Public Preferences towards Future Energy Policy in the UK: A Choice Experiment Approach

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Declaration

In accordance with the Regulations for Higher Degrees by Research, I hereby declare that the whole thesis now submitted for the candidature of Doctor of Philosophy is a result of my own research and independent work except where reference is made to published literature. I also hereby certify that the work embodied in this thesis has not already been submitted in any substance for any degree and is not being concurrently submitted in candidature for any degree from any other institute of higher learning. All errors remain my own.

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ABSTRACT

The key focus of this dissertation is to produce research upon energy and climate change issues in the UK in a policy relevant and theoretically sound way. It aims to inform industry and policy makers to allow politically palatable, successful and effective future energy and climate change policy to be developed by identifying the preferences of the public for different policy scenarios. The Choice Experiment method was employed throughout this dissertation as the consistent methodological approach allowed for greater comparability of the results in addition to allowing the method's robustness and reliability to be tested.

The first part of this research (Chapter 3) is concerned with investigating attitudes and willingness to pay for future generation portfolio of Scotland by investigating household preferences for various energy generating options, such as wind, nuclear and biomass compared to the current generation mix. We identified the Scottish public have positive and significant preference towards wind and nuclear power over the current energy mix. We also found heterogeneity in public preferences depending on where respondents live which is reflected in their preferences towards specific attributes. Presence of non-compensatory behaviour in our sample is another element which was investigated in this part.

Chapters 4 and 5 contain analyses of two independent choice experiments which were run in parallel. They take a UK-wide approach and investigate public preferences for more general areas of future energy and climate change policy, such as: carbon reduction targets, focus on energy efficiency improvements and

attitudes to micro-generation versus large scale renewable generation. In addition the preferences for adaptation to and mitigation of climate change are investigated.

Micro-generation is not often considered by energy companies when it comes to planning their generation strategies and was therefore of particular relevance to this research. As such Chapter 6 identifies the importance that the public places on this particular energy option and how it compares with their preferences towards other key energy and climate change policies of the UK. To analyse reliability of the results and to contribute to the theoretical field of stated preference valuation, each of the experiments contained two overlapping attributes, i.e. increase in level of micro-generation and an increase in total cost to a household, comparison of which was also carried out in Chapter 6.

Finally in Chapter 7 the results found in the sections described above are discussed with reference to the policy background in the UK and Scotland. Also issues with the research and areas for further study are identified.

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Chapter 1. Preface

1.1 Background

The key principles that lay the foundation of the energy policy of the UK are the ability to maintain the security of supply, deliver affordable energy prices to the consumers and, more recently, meet tough climate change targets. As part of the legally binding EU Directive, the UK is committed to cut greenhouse gas emissions by 20% by 2020 (compared to 1990 levels). In addition, the UK Government adopted even more challenging national targets of a 34% reduction in carbon emissions by 2020 that was set in law by the Climate Change Act 2008. Scotland's commitment to reducing its carbon emissions is even more ambitious. As part of the Climate Change Bill passed by the Scottish Parliament in 2009, it aims to achieve 42% cut in carbon emissions by 2020 (compared to 1990 levels) rising to 80% reduction by 2050.

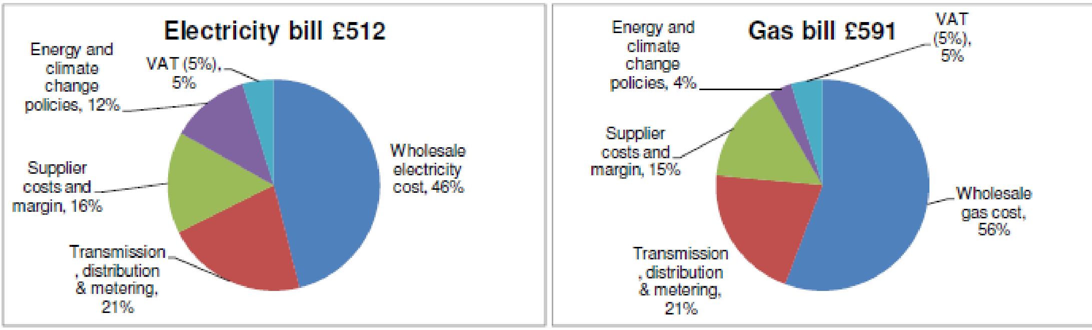
The major challenge that is facing policy-makers in the UK in the decade to come is an impending closure of almost one fifth of today's generation capacity of the UK and potential phase out of the entire thermal generation capacity by 2030 in Scotland. These changes are happening alongside growing electricity demand. Policy decisions to address these issues will have to be weighed against their ability to meet strict climate change targets that the UK is committed to. In response to this the UK and European Governments put in place a range of policies designed to stimulate "clean energy" investment that include a carbon price floor of the power sector (HM Treasury, 2011), EU Emissions Trading Scheme (EU ETS), Renewable Obligation (RO) and Feed-in Tariffs (FITs) (Npower Future Report, 2011). According to DECC (2011) estimates, the UK's energy sector requires an investment of at least £200 billion to meet decarbonsation targets by 2020. To put this into perspective, that is more than £3,000 per head for the UK.

At a time when the future of nuclear generation is uncertain with almost all of the UK's existing nuclear capacity due to shut down in the next ten years[1] and replacement unlikely to be built as early as 2020, gas and renewable energy will remain the key sources of providing energy in the overall generation portfolio of the country. Other policy areas that could also play a significant role in meeting the UK's emissions targets are the expansion of micro-generation and improvements in energy efficiency across all sectors of the economy, all of which are on the political agenda of the UK Governments.

Such ambitious policy, however, implies costs that are passed on to consumers in the form of taxation, rising energy bills and increases in consumer good prices. Costs of climate change and energy policies are already being felt by UK consumers. According to DECC estimates (see Fig. 1) in 2010, 12% of an average domestic electricity bill and 4% of an average domestic gas bill were made up of the costs of climate change and energy policies.

[1] On the 4th December 2012 EDF Energy firm announced that Hunterston B will remain in operation until 2023.

Figure 1.1 Estimate breakdown of an average annual domestic gas and electricity bill in 2010.



Source: DECC 2010, Figures in real 2009 prices

Future projections of the impact of accelerated climate change policies in 2020 on consumer bills vary. Some experts estimate it to be as high as £400 a year (Policy Exchange, 2012); some predict it to be as low as £13. The latter assumes that the predicted rise in the electricity prices of 33% and gas prices of 18% as a result of climate change and energy policies will be counteracted by the savings in consumer bills that stem from these policies being in place (DECC, 2010).

Irrespective of whether the UK is successful in reducing its carbon emissions or not, extensive scientific evidence shows that climate change will still happen (UK Climate Change Projections, 2009). Moreover, in 2011 the concentration of greenhouses gas emissions in the atmosphere hit record levels (WMO, 2012). Impacts of these emissions will be felt for centuries to come (WMO Secretary-General, 2012). Some of the climate change impacts that the UK will be faced with include: temperature rise; an increased risk of heat waves; less rainfall in summer and more in winter; sea level rises; and flooding (UKCIP, 2009). All of these changes in the current climate will have potentially significant economic and social impacts that need to be planned for and addressed in the future policy of the UK.

It does not come down to a choice between adaptation or mitigation, clearly there is a role for both in Government policy, which will need to include measures addressing not only reduction in carbon emissions but also adapting to the consequences of past human activity. No estimates of the impact of adaptation measures on future consumer bills could be found in the literature; but the potential costs may be incurred in the form of: rising council tax bills associated with the need for maintenance of public properties and infrastructure; decrease in value of private properties resulting from, for example, an increased risk of flooding of particular areas; and in the form of rising utility bills due to the need for the water and power sector to adapt their infrastructure to the impacts of changing climate (Consumer Focus, 2012).

1.2 Motivation for This Thesis

The idea for this research was born during my employment in the energy sector prior to undertaking my studies. For a number of years I was involved in planning and analysing the UK's generation as well as participation in economic appraisal of various energy-related projects. It was then that it became apparent to me that one area that industry lacks understanding of and often fails to appropriately take into account are the social costs and benefits associated with a development of a new generation plant or a particular strategy. If properly accounted for, understanding of public preferences can help to bridge the gap between industry, households and policy makers in the development of a successful and effective energy and climate change policy for a country. The ultimate goal for my research was to produce policy relevant results as well as to contribute to academic literature by applying public preference valuation techniques to potentially novel areas.

1.3 Key Objectives

The work in this dissertation aims to identify public preferences towards key elements of future energy and climate change policy of the UK. The first part of this research is concerned with investigating attitudes of households and their willingness to pay for various energy generating options, such as wind, nuclear and biomass compared to the current generation mix all of which may form an integral part of the future generation portfolio. This study also attempted to analyse divergence in regional preferences of the public towards different technologies as well as to investigate the presence of non-compensatory behaviour within the sample. The second section of this thesis takes a UK wide approach and attempts to reveal public preferences towards more general policy areas, such as: focus in improvements in energy efficiency, attitudes to micro-generation versus large scale renewable generation and public preferences and willingness to pay for various levels of carbon reduction targets. Another issue that is addressed in this section is the issue of adaptation to and mitigation of climate change. Micro-generation was a particular area of interest to me, again something that is not often considered by energy companies when it comes to planning their generation strategies. I wanted to identify the importance that the public places on this particular energy option and how it compares with their preferences towards other key energy and climate change policies of the UK.

1.4 Dissertation Structure and Summary of Empirical Chapters

Literature review: Given the variety of topics addressed in each of the empirical Chapters, each contains a separate literature review that covers valuation studies relevant to the particular area and a distinct policy framing. The literature presented in these chapters only overlaps in terms of general policy literature (such as the recent Energy Bill etc.) which are briefly summarised in this chapter. As such the structure of separate literature reviews can be seen to clarify the message of this dissertation and also identify the key and unique policy framing of each chapter.

Following this Chapter, the thesis is structured in the following way:

Chapter 2 describes the methodological and theoretical framework. It begins with an overview of existing preference valuations techniques and explains the reasons for primarily applying the Choice Experiment (CE) method in this dissertation. Then it moves to outline the model specifications adopted in this dissertation (such as Conditional Logit, Random Parameters and Latent Class Models) and also gives a brief overview of experimental design. Given that the same consistent method has been applied throughout this dissertation, each chapter that follows refers to this methodological chapter for theoretical background and model specifications. The next four Chapters contain empirical applications of the choice experiment methodology to energy and climate policies.

Chapter 3 is a study of public preferences for energy generating options (wind, biomass and nuclear compared to current energy mix) in Scotland. It employs a labelled choice experiment, with each energy option described in terms of the following attributes: distance from respondent's home, carbon emissions reduction, local biodiversity impacts, land requirements (fixed attribute) and annual electricity bill increase (cost attribute). The results show that the Scottish public on average has strong positive preference towards wind power over current generation mix. In addition we find that the Scottish public also prefers to see nuclear energy in the future generation portfolio. This result is particularly interesting in the light of the current "no nuclear" policy for Scotland. We also find heterogeneity in public preferences depending on where respondents live. For example residents of the Highlands and Islands consistently valued biodiversity more than other attributes; whereas distance and reduction in carbon emissions were the most important attributes for people living in the Central and Southern areas of Scotland. We also identified the presence of non-compensatory behaviour within our sample, although this did not have a significant impact on overall results.

The empirical work contained in Chapters 4 to 6 is interlinked. Chapters 4 and 5 contain analyses of two independent choice experiments related to key areas of future energy policy of the UK which were run in parallel. Policy areas analysed in Chapter 4 contained direct policy measures for dealing with climate change, whereas attributes analysed in Chapter 5 were more general in terms of identifying the potential focus and aims of future policy. To analyse reliability of the results and to contribute to the theoretical field of stated preference valuation, each of the experiments contained two overlapping attributes, i.e. increase in level of micro-generation and an increase in total cost to a household.

Chapter 4 is aimed at determining public attitudes towards the issue and willingness to pay for measures of adaptation framed alongside such energy policy areas as increase in large scale renewable energy, increase in level of micro-generation and increase in total cost to household. In other words, we describe the UK's future energy policy in terms of attributes, each of them representing a direct approach to deal with or reduce impacts of climate change. Our results confirm the existence of positive utility and WTP derived by the public for an increase in low-carbon energy in the UK (both on macro and micro scales), but their attitudes towards adaptation are not as straightforward and present the scope for future research.

Chapter 5 investigates the preferences of the public for carbon emissions reduction targets. This is of particular policy relevance in the light of the new UK Energy Bill 2012 that was published on the 29th November 2012 (DECC, 2012). As part of the Bill, the UK Coalition Government made a decision to delay setting carbon reduction targets for 2030 and to approve a cost of £7.6bn to be passed on to the consumer by energy companies to pay for "clean energy investment" (BBC, 2012). We show that the UK public have significant positive preference for higher carbon reduction targets but are realistic about the level which can be achieved. It appears that WTP for carbon reduction targets follows a non-linear pattern, reaching a maximum at around 40%.

We also investigate public preferences for investment in energy efficiency between different sectors of the economy and increase in the level of micro-generation. We find that increases in micro generation and focus upon the private sector for investment in energy efficiency are preferred.

Chapter 6 investigates public preferences towards the scale of micro-generation development in the UK. It also compares results of two previously reported discrete choice experiments both of which include increase in level of micro-generation and the total increase in cost to a household as overlapping attributes thus testing robustness and reliability of choice experiment results. We find that the public does want to see more micro-generation in the UK and their willingness to pay for it increases with scale. We also find that although context of the policy in which attributes are described does have some impact on the magnitude of the results, the actual values of willingness to pay were not statistically different from each other, thus supporting the robustness of the choice experiment method and its validity for use in policy making. Finally **Chapter 7** concludes and outlines key outputs from this work as well as highlighting some limitations and identifying potential areas for future research.

Chapter 2. Methodology and Theoretical Framework

2.1 Introduction

The key thesis of this dissertation is whether the preferences of the public for future energy and climate change policy can be identified. Within the framework of investigating the preferences of the public for future policy scenarios there are limited options available and it is important that results produced from research are policy relevant. The use of a monetary measure of preference allows policy to be prioritised in terms of their value (and therefore political palatability) to society, as such economic valuation was considered to be the optimal methodology with which to investigate the thesis. It was also imperative that a consistent approach was adopted so that comparison between elements of the research was possible. The requirements of the methodology to be adopted were relatively simple: the analysis needed to account for preferences for future policies and to consider a range of scenarios given the uncertainty about future energy policy and costs.

This chapter attempts to give a theoretical rationale behind the empirical research employed in this dissertation. It begins by introducing the concept of the total economic value; briefly reviews available methods for measuring use and non-use values of non-market goods; gives a more detailed background of choice experiments and their underlying theoretical foundations; provides a description of econometric models used in discrete choice modelling adopted in this dissertation; briefly introduces design methodology; and concludes with a summary.

2.2 Economic Value

From an economic perspective, values can be associated with a good or service purchased in the market or with a good or a service for which no monetary payment was made (Kjær (2005)). Total economic value consists of use and non use values. Use values are made up of: consumptive direct use values, non-consumptive direct use values and indirect values. Non-use values (Krutilla, 1967) include: existence, bequest, altruistic, option (Weisbrod, 1964) and quasi-option (Hediger, 1994) values. To put it simply, non-use value implies the value that an individual places upon a good or a service that is beyond its current or future consumption. For a more detailed discussion of non-use values see Carson (1999), Freeman (1999), Hanemann (1995).

In the absence of markets or market prices, estimation of total economic value is not a straightforward exercise. Several techniques have been developed that attempt to capture use and non use values of a non-market good or a policy. Economists tend to split them into two branches: Reveal Preference (RP) methods and Stated Preference methods (SP).

2.3 Revealed Preference 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 and hedonic pricing (see Braden and Kolstad, 1991).

Travel cost method is the oldest approach in non-market valuation and the idea of travel costs was first outlined by Harold Hotelling in a letter to the US park service (Hanley and Spash (1993), Perman et al. (2003)). Travel cost method is most commonly used to estimate economic use value associated with ecosystems or services used for recreation. The idea is that time and travel costs incurred to visit a site can be used to estimate utility that people derive from a particular site. Therefore public willingness to pay to visit the site can be estimated based on number of trips.

The hedonic pricing method is another way of eliciting public preferences for non-market goods. It is used to estimate economic values of a non-market resource (e.g. air and water quality, proximity to recreation sites etc.) that directly affect market prices. It is most commonly applied to variations in housing prices (e.g. Garrod & Willis, 1992). The basic assumption to hedonic pricing is that the price of a marketed good is related to its characteristics or the services it provides (e.g. the price of a house is affected by its proximity to a power station or a recreation site in addition to other factors such as size, age and construction method).

This branch of methods has been quite popular in non-market valuation, but also has a number of drawbacks, the key one is that they can't capture non-use values (Alpizar et al, 2001), (e.g. social costs associated with a particular energy option in our case). It is equally difficult to use revealed preference methods for future policy analysis since the service or good does not yet exist, so there is nothing against which to "reveal" preferences. As such revealed preference methodologies were not appropriate for the current analyses.

2.4 Stated Preference Methods

The other branch of non-market goods valuation methods, and the one which is appropriate to the current research, is stated preference techniques. These techniques assess an individuals' stated behaviour in a hypothetical setting (Alpizar et al, 2001). The advantage of stated preference over revealed preference methods is that they are capable of capturing the total economic value (use and non-use) of non-market goods. Some examples of stated preference techniques include contingent valuation and choice experiments (for a detailed review see Hanley, Mourato and Wright, 2001). In answering this thesis and given the absence of revealed preference data, stated preference techniques were the only way to identify public preferences.

2.5 Contingent Valuation

The idea of contingent valuation was first mentioned by Ciriacy-Wantrup (1947) who proposed that one way to value public goods would be to ask the public (D. Tinch (2009)). However, it took over a decade for this approach to be applied in academic research (Bateman and Willis 1999). Contingent valuation method is used to estimate the total economic value of non-market goods by asking people directly how much they would be willing to pay (or in some cases "to accept") for a particular good or a service. Asking people rather than observing their behaviour is a source of multiple critiques that CV methods are often subjected to. Key drawbacks of CV methods are issues of sample size and the inability to simultaneously incorporate multiple attributes – a key requirement of this study. For such reasons in the late 1990s researchers began to explore alternative approaches to stated preference valuation and turned their attention to choice experiments (Foster & Mourato 2003).

2.6 Choice Experiments

In investigating the preferences for future energy policy the high levels of uncertainty and cost of implementing studies played a role in the choice of methodology. Choice experiments can handle a multiple number of attributes that describe a particular policy and can elicit multiple responses from the same individual for the same survey costs, key advantages over alternative stated preference methods, e.g. Contingent Valuation (CV).

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), therefore the remainder of this section draws heavily upon this literature.

The Choice experiment techniques (CE) draw their roots from traditional microeconomic theory whereby consumers are asked to maximise their utility subject to their budget constraint. Choice experiments were first used in marketing and transport economics (Louvierre, 1993 and Polak and Jones, 1993). The first study to apply choice experiment to non-market goods valuation was Adamovitz et al. (1994). CEs are based upon the characteristics theory of value (Lancaster, 1966), and the random utility theory (McFadden, 1974; Manski, 1977).

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:

$$U_{ij} = V_{ij}(X_{ij}) + e_{ij} = bX_{ij} + e_{ij} \qquad \text{(Eq. 1)}$$

Where U_{ij} – 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:

$$P[(U_{ih})\forall h \neq g] = P[(V_{ig} - V_{ih}) > (e_{ih} - e_{ig})] \qquad \text{(Eq. 2)}$$

To calculate this probability, distributions of the error terms (e_{ij}) should be assessed. A starting point is to assume 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):

$$P(U_{ih} > Ui_{h}, \forall h \neq g) = \frac{\exp(\mu V_{ig})}{\sum_{j} \exp(\mu V_{ij})} \qquad \text{(Eq. 3)}$$

The specification above is known as the Multinomial Logit (MNL) specification, where μ is a scale parameter, which is inversely related to the standard deviation of the error term, hence the contribution of utility of estimated coefficients cannot be directly compared as they are confounded with the scale parameter (Hanley, 2001). MNL is often referred to as Conditional Logit (CL), as it was originally called by McFadden, given that it could be interpreted as conditional distribution of demand given the feasible set of alternatives (McFadden 2001, Trine Kjær, 2005).

