-offs and that such non-compensating behaviour can also be a fully rational process (Payne et al., 1990) (for more details see Arana, 2009). Presence of such non-compensatory behaviour, however, may have direct implications on the way the results of CE are interpreted and therefore, policy decision-making associated with them.

We found that a surprisingly large proportion (42%) of sampled respondents in our study consistently chose one energy option over the others. Out of those 46% of people chose wind in all cases, 4% chose biomass, 30% chose nuclear and 20% chose the current generation mix. Although consistent with random utility theory, such behaviour presents a challenge to a researcher in identifying rationality behind these choices. To test whether this behaviour affects the results of the original RPL model, we estimated a new model using RPL where all respondents that consistently chose one option over the others (e.g. wind energy option in all cases), were excluded from the analysis (see Table 11 for the results).

When comparing the results of the restricted sample with the original model, we found that the results were reasonably stable with regards to the alternative model specification. All of the signs remained unchanged and most of the attributes kept their level of significance with the exception of an increase in biodiversity, which appeared to be insignificant in the restricted model. As for alternative specific constants on the other hand, all of them, including the constant for biomass, came through as highly significant. Some changes were also observed in socio-economic variables, for example unlike in the original model, households with children as well as gender of respondents did not appear to have any significant impact on the respondents choices. With regards to implicit prices, however, values were relatively constant, except for the willingness to pay for an increase in biodiversity, which

Table 11: Results excluding respondents with "non-compensatory preferences"

Variable	Comment	Restricted Sample accounting for Non-compensatory Preferences	
		Mean effect	**t-statistic**
Random Parameters in Utility Functions			
Distance	Distance Attribute	0.09***	3.36
Biodiversity-no change	No change in biodiversity	0.01	0.04
Biodiversity - more	Increase in biodiversity	0.31	0.71
Emissions reductions	Reduction in carbon emissions	0.01**	2.09
Non-Random Parameters in Utility Functions			
Asc Wind	Alternative specific constants - Wind, Biomass and Nuclear	5.66***	3.8
Asc Biomass		4.69***	3.07
Asc Nuclear		3.82***	2.62
Cost	Cost attribute (increase in electricity bill)	-0.01***	-6.47
Sex*Asc wind	Gender	-0.38	-0.93
Sex*Asc biomass		-0.23	-0.55
Sex*Asc nuclear		0.33	0.76
Children*Asc wind	Households with children	-0.15	-0.68
Children*Asc biomass		-0.23	-0.95
Children*Asc nuclear		-0.18	-0.75
Age*Asc wind	Age	-0.64***	-4
Age*Asc biomass		-0.50***	-3.24
Age*Asc nuclear		-0.34**	-2.13
	We should all change our behaviour to tackle climate change	-0.18*	-1.66
BNB*Asc biomass		-0.25**	-2.3
BNN*Asc nuclear		-0.35***	-3.06
More nuclear*asc wind	The UK should invest more in nuclear power stations to tackle climate change	1.50***	2.82
More nuclear*asc biomass		1.35***	2.62
More nuclear*asc nuclear		2.20***	3.9
ENW*Asc wind	Solving environmental problems should not be one of the top 3 priorities for public spending in the UK	0.54***	2.94
ENB*Asc biomass		0.59***	3.23
ENN*Asc nuclear		0.69***	3.6
Derived standard deviations of parameter distributions			
Distance		0.07**	1.96
Biodiversity-no change		0.37	0.69
Biodiversity - more		0.41	0.19
Emissions reductions		0.01*	1.75
Number of Observations			692
Log Likelihood Value			-750.43

Note: ***, **, * = Significance at 1%, 5%, 10% level.

Table 12: WTP estimates for the restricted sample accounting for non-compensatory preferences

Variable	Mean effect	95% confidence intervals	t-statistic
Distance (per mile)	£4.5***	2.39 – 7.6	3.76
Biodiversity-no change (from baseline ‘less’)	£0.43	-19.15 – 20.01	0.04
Biodiversity – more (from baseline ‘less’)	£22.56	-43.46 – 88.58	0.67
Emissions reductions (for % reduction)	£0.86**	0.04 – 1.68	2.05

Note: ***, **, * = Significance at 1%, 5%, 10% level.

came through as just insignificant. Although relatively robust, our results suggest that further investigation of the displayed non-compensatory preferences is needed to fully understand underlying reasons behind them including those at a regional level.