This is historically the most commonly used model and has been applied to a vast number of empirical studies (e.g., Sadler, 2003; Ban et al., 2008; Kwak et al., 2010). It also tends to be the starting point for the majority of modern discrete choice experiment studies, to which ours is no exception. Despite being relatively simple and robust (Bennett & Blamey 2001), this model has a property that assumes independence of irrelevant alternatives (IIA), the violation of which may lead to biased estimates. The IIA property states 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, latent class or error component model. After extensive testing, two of these models were found to be the most appropriate to the analyses carried out in this dissertation (Latent Class and Random Parameters Logit). The following section gives a further description of these models.

2.6.1 Random Parameters Model

As with the multinomial 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 (Z_j), with parameters β, which may vary across individuals by a random parameter η_i, and of the socio-economic and attitudinal characteristics (S_i) (Birol et al. 2006, Louviere et al., 2000; Train, 1998).

$$U_{ij} = V(Z_j(\beta + \eta_i), S_i) + e(Z_j, S_i) \qquad \text{(Eq. 4)}$$

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

$$P_{ij} = \frac{\exp(V(Z_j(\beta + \eta_i), S_i))}{\sum_{h \in C} \exp(V(Z_h(\beta + \eta_i), (Si))} \qquad \text{(Eq. 5)}$$

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).

This model is superior to the MNL model in that it allows accounting for heterogeneity across sampled respondents. Given that the attributes investigated in the current dissertation form just a part of the overall future energy policy and there are a number of other factors that may have an impact on public preferences towards a particular energy policy related attribute, e.g. increase in level of micro-generation, increase in renewable energy etc., a model which allows for heterogeneity to be captured was deemed most appropriate for the analysis.

2.6.2 Latent Class Model

Latent Class models (LCM) are becoming increasingly popular in the field of stated preference valuation (Heckman and Singer (1984), McCutheon (1987), Swait (1994), Louviere et al. (2000), Boxall and Adamowicz (2002), Greene and Hensher (2003)). LCM accounts for heterogeneity by specifying discrete distribution over endogenous (or latent) classes (or segments) of respondents (Wedel and Kamakura 2000). This model assumes the sampled population as consisting of finite and identifiable number of segments (or groups of individuals), whose preferences are homogeneous within those segments, but different in between them. Overall, LCM models are particularly useful to identify the presence of any underlying classes within the sample of respondents, preferences between which could vary significantly.

Given a finite and fixed number of segments, the LCM calibrates segment-specific sets of parameters, and the likelihood of the respondents belonging to a segment is a probabilistic function, which depends on individual characteristics (Wen et al., 2010). The utility of an individual *i* belonging to a segment s can be expressed as:

$$U_{ij|s} = \alpha_s + \beta'_s X_{ij} + e_{ij|s} \qquad \text{(Eq. 6)}$$

Where: a_s is a vector of unknown parameters for segment *s;* X_i is a vector of attributes that are varied between the alternatives; B_s is a vector of segment-specific sets of parameters to be estimated; $e_{ij|s}$ is a random error of the utility function.

In the LCM, the probability of an alternative j being chosen by an individual I is given by:

$$P_i(j) = \sum_{s=1}^{S} P_i(j|s) \cdot M_i(s) \qquad \text{(Eq. 7)}$$

Where

$$P_i(j|s) = \frac{\exp(\alpha_s + \beta'_s X_{ij})}{\sum_{j' \in c_i} \exp(\alpha_s + \beta'_s X_{ij'})} \quad \text{and} \quad M_i(s) = \frac{\exp(\gamma'_s Z_i)}{\sum_{s=1}^{S} \exp(\gamma'_s Z_i)} \qquad \text{(Eq. 8 and 9)}$$

Where: Z_i is a vector of segmentation variables consisting of individual socioeconomics and attitudinal characteristics; y_s is a vector of parameters for segment s (s=1, 2, …,s).

The choice probability for alternative j is split into two parts: Pi(j|s) is the multinomial logit model, and the choice set Ci contains a set of alternatives j; Mi(s) is also determined by using a standard logit formulation as functions of respondent's characteristics. For identification, segment membership coefficients for one of the segments are normalised to zero (Op cit). Table 2.1 below contains an overview of the drawbacks and disadvantages associated with the models described above.

Table 2.1 Overview of Discrete Choice Models used in This Dissertation

<table>
<tr><th colspan="2">Multinomial Logit (MNL) – also called Conditional Logit (CL)</th></tr>
<tr><td rowspan="2">The most commonly used model and a starting point for most valuation studies.</td><td>Advantages:
- Simple and robust</td></tr>
<tr><td>Disadvantages:
- Has an ‘independence from irrelevant alternatives’ (IIA) property, violation of which causes bias (see Luce 1959 or Chapter 3 for more details).
- Does not account for correlation within each respondent’s series of choices.
- Does not account for unobserved preference heterogeneity.</td></tr>
<tr><th colspan="2">Mixed Logit (ML) or Random Parameters Logit (RPL)</th></tr>
<tr><td rowspan="2">RPL accounts for preference heterogeneity by assuming that there are no fixed utilities for attribute-levels across the population and the utility parameter is random.</td><td>Advantages:
- Theoretical robustness.
- Not subject to IIA.
- Can deal with correlations within the data.
- Allows the unobserved factors to follow any distribution path.</td></tr>
<tr><td>Disadvantages:
- Long modelling time (esp. when applying large number of iterations using random draws).
- Typically assumes constant error variance.</td></tr>
</table>

Latent Class model (LCM)	
LCM accounts for heterogeneity by specifying discrete distribution over endogenous (or latent) classes (or segments) of respondents (Wedel and Kamakura 2000). Preferences are homogeneous within each class, but allowed to vary significantly between classes. The population is represented by a finite number of classes and the number of classes is determined endogenously by the data.	*Advantages:* - IIA assumption is relaxed. - Can pick out unobservable differences within the sampled population. *Disadvantages:* - Quite complex, can be limiting for a small sample size.

Source: Birol, 2009; Kjær, 2005

2.7 Implicit Prices and Willingness to Pay

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).

$$WTP = \frac{-b_y}{b_c} \qquad \text{(Eq.10)}$$

Where, b_y is coefficient of any of the estimated attributes and b_c is a cost attribute.

WTP estimates are not subject to the scaling problem mentioned above, as the scaling parameter μ in equation 3 cancels out by dividing one attribute by the other and are, therefore, directly comparable.

2.8 Welch's T-test: Two Sample Test Assuming Unequal Variances

An essential part of the analysis carried out throughout this dissertation is to compare willingness to pay estimates in order to get an idea of public preferences towards different energy generation options and/or energy policy areas. In addition to analysing confidence intervals, derived using WALD method, Welch's T-test for two independent samples assuming unequal variances has also been carried out to support robustness of the results.

Welch's T-test has been identified as an appropriate test given that it allows for inequality of variances and differences in samples sizes, i.e. conditions that match the requirements of current analysis. The t statistic to the test whether the population means are different is calculated as:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{\overline{X}_1 - \overline{X}_2}} \qquad \text{(Eq. 11)}$$

Where

$$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}. \qquad \text{(Eq.12)}$$

Here s_2 is the unbiased estimator of the variance of the two samples, n_i = number of sample respondents $_i$. In this case $s_{\overline{X}_1 - \overline{X}_2}{}^2$ is not a pooled variance. For use in significance testing, the distribution of the test statistic is approximated as an ordinary Student's t distribution with the degrees of freedom calculated using

$$\text{d.f.} = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{(s_1^2/n_1)^2/(n_1-1) + (s_2^2/n_2)^2/(n_2-1)}. \qquad \text{(Eq.13)}$$

Source: Sawilowsky et al. (2002).

2.9 Log-Likelihood Ratio Test

A likelihood ratio test has been applied in this dissertation to further test the relationships between the two experiments reported in Chapters 4 and 5, where an investigation of differences in scale parameter between the experiments has been carried out. The test was used to compare fit of the models that contained multiple relaxations of the analysed attributes to select the one that provided us with the best fit.

Log-Likelihood ratio was used to compare the level of fit of one model to another. It was then used to calculate a p-value which was compared to the critical value on the basis of which the alternative model was either accepted or rejected in favour of the original.

This test can be more formally expressed as:

$$D = -2ln\left(\frac{L_0}{L_1}\right) = -2\ln(L_0) + 2\ln(L_1) \qquad \text{(Eq. 14)}$$

Where, D is the test statistics, L_0 is an original (null) model and L_1 is an alternative model.

2.10 Experimental Designs

There are a number of designs that have been historically used in non-market valuation studies, examples of those are: full factorial, orthogonal and efficient designs, the latter being the most up to date design approach. The comparative advantages of these designs are outlined in the Table 2.2 (see J. Rose et al., 2007 for more details on all of the methods).

Table 2.2. Types of Experimental Designs: Advantages and Drawbacks

Name of the Design	*Advantages*	*Disadvantages*
Full-factorial	- Includes all possible combinations of attribute levels.	- Too many questions for a single respondent
Orthogonal	- Less choices than full-factorial	- It may not be possible to find an orthogonal design - May contain "useless" choice situations
Efficient	- Less choices than orthogonal - Aimed to avoid "useless" choice situations - More reliable parameter estimates.	- Requires prior parameter estimates - More complicated to perform
Baysean efficient	- More "stable" design that is used when priors are unreliable.	- Increased complexity

Source: J. Rose et al., 2007

2.11 Summary

Analytical work presented further in this dissertation is entirely reliant on the above theoretical grounding given that it employed Choice Experiments as a preferred tool for valuation of public preferences in the energy sector. The following sections of this thesis will contain empirical analysis of the energy sector of the UK and Scotland and consist of four fundamental Chapters all of which carried choice experiment as part of the analysis.

Chapter 4 contains analysis of energy generating options in Scotland. We investigate public preferences towards such types of electricity generation as nuclear, biomass and on-shore wind against current status (status quo) in the overall generation portfolio.

Chapters 5, 6, and 7 are aimed at investigating public preference towards future energy policy of the UK. Unlike the previous chapter where we specifically concentrated on the generation portfolio, in this work we took a broader approach and investigated fundamental areas that comprise (in one way or another) future energy policy of the UK.

Chapter 3. Preferences for Energy Futures in Scotland[2]

3.1 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 (see Chapter 2 for a theoretical review). 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

[2] This Chapter is based on the paper that has been published in a Special Edition of Fraser Allander Economic Commentary on Energy and Pollution, Jan. 2011. Authors: Elena Tinch and Nick Hanley.

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 3.2 gives a brief summary of Scotland's energy policy and current generation mix. Section 3.3 outlines the methodology and theoretical framework, Section 3.4 describes the design of the current study and discusses attributes and levels in more details. Section 3.5 presents the results and findings and, finally, Section 3.6 concludes the paper with a final summary of the research and a discussion of further research and potential policy implications.

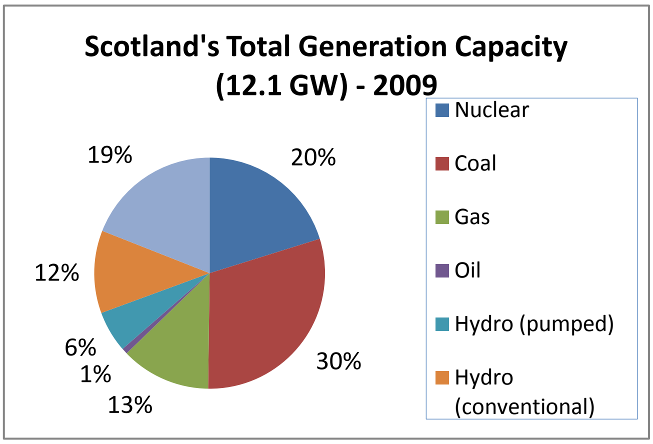
3.2 Scotland's Energy Policy and Current Generation Mix

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 3.1, 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 3.1. Scotland's Total Generation Capacity



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)[3] and will be shut down by the end of 2015 (BERR, 2007). As can be seen from Table 3.1, 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.

Table 3.1 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[4]
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

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

[3] 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.*

[4] On the 4th December 2012 EDF Energy firm announced that Hunterston B will remain in operation until 2023.

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.

3.3 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. The design of this experiment was 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). Other than the results presented below this research aimed to compare results for the South East of England and Scotland (this was a joint work unlike results presented in this dissertation and as such is not reported here). 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.

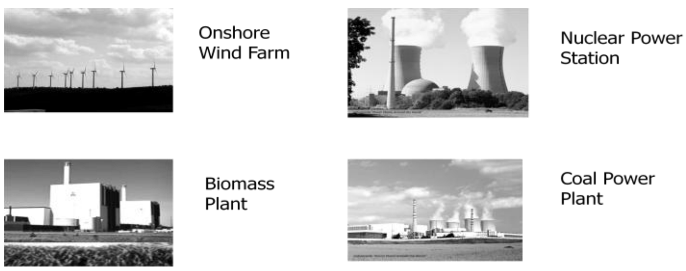
3.3.1 Survey Structure

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” is 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 as well as being supplied with a picture for each of the power plant technologies (see Figure 3.2).

Figure 3.2 Examples of Power Plant Technologies



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.

3.3.2 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 3.2 contains more detailed information on the attributes and its levels and coding.

Table 3.2 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	

3.3.3 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.

Table 3.3 Example of a 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	☐	☐	☐	☐

3.3.5 Sample Selection and Questionnaire Logistics

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).

3.4 Results

3.4.1 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 3.4 below.

Table 3.4 Sample's Statistics Comparing to a Typical Scottish House Owner.

Variable	*Units*	*Scottish Sample*	*Typical Scottish house owner**
Age (share of > 60)	Years	26%	28%
Gender (percent male)	%	46%	48%
Average household income	£	25,000	21,892
Share of Sample with Children	%	24%	26%

** - Scottish Household Survey 2007/2008*

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 3.5 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.

Table 3.5 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%

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 general statements described in Table 3.6.

Table 3.6 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%

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.

3.4.2 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).

3.4.3 Random Parameters Logit Model

As was mentioned earlier in Chapter 2, 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 provided us with the best fit and therefore the remainder of the paper will focus on the results estimated using RPL specification (see Chapter 2 for model specification). This model has an advantage over the Multinomial Logit model in that it allows the coefficients of observed variables to vary randomly over the respondents rather than being fixed thus allowing for investigation of heterogeneity across respondents (Train 1998).

In our study the RPL model with a non-random cost attribute[5] was employed. This assumption has been made given that people may have different preferences towards attributes associated with each energy option, i.e. they may either prefer to live close to the power plant (e.g. closer to work, cheaper house prices etc.) or not for a variety of different reasons. The same assumption applies to all non-monetary attributes.

In order to estimate RPL model, an assumption needs to be made about distributions of random parameters. In our model all random parameters were assumed to be normally distributed thus allowing preferences to be negative as well as positive, but other distributions were tested as well.

The model was estimated using NLOGIT 4.0.4. Distribution simulations were based on 500 draws using Halton's method.

3.4.4 Total Scottish Sample

Table 3.7 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.

[5] Cost attribute was also tested for its "randomness", but was assumed to be non-random in the final model due to insignificance of standard deviation associated with it.

Table 3.7 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	*Gender*	-0.66**	-2.16
Sex*Asc biomass		-0.49	-1.52
Sex*Asc nuclear		0.04	0.14
Kids*Asc wind	*Households with children*	0.6***	2.65
Kids*Asc biomass		0.49**	2.13
Kids*Asc nuclear		0.22	0.95
Age*Asc wind	*Age*	-0.45***	-4.47
Age*Asc biomass		-0.32***	-3.16
Age*Asc nuclear		-0.17*	-1.68
BNW*Asc wind	*We should all change our behaviour to tackle climate*	-0.03	-0.43
BNB*Asc biomass		-0.09	-1.12

BNN*Asc nuclear	*change*	-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.

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). The significance of the distance standard deviations may be related to anticipation of lower property prices or to the expected local technologies, i.e. some individuals may rationally expect low impact local energy production due to the prevailing conditions and suitability for different technologies of their local area. In terms of emissions reduction attributes the significant standard deviation may suggest that some individuals see emissions reduction as likely to have negative impacts in the wider economy. The insignificance of the standard deviations for biodiversity attributes suggests that preferences for these attributes were relatively consistent across the sample. 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 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 3.8. 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.

Table 3.8 Willingness to Pay (WTP) Estimates

Variable	***WTP***	***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.

3.4.5 Total Welfare Measures

This section aims to estimate compensating surplus values for the move away from the current 'status quo' option towards alternative scenarios such as wind, biomass and nuclear mixes. The compensating surplus is estimated as:

$$CS = -\left(\frac{1}{\beta_{price}}\right)\left(v_0 - v_1\right) \qquad \text{(Eq. 15)}$$

Where β_{price} is the price coefficient, v_0 is the utility of the current status quo option and v_1 is the utility of a new scenario that represents the move away from 'status quo'.

Table 3.9 shows the willingness to pay estimates to move away from the current energy mix for a number of wind, biomass and nuclear scenarios. The selected scenarios were based on the significance of the analysed attributes as well as common sense, i.e. unrealistic ones were excluded.

The results presented in Appendix 4 below indicate that the respondents want to move away from status quo to a "greener" option, whether it is nuclear, wind or biomass. Their preference towards a particular option is not straightforward and is broadly comparable. The results indicate that the Scottish respondents are willing to pay on average £474.65 per household per year to produce 20% of their electricity by 2020 from wind power plants that are located 10 miles away from their homes and achieve 98% reduction in CO_2 targets. They are willing to pay on average £217.5 per household per year to achieve 20% of electricity generation from biomass with the plant located 18 miles away from their house with the total reduction in emissions equal to 90% and £418.7 per household per year to live 18 miles away from nuclear power plant, to achieve 98% reduction in emissions and greater biodiversity.

Future projections of the impact of climate change policies on consumer electricity bills vary, but they range from excess of £400 a year (Policy Exchange, 2012) to £13 (DECC, 2010). Our results indicate that the Scottish householders' willingness to pay to achieve legally binding climate change targets of generating 20% of electricity from renewable sources is broadly in line and within the range of anticipated increases in consumers' electricity bills given the planned policies to achieve such changes.

3.4.6 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 region of residence. As discussed earlier in section 3.4, 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 3.9 and 3.10.

Table 3.9 RPL Model Results of the Regional Analysis

Variable	Central		South		Highlands and Islands	
	Perth, Stirling and Aberdeen		*Glasgow, Edinburgh and Dumfries*		*Harris, Lewis, Orkney, Inverness, Fort William, Oban*	
	WTP	*t-statistic*	*WTP*	*t-statistic*	*WTP*	*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.

Table 3.10 Willingness to Pay Estimates - Regional Analysis

Variable	Central WTP	*95% conf. interv.*	*t-stat*	South WTP	*95% conf. interv.*	*t-stat*	Highlands and Islands *WTP*	*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.

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 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.

Standard deviations associated with parameter distributions were insignificant for all of the random parameters due to the sample size restrictions leaving uncertainty around the heterogeneity of public preferences. It was observed, however, that willingness to pay estimates for distance attribute for the respondents living in the South region, varied considerably with some proportion of sampled population displaying negative preference toward living further away from the power station. Given that South is the region where most of the existing fossil fuel power plants are located, it is not unreasonable to assume that some respondents associate proximity to power plants with convenience in terms of, for example, travelling to work and do not find that the externalities associated with such plants actually impact them on a day to day basis. This same negative preference was also observed for the respondents living in Highlands and Islands towards "More Biodiversity" attribute, this may relate to some individuals living in some of the most protected regions of the UK in terms of SSSIs etc. may relate increases in biodiversity to restrictions to what they can do with their land and at times a sense of the landscape becoming less managed with resultant visual impacts (for example this was shown to hold for the Peak District National Park by Tinch, 2009). 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.

3.4.7 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 3.11 for the results).

Table 3.11 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
BNW*Asc wind	*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 3.12 WTP Estimates for the Restricted Sample Accounting for Non-compensatory Preferences

Variable	*Mean effect*	*95% conf. 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.

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.

Distributions associated with random parameters were significant at 5% and 10% respectively for Distance and Emissions reductions attributes suggesting heterogeneity in peoples' preferences. Heterogeneity amongst the same attributes was also observed in the original model suggesting that consistency of preferences across the respondents in the restricted model remained unaffected by excluding the respondents that displayed non-compensatory behaviour.

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 consistent, except for the willingness to pay for an increase in biodiversity, which came through as marginally 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.

3.5 Conclusion 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 in line with the 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 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 and renewable generation capacity. 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.

Chapter 4 Public Preferences towards Adaptation to and Mitigation of Climate Change in the UK

4.1 Introduction and Policy Framing

Climate change is a problem recognised worldwide and is potentially one of the greatest ones facing not only our own but future generations. Population all over the world have already felt the impacts of climate change and the UK is no exception. Take for instance the heat wave in August 2003, which according to Defra (2009) caused more than 2000 premature deaths in the UK. Another example is flooding in 2007 which caused devastation throughout the country, caused 13 fatalities, flooded 50,000 properties and left more than 350,000 people without mains water (Defra, 2009). The economic impact of 2007 flooding was estimated to be £3 billion in damage (Consumer Focus, 2012).

Scientific evidence shows that the dramatic increase in greenhouse gas emissions since the mid 20th century is largely due to human activity and impacts of climate change will be felt irrespective of whether we take any action or not (UK Climate Change Projections, 2009). In 2011 the concentration of greenhouse gases in the atmosphere hit a record high since the beginning of the industrial era in 1750 and is largely caused by the fossil-fuel related activity (Greenhouse Gas Bulletin, WMO, 2012). As highlighted by the WMO Secretary-General Michel Jarraud: "These billions of tonnes of additional carbon dioxide in our atmosphere will remain there for centuries, causing our planet to warm further and impacting on all aspects of life on earth. Future emissions will only compound the situation." This does not imply, however, that we should do nothing; on the contrary, we can and should do everything we can to reduce any further impacts and costs associated with climate change.

Some of the consequences of climate change that the UK will potentially be faced with are sea level rise, droughts, floods, overheating, an increase in extreme weather events and impacts on public health (Metoffice, 2011, UKCIP, 2009). In certain cases climate change has the potential to provide win-win scenarios such as softening sea defences in the face of sea level rise leading to greater biodiversity or increase in agricultural produce or tourism due to higher temperatures in the North of the country. Generally, however, this will be costly in terms of diverted resources and it has the potential to severely limit future consumption opportunities. It is evident that along with trying to reduce greenhouse gas emissions, i.e. to mitigate climate change, we also have to adapt to it.

"Adaptation" is defined in the literature in many different ways (Tobey 1992, Markantonis 2010). Various researchers explored multiple dimensions of adaptation, such as purpose, timing, duration and location (see Schipper, 2007; Smit and Wandel, 2006; Klein, 2003; Fankhauser et al., 1999; Kates, 1985). This paper adopts the definition of adaptation originally proposed by the IPCC, 2001 and since used by many agencies such as UNDP 2005, UKCIP 2003 and the World Bank. They define adaptation as: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation." (IPCC TAR, 2001)

This study focuses on the human response to climate change that can occur through private or public actions. As highlighted by Mendelsohn (2000), private adaptive actions tend to be efficient if costs and benefits are met solely by the private agent. In this case privately and socially optimal levels of adaptation are identical and will be achieved without government intervention (Oates 1983, Mendelsohn, 2000, Markantonis 2010).

In the presence of externalities, however, it is unlikely that private agents will have enough of an incentive to adapt to this socially optimal degree. Take for instance, building a property on flood plains with associated protection of the river bank that will lead to an increased flood risk downstream. Such action implies negative externalities that will require public bodies' intervention at local, regional or national levels. Along with negative externalities, adaptation measures can also carry external benefits to society. For example, where large populations are to be impacted, it is unlikely that private agents will have sufficient incentive to co-ordinate the appropriate level of action to fully adapt to climate change to the socially optimal level. The cost of this action would likely fall on the few individuals at greatest risk – to the extent that action would not be carried out in some cases – whilst a larger population would benefit from the externalities associated with their action.

Another barrier that prevents private agents from taking adaptive actions is uncertainty over the impacts of climate change (House of Commons, 2010) and the lack of knowledge (Fankhauser, 1997). The Government's intervention in this case can take the form of actions aimed at helping individuals to make informed decisions, e.g. by providing high quality information or raising public awareness to the issues of climate change.

The Governments in the UK, however, recognise that their work on adaptation is at an early stage and that the need to adapt to climate change is 'poorly understood by the public, much of business and many in the public sector' (Environmental Audit Committee, 2010).

Our study is aimed at investigating public acceptance of the issue and willingness to pay for measures of adaptation framed alongside the scale of future renewable energy. We take a UK wide approach and employ a choice experiment method in our analysis. To the authors' knowledge, this is the first stated preference study in the UK that attempts to estimate public willingness to pay and identify a trade-off between adaptation and mitigation measures as part of the future climate change policy of the UK.

4.2 Literature Review on Adaptation to Climate Change

This section contains a review of recent works that have been carried out in the literature covering both mitigation and adaptation to climate change. It begins with the outline of the major projects and reports that have been published both locally and internationally in the area of adaptation, then it moves on to review some stated preferences work in this area and concludes with a review of stated preference valuation studies published on large scale renewable energy, i.e. the alternative policy trade-off in our choice experiment.

4.2.1 Global and National Work

The importance of adaptation at an international level was first highlighted by the 1992 United Nations Framework Convention on Climate Change (Bayliss et al., 2009). As part of it, Governments are required to report on the progress they made in tackling climate change (both adapting and mitigating) via National assessments at regular intervals. For a number of years, however, the issue of adaptation tended to be largely ignored by policy makers for the fear of "accepting a defeat" thus focussing predominantly on mitigation measures (UKCIP, 2011). More recently, however, significant progress has been made both at the national and international levels in recognising the importance of adaptation to climate change.

The World Bank's official strategic approach to climate change and development was finalised in 2008. It has also put in place a number of grants and funding programmes for developing countries aimed at helping them to deal with the impacts of climate change (e.g. the Least Developed Countries Fund (LDCF), the Special Climate Change Fund (SCCF), the Adaptation Fund, the Climate Investment Fund etc.) (World Bank, 2012). In 2010 as part of the comprehensive study "Economics of Adaptation to Climate Change: Social Synthesis" it produced a set of guidelines for approaching adaptation in developing countries that is summarised in the "Checklist for Good Adaptation Practice" (World Bank, 2010).

In April 2009, the European Commission published the White Paper "Adapting to climate change: Towards a European Framework for Action". It proposes a two-phased approach to adaptation across the EU. Phase 1 (2009-2012) will set out the foundation for EU Adaptation Strategy, which will be implemented in Phase 2 (2013 onwards) (Bayliss et al. 2009).

At a national level, the Climate Change Act 2008 is an example of one of the first actions of the UK governments to frame the issue by including clear adaptation measures, such as the UK Climate Change Risk Assessment (to be completed by 2012), Government's Departmental Adaptation Plans and the Adaptation Reporting Power on public agencies and statutory undertakers (Environmental Audit Committee, 2010). Among other actions, the national governments within the UK are all developing programmes for adaptation, such as Scotland's Climate Change Adaptation Framework published in December, 2009; Northern Ireland Adaptation Programme, which is expected to be laid before the Assembly by late 2012; and Climate Change Strategy for Wales published in 2010, which resulted in publication of Adaptation Delivery Plan as part of The Welsh Government's Adaptation Framework. There has also been an increase in enquiries, by agencies, such as the National Audit Office (NAO, 2009) and Royal Commission on Environmental Pollution (RCEP, 2010), as well as professional bodies such as The Institution of Engineering and Technology (IET, 2011).

4.2.2 Review of Cost and Benefit Studies

First estimates of costs and benefits of adaptation appeared in the literature in 1990s (Nordhaus 1994, Fankhauser 1995, Pearce et al 1995 and Tol 1995) as part of the attempt to "refine our understanding of climate change impacts" rather than explicitly measure costs of adaptation (Fankhauser 2009). It appears that the majority of climate change valuation studies over that past couple of decades tended to focus predominantly on mitigation issues (such as, for example, reduction in carbon emissions[6] and renewable energy).

In response to a growing priority placed on adaptation measures by the various Governments, a number of international reports have been published relatively recently that estimate costs of adaptation to climate change, the key ones being: World Bank (2010); Oxfam (2007); and a report commissioned by the UNFCCC (2007) that provided adaptation costs estimates for five sectors of the economy, such as agriculture, forestry and fisheries; water supply; human health; coastal zones and infrastructure. This was followed by the review study conducted by Parry et al. (2009) that highlighted a few shortcomings of the UNFCCC report suggesting that if additional sectors were included in the estimate of global costs, the costs estimates will be even higher. De Bruin at al. (2009) estimated global costs and benefits of adaptation to climate change by incorporating adaptation as a policy variable in the global Dynamic Integrated model for Climate and the Economy (DICE)[7] and the Regional Integrated model for Climate and the Economy (RICE). To the authors' knowledge this was the first study that explicitly modelled

6 See Chapter 6 for a literature review.
7 Dynamic Integrated model for Climate and the Economy (DICE) was originally developed by Nordhaus (1994) and updated in 2007.

various levels of adaptation rather than assuming "an optimal" level when calculating the total costs of climate change. A comprehensive review of adaptation studies was carried out by Fankhauser (2009) that reports a range of adaptation cost estimates from around $25 billion a year to over $100 billion for the next two decades globally.

4.2.3 Stated Preferences Studies on Adaptation

One key aspect when it comes to fully accounting for costs of adaptation measures is identifying public preferences associated with it. There seems to be a gap in the stated preference literature, filling which could help policy-makers to establish an appropriate level of adaptation measures when it comes to including it in the overall climate change policy of a country as well as to identify the right balance of mitigation and adaptation measures.

Only a handful of papers were found in the literature that attempted to reveal public preferences toward this policy area. Veldhuizen (2011) reported the results of the pilot choice experiment study aimed at investigating public preferences for 100 households in Australia. She compared preferences for adaptation and mitigation by describing them in terms of the different taxation policies, i.e. "would households prefer to pay the government in the form of an income tax, so that they do not have to change their daily behaviour" or "would they prefer to change their behaviour to reduce carbon emissions". She found positive preference of Australian households for mitigation measures, which however varied depending on their political views.

Rajmis et al. (2009) carried out a CE study on economic preferences for biodiversity based climate change mitigation and adaptation measures in the region surrounding Hainich National Park (Thuringia, Germany). Attributes included were: additional carbon sequestration by afforestation (mitigation), increasing forest resistance and resilience to pests and storms (adaptation), removal of potentially invasive plants (adaptation) and increasing general forest ecosystem resistance and resilience (adaptation). They found positive and significant WTP for climate change mitigation by afforestation. The results of public WTP for adaptation measures, however, were mixed: more specifically, WTP was positive for such attributes as "increasing forest resistance and resilience to pests and storms" and "increasing general forest ecosystem resistance and resilience" and negative for "removal of potentially invasive plants, although, according to the author, respondents were willing to support moderate programs to eradicate invasive plants.

Glenk and Fischer (2010) conducted a survey of Scottish households to identify their preferences towards two policies of adapting to increased flood and water flow risk, such as implementation of soft engineering measures and a council insurance against damage to public property. They found that the Scottish public supports both measures with the most preferred being soft engineering measures, although a large proportion of respondents "opted for financing some of both policy options".

4.3 Stated Preference Studies on Large Scale Renewable Energy

What follows is a review of stated preferences studies concerned with large scale renewable energy, another attribute in the choice experiment. A large number of energy valuation studies have been carried out worldwide with a significant proportion of those addressing public preferences towards large scale renewable energy. Roe et al. (2001) used hedonic analysis and conjoint valuation methods to elicit US citizens' willingness to pay for electricity generated using renewable (hydro and wind power) and nuclear energy. They identified median willingness to pay values for a 1% reduction in GHG emissions to lie in the range from $0.11 to $14.22 and a WTP for a 1% increase of green energy sources in the overall portfolio of approximately $6.00.

Alvarez-Farizo and Hanley (2002) carried out both contingent ranking and a choice experiment to determine social costs associated with potential environmental impacts of wind farm developments in Spain. Environmental impacts on cliffs, fauna and flora and landscape were considered. They found significant social costs associated with all of the attributes, although impacts on flora and fauna were valued more highly. Ek (2005) conducted a choice experiment to identify public preferences of Swedish households towards wind power and found that public in general had positive willingness to pay (WTP) for this energy option. Bergmann et al. (2006) investigated public WTP for environmental improvements associated with energy production in Scotland and found that households had statistically significant WTP to minimise the landscape, wildlife and air pollution impacts associated with energy production.

Borchers et al. (2006) estimated households' WTP for "green energy electricity" in the US and whether it varies by source. They found higher preference displayed by the public towards solar rather than wind energy with biomass and farm methane being the least preferred. Navrud et al. (2007) investigated public preferences for green and brown electricity in Norway. They showed that Norwegian public prefers wind power relative to electricity imports from coal-fired plants, domestic gas plants or hydropower plants. They also showed public preference to see a few large wind farms rather than many small ones, although the Not-In-My-Back-Yard (NIMBY) effect of wind farms was also observed. Longo et al. (2008) conducted a choice experiment amongst the residents of Bath, UK aimed at determining public WTP for a renewable policy represented in terms of different attributes. Their results identified positive preferences of the sampled Bath's residents for renewable energy policy with the highest value attached to the policy that offers both private and public climate change and energy security benefits. Yoo and Kwak (2009) in their contingent valuation study for Korea determined positive WTP by households for electricity generated from renewable sources. Greenberg (2009) conducted a survey of public preferences towards alternative energy sources and found that majority of sampled US residents wanted greater reliance on some kind of renewable energy over conventional energy sources. Meyerhoff et al. (2010) applied latent class modelling to identify WTP for landscape externalities from onshore wind power in Germany. He found negative landscape externalities associated with expanding wind power generation. Krueger et al. (2011) investigated the WTP for offshore wind farms in Delaware, U.S. They found higher WTP to move wind farms further offshore for residents living near the Atlantic coast, than for inland residents.

Klinglmair (2012) conducted a choice experiment to estimate public preferences for the construction of a hydropower plant in Austria. They found overall positive public preference towards the benefits provided by the plant in terms of "green" electricity and recreation, although their WTP goes down with the awareness of the environmental impact provided by the plant.

To summarise, the reported studies are unanimous in demonstrating public preference for renewable energy, although the level of public support varies depending on the scale and environmental impacts associated with the development of a particular energy option.

4.4 Study Design

As mentioned in the section above, the issue of adaptation to climate change is arguably the area of UK's energy policy that is least understood by the general public. Until very recently (with the publication of The Climate Change Act in 2008) the government as well as mass media sources predominantly focussed on the issue of mitigation, i.e. reducing greenhouse gas emissions. As a result this created a gap in not only academic, but also the "grey" literature that addresses public acceptance and recognition of adaptation to climate change. This study is aimed at investigating public willingness to pay for adaptation measures in comparison to mitigation and is framed alongside such energy policy areas as increase in large scale renewable energy, increase in level of micro-generation and increase in total cost to household.

The study took the form of a non-labelled choice experiment, where the respondents were presented with three possible scenarios (A, B and C) and each of those consisted of four attributes. An important point to note at this stage is that our choice experiment did not contain an opt-out option. The rationale behind this being that given the current commitment of the Government to reduce its carbon emissions and the legally binding EU directive, the changes to future energy policy will and (should happen) no matter what and therefore the public will face rising costs of their bills anyway with the only difference being the level of the rise. In terms of adaptation it is clear that any issues arising because of climate change will have to be dealt with and that the choice is therefore between levels of adaptation and mitigation rather than whether to adapt and mitigate or not.

4.4.1 Focus Groups

An initial version of the survey was distributed amongst a group of 24 random members of public. After collecting the completed questionnaires and processing the results we found that the respondents were generally happy with the levels of the attributes and socio-economic questions as well the layout of the questionnaire. The majority, however, found "quantitative" levels of the attributes too complicated to comprehend. To overcome this, qualitative descriptions of the levels, such as "large, medium, slight and no change" for the "increase in large scale renewable energy" and "increase in level of micro-generation" attributes and with "high and low" for "spending on adaptation to climate change" were added to complement the original descriptions.

The total number of attributes was decreased as well, more specifically, originally included energy policy attributes, such as "carbon reduction targets" and "improvements in energy efficiency" were removed from this choice set and formed part of a separate choice experiment run in parallel, results of which are reported in Chapter 5. This is in line with the work of such authors as Adamowicz (1998) and Bradley (1988), who showed that the task complexity affects the decision making process (Alpizar et al., 2001).

4.4.2 Experimental Design

The final version of the survey was piloted across 35 randomly selected individuals. Respondents were satisfied with the levels of the choice cards and found the survey relatively easy to complete and understand. The experimental design of the choice cards was generated using Bayesian efficient design principles in NGENE software (see Chapter 2 for a theoretical overview). After inputting priors obtained during the pilot study the level of D-error of the final design was 0.006. The primary aim of the Bayesian efficient design is to minimise D-error, which is extremely low in our case indicating high efficiency of the design. As such the final design represented a total number of 16 choice cards split into two blocks, i.e. each block contained 8 choice cards and was sent randomly to half of the total sample.

4.4.3 Survey Structure

The final survey was distributed by post to 1000 randomly selected individuals across the UK. They were mailed a version of the questionnaire survey along with the signed covering letter summarising the aims and rationale behind the research. As an incentive to respond participants were given an option to be entered in a prize draw of 4 prizes of £25. The respondents were informed that the survey is confidential, voluntary and no information would be passed on to any third party.

The questionnaire was structured as follows (see Appendix 2 for a copy of the questionnaire):

- Front page of the survey explained the aims, requirements and selection criteria as well as the process for returning the questionnaire along with the contact details in case of any queries. On the following page respondents were provided with the background and key questions addressed by the survey.
- Part 1: "General Public Attitudes" was split into three separate sections, each containing a specific choice of questions: 1.1. Attitudes towards climate change; 1.2. Attitudes towards existing energy policy of the UK; 1.3. Attitudes towards renewable energy and micro-generation.

- Part 2: "Choice Cards/ Explanation of Attributes", the key part of the questionnaire containing explanation of the attributes, an example of and the instructions to completing the choice cards and the actual choice set of 8 cards that respondents were asked to complete. Each card contained three possible options (A, B or C), each of them containing different combinations of the attributes' levels.

The respondents were asked to consider all the options but to choose *one* depending on which scenario they prefer most (see Table 4.2 for an example of a choice card).

This part also contained follow up questions where participants were asked to rate the attributes they faced in the choice cards in order of importance (from "important" to "not important at all"). This was done to enable us to test for the presence of potential bias in sample's responses. We also tested their attitudes towards two other policy aspects not included in the current choice experiment: "Levels of carbon reduction targets" and "Improvements in Energy Efficiency".