6. Conclusions and future research

The fundamental purpose of this study was to determine public preferences and willingness to pay for alternative energy options, such as wind, nuclear, biomass and current generation mix, all of which may form an integral part of Scotland’s future generation portfolio. To achieve this we used a choice experiment approach involving a countrywide mail survey sent out to a random sample of 1000 households across Scotland. We compared public preferences across four energy options wind, biomass and nuclear relative to the current generation mix (the status quo option). These options were described in terms of the following attributes: distance from respondent’s home, carbon emissions reduction, local biodiversity impacts, land requirements (fixed attribute) and an annual electricity bill increase (cost attribute).

Our results show that respondents in Scotland display strong positive preferences towards wind power over the current generation mix. In addition it was found that the nuclear energy option is also more attractive to the sampled population rather than the status quo. While the first finding is inline with current Scottish policy of heavily backing renewables, the positive attitudes towards nuclear suggest that the current “no nuclear” policy for Scotland should perhaps be further examined.

According to the results, respondents want to live further away from energy generating options and consistently identify an increase in biodiversity as an attribute, which is important to them. They also display positive willingness to pay for a reduction in carbon emissions.

A large number of studies (e.g. Clarkson, R. and K. Deyes, 2002, Fankhauser, S. (1994), Haraden, J. (1993), Stern, N.H. et al (2006)) have investigated reductions in carbon emissions and estimated the shadow price of carbon (for a meta-analysis of social cost of carbon listing over 40 studies see Tol R., 2008). The comparison of our values (for WTP for a 1% reduction in carbon emissions) with these studies, however, is difficult, as the values are typically reported in pounds per tonne of carbon (£/tC) or in pounds per tonne of CO2 equivalent (£/tCO2e). Indeed, the shadow price of carbon values recommended for use in economic appraisal in the UK (DEFRA, 2007) also estimate this figure as £/tCO2e. No studies reporting directly comparable results, for a 1% reduction in emissions, could be found in the literature. Despite these issues of comparability applying our average WTP of £1.3 for a 1% reduction in carbon emissions (using annual emissions from power generation) to all UK households gives an estimate of £15.1/tCO2e. Comparing this to the shadow price of carbon value as per DEFRA 2007 of 25 £/tCO2e, represent a surprisingly close match, especially when taking into account our 95% confidence intervals (12.5-93.6 £/tCO2e).

With regards to identification of regional preferences across Scotland, we found that depending on the location respondents identify different attributes as important to them. For example, those who live in the Highlands and Islands displayed consistent preferences towards an increase in biodiversity, indicating that this attribute is more important to them than distance and level of reduction in carbon emissions. On the contrary, respondents living in the Central and Southern regions (see section 5.2.2 for more details) identified distance and reduction in carbon emissions as the most important attributes. Although somewhat statistically limited, it is felt that these results may have direct implications on the development of Scottish energy and policy planning, especially when it comes to the placement of future power plants.

Another area that calls for further investigation is the presence of non-compensatory behaviour amongst the sampled population. It was found that almost half of the sample (42%) consistently chose one energy option above the others, independently of attribute levels. Although when tested our results proved to be fairly robust, i.e. when respondents who displayed “non-compensatory preferences” were excluded from the analysis, we found little impact on the overall results (other than the significance of increasing biodiversity), the underlying reasons behind such behaviour are still to be understood.

In summary it is felt that our research will provide a fresh and important contribution to future decision-making in the area of energy policy. Scotland is faced with upcoming changes to the generation portfolio of the country and significant targets have been set for reductions in emissions from this sector of the economy. Decision-making has been based on relatively sparse information given the lack of literature aimed at the investigation of energy preferences for Scotland. Our research is suggestive of which technologies would be most acceptable to the Scottish public. It is also indicative that further investigation is required to identify where given technologies would be most preferred in Scotland, which in combination with generation potential may suggest an optimal future generation portfolio that will be politically palatable in achieving Scotland's world-leading emissions reduction targets.

Acknowledgements:

We would like to thank Eleni Fimereli from the Centre for Energy Policy and Technology (ICEPT), Imperial College London and Dr. Susanna Mourato from the Department of Geography and Environment at London School of Economics and Political Science for their great contributions and collaboration throughout the project and also Dugald Tinch from the Economics Department, University of Stirling for his helpful comments and assistance with editing this paper.

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Endnotes

[1]The LCPD requires large electricity generators, and other large industrial facilities, to meet stringent air quality standards from 1 January 2008. If generators opt-out of this obligation, the plant will have to close by the end of 2015 or after 20,000 hours of operation from 1 January 2008, whichever is the sooner. According to BERR, approximately 12 GW of coal and oil-fired generating plants have opted-out and will have to close by the end of 2015, representing about 15% of Great Britain's present total capacity. Energy Industry Markets Forecast 2008-2015, Scottish Enterprise.