- Part 3: "Respondents / Household Profile". In this section we asked respondents to provide some information about themselves, such as gender, age, level of education as well as some questions about their home (see Appendix 2 for more info). Participants were given an option to opt-out from answering any questions they were not comfortable with and reminded that the survey is strictly confidential and any information provided will only be used for statistical purposes and will not be passed on to any third party.

4.4.4 Levels and Attributes

As already mentioned, the design of the choice experiment was such that the participants were presented with a set of 8 choice cards, each consisting of three possible scenarios (A, B and C) and each of these scenarios was described by four attributes, namely: spending on adaptation to climate change, increase in large scale renewable energy, increase in level of micro-generation and increase in annual cost to household. Each of these attributes represented a specific aspect of future energy policy of the UK and contained different levels of attributes to identify trade-offs by the respondents.

1. *Spending on Adaptation to Climate Change* – is essentially the level of spending on such adaptation measures as building flood defences in areas with higher potential risk of flooding, reinforcing homes where required, improving buildings insulation etc. Each scenario in a choice card contained one of two possible levels:

a. *High* – adaptation measures are given much greater priority and attention compared to current levels.

b. *Low* – adaptation measures are given no or very little attention.

2. *Increase in Large Scale Renewable Energy (onshore and offshore wind, tidal, hydro etc.)* – this is the level of total UK energy generated from large scale renewable sources. Currently just 6.7% of UK's energy is generated using renewable sources, but in line with the EU's renewable targets, the UK made a legally binding commitment to generate 20% of its energy from renewable sources by 2020.

Picture 4.1 Some of the most commonly used renewable technologies

Off-shore windfarm | Onshore windfarm | Hydroelectric plant | Wave energy | Tidal energy | Biomass plant

This can represent a significant rise in the number of large scale renewable energy plants (see Pic. 4.1) (especially onshore windfarms, as they remain the most cost effective options at the moment in comparison to other sources of renewable energy in the UK) and is reflected in four different levels:

- *Large* – 40% of total UK's energy generated from large scale renewable sources.
- *Medium* – 20% of total UK's energy generated from large scale renewable sources.
- *Slight* – 10% of total UK's energy generated from large scale renewable sources.
- *No change* – 6.7% of total UK's energy generated from large scale renewable sources.

3. *Increase in Level of Micro-generation* - this represents the number of households that will have at least one micro-generation unit (see Picture 4.2 for examples of technologies) installed in their homes. [8]

Picture 4.2 Examples of Micro-generation Technologies

Solar PV | Wind turbine | Solar hot water | Micro-hydro | Ground source heat pump

The levels of increase in micro-generation are reflected as follows:

-*Large* – 1 in 2 households will have a micro-generation unit installed in their homes.

-*Medium* - 1 in 10 households will have a micro-generation unit installed in their homes.

-*Slight* - 1 in 50 households will have a micro-generation unit installed in their homes.

- *No change* - 1 in 260 households will have a micro-generation unit installed in their homes.

[8] Currently in the UK approximately 1 out of 260 households has some type of micro-generation installed. To provide 40% of total UK energy needs, pretty much every house will have some sort of micro-generation technology installed.

4. *Increase in Annual Total Household Cost* – Achieving a reduction in carbon emissions and switching to renewable generation implies additional costs to the consumers, which will result in the increase in total cost to the households. Experts' estimates vary, but it can range from £40 to £260 pounds depending on the policy chosen (e.g. Less, 2012, REF 2011). The attribute therefore reflects this cost increase and serves as a payment vehicle for the analysis.

Respondents were asked to consider four possible levels of annual increase in total household's cost:

£40 – i.e. your total expenditures will go up by £40 a year.
£80 – i.e. your total expenditures will go up by £80 a year.
£160 – i.e. your total expenditures will go up by £160 a year.
£260 – i.e. your total expenditures will go up by £260 a year.

More details on the attributes, its levels and coding can be found in the Table 4.1.

Table 4.1 Attributes, Corresponding Variables, Levels and Coding

Attribute	**Variable**	**Description**	**Levels**	**Coding**
Spending on adaptation to climate change	Adaptation	Level of spending on adaptation measures, e.g. building flood defences, homes reinforcement, insulation improvements etc.	High, Low	1 - High, 0 - Low
Increase in Large Scale Renewable Energy	Large Renewables	Increase in level of large scale renewable projects comparing to current level of 6.7%.	Large (40%), Medium (20%), Slight (10%), No change (6.7%)	40, 20, 10, 6.7
Increase in Level of Micro-generation	Microgen	Increase in number of households that have micro-generation unit installed in their homes	Large (1 in 2) Medium (1 in 10) Slight (1 in 50) No change (1 in 260)	0.5 0.1 0.02 0.004
Increase in Total Annual Cost to a Household	Cost	The amount by which the total annual expenditure of a particular household will rise.	£40 £80 £160 £260	40 80 160 260

4.4.5 Choice Alternatives

Each of the choice cards contained three possible scenario options (A, B and C), which had varied mixture of attribute levels and respondents were asked to choose the one option they preferred the most. Participants could not opt-out of the decision as the underlying assumption was that the future policy changes will happen anyway, but that their choices would be likely to influence the level of policy changes. They had to make 8 choices in total which was reflected by the number of choice cards. An example of a choice card is presented below:

Table 4.2. Example Choice Card

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change (flood defences, building reinforcements etc.)	**Low** (adaptation measures are given no or very little attention)	**High** (much greater priority compared to current levels)	**Low** (adaptation measures are given no or very little attention)
Increase in Large Scale Renewable Energy (onshore and offshore wind, tidal etc.)	**Large** (40% of total UK's energy)	**Medium** (20% of total UK's energy)	**No change** (6.7% of total UK's energy
Increase in Level of Micro-generation (e.g. small wind turbines, solar panels etc.)	**Medium** (1 out of 10 houses have micro-generation installed)	**No change** (1 out of 260 houses have micro-generation installed)	**Sligh**t (1 out of 50 houses have micro-generation installed)
Increase in Annual Total Cost to Household	£160	£260	£40
PLEASE TICK ONE SCENARIO YOU PREFER:			

4.4.6 Sample Selection and Questionnaire Logistics

The survey was administered using a postal mail out in accordance with the "Dillman's method" (Dillman, 1991), the main goal of which is to minimise four sources of error: sampling, non coverage, measurement and non response (see Dilman (1991) for more details on the methodology and exact procedure).

As the primary objective of our research was to identify public preferences towards future energy policy in the UK, our survey was sent out to a sample of 1000 households randomly selected across the UK. Addresses were obtained from a combination of 2010 Electoral register and the 2010 Phone Book databases. The sample size was predominantly limited by budget constraints and would have ideally been higher had the funds been available. The above limitation stands true with regards to selection of the distribution method itself. The postal method was chosen largely due to its cost-efficiency and relatively small sampling bias when comparing to other methods, such as internet based surveys.

The survey mail out was carried out in summer 2011 and involved three stages. Firstly, we sent out full version of the survey along with a covering letter to the entire sample of 1000 households across the UK. Two weeks later this was followed up by sending out the reminder cards to every sample member who was yet to respond. Two weeks after that, we did another mail out of the full version of the questionnaire to all non-respondents. We received a total of 177 completed questionnaires, which after accounting for undeliverable and unusable responses gave us the total response rate of 21%.

4.5 Results

4.5.1 Demographic and household profile

Our aim was to obtain a sample of respondents, representative of the population of the UK. When comparing our average values to a typical UK householder, we found that overall our sample was a good representation of the population of the UK, although the proportion of males in our sample was slightly higher than the UK's average (53% versus 49%) and the share of the respondents over 65 is 7% lower in our sample in comparison with the UK average (see Table 6.3, Chapter 6 for more details). In addition to their demographic profile we also asked respondents to answer some questions about their homes (see Table 4.3).

Table 4.3 Information about the Respondents' Homes

<table>
<tr><th>Question</th><th colspan="3">Response</th></tr>
<tr><td rowspan="2">Is your home well insulated?</td><td>"Yes"</td><td>"Unsure"</td><td>"No"</td></tr>
<tr><td>76%</td><td>10%</td><td>14%</td></tr>
<tr><td rowspan="2">Do you live in the area affected by flooding or any other climate related impacts?</td><td>"Flooding"</td><td>"Other climate related impact"</td><td>"None"</td></tr>
<tr><td>9%</td><td>5%</td><td>86%</td></tr>
<tr><td rowspan="2">Do you have any micro-generation technologies already installed in your home?</td><td colspan="2">"Yes"</td><td>"No"</td></tr>
<tr><td colspan="2">5%</td><td>95%</td></tr>
<tr><td rowspan="2">Do you feel you have any space for micro-generation to be installed in your home or garden?</td><td>"Yes"</td><td>"Unsure"</td><td>"No"</td></tr>
<tr><td>46%</td><td>32%</td><td>20%</td></tr>
</table>

We found that the majority of our sample, i.e. 76%, thinks that their home is already well insulated. This makes an interesting observation and suggests the potential for future research in the area of energy efficiency improvements. The next Chapter will address this issue in more details. We also found that 95% of our respondents do not generate their own energy, i.e. they are entirely reliant on the large scale grid. Only 20% of our sample, however, felt sure that they do not have space in their house or a garden for a micro-generation technology. 14% live in houses affected by flooding or some other issues, for example, cliff erosion, wind damage, sea defence failure etc. that they feel may be linked to climate change. This might not seem high, but for our sample this represents more than 1 in every 10 houses are already potentially affected by the climate change related impacts.

4.5.2 Attitudes Towards Climate Change and Existing Energy Policy of the UK

This section describes participants' attitudes towards the issue of climate change and existing energy policy of the UK. More specifically, we asked the respondents to express their opinions towards some key statements (see Table 4.4 for more details and the exact statements).

Table 4.4 Sample's Attitudes Towards Climate Change

Question	Response		
Climate change is a global problem that needs to be addressed by everyone.	"Agree"	"Unsure"	"Disagree"
	89%	5%	5%
The issue of climate change is exaggerated and doesn't need as much attention as it currently has been given.	"Agree"	"Unsure"	"Disagree"
	15%	24%	60%
I believe that energy should be in the top three priority areas in the Government's budget.	"Agree"	"Unsure"	"Disagree"
	71%	18%	11%
I don't mind where my energy comes from as long as its cheaper.	"Agree"	"Unsure"	"Disagree"
	39%	19%	40%
I believe that rather than trying to prevent climate change, we should learn to adapt to it.	"Agree"	"Unsure"	"Disagree"
	43%	27%	28%

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

Although the vast majority of our sample recognised climate change as a global problem that needs to be addressed by everyone, only 60% of them disagreed with the statement that "the problem of climate change is exaggerated and doesn't need as much attention as it currently has been given". Also a relatively large proportion of the sample was unsure about this statement. This may indicate a signal to the policy makers that although the public recognises the problem of climate change, the steps that are taken to deal with it should perhaps be chosen more cautiously. The majority (71%) of the sampled population also place energy in the top three priority areas in the Government's and 39% of respondents stated that they don't mind where their energy comes from, as long as it is cheaper. The final statement described in this section was aimed at testing public perceptions towards the issue of adaptation (see Table 4.5). More specifically we found that 70% of the respondents either agree or are unsure about the statement that we should learn to adapt to climate change rather than preventing it. This backs up the UK Government's recent recognition of the problem of adaptation (see Sections 4.1 and 4.2.1) and reflects the need for putting in place clear steps that are supported by the public for dealing with the problem.

The rest of the chapter contains the results of our discrete choice modelling. It report findings on preferences and respondents' willingness to pay for policy measures aimed at an increased focus on adaptation to climate change in the UK and various levels of deployment of large scale renewable energy projects. We also briefly touch upon public attitudes for micro-generation, although this particular area will be investigated in more detail in Chapter 6.

4.5.3 Model Specification

Our model was initially estimated using multinomial logit specification (MNL) (McFadden 2001, Kjær, 2005). This is historically the most commonly used model and has been applied to a vast number of empirical studies (e.g., Sadler, 2003; Ban_ et al., 2008; Kwak et al., 2010 etc.). It also tends to be the starting point for the majority of modern discrete choice experiment studies, to which ours in no exception.

Despite being relatively simple and robust (Bennett & Blamey 2001), this model has a property that assumes independence of irrelevant alternatives (IIA), the violation of which may lead to biased estimates (see Chapter 2 for a detailed model specification). This property, however, can be relaxed by applying alternative model specifications, for example Random Parameters Logit Model (RPL) (Train, 1998, Hanley et al. 2001) (see Chapter 2 for a model specification), nested logit or latent class models.

Having run multiple estimations and having tested our model specifications taking into account the best fit, potential policy implications and relevance of the results, the remainder of this Chapter will include results of both Random Parameters and Latent Class models given that each of these models gives us complimentary insights into the analysis. All models were estimated using NLOGIT 4.0.4.

4.5.4 Multinomial Logit

Table 4.5 below reports the results of the basic model estimation, i.e. with no interactions, using Multinomial Logit specification.

Table 4.5 Multinomial Logit Estimation Results

Variable		Multinomial Logit Model		
		Coefficient	**St. error**	**t-stat.**
Adaptation – High Represents much greater priority placed on adaptation measures compared to current levels.		0.278***	0.07	4.14
Increase in Large Scale Renewable Energy (compared to current level, i.e. 6.7%)	*10% of UK's energy*	0.716***	0.11	6.77
	20% of UK's energy	0.849***	0.12	7.2
	40% of UK's energy	0.966***	0.15	6.2
Increase in Level of Micro-generation (compared to current level, i.e. 1 out of 260 houses)	*1 out of 2 houses have micro-generation installed*	0.6***	0.13	4.55
	1 out of 10 houses have micro-generation installed	0.75***	0.1	7.12
	1 out of 50 houses have micro-generation installed	0.31**	0.15	2.17
Increase in an Annual Total Cost to a Household		-0.004***	0.00	-11.1
AIC		2.038		
BIC		2.068		
Pseudo R2		0.073		
Number of Observations		1416		
Log Likelihood Value		-1434.76		

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

As can be seen from Table 4.5, all of the tested variables in the MNL model came through as highly significant at 1% level with the exception of "Increase in Micro-generation level (1 out 2 houses)", which was significant at 5%.

4.5.5 Random Parameters Logit

Analysis presented below employs Random Parameters Model (RPL) specification to estimate the results. This model relaxes IIA assumption and also captures heterogeneity in respondents' preferences. Given that the key focus of the current analysis was to identify public preferences towards key elements of future energy policy, accounting for heterogeneity was key to obtaining meaningful results from the analysis, e.g. preferences towards the considered attributes can be affected by the factors not captured in the choice experiments and are influenced by the underlying individual preferences. For example, WTP for an increase in levels of micro-generation can be affected by the attitude of the particular household to a switch in the future to electric vehicles etc.

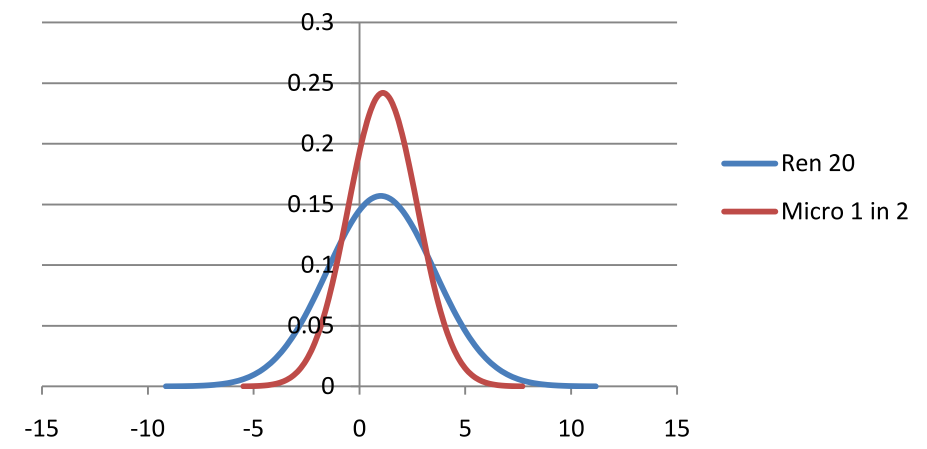
To capture negative as well as positive preferences, all random parameters were assigned normal distributions (although other distributions were investigated) and distribution simulations were based on 2000 draws for the maximum simulated likelihood estimation using Halton's method (see Hole, 2007). The results of the RPL analysis are presented in Table 4.6 below.

Table 4.6 Basic RPL Model Estimation

Variable		Random Parameters Model		
		Coefficient	St. error	t-stat.
Random Parameters in Utility Functions				
Increase in Large Scale Renewable Energy (compared to current level, i.e. 6.7%)	*10% of UK's energy*	0.919***	0.15	5.95
	20% of UK's energy	1.111***	0.24	4.64
	40% of UK's energy	1.402***	0.37	3.74
Increase in Level of Micro-generation (compared to current level, i.e. 1 out of 260 houses)	*1 out of 2 houses have micro-generation installed*	1.007***	0.35	2.89
	1 out of 10 houses have micro-generation installed	0.93***	0.16	5.77
	1 out of 50 houses have micro-generation installed	0.502**	0.21	2.33
Non-Random Parameters in Utility Functions				
Adaptation – High Represents much greater priority placed on adaptation measures compared to current levels.		0.406***	0.08	4.70
Increase in an Annual Total Cost to a Household		-0.005***	0.00	-9.3
Derived Standard Deviations of parameter Distributions				
Increase in Large Scale Renewable Energy	*10%*	0.001	0.52	0.0
	20%	1.648**	0.68	2.4
	40%	0.399	1.74	0.2
Increase in Level of Micro-generation	*1 out of 2 houses*	2.54**	1.2	2.1
	1 out of 10 houses	0.031	0.68	0.1
	1 out of 50 houses	0.006	1.17	0.0
R squared		0.08		
AIC		2.04		
BIC		2.09		
Number of Observations		1416		
Log Likelihood Value		-1431.29		

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

Figure 4.3 Distributions Suggested by Random Parameters



In line with MNL estimation, all of the variables employed in our model came through as highly significant. We find that although overall the public displays positive preferences towards large scale renewable energy, the level of public support varies. The same argument holds for our sample's preferences towards increased level of micro-generation in the UK. Our results confirm that UK's householders do want to see more micro-generation compared to current levels, the scope of which will be explored further in chapter 6. Interestingly we find on average the respondents prefer to see increased priority placed on adaptation measures in the UK's energy policy. This result in itself may have direct policy implications and the reasons behind it represent scope for further analysis.

Looking at the standard deviations of the random parameters it can be seen that there is significant heterogeneity between individual preferences for the 20% large scale renewables and increase in micro-generation levels (1 in 2 houses). The graph above shows that the distribution of estimates associated with an increase in level of micro-generation (1 in 2 houses) is slightly tighter grouped around the mean, whereas distribution of an increase in large scale renewable energy is broader, indicating higher uncertainty in public preferences.

The second of these can be considered in terms of the number of houses with micro-generation reaching 50% of properties. This may by some be considered to be too many but others are indifferent to any visual impact, hence some level of heterogeneity. The large scale renewables is more difficult to explain but perhaps 20% is the point at which those who want to see as much renewable energy as possible to reduce GHGs and those who want to see less if possible to reduce visual impact. Both still hold positive values for the level before feeling it is either too little or too much.

4.5.6 Willingness to Pay Estimates from RPL model

Implicit prices or 'willingness to pay' (WTP) amounts (see Chapter 2 for a theoretical review) associated with the above attributes are reported in Table 4.7. These represent monetary values that respondents place on a change in a given attribute.

All of the tested coefficients came through as highly significant at the 1% level, indicating consistency in public preferences. Firstly, we find positive willingness to pay towards adaptation; as such the sampled population is willing to pay on average £82.7 per year for an increased priority placed on adaptation measures when compared to current levels. Willingness to pay for an increase in large scale renewable energy varies depending on the level, from £187.4 to £285.6 per year for 10% and 40% increase accordingly. Although willingness to pay of an average sampled respondent does go up with an increase in level of large scale renewable energy, the results of the Welch's T-test, which was used to test the hypothesis of means equality for two populations with different sample sizes and unequal variance, showed that the hypothesis of the means equality between the populations cannot be rejected (see Appendix 6). This is also confirmed by the overlapping confidence intervals between these attributes. In other words there is not enough evidence to claim that the WTP values are significantly different from each other.

Based on the results of the Welch's t-test (see Appendix 6), we note similarity in public willingness to pay for an increase in renewable energy and micro-generation. More specifically WTP for a 40% increase in large scale renewable energy is not significantly different from the willingness pay for micro-generation installed in every second house in the UK, as was also confirmed by the overlapping confidence intervals.

Our respondents also do want to see an increase in level of micro-generation in the overall generation portfolio of the UK. It appears that respondents derive positive utility from having micro-generation installed in other people's houses as well as their own. They are willing to pay on average £102.3 per year to have micro-generation installed in one out of 50 houses in the UK compared to current levels (1 out of 260), and their willingness to pay does go up to £205.3 per year to see micro-generation in every second house.

Higher respondents' WTP for an increase in both large scale renewable energy and micro-generation may indicate the public's acceptance of the visual impact of renewable energy both on large and micro levels. Another worthwhile observation is the magnitude of WTP between these two attributes, which is in fact very similar, indicating that the public does want to see an increase in low carbon energy but their preference toward the scale of it (i.e. large scale or micro) is not as straightforward.

Table 4.7 Willingness to Pay (WTP) Estimates (per household per year)

Variable	WTP (household/year)	St. error
Adaptation – high	£82.7*** (£46.6-£118.8)	18.44
10% increase in large scale renewable energy	£187.4*** (£130.3-£244.5)	29.13
20% increase in large scale renewable energy	£226.4*** (£135.9-£316.8)	46.14
40% increase in large scale renewable energy	£285.6*** (£156-£415.2)	66.12
Increase in level of micro-generation (1 out of 2 houses)	£205.3*** (£78.1-£332.5)	64.88
Increase in level of micro-generation (1 out of 10 houses)	£189.7*** (£130.2-£249.2)	30.38
Increase in level of micro-generation (1 out of 50 houses)	£102.3*** (£26.6-£177.9)	38.6

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

4.5.7 Extended Random Parameters Model

According to Boxall and Adamowicz (2002), although unobserved heterogeneity is accounted for in RPL model (see Table 4.6 above), the sources of heterogeneity are not explained. To find out more about the factors that affected public preferences and to better explain the model, the next stage of our analysis represents the RPL estimation with added interactions. Interestingly, socio-economic characteristics, such as age or gender did not have any significant impact on the model fit, so they were excluded from the final analysis. We found that preferences of those who rated adaptation to climate change as the most important attribute and those who had been affected by flooding or any climate change related events in the past were the variables that explain our model the best. Table 4.8 below contains results of this analysis. As before, we employed RPL specification with 2000 Halton probability draws.

Table 4.8 Results of Extended RPL model

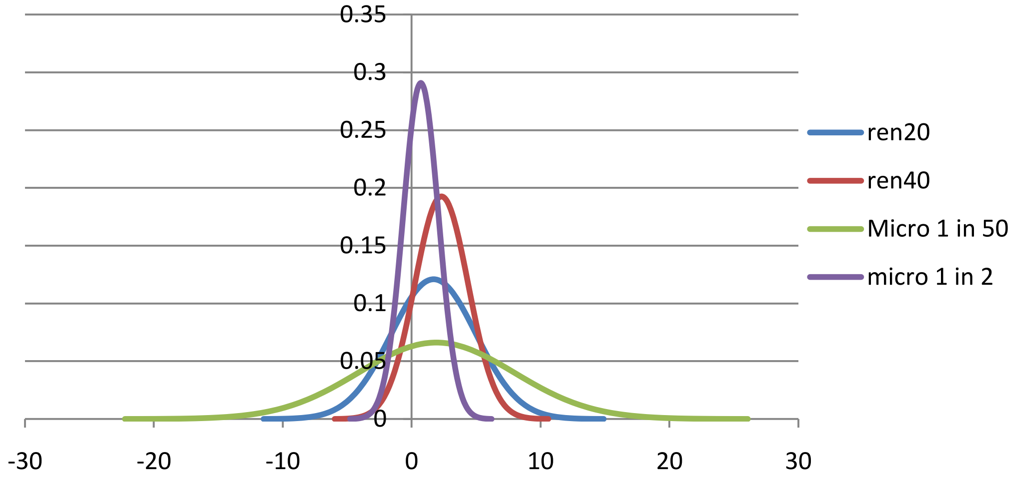
Variable		Random Parameters Model		
		Coefficient	St. error	t-stat.
Random Parameters in Utility Functions				
Increase in Large Scale Renewable Energy (compared to current level, i.e. 6.7%)	*10% of UK's energy*	1.159***	0.18	6.33
	20% of UK's energy	1.705***	0.48	3.54
	40% of UK's energy	2.312***	0.69	3.33
Increase in Level of Micro-generation (compared to current level, i.e. 1 out of 260 houses)	*1 out of 50 houses have micro-generation installed*	1.922***	0.72	2.66
	1 out of 10 houses have micro-generation installed	1.167***	0.2	5.84
	1 out of 2 houses have micro-generation installed	0.7***	0.25	2.76

Non-Random Parameters in Utility Functions			
Adhigh*FlY Preferences towards higher level of adaptation for those who stated that their house was affected by flooding or other climate change impacts	0.622***	0.23	2.71
Adhigh*FLN Preferences towards higher level of adaptation for those who stated that their house was *NOT* affected by flooding or other climate change impacts	0.309**	0.12	2.55
Adhigh*SPY Preferences towards higher level of adaptation for those who rated adaptation as the most important attribute	0.629***	0.19	3.3
Adhigh*SPN Preferences towards higher level of adaptation for those who rated adaptation as *NOT* important attribute	-0.57**	0.25	-2.23
Increase in an Annual Total Cost to a Household	-0.01***	0.00	-9.37

Derived Standard Deviations of parameter Distributions				
Increase in Large Scale Renewable Energy	*10%*	0.00	1.13	0.00
	20%	3.30***	1.2	2.77
	40%	2.07*	1.23	1.69
Increase in Level of Micro-generation	*1 out of 50 houses*	6.04*	3.22	1.88
	1 out of 10 houses	0.175	0.56	0.03
	1 out of 2 houses	1.372*	0.96	1.97
Pseudo R2		0.09		
AIC		2.03		
BIC		2.09		
Number of Observations		1416		
Log Likelihood Value		-1418.43		

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

Figure 4.4 Distributions Suggested by Random Parameters



We find that although the overall model fit of the RPL model with added interactions was better than that of the "simple" RPL model, which is reflected by the lower Log Likelihood value, the significance, signs and values for all of the analysed variables were quite similar between the two models. Our results show that whether an individual's house is affected by climate change does not impact upon the positive sign attached to higher levels of adaptation although it does impact on the scale of the coefficient. When it comes to preferences of those members of the sample that identified spending on adaptation as an important attribute, their preferences are consistently positive. On the other hand, preferences of those who stated that spending on adaptation is not important to them are negative. Although this result is not surprising in itself, it does support the robustness of our model.

The most significant result in terms of the standard deviations of the random parameters is the 20% large scale renewables, again the argument proffered above that this is the point at which preferences switch for those who are both pro and somewhat anti-renewables is suggested. No other standard deviations were significant at the 5% level. The results of the Willingness to Pay for the above model are presented in the Table 4.9 below.

This model reinforces the earlier claim that sampled population consistently prefers and is willing to pay for an increase in the level of large scale renewable energy as well as micro-generation. Although, not statistically different, willingness to pay of an average sample's group member whose house is affected by climate change related impacts (e.g. flooding, cliff erosion, etc.) is 25% higher than that of an average member of the total sample (£110.5 per year in comparison with £82.7 (see Tables 4.8 and 4.9). On the other hand, WTP of the average member of the rest of the sample, i.e. those not impacted by climate change related impacts, is only £54.9 per year. Those who stated that spending on adaptation is not important to them (10% of the total) did actually display negative WTP of -£100.6 per year for the above attribute. Those respondents, who considered spending on adaptation to be important, were willing to pay on average £111.8 per year. These results suggest that individual's are behaving in an economically rational way relative to their individual circumstances and opinions. As such these results give some evidence that respondents understood the choice tasks before them and are choosing in a rational way.

Table 4.9 Willingness to Pay (WTP) Estimates for Extended RPL model

Variable	WTP	St. error
10% increase in large scale renewable energy	£206.139*** (£151.14-£261.1)	28.06
20% increase in large scale renewable energy	£303.194*** (£146.7-£458.8)	79.84
40% increase in large scale renewable energy	£411.128*** (190.3-631.9)	112.65
Increase in level of micro-generation (1 out of 50 houses)	£124.514*** (£56.3-£205.3)	41.25
Increase in level of micro-generation (1 out of 10 houses)	£207.592*** (£149.2-£265.9)	29.79
Increase in level of micro-generation (1 out of 2 houses)	£341.772*** (£104.9-£578.6)	120.83
Adhigh*FlY Preferences towards higher level of adaptation for those who stated that their house was affected by flooding or other climate change impacts	£110.540*** (£29.2-£191.9)	41.50
Adhigh*FLN Preferences towards higher level of adaptation for those who stated that their house was *NOT* affected by flooding or other climate change impacts	£54.922** (£12.2-£97.6)	21.79
Adhigh*SPY Preferences towards higher level of adaptation for those who rated adaptation as the most important attribute	£111.822*** (£46.7-£176.9)	33.22
Adhigh*SPN Preferences towards higher level of adaptation for those who rated adaptation as *NOT* important attribute	-£100.632** (-£189.4--£11.9)	45.27

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

4.5.8 Latent Class Analysis

To further explore preferences within the sample and to identify existence of any underlying class differences amongst the respondents we also estimated our model using Latent Class Modelling approach (LCM) which allows for such analysis. LCM assumes the sampled population as consisting of finite and identifiable number of segments (or groups of individuals), whose preferences are homogeneous within those segments, but different between them (see Chapter 2 an overview). Having tested a different number of segments and having taken into account the relatively small size of our sample, similar models' statistics and variables significance, the model reported below is a two-segment model that in our opinion is the best addition to the RPL analysis reported earlier. There is, however, further scope for analysis and investigation of any additional classes, although this would be suited to a larger sample size.

Table 4.10 Results of the Two-segment Latent Class Model

Variable		Latent Class 1			Latent Class 2		
		Coefficient	**St. error**	**t-stat**	**Coefficient**	**St. error**	**t-stat**
Adaptation – High		1.116***	0.13	8.35	-0.744***	0.08	-8.9
Increase in large scale renewable energy	10%	0.731***	0.15	4.988	0.559***	0.15	3.7
	20%	0.986***	0.19	5.23	0.703***	0.14	5.08
	40%	1.055***	0.23	4.55	0.676***	0.18	3.68
Increase in level of micro-generation	1 in 50 houses	0.292	0.24	1.2	0.447**	0.18	2.47
	1 in 10 houses	0.747***	0.16	4.63	1.098***	0.14	8.03
	1 in 2 houses	0.38**	0.18	2.11	0.943***	0.17	5.59
Increase in Total Annual Household Cost		-0.008***	0.00	-11.3	-0.001**	0.00	-2.13
Average Class Probabilities		Class 1 probability			Class 2 probability		
		0.624***	0.01	42.28	0.375***	0.05	7.9
Number of obs.		1416					
Pseudo R2		0.13					
Log-likelihood		-1355.97					
AIC		1.939					
BIC		2.002					

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

As can be seen from the results reported in the above table, we identified the existence of two distinct classes in our sampled population, preferences of which vary significantly. We find that the attribute that had the dominant impact on the existence of distinct latent classes in our model is preferences towards increased focus and spending on adaptation measures as part of the overall energy policy of the UK. More specifically, respondents belonging to Class 1 expressed consistent preferences and derived utility from increased focus placed on adaptation measures in the UK in comparison to current levels. On the other hand, respondents in Class 2 do not want to see an increase in spending on adaptation measures. This attribute came through as highly significant for both classes 1 and 2 (at 1% level). Although the magnitude of respondents' preferences towards other attributes, such as increase in large scale renewable energy and micro-generation did vary, both classes identified positive and significant preferences towards these attributes.

4.6 Conclusions and Future Research

This research addressed three key areas of the energy policy of the UK and attempted to reveal public preferences towards the controversial issue of mitigation versus adaptation to climate change. We employed a stated preference approach, namely a choice experiment, which in recent years has been increasingly applied to non-market valuation studies including a large number of energy-related studies. Most of them, however, tend to focus on specific policy areas predominantly aimed at mitigation of climate change. This to our knowledge, is the first choice experiment study that included both adaptation and mitigation measures as part of the overall energy and climate policy of the UK.

More specifically we carried out a UK wide postal survey that was sent to a random sample of 1000 households across the UK. This was an unlabelled choice experiment, i.e. participants were presented with three scenarios (A, B and C), each containing different levels of attributes. Investigated attributes were: level of priority and spending on adaptation measures in the UK (e.g. building sea defences, reinforcing homes etc.), level of large scale renewable energy and level of micro-generation installations in the overall generation portfolio of the UK and increase in annual total household cost.

We find that although on average our sampled population identified positive preferences towards an increase in focus on adaptation measures, there is evidence of underlying classes where class participants displayed opposite preferences towards 'adaptation'. Our results show that average willingness to pay for adaptation measures is comparatively higher for those respondents whose houses were affected by any of the climate change related impacts (i.e. flooding, wind erosion, sea level rise etc.). They on average are willing to pay £110 per year in comparison to £54 for the rest of the sample. We also find statistically significant divergence in preferences between those who identified 'adaptation' as an important attribute (WTP = £110.8 per year) versus negative WTP for those who stated that adaptation was not important to them (WTP = £-100.6 per year).

When it comes to mitigation measures, we find that the public wants to see more large scale renewable energy compared to current levels, and although the magnitude of their preferences and willingness to pay does go up depending on the level (i.e. 10%, 20% or 40% respectively), there wasn't enough evidence to claim a significant difference in the willingness to pay between these levels. Similar findings were displayed with regards to respondents' attitudes towards increased level of micro-generation in the UK. Throughout the analysis public displayed consistent willingness to see more micro-generation in the UK compared to current levels, although the levels of WTP for different levels were too similar to have non-overlapping confidence intervals. This indicates that the public does want to see a mix of renewable technologies, but when it comes to choosing between these technologies and their levels of deployment, public preferences require further investigation.

In summary, our results confirm the existence of positive utility and WTP derived by the public for an increase in low-carbon energy in the UK, but their attitudes towards adaptation are not as straightforward and present the scope for future research. When it comes to planning energy policy of any country, it is vital that policy-makers base decisions upon a full understanding of public preferences. As such the research presented in this paper gives a firm basis and grounding for such planning and provides an insight into public's attitudes and preferences towards key policy areas in the UK.

Chapter 5 Carbon Reduction Targets from the UK Public's Perspective

"A key objective of the Climate Change Act was to set a target which would not vary with the ups and downs of global negotiations, but would provide certainty within which policies and technologies could be developed".
The Fourth Carbon Budget, December 2010

"A decision about setting carbon emission targets for 2030 has been delayed until 2016, after the election." ***BBC, November 2012***

5.1 Introduction

Countries worldwide are committed to tackling climate change and there is little doubt that anthropogenic climate change is occurring (WMO, 2012). Various targets and goals have been set both globally and on a national level aimed at reduction of greenhouse gas emissions. The UK is no exception and has a number of legally binding targets. More specifically under the Kyoto protocol the UK is committed to cut greenhouse gas emissions by 12.5% below 1990 levels by 2012 and under EU statutes must cut by 20% by 2020. A legally binding target has been set internally by the Climate Change Act 2008, which requires an 80% cut in greenhouse gas emissions by 2050 and at least 34% reduction by 2020 (Climate Change Act, 2008). The UK Government is committed to achieving this goal though a system of carbon budgets[9], each covering a five year period starting from 2008. Scotland has adopted even more ambitious targets and aims to cut its greenhouse gas emissions by at least 42% by 2020, which is more than double the EU's legally

[9] "The Carbon budget is a cap on the total quantity of greenhouse gas emissions emitted in the UK over a specified time" (DECC, 2008)

binding 20% target and commits Scotland to cut a further 8% than the rest of the UK.

The future of carbon reduction targets beyond 2020 is more than uncertain. On the 29th November 2012 the UK Government announced that although it is still "committed to meet legally binding carbon reduction and renewable energy obligations for 2020", it will delay setting any emissions reduction targets for 2030 until 2016 (The UK Energy Bill, 2012). What is certain, however, is that achieving these targets will come at a cost to consumers. As part of the Bill, the Government officially approved a cost of £7.6bn (in 2012 prices) to be passed on to the consumer by energy companies to pay for a "clean energy investment" (BBC, 2012). According to the estimates of DECC (2012) and an Independent Advisory Committee, this will add between £95 and £110 a year to the average household's energy bill by 2020.

From a policy perspective targets seem to be the most obvious aspect, to the public, of approaches to control reduction in greenhouse gas emissions. That is: the public will likely be much more familiar with the headline (and manifesto) grabbing aspects of climate change policy such as targets set rather than the suite of policies adopted to achieve those targets. Despite a great deal of work carried out by researches and scientists worldwide to address multiple aspects of climate policy and reductions in carbon emissions, previous research has not focussed upon the level at which these targets are set or the public support towards these levels. To the authors' knowledge no studies to date investigated public preferences towards levels of carbon reduction targets in the UK – the key objective of this chapter.

Another policy area addressed in this paper is energy efficiency. It is widely accepted that improvements in energy efficiency in order to mitigate climate change and reduce carbon emissions can be low cost, effective and easily achieved (see for example Hanley et al., 2007). The effects of energy efficiency measures are immediate. This has been recognised by the UK Government with the most significant of the measures adopted aimed at energy efficiency improvements being the upcoming Green Deal[10] and Energy Company Obligation[11] (DECC, 2012). Both of these measures are predominately focused on the private sector.

On the 29th of November 2012, the UK Government launched a consultation on electricity demand reduction across all sectors of the economy. It aims to capture an additional 92TWh of energy saving potential representing 26% of electricity consumption in 2030 (DECC, 2012). It seeks to introduce a range of financial measures (e.g. a premium payment, use of the capacity market and a new obligation relating to energy efficiency for non-domestic customers), that should encourage industry and businesses to be more energy efficient (DECC, 2012). The consultation has received mixed reviews in the press with the main critique being that the costs of any measures introduced by Government are likely to be passed

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[10] Green Deal is a financing mechanism that will allow people pay for energy-efficiency improvements through savings on their energy bills. It will replace current policies such as the Carbon Emissions Reduction Target (CERT) and the Community Energy Saving Programme (CESP) (EST, 2012).

[11] Energy Company Obligation is an obligation for six big energy suppliers in the UK to provide energy saving measures to lower income and vulnerable households (EST, 2012).

on to the consumers as with the case of renewable energy investment (Consumer Focus, 2012). Our research is extremely timely in this case in that it can help to understand public preferences for investment in energy efficiency across sectors of the economy and ensure that public views are appropriately accounted for.

The remainder of the paper is structured as follows: section 5.2 contains a literature review of relevant stated preference studies; section 5.3 outlines the methodological approach; sections 5.4 and 5.5 describe the design and implementation of the analysis; section 5.6 reports the results and findings; and, finally, section 5.7 presents conclusions and policy implications of the research undertaken.

5.2 Literature Review

5.2.1 Application of Stated Preference Studies to Climate Change Policies

Much has been published with regards to damage and abatement costs of greenhouse gas emissions since the problem of climate change first became recognised. Tol (2008) conducted a comprehensive meta-analysis of the social cost of carbon including over 200 valuation studies all of which dealt with the issue of mitigation in one way or another. He reported the mean social cost of carbon / marginal costs of climate change to be equal to $23 per tonne of carbon. Previous research in this area includes works by such authors as Haraden (1993), Fankhauser (1994), Clarkson and Deyes (2002), Stern et al. (2006), Nordhaus (2007), Anderson (2007), Akter and Bennett (2011), Gerlagh (2012).

Researchers have also applied stated preference approaches to understand public preferences with regards to climate change policies and elicit public WTP for reduction in carbon emissions.

Layton and Brown (2000) examined public preferences towards long term (60 years and 150 years) impacts of global climate change amongst the randomly sampled population of Denver, Colorado. Respondents were asked to choose a preferred climate change mitigation program that varied in terms of costs, the degree of ecosystem change and the mitigation method. The results showed that, although heterogeneous in their preferences, the public cared about the long term impacts of climate change and their WTP was increasing with the scope of the impact. Authors also found that public preferences were very similar when comparing between the two different time horizons. Cameron (2005) investigated individuals' willingness to pay for climate change mitigation programs. Although not representative of the US population due to a type of the sampled respondents (undergraduate students), her results indicate that the level of support for these mitigation programs largely depends on the individual's subjective uncertainty associated with the scope of climate change. Lee and Cameron (2008) conducted a survey of the general population of the US to determine their preferences towards climate change mitigation policies. They showed that public WTP for mitigation policies varied depending on their perception of severity of climate change associated impacts. They also report higher WTP for policies, costs of which are shared internationally and identify energy taxes (carbon taxes) as a preferred way of recovering costs for climate change mitigation programmes at a domestic level.

Carson et al. (2010) conducted a choice experiment study of the Australian public to investigate their willingness to pay for alternative climate change policies. Climate change policy was described in terms of 5 attributes, namely: "year emission trading starts, how to return any revenue generated; whether to initially exempt the transport sector; whether to invest in an R&D program; and whether energy intensive sectors should receive special treatment". They found that public preferred policies starting sooner rather than later (2010 rather than 2012), which include spending 20% of the generated revenue on energy related R&D, with no special treatment being given to the energy-intensive sector of the economy. Carlsson et al. (2010) carried out a multi-country contingent valuation study to determine public WTP for a global reduction in CO2 emissions by 2050. The survey was administered in China, Sweden and the United States. The authors found significant and positive WTP for a reduction in CO2 emissions for the respondents in all three countries. The levels of WTP, however, varied significantly between the countries. Respondents in Sweden revealed significantly higher WTP, than those in the United Stated and China with the latter being the lowest. In terms of WTP as a share of households' income, it was found that to reduce carbon emissions by 85% by 2050, Swedish respondents were willing to pay 1.6% of their household income, the United States respondents' were willing to pay 1.1% and Chinese respondents' WTP was 0.9%. Komarek et al. (2011) estimated public preferences for alternative greenhouse gas reduction strategies of a single institution (a large university campus). Preferences between three constituent groups were analysed (students, staff and faculty). The respondents in a choice experiment were asked to trade-off between such attributes as: year reduction in emissions is achieved (2015, 2020, 2025); alternative mixes of fuels (coal, gas, biomass, wind, solar and nuclear); varying levels of energy conservation effort (minimal, moderate, extensive); alternative carbon emissions targets (15%, 17%, 19%, 21%, 23%) and cost to a respondent expressed in terms of an additional semester fee per person ($25, $50, $100, $150). Although applied to an institution, the results appear to be consistent with the findings previously reported in the literature. The authors report positive and significant WTP for emissions reductions across the sample. In line with the findings of Carson et al. (2010), respondents prefer reductions in the shorter rather than longer term. In terms of the type of fuel mix, respondents' WTP was the highest for solar and wind energy. Respondents' preferences for nuclear power, on the other hand, were mixed (negative and significant for staff and not significant for the other groups. Longo et al. (2012) applied contingent valuation to elicit public preferences for ancillary and global benefits associated with climate change mitigation policies in the Basque Country. Respondents faced three dichotomous choice single-bounded WTP questions to cut GHG emissions: 1. "by 4% compared to the current emissions levels through an increase in the production of renewable electricity"; 2. "by 0.5% compared to current emissions levels through the implementation of energy efficient measures in the residential sector"; 3. "by 16% compared to the current emissions levels by incorporating the previous two measures and a set of other measures to reduce GHG emissions as part of the "Basque Plan to Combat Climate Change 2008–2012" (BPCCC)". The results of their study confirmed previously reported findings of Layton and Brown (2000) that the public is concerned about the long term impacts of climate change even if they will not occur during their lifetime. They also reported heterogeneity in respondents' preferences. In terms of ancillary benefits of climate change mitigation, WTP estimates for all three programmes were significantly higher when ancillary benefits are considered. Overall respondents' WTP was the highest for the mitigation programme introduced as part of the BPCCC (combination of renewable and energy efficiency measures) with the second most preferred being an increase in the level of renewable energy as a way of reducing carbon emissions. Akter et al. (2012) conducted a choice experiment of the Australian public, the primary focus of which was to explore the nature and sources of public scepticism in relation to climate change and its impact on public preferences towards implementation of climate change mitigation policies. They found that the presence of scepticism does have a significant impact on public WTP for mitigation policies, although the level of the impact varies depending on its type. Respondents were much more sceptical over the effectiveness of mitigation measures and global co-operation than the cause and impact of climate change.

None of the studies reviewed above, however, attempted to estimate public preferences towards levels of carbon reduction targets in the UK. This Chapter aims to add to the literature in the following way; it aims to investigate the public acceptance of the various levels of carbon reduction targets; and identify the relationship of willingness to pay relative to an increase in emissions target. Another area addressed in this chapter is focus on energy efficiency improvements across multiple sectors of the economy. What follows is a review of the recent studies carried out in this field.

5.2.2 Stated Preference Studies on Energy Efficiency

There are limited studies exist in the literature that estimate consumer preferences towards various energy efficiency measures, most of them tend to focus on specific technologies. Banfi et al. (2008) conducted a choice experiment amongst residents of Switzerland to estimate their preferences towards such energy-saving measures as ventilation systems and insulation of windows and facades. They found positive and significant preferences amongst house owners and tenants towards these measures and their willingness to pay for them was generally higher than market prices.

Achnicht (2010) conducted two separate choice experiments, both of which are based on the data collected as part of the same survey of German households. In his first paper, Achnicht reports on house-owners preferences and willingness to pay for heating and insulation schemes (a choice between modern heating system and improved thermal insulation). He finds that cost of the system, payback period and energy savings all have significant impact on consumers' preferences. The environmental benefits associated with new heating systems also have significant impact on German house-owners preferences. On the other hand they played no significant role in their preference for improved insulation.

In his second paper, Achnicht attempted to address German households' willingness to pay for energy efficiency in an upcoming move. If the previous study was explicitly focused on house-owners, this sub sample included tenants as well, all of whom stated that they consider moving in the next five years. Respondents were asked if they were to accept a higher purchase price/rent for an energy efficient building. The results revealed that such factors as environmental concern and energy awareness (e.g. positive attitude towards climate change mitigation or willingness to pay for green consumer goods) had more significant impact on public willingness to pay for moving into energy efficient homes than socio-economic characteristics, e.g. income or level of education.

More recently, Zhao (2012) conducted a survey of residents of Florida, United States to estimate their preferences for energy efficient and renewable energy products (EERE), such as: solar panels, solar thermal pool heaters, house insulation, heating and air conditioning systems and Energy Star appliances. Financial incentives were offered in the form of tax credits and interest-free loans. The results showed that consumers are generally interested in EERE products, but cost played a major impact on their decisions. The energy saving products most preferred by the public were Energy Star appliances followed by the air conditioning and heating systems and house insulation. In terms of financial incentives, householders much preferred tax credits to interest free loans.

As mentioned earlier, the studies reviewed above attempted to reveal public preferences towards specific technologies that provide improvements in energy efficiency. Authors seem to agree that the public is positive towards installing energy efficiency measures and that the cost seems to be the most significant factor affecting their decisions. The current study is different and adds to the general literature in a sense that it adopts a broader approach and frames improvements in energy efficiency as one of the key areas of the future UK Government's energy and climate policy along with increase in levels of micro-generation and carbon reduction targets. It aims to identify if public wants to see energy efficiency improvements being made in other sectors of the economy and is willing to support the Government's proposed financial incentives (DECC, 2012) to encourage this.

5.3 Methodology

Consistent with the approach undertaken in Chapter 4, a stated preference method, namely, a choice experiment has been applied to the current research below there is a brief revision of the methodology. This method has been increasingly popular in non-market valuation and is based upon the characteristics theory of value (Lancaster, 1966), and random utility theory (McFadden, 1974; Manski, 1977). Individuals in a choice experiment setting are assumed to maximise their utility subject to a budget constraint. The theory behind choice modelling is well described and reviewed in the literature (e.g. Adamowicz et al. 1995, Hanley et al. 2001, Louviere et al, 2000, Ek, 2005, Birol et al., 2006), (see also Chapter 2 of this dissertation). The fundamental assumption of choice experiments is closely related to hedonic analysis in that it is assumed that consumers derive utility from the different characteristics of a good rather than from the good itself (Lancaster, 1966). As such they are asked to choose between different levels of attributes of a good (in this case a policy scenario). By including a cost attribute it is then possible to calculate WTP from the relative preference for different attributes in the choice set.

5.4 Study design

The focus of this Chapter is an investigation of public attitudes and willingness to pay for different levels of reduction in carbon emissions in the UK, focus on energy efficiency improvements, increase in level of micro-generation and increase in total household cost.

5.4.1 Focus Groups and Piloting

As discussed in Chapter 4, the original version of the survey included a total set of 6 attributes. Focus groups results, however, showed that this number of attributes in a single choice set was difficult to process, although all of the attributes were found to be relevant to the policy in question. Having taken on board all the comments and suggestions, the survey was split into two separate choice experiments, with four attributes each. This presented us with the opportunity to test the reliability of the choice experiment results obtained from two experiments run in parallel containing two overlapping attributes each (see Chapter 6 for a detailed comparison of the choice experiments and reliability testing). We split attributes in such a way that Experiment 1 (see Chapter 4 for the analysis) contained direct policy measures for dealing with climate change, such as an increase in large scale renewable energy and adaptation measures, whereas attributes in Experiment 2 (the current experiment) were more general in terms of identifying potential focus and aims of future policy, i.e. carbon reduction targets and the focus of energy efficiency improvements. The micro-generation attribute was described in such a way that it was relevant to both of these scenarios.

We employed a non-labelled choice experiment (CE), where each choice card contained three policy scenarios (A, B and C), each of them containing different combinations of the attributes' levels (see Table 2 for an example choice card). The choice experiment formed a part of a mail questionnaire. The final Bayseian efficient design (developed on NGENE with a D-error of 0.02), consisted of 16 choice cards split equally into two blocks each sent randomly to half of the total sample.

5.4.2 Survey Structure, Levels and Attributes.

The questionnaire consisted of four parts that are briefly described below:

- Aims, requirements, selection criteria and background information were explained to respondents.
- Tests of respondents' attitudes towards climate change, existing policy of the UK, renewable energy and micro-generation.
- Description of the attributes and 8 choice cards that respondents were asked to complete. The respondents were then asked to rate the attributes they faced earlier in order of importance. Finally in this section attitudes to additional policy areas "Adaptation to Climate Change Measures" and "Share of Large Scale Renewable Energy" were investigated.
- Socio-demographic profile questions about respondents and their households.

All of the attributes included in the experiment contained four different levels and are described below:

1. *Carbon Reduction Targets* – is the reduction in carbon emissions that UK could choose to achieve by 2020 compared to 1990 levels. The possible levels given were: 20%[12], 30%, 40% and 50%.

2. *Improvements in Energy Efficiency* – future energy policy could focus on:

Private homes	*Public buildings*	*Service Sector*	*Industrial Sector*
Focus on energy efficiency improvement in private houses	Energy efficiency measures will be implemented in public and community buildings (village halls, schools etc.)	Energy efficiency measures will be implemented in service sector (pubs, shops etc.).	Energy efficiency measures will be implemented in industrial sector (factories, offices etc.).

3. *Increase in Level of Micro-generation* – levels represent the number of households that will have at least one micro-generation unit installed in their homes[13] (pictorial information about potential technologies were provided).

Large	*Medium*	*Slight*	*No Change*
Every second household will have a micro-generation unit installed	1 in 10 households will have a micro-generation unit installed.	1 in 50 households will have a micro-generation unit installed.	1 in 260 households will have a micro-generation unit installed.

4. *Increase Annual Total Household Cost* - Reflects the cost increase and serves as a payment vehicle for the analysis. Respondents were asked to consider four possible levels of annual increase in total household cost: £40, £80, £160 and £260.

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12 20% reduction in carbon emissions is a legally binding target for the UK set by the European Union. Has already been reached to date.

13 Currently in the UK approximately 1 out of 260 households has some type of micro-generation installed. To provide 40% of total UK energy needs, pretty much every house will have some sort of micro-generation technology installed.

They were informed that achieving a reduction in carbon emissions implies additional costs to a household in form of an increased cost of energy bills, higher taxes or prices of consumer goods. Experts' estimates of additional costs to the consumers from implementing carbon reduction policies vary, but can range from £40 to £400 pounds depending on the policy chosen (see for example Renewable Energy Review (2011), Green (2010) or Less (2012), DECC (2012)). Table 5.1 provides more details on the attributes, levels and coding:

Table 5.1. Attributes, Corresponding Variables, Levels and Coding

Attribute's Name	**Description**	**Levels**
Carbon reduction targets	Reduction in carbon emissions that the UK will have to achieve by 2020 compared to 1990 levels.	20% 30% 40% 50%
Energy Efficiency Improvements	Focus on energy efficiency improvements.	Private homes Public Sector Service Sector Industrial Sector
Increase in Level of Micro-generation	Increase in number of households that have micro-generation unit installed in their homes	Large (1 in 2) Medium (1 in 10) Slight (1 in 50) No change (1 in 260)
Increase in Total Annual Cost to a Household	The amount by which the total annual expenditure of your household will go up.	£40 £80 £160 £260

Each of the eight choice cards contained three possible future policy scenarios (A, B and C). Given the experiment was based upon a policy area where commitments are legally binding and the public will be faced with increased costs in the future, participants could not opt-out of the decision.[14] Their choices were identified as likely to influence the level of policy changes. An example of a choice card is presented below:

Table 5.2. Example Choice Card

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	**20%**	**40%**	**30%**
Improvements in Energy Efficiency	**Private Homes**	**Public Buildings** *(schools, village halls etc.)*	**Industrial Sector** *(i.e. factories, offices etc.)*
Increase in Level of Micro-generation *(e.g. small wind turbines, solar panels etc.)*	**Medium** *(1 out of 10 houses have micro-generation installed)*	**No change** *(1 out of 260 houses have micro-generation installed)*	**Slight** *(1 out of 50 houses have micro-generation installed)*
Increase in Annual Total Cost to Household	**£160**	**£260**	**£40**
PLEASE TICK ONE SCENARIO YOU PREFER:			

[14] Given the UK government's legally binding commitment to reduce carbon emissions by 20% by 2020 compared with 1990 levels and the UK's interim target set out by the Climate Change Act 2008 to reduce its emissions by 34% by 2020. Scotland aims to reduce its emissions by 42% by 2020 compared to 1990 levels.

The survey was administered using a postal mail out following "Dillman's method" (Dillman, 1991). The survey was sent out to a randomly selected sample of 1000 households across the UK. Addresses were obtained from a combination of 2010 Electoral register and the 2010 Phone Book databases. The survey was implemented in summer 2011 in three stages (see table 5.3 below):

Table 5.3. Survey Distribution Timeline

No.	Stage	Time period	Survey version
1	Initial mail out to a 1000 randomly selected individuals across the UK	July 2011	Full copy
2	Follow up reminder card to all yet to respond	Two weeks later	Reminder card
3	Second mail out of a full survey to all non-respondents	Two weeks later	Full copy

We received a total of 194 completed questionnaires, which after accounting for undelivered and unusable responses gave us a total response rate of 21%.

5.5 Results

5.5.1 Demographic and Household Profile

The demographic profile of our sample compared fairly well with the overall population of the UK (see Table 6.3, Chapter 6 for a full comparison). As such, the median age of our sample was 51 compared to the UK median age of 40.2, but the youngest person who completed the survey was 19 and the oldest was 88, hence the higher median estimate. 18% of the respondents in our sample were over 65 years old compared to the UK estimate of 16.1%. 54% of the respondents were males relative to 49% for the whole of the UK, suggesting that females in our sample were slightly underrepresented. Average total household income before tax was £37,773 versus the UK's average of £37,701. Despite comparable statistics, we have to allow for a potential presence of positive self-selection and non-response biases given the nature of distribution of the survey. In addition to the data above respondents were also asked to provide some information about their homes (see Table 5.4 for details).

Table 5.4 Information about the Respondents' Homes.

Question	Response		
Is your home well insulated?	"Yes"	"Unsure"	"No"
	78%	6%	13%
Do you live in the area affected by flooding or any other climate related impacts?	"Flooding"	"Other climate related impact"	"None"
	12%	3%	85%
Do you have any micro-generation technologies already installed in your home?	"Yes"	"No"	
	5%	95%	
Do you feel you have any space for micro-generation to be installed in your home or garden?	"Yes"	"Unsure"	"No"
	53%	28%	16%
Would you like to generate your own energy?	"Yes"	"Unsure"	"No"
	61%	23%	16%

78% of our sample stated that their home is well insulated. 15% live in the houses affected by flooding or other climate change related impacts, such as cliff erosion, wind damage, sea defence failure etc. 95% do not generate their own energy, but 61% of them would like to do so.

5.5.2 Attitudes towards Climate Change and the Existing Energy Policy of the UK

This section describes participants' attitudes towards the issue of climate change and existing energy policy of the UK (see Table 5.5 for more details and the exact statements).

Table 5.5 Sample's Attitudes towards Climate Change

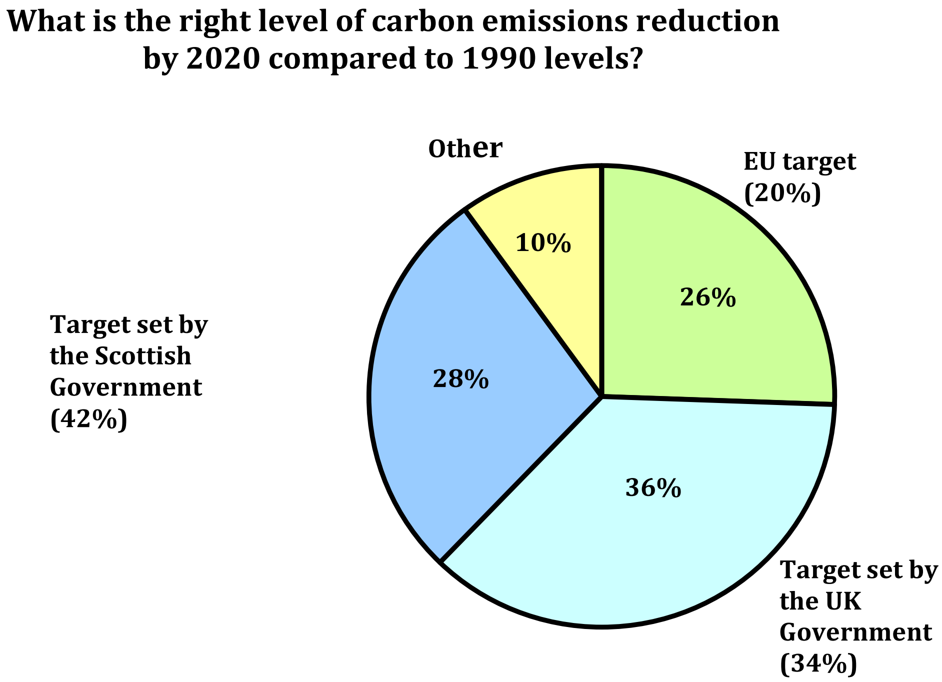
Question	Response		
Climate change is a global problem that needs to be addressed by everyone.	"Agree"	"Unsure"	"Disagree"
	84%	8%	7%
The issue of climate change is exaggerated and doesn't need as much attention as it currently has been given.	"Agree"	"Unsure"	"Disagree"
	15%	32%	52%
I believe that energy should be in the top three priority areas in the Government's budget.	"Agree"	"Unsure"	"Disagree"
	75%	15%	8%
I don't mind where my energy comes from as long as it is cheaper.	"Agree"	"Unsure"	"Disagree"
	42%	16%	42%
I believe that rather than trying to prevent climate change, we should learn to adapt to it.	"Agree"	"Unsure"	"Disagree"
	49%	20%	29%

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

The vast majority of our sample (84%) agreed that climate change is a global problem and needs to be addressed by everyone and 75% of the respondents believe that energy should be in the top three priority areas of the Government's budget. 52% of respondents disagreed that climate change is exaggerated and doesn't need as much attention as it currently has been given and 49% felt that rather than trying to prevent climate change, we should learn to adapt to it. 42% of the sample do not mind where their energy comes from as long as it is cheaper, and exactly the same proportion of the respondents disagreed with this statement.

In this section we also tested public perceptions towards different levels of carbon reduction targets currently adopted by the Governments in the UK. Respondents were asked to choose the level of carbon emission reduction by 2020 (compared to 1990 level) that they feel most appropriate. They were offered a choice between three different targets: 20% reduction in carbon emissions (compared to 1990 level) - target adopted by the EU; 34% reduction – UK Government's target and 42% reduction in carbon emissions – target set by the Scottish Government. Distribution of their preferences can be seen below in the Fig. 5.1.

Figure 5.1 Preferences of the sampled population towards different levels of carbon reduction targets.



We find that public perceptions of the right levels of carbon targets were fairly uniformly distributed with 36% supporting the target set by the UK Government; 26% supporting the EU's target and 28% felt that the level set by the Scottish Government is optimal. It is worth noting at this point that Scottish population formed 11% of the total sample and with the Scottish sample removed from the analysis 27% of the rest of the UK still supported the Scottish targets over their own.

5.5.3 Results of the Choice Experiment

This section of the paper presents the results of discrete choice modelling. We report our findings on preferences and respondents' willingness to pay for various levels of reduction in carbon emissions and improvements in energy efficiency, both of which represent key areas of the overall future energy policy of the UK.

5.5.3.1 Model Specification

Our model was initially estimated using a Multinomial Logit model and although variables came through as significant and had the expected signs, we found that the IIA property, that has to hold in order for the model to produce valid results, was rejected in our case. This was tested using Hausman and McFadden chi-square test (1984). We then estimated our model using a number of different specifications and found that Random Parameters Model (RPL) produced the best fit (see Chapter 2 for model specifications).

5.5.3.2 Random Parameters Model Results

Our RPL model was estimated using NLOGIT 4.0.4. All random parameters were assigned normal distributions, although alternative distributions were also considered. Such attributes as "Focus on Improvements in Energy Efficiency" and "Increase in Households Costs" were include in the model as non-random due to insignificance of standard deviations associated with them. Distribution simulations were based on 2000 draws using Halton's method.

It was found through testing that adding a variable interacting respondents' income with their preferences towards energy efficiency improvements in the private sector we were able to obtain the best model fit reflected in the R-squared, Log-likelihood, AIC and BIC values. All of the variables in the model came through as highly significant at either the 1% or 5% levels.

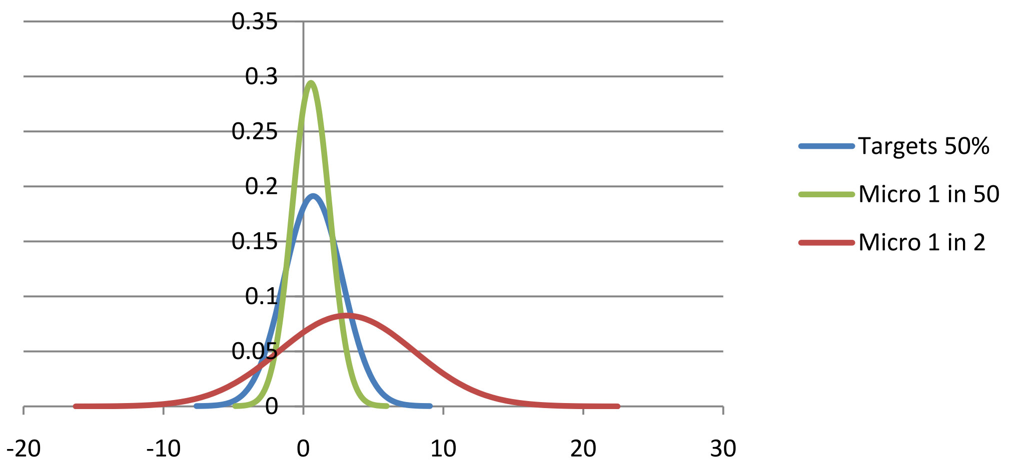
Table 5.6 Results of RPL Model

Variable		**Random Parameters Model**		
		Coefficient	**St. error**	**t-stat.**
Random Parameters in Utility Functions				
Carbon reduction targets (compared to 20% level)	*30%*	0.418**	0.21	1.9
	40%	0.905***	0.23	3.9
	50%	0.704***	0.16	4.5
Increase in Level of Micro-generation (compared to current level, i.e. 1 out of 260 houses)	*1 out of 2 houses have micro-generation installed*	3.098**	1.43	2.2
	1 out of 10 houses have micro-generation installed	1.38469**	0.54	2.55
	1 out of 50 houses have micro-generation installed	0.54057**	0.27	2.0

Non-Random Parameters in Utility Functions				
Improvements in energy efficiency (compared to improvements in private homes)	*Service sector*	-0.953***	0.26	-3.7
	Public sector	-0.572**	0.25	-2.3
	Industrial sector	-0.599**	0.29	-2.1
Income * Improvements in Energy Efficiency in the Private Sector		-0.163***	0.05	-2.9
Increase in Annual Total Cost to Household		-0.012***	0.00	-6.1
Derived Standard Deviations of parameter Distributions				
Carbon reduction targets (compared to 20% level)	*30%*	0.048	1.34	0.0
	40%	0.91	0.65	1.4
	50%	2.087**	0.84	2.5
Increase in Level of Micro-generation	*1 out of 2 houses*	4.848**	2.11	2.3
	1 out of 10 houses	0.003	1.08	0.0
	1 out of 50 houses	1.356*	0.76	1.8
Number of Observations		1552		
Log Likelihood Value		-1295.98		
AIC		1.85		
BIC		1.908		
R-squared		0.171		

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

Fugure 5.2 Distirubions Suggested by Random Parameters



The significance of derived standard deviations in the parameter distributions identifies heterogeneity in preferences between respondents. Along with the plotted distributions this shows that such heterogeneity exists for a 50% carbon reduction target and 1 in 2 homes and 1 in 50 homes having micro-generation technologies. Heterogeneity in preference for 50% targets may be explained by some respondents feeling that a 50% target is likely to have negative impacts in the wider economy as it is constrained to meet the targets and is related to the discussion below about the possible non linear nature of carbon targets. Preferences for increase in Micro-generation levels (1 in 2 houses) are consistent with the results found in chapter 4 and is possibly related to opinions of negative visual impact if 50% of properties had technologies installed.

The results show that respondents in our sample have positive utility associated with all levels of carbon reduction targets relative to the base level. People want to see a reduction of carbon emissions compared to the 20% level set by the European Union. All three variables (30%, 40% and 50% reduction in carbon emissions) came through as highly significant and positive. The level of public preference, however, differs. We find that the highest utility is associated with the 40% reduction in emissions, thus suggesting a non-linear pattern.

In terms of public preferences towards micro-generation in the UK, people want to see an increase from current levels. All levels of this variable came through as significant and positive. Respondents seem to accept the visual and other impacts associated with increased levels of micro-generation and have higher utility for these technologies to be installed in every second house than in 1 in 10, 1 in 50 or 1 in 260 houses in the UK.

Public preferences towards improvements in energy efficiency in service (shops, pubs etc.), public (schools, community halls etc.) and industrial (factories, plants etc.) sectors were measured against their utility associated with energy efficiency improvements in private houses. We find that people with higher incomes are less likely to favour energy efficiency improvements in the private sector. One possible explanation of this might be that people with higher incomes live in better insulated houses and as a result will not directly benefit from a government policy that focuses on the private sector. However, they will still incur the costs in terms of increased energy bills and Government taxes associated with such policy being introduced, given the experiment identified that the cost of these measures would be incurred by households generally through blanket increases in total cost to all households. Despite this our results show that the majority of the sample does want to see energy efficiency improvements in private homes to be prioritised over other sectors in the UK. Respondents displayed negative preference towards improvements in energy efficiency elsewhere (when compared against private sector), with the improvements in the service sector being least preferred.

5.5.5 Willingness to Pay (WTP) Results

In this section of the paper we report implicit prices or 'willingness to pay' (WTP) values for the above model. These represent monetary values that respondents place on a change in a given attribute. WTP was calculated using WALD function in NLogit, which allows the confidence intervals associated with the WTP to be simultaneously calculated. The results are reported in the Table 5.7 below.

Table 5.7 Willingness to Pay (WTP) Estimates

Variable		WTP (£/year)	St. error	t-stat.
Carbon reduction targets (compared to 20% level)	30%	£35.5** (£1.02-£69.9)	17.59	2.0
	40%	£76.9*** (£47.7-£106.1)	14.89	5.2
	50%	£59.9*** (£35.2-£84.6)	12.60	4.8
Increase in level of micro-generation (compared to current level, i.e. 1 out of 260 houses)	1 out of 2 houses have micro-generation installed	£263.3** (£32.9-£493.4)	117.4	2.2
	1 out of 10 houses have micro-generation installed	£117.7*** (£29.6-£205.8)	44.96	2.6
	1 out of 50 houses have micro-generation installed	£45.9** (£1.94-£89.9)	22.43	2.0
Improvements in energy efficiency (compared to improvements in private homes)	Service sector	-£80.9*** (-£119.5--£42.3)	19.68	-4.1
	Public sector	-£48.6** (-£87.6--£9.6)	19.90	-2.4
	Industrial sector	-£50.9** (-£93.1--£8.7)	21.52	-2.4

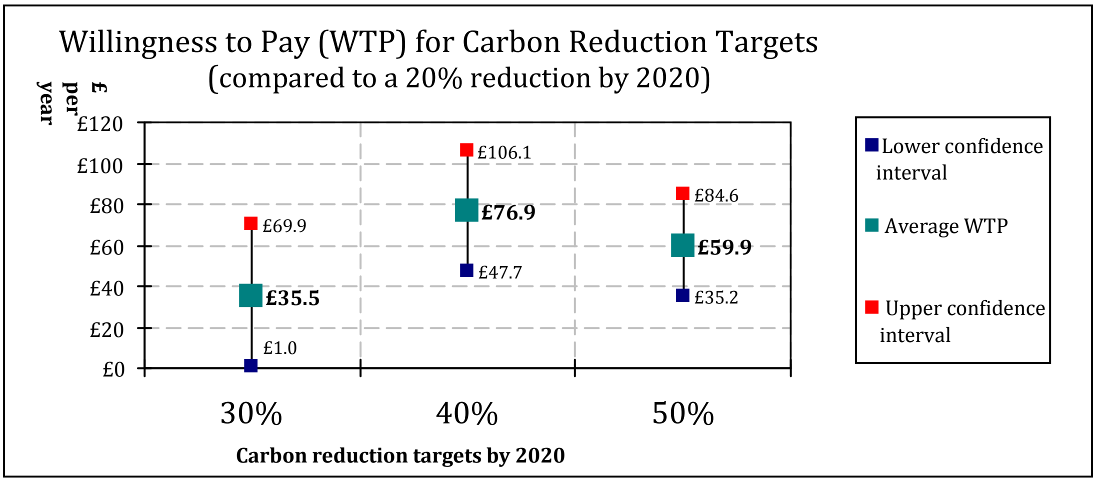
*Note: ***, **, * = Significance at 1%, 5%, 10% level*

We find that respondents' average willingness to pay for an increase in micro-generation ranges from £45.9 to £263.3 per year for some type of micro-generation technologies to be installed in every 50th and every second house in the UK respectively when compared to current (1 in 260 houses) level. To test the hypothesis of the significantly different means between the models, Welch's test that allows testing between populations with different sample sizes and unequal variance, has been carried out (see Appendix 6). The results showed that there is not enough variability within the sampled populations and as such we cannot claim that the WTP for different levels of increase in Micro-generation significantly varies from each other. This is also confirmed by the overlapping confidence intervals. Our results do provide some indication, however, that public does want to see some level of micro-generation in the overall generation portfolio of the UK and is willing to pay a premium for it.

Respondents' WTP for improvements in energy efficiency, when compared to the private sector, were negative and significant at 5% level for public and industrial sector and significant at 1% level for service sector. As such respondents were willing to pay on average £80.9 less per year for energy efficiency measures to be implemented in the service sector and £48.6 and £50.9 less per year for public and industrial sectors respectively when compared to the private sector. The cost to a household in this case is assumed to be passed on via increase in the cost of services and prices of consumer goods in the case of the industry and service sector and through increase in the Government's taxes in the case of the public sector. When it comes to public preferences in the area of improvements in energy efficiency in the UK the private sector remains the dominant focus that pubic would support.

WTP for a reduction in carbon emissions was much less straightforward and intuitive. Public WTP for a change in carbon emissions reduction targets from 20% (as set out by the EU) to 30% was on average £35.5 pounds per year and £76.9 per year for a change to 40%. Average WTP for an increase from 20% to 50% reduction was only £59.9, which was less than the reported increase to 40%, thus indicating that the public WTP for carbon reduction targets may follow a non-linear pattern. This is graphically presented in the Figure 5.2 below.

Figure 5.3 WTP for Carbon Reduction Targets



Based on the results reported above one might argue that as we reach a certain level of reduction in carbon emissions, public willingness to pay may reach a maximum, beyond which every incremental increase in carbon reduction targets will lead to reduced WTP and may not be as accepted by the general public.

One explanation for this results is that individuals trust government to have taken everything into account when deciding the levels of targets to set and are aware that none has gone as far as a 50% reduction target (by 2020). Alternatively the results above may demonstrate that the public are realists, it is not argued that this research has shown that additional emissions reductions given no difference in cost would be preferred. Rather that the public are allowing for costs outside those presented in this research to enter their decision matrix. These costs may be expectations of rising prices given that stricter targets may drive up costs of production. Equally non monetary costs may be being considered such as impacts upon time and convenience. For example large emissions reduction targets will require changed behaviour from the public such as reduced usage of cars and may lead to a less reliable energy supply.

5.6 Conclusions

The primary aim of this paper was to investigate public preferences for the various levels of carbon reduction targets. In addition it also addressed energy efficiency and attempted to reveal public preferences for where energy efficiency improvements are targeted in such sectors of the UK economy, as industrial, public and service sectors in addition to private homes.

The choice experiment method, a stated preference approach, has been applied to this study. We carried out a UK wide postal survey using an unlabelled choice experiment. The future UK energy and climate change policy was framed in terms of the following key areas: level of carbon reduction targets, energy efficiency improvements in various sectors of the UK economy, level of micro-generation installations in the overall generation portfolio of the UK and increase in an annual total cost to the household.

In terms of micro-generation, our results are consistent with those reported in the previous Chapter that public wants to see more micro-generation installed in the UK compared to current levels. They are willing to pay on average £263.3 per year for some type of micro-generation technologies to be installed in every second house and £45.9 for it to be installed in every 50th house when compared to current level (i.e. 1 in 260 houses). Comparison and more detailed analysis of public willingness to pay for this particular attribute will be discussed more in Chapter 6.

When it comes to UK Government spending on energy efficiency - we find that the majority of our sample want energy efficiency improvements in private homes to be prioritised over the other sectors, industrial, public and service with the industrial sector being the least preferred. As such their average WTP was negative and significant for energy efficiency improvements in all investigated sectors when compared to private homes. We also find that there is a negative and highly significant relationship (at 1% level) between respondents' income and their preference towards energy efficiency improvements in private homes with richer respondents being more likely to prefer the Government to focus on energy efficiency improvements in other sectors of the economy, such as industry, public or service sector. Policy relevance of these results has been reflected by the recently launched Consultation by the UK Government that seeks to implement financial incentives aimed at demand reduction measures in both the domestic and non-domestic sectors (DECC, 2012). By providing insight into public preferences, these results can help to ensure that public views are appropriately accounted for when it comes to implementing another set of financial measures by the Government, the impact of which is likely to be felt by the general public.

Finally, we showed that the public have a positive WTP for an increase in emissions targets beyond those set out by the EU (20% reduction from 1990 levels by 2020). The results suggest that there may be a non linear relationship and a tipping point beyond which people do not want to see targets set: WTP drops back between a 40% reduction target and 50% reduction target (although the differences are not statistically significant). The tipping point falls between 30 % (£35.50) and 50% (£59.90) with 40% (£76.90), providing the evidence of higher intermediate WTP. It does not, however, indicate if WTP would be maximised above or below the 40% target. As such it is not possible to identify if the Scottish or UK Government targets are set at the most appropriate level, however, it is clear that both Governments in the public's mind have set targets at a more appropriate level than the 20% target set out by the EU.

Chapter 6. Willingness to Pay for Micro-Generation in the UK: Evidence from Two Comparative Discrete Choice Experiments.

"Strictly speaking no hypothesis or theory can ever be proven, it can only be disproven. When we say we believe a theory what we mean is that we are unable to show a theory is wrong not that we are able to show beyond doubt that that theory is right." ***Gerhard Robbins.***

6.1 Introduction

The UK's carbon reduction targets are amongst the most ambitious in the world. The UK government reached beyond the EU's goal to achieve a 20% reduction in carbon emissions and went 14% higher. This resulted in a legally binding target of 34% reduction in carbon emissions by 2020 and 80% cut by 2050 compared to 1990 levels (Climate Change Act, 2008).

Alongside the challenge of meeting its carbon targets the UK is facing an impending energy gap. The UK's domestic electricity production is currently able to meet 97% of its total electricity demand (Electricity Commodity Balances, DUKES 5.1, DECC, 2012). This, however, may change in the next 5 years due to the closure of a 12 GW of coal plants[15], currently forming nearly 15% of the country's generating capacity. Not only will this generation have to be replaced to maintain the same level of demand requirements by 2015, but new generation will have to come from low-carbon sources in order for the country to meet its carbon targets.

[15] Coal plants that have opted out of LCPD are scheduled to close either 2015 or after 20000 hours of operation (whichever is sooner).

Overall energy demand in the UK increased by 2% between 1990 and 2010 (ECUK, DECC, 2012). Over this time energy consumption in the industrial and service sectors fell by nearly 30% and 5% respectively. The domestic sector on the other hand was responsible for a 19% increase in electricity consumption during the same 20 year period[16]. This is largely due to the consumption of consumer electronic goods that nearly doubled from 12.1 TWh to 20.8 TWh between 1990 and 2009 (EST, 2011). This makes it the largest area of total household electricity demand with 24% of the total electricity used in residential homes being spent on consumer electronics. In 2011 total domestic energy use was responsible for 26% of the total CO2 emissions in the UK (DECC, 2012). To achieve the Government's targets of a 34% reduction in carbon emissions by 2020, the residential sector will have to play a significant part.

Carbon targets combined with the impending energy gap and rising demand represent a great challenge for the UK. Micro-generation can deliver benefits to each of those policy areas. Government defines micro-generation as "the generation of low, zero carbon or renewable energy at a 'micro' scale" (DECC, 2012). It covers decentralised generation of both heat and electricity. Micro-electricity technologies include: solar PV, micro-wind turbines, micro-hydro and micro-CHP. Micro-heat technologies are heat pumps (air, water and ground source), biomass and solar thermal. Under the Energy Act 2004 micro-generation is legally defined as <45kWs (micro-heat) and <50kWs (micro-electricity) (Energy Act 2004, DECC).

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[16] The only other sector that saw an increase in energy consumption was a transport sector (increase of 13%).

Micro-generation potential is recognised by the UK government which put in place a range of measures designed to promote the development of small-scale onsite renewable energy in the country. In April 2010 Feed-in Tariffs (FITs)[17] were introduced to support small-scale electricity installers and the Renewable Heat Incentive (RHI)[18] that will cover domestic heat is due to come into force in summer 2013. In June, 2011 the UK Government published a micro-generation strategy that outlined a set of non-financial actions that will support and develop micro-generation in the UK alongside FITs and RHI (Microgeneration Strategy, DECC, 2011).

As reflected in the report by Element Energy in 2008, however, “for micro-generation to play a serious role in the UK’s energy mix and in meeting CO2 reduction targets, these technologies would have to achieve widespread penetration within the UK population – with uptake measured in the millions”. To put it into perspective, for example, in order to meet 30% of the UK’s current residential demand, over 27 million 3.5 KW units will need to be installed. This implies that, if the current average installation size is maintained, every household in the UK will have a micro-generation unit installed in their homes[19].

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[17] Feed In Tariffs - payments to anyone who owns a renewable electricity system, for every kilowatt hour they generate. Export Tariffs – 3p/kw for any surplus exported.

[18] Renewable Heat Incentive - the scheme will make payments to those installing renewable heat technologies, for a fixed period of time.

19 The total number of households in the UK was just under 26.5 million in 2010 (ONS, 2011; Scottish Government, 2010; NISRA, 2010). For simplicity – an average load factor of all of the combined micro-generation stock is assumed to be 30%.

6.1.1. Impact of Feed in Tariffs on Take up of Micro-generation

The introduction of Feed in Tariffs resulted in a massive increase of micro-generation units installed in the UK. There are currently over 390 thousand electricity generating units in the UK with a total installed capacity of about 244.3 MW (Ofgem, 2012). 29.3 thousand micro-generation units were installed in 2010 compared to 217 thousand in 2011 and 144 thousand in the first seven months of 2012 (MCS Installation Database, 2012). Post 2010 vast majority (between 83%-95%) of all the units installed were Solar PV, whereas pre 2007 solar PV contributed only 2% of the total number of micro-generation units installed with solar thermal being the most popular. See Table 6.1 for a detailed breakdown.

Table 6.1 Total Number of Micro-generation Units Installed in the UK

Technology	up to 2007 *(units installed)*	%	2010 *(units installed)*	%	2011 *(units installed)*	%	Jan – July 2012 *(units installed)*	%
Air Source Heat Pumps	>150	0%	1,272	4%	3,591	2%	3,471	2%
Biomass	500-600	1%	146	0%	639	0%	640	0%
Exhaust Air Source Heat Pumps	-	-	28	0%	133	0%	88	0%
Ground Source Heat Pumps	745-2000	1%-2%	555	2%	1,233	1%	1,047	1%
Micro CHP	200-1000	0%-1%	124	0%	329	0%	55	0%
Micro Hydro	65-75	0%	18	0%	37	0%	8	0%
Small Wind	1,100	1%	586	2%	969	0%	1,028	1%
Solar PV	2,300	2%	24,316	83%	205,395	95%	134,815	94%
Solar Keymark	-	-	1,811	6%	3,342	2%	2,288	2%
Solar Thermal	90,000	93%-95%	450	2%	1,618	1%	735	1%
Total	**96152**		**29306**	**100%**	**217286**	**100%**	**144175**	**100 %**

Source: Element Energy (2008) – estimates up to 2007. MCS Installation Database (2012)- estimates from 2010 to 2012.

It is beyond the scope of this paper to argue the effectiveness and levels of Feed-in Tariffs in the UK, the installations numbers reported above simply illustrate the scale and magnitude of the take up.

Along with the benefits of such an increase in uptake, this also implies a significant visual impact that can potentially affect public acceptance of micro-generation in the UK. This paper aims to achieve two primary goals. It investigates public preferences towards different levels of micro-generation framed alongside other areas of the UK's future energy policy. To contribute to the field of stated preference valuation, this paper also compares the results of two separate choice experiments that were run in parallel, each containing "an increase in level of micro-generation" and "a total increase in household cost" as overlapping attributes thus testing reliability of the method applied and the impact of framing on households' WTP.

The remainder of the paper is structured as follows: section 6.2 contains a review of relevant literature; section 6.3 briefly outlines the methodological approach; sections 6.4 to 6.8 describe the design and implementation of the analysis; section 6.9 reports the results and section 6.10 presents conclusions and policy implications of the research.

6.2 Valuation Studies Review

This section presents a review of the relevant literature to the topics covered in this Chpater. More specifically, it begins with providing a few examples of comparative choice experiments that have been carried out to date; then it moves on to review available stated preference literature in the area of micro-generation and concludes with an outline of the works that address some type of reliability testing in the field of stated preference.

6.2.1. Comparative Choice Experiments

A few examples of comparative choice experiments in the literature include: in health economics Slothuus-Skoldborg and Gyrd-Hansen (2003) investigated WTP for screening methods of different types of cancer; Merino-Castello applied CE to study the demand for two different drugs (Tesler et al., 2008). In the field of environmental economics, DeShazo and Fermo (2002) addressed complexity and choice consistency in stated preference methods by carrying two choice experiments in Costa Rica and Guatemala to assess the economic value of services and infrastructure at new national parks. Campbell et al. (2006) ran two choice experiments to value landscape improvements under the Rural Protection Scheme in Ireland. By applying some advanced stated preference techniques they compared trade-offs in WTP for different attributes between two choice experiments with an overlapping cost attribute.

The most relevant to our study in terms of the undertaken approach is the analysis carried out by Tesler et al. (2008), who designed two separate choice experiments to measure willingness-to-accept (WTA) of the Swiss public for proposed changes to the health care system. Similar to the current paper they had three overlapping attributes in each of the choice sets to enable them to examine validity and reliability issues. They found that WTP for one of the attributes (Generics) was not statistically different between choice experiments, whereas WTP values for the second attribute (Innovation) did vary significantly, thus "indicating a likely presence of a systematic bias".

6.2.2 Stated Preference Studies on Micro-generation

A lot of attention in the literature in the past decade has been devoted to identifying social preferences for large scale renewable energy[20]. Much less, however, has been published in the area of public preferences towards micro-generation and decentralised energy. Achtnicht (2010), conducted a choice experiment estimating public preferences towards retrofitting heating systems in residential buildings in Germany. He found a positive relationship between CO2 savings and public preference and their choice of a heating system. Scarpa and Willis (2010) carried out a choice experiment to determine households' WTP for micro-generation technologies and the factors influencing the adoption of these technologies by households in the UK. They found that households have generally positive WTP for renewable technologies and are willing to pay approximately the same for solar PV (GBP 2,831±244) and solar hot water (GBP 2,903±255), but less

[20] For a literature review of stated preference studies on large scale renewable energy, see Chapter 4 of this thesis.

than half the amount for wind turbines (GBP 1,288±241). Stemming from this work is another study that was conducted by Claudy et al. in 2011 where a contingent valuation (CV) method was used to investigate Irish public preferences towards different types of micro-generation technologies, such as wood-pellet boilers, small wind turbines, solar panels and solar water heaters. Households' median WTP were €5431, €4231 and €3476 and €2380 for micro wind turbines, solar panels and wood pellet boilers and solar water heaters respectively[21,22]. Similar to Scarpa and Willis, Claudy et al. found that households' WTPs for micro-generation technologies, although positive, are significantly lower than their market prices. The authors also showed that people's WTP was not entirely based on financial reasoning, but is also influenced by subjective perceptions of the characteristics of a particular technology.

Where this paper differs from the above literature is that is does not concentrate on specific technologies – rather it attempts to identify preference for micro-generation within and compared to an appropriate policy framing, focussing on the scale of uptake.

[21] Authors use SEAI (2010) estimates of the average costs of installing above mentioned technologies. More specifically, wood pellet boiler is estimated to cost between €10,000 and €16,000, a 5 kWh micro wind turbine or a 3 kWh solar panel system estimated to be in the range of €20,000 to €25,000. Costs of solar water heating systems are estimated to be between €2400 and €5000.

[22] One might argue that market prices for micro-generation technologies (in particular for solar PV) decreased significantly in the UK since the publication of Claudy's paper. For example, according to "TheEcoexperts.co.uk" price comparison site, costs of installing a typical 3 kW solar panel system ranges between £5000 and £6000, which is brings Claudy's estimates of households WTP much closer to market price estimates.

6.2.3 Concept of Reliability in Stated Preference Valuation

Arguably the most important question in the field of stated preference valuation is whether the results are reliable enough to be used for policy making decisions.

Bateson et al. in 1987 were the first to our knowledge to apply a structural approach to reliability in the field of stated preference. They identify four reliability measures: reliability over time tasks, reliability over stimulus set tasks, reliability over attribute set tasks, reliability over data collection procedure tasks. They argue that each of these could be a source of producing non-reliability and each could contribute differently to the overall reliability measure (Reibstein et al., 1988).

Table 6.2 Types of Reliability

Reliability over time tasks	"Would the results be the same at a different point in time?"
Reliability over stimulus set tasks	"Would the results be the same if a different set of stimuli or profiles had been used?"
Reliability over attribute set tasks	"Would the utilities for a given set of attributes be the same if these attributes have been included in a study with other attributes?"
Reliability over data collection procedure tasks	"Would the results have been the same if a different data collection procedure had been used?"

Source: Reibstein et al., 1988

Unsurprisingly, a number of studies over time scrutinised almost every aspect of stated preference approaches with many investigating some form of reliability. Causes of potential bias in choice experiments such as task complexity (e.g. De Shazo and Fermo in 2002; Hanley in 2003; Boxall et al in 2009), experimental design (e.g. Ferrini and Scarpa in 2007, Lusk and Norwood in 2005) and ordering effects (e.g. Day et al., 2012, Carlsson et al. in 2012) have all been explored in the literature to some extent.

Reliability of values through time or “temporal” reliability has been addressed extensively in the past, but mainly in the field of health economics (Bryan et al, 2000, Cairns et al. 2004, Ryan et al. 2006, Skjoldborg et al., 2009). A few recent studies applied the concept of “temporal” reliability to environmental valuation. For example, Bliem et al (2012) in their study of preferences for river restoration in Austria, conducted two identical choice experiments with a time difference of one year. Almost in parallel Liebe et al. (2012) investigated temporal reliability in a choice experiment concerning landscape externalities of onshore wind power in central Germany. They also conducted two identical choice experiments at two different points in time (11 months). The key difference between their experiment and Bliem’s, is that Liebe’s repeat sample consisted of the same participants, whereas Bliem used two independently drawn samples of respondents. Both authors found evidence in support of temporal stability of their results.

Other forms of reliability measures, such as reliability over stimulus set tasks and over the data collection procedure have also been explored in the literature. Carlsson and Martinsson (1999) tested the presence of hypothetical bias in choice experiments with donations to environmental projects as the payment vehicle. They found no evidence of such bias and reported stable and transitive preferences in both experiments. Lusk et al. (2004) tested the presence of hypothetical bias in a choice experiment involving beef steaks with different quality attributes. Contrary to Carlsson and Martinsson they found statistical divergence in hypothetical CE responses from actual CE responses. Despite this they found that marginal WTP for steak attributes were similar for both settings. List et al. (2006) explored hypothetical bias by analysing divergence in public preferences by examining three treatments: real, hypothetical and hypothetical setting with "cheap talk". They report consistent results between the hypothetical and real treatments, thus supporting validity of choice experiments. Yet, they also found that the "cheap talk" component might be the cause of inconsistency in respondents' preferences.

Olsen (2009) addressed reliability over data collection procedure by comparing results of two identical choice experiments obtained using mail and internet sampling. Although some divergence was present between the samples, he found no significant difference in respondents' willingness to pay. Börjesson et al. (2011) compares internet and telephone-based responses in the context of Swedish Value of Time study conducted in 2008. They find a lower random error in the data collected over the internet, but that the response rate is also lower when collected using this method. To increase the response rate, they recommend a mixed approach where internet is the primary method of data collection followed up by a telephone survey.

This paper is concerned with the reliability over attribute set tasks. The hypothesis that is central to this Chapter is: ""Would the utilities for a given set of attributes be the same if these attributes were included in a study with other attributes?" (see Table 6.2 above).[23] To achieve this we compare marginal willingness to pay for an increase in level of micro-generation in the UK, a common attribute that is framed alongside different policy areas in two separate discrete choice experiments run in parallel. See Chapter 2 for an overview of the methodological approach and Chapters 4 and 5 for models specifications.

6.3 Study Design, Levels and Attributes

To address the primary goal of the analysis and identify public trade-offs in WTP for different levels of micro-generation in the UK with other areas of the UK's future energy policy, the initial version of the choice experiment consisted of 6 policy attributes. These attributes were: Improvements in Energy Efficiency, Carbon Reduction Targets, Spending on Adaptation to Climate Change, Increase in Large Scale Renewable Energy, Increase in Level of Micro-generation and Increase in a Total Cost to a Household. Focus group and cognitive interview results, however, indicated that although all of the attributes were relevant, people found it too hard to process such large amounts of information, so it was necessary to account for this in the final design.

[23] To authors' knowledge, the only study has been found in the literature to date that followed a similar approach is Telser et al. (2008) (see Section 6.2.3 "Comparative Choice Experiments")

Over time a number of studies addressed task complexity in stated preference methods. Swait and Adamowicz (1997) and Bradley (1988) showed that task complexity may affect the decision making process; Hanley et al. (2003), found that increasing the number of choices influences parameter estimates; Caussade et al. (2005) empirically proved that the "number of attributes had a clear detrimental effect on the ability to choose, contributing to a higher error variance"; Louviere et al. (2008) also showed the negative impact of the task complexity, in particular, the number of attributes, on choice consistency; and, more recently, Zhang and Adamowicz (2011) in their study of the "choice format effect" highlighted the importance of reducing task complexity by decreasing either number of attributes, the number of alternatives or the number of choice tasks. They also pointed out that decreasing the number of attributes to control for choice complexity tends to be the least common option, and that most authors seem to rely on controlling either the number of choice tasks or the number of alternatives.

Our study takes account of the above findings in a way, that hasn't yet been extensively explored in the literature. In order to control for a choice complexity, we split the attributes into two independent choice sets each containing two overlapping attributes (increase in levels of micro-generation and increase in total cost to a household), thus allowing the opportunity to investigate public preferences for micro-generation under different framings and to test the reliability of the estimates derived.

The attributes were split in such a way that each choice set represented a distinct policy framing aimed at dealing with climate change. More specifically, Experiment 1 contained attributes that represent direct measures for dealing with climate change, such as an increase in large scale renewable energy and adaptation measures. The attributes in Experiment 2 were more general identifying the potential focus and aims of future policy, i.e. carbon reduction targets and the focus of energy efficiency improvements, rather than the exact measures taken to deal with climate change. The micro-generation attribute was described in such a way that it was relevant to both theses scenarios. We designed two separate choice experiments that were run simultaneously to allow for maximum comparability of results.

In both cases we employed a non-labelled choice experiment containing three possible policy scenarios (A, B and C) each consisting of four attributes. Both experiments were designed following Bayesian efficient design principles. The final choice sets consisted of a total number of 16 choice cards split equally into two blocks each sent randomly to half of the total sample. Both choice experiments (Experiment 1 and Experiment 2) were identical in terms of the accompanying information and attitudinal and socio-demographic questions with the only difference being the attributes in the choice sets. (See Chapters 4 and 5 for detailed information about piloting, experimental design and survey implementation).

The context of the choice experiments was such that the respondents could trade-off between key areas of the future energy policy of the UK in terms of the increase in a total annual cost to their household. They were informed that given the UK Government's legally binding commitment to reduce carbon emissions to address the problem of climate change, the changes to the policy will happen no matter what at some cost to households (REF, 2011), but the respondents could influence the level of the increase and their preference towards the areas that Government should focus on in terms of future energy budget spending.

In Experiment 1 respondents could trade-off an increase in levels of micro-generation against an increase in Government spending on adaptation to climate change or an increase in large scale renewable energy. In Experiment 2 respondents could trade-off an increase in levels of micro-generation with different levels of carbon reduction targets and improvements in energy efficiency. See Table 6.3 for a description of the attributes and their levels.

Each CE was distributed by post to a sample of 1000 randomly selected households across the UK. We received in total 177 and 194 completed and usable questionnaires to Experiments 1 and 2 respectively[24].

[24] A total response rate of 21% (number of returned responses divided by the difference between total sent out and undeliverable).

Table 6.3 Choice Attributes and Levels.

Attribute's Name	Variable Name	Description	Levels
EXPERIMENT 1 – NON-OVERLAPPING ATTRIBUTES			
Spending on adaptation to climate change	Adaptation	Level of spending on such adaptation measures, as building flood defences, homes reinforcement, insulation improvements etc.	High, Low
Increase in Large Scale Renewable Energy	Large Renewables	Increase in level of large scale renewable projects comparing to current level of 6.7%.	Large (40%), Medium (20%), Slight (10%), No change (6.7%)
EXPERIMENT 2 – NON-OVERLAPPING ATTRIBUTES			
Carbon reduction targets	Carbon	Reduction in carbon emissions that the UK will have to achieve by 2020 compared to 1990 levels.	20% 30% 40% 50%
Energy Efficiency Improvements	Efficiency	Location of energy efficiency improvements.	Private homes Public Sector Service Sector Industrial Sector
OVERLAPPING ATTRIBUTES			
Increase in Level of Micro-generation	Microgen	Increase in number of households that have micro-generation unit installed in their homes	Large (1 in 2) Medium (1 in 10) Slight (1 in 50) No change (1 in 260)
Increase in Total Annual Cost to a Household	Cost	The amount by which the total annual expenditure of a particular household will go up.	£40 £80 £160 £260

6.4 Results

6.4.1 Public Attitudes and Demographic Profiles

In terms of demographic data, there were some divergences between two samples, i.e. respondents in Experiment 1 are on average slightly younger, more educated and have more kids, although on average they seem to earn less than those in Experiment 2. Male population represent 53% of the sample in the Experiment 1 and 54% in Experiment 2. Average age of our samples is 49 and 50 years old for Experiments 1 and 2 respectively. Respondents in Experiment 2 have slightly higher average household income before tax of £37,773 in comparison to £35,800 for respondents in Experiment 1. 86% and 90% of the samples own their homes in Experiment 1 and 2 respectively. 14% and 15% of the households live in the houses affected by either flooding or some other climate change related impacts. 5% in both samples have some type of micro-generation already installed in their homes; and 22% in Experiment 1 and 19% in Experiment 2 don't feel that they have space for some type of micro-generation technology to be installed in their houses or gardens. See Table 6.4 for more details on the demographic and socio-economic profile of our samples. Given the fact that selection of the sampled population for both experiments was completely random and independent on each other, distribution of public attitudes appeared to be very similar and consistent across the samples.

More specifically, 89% and 84% in Experiments 1 and 2 respectively, agreed that climate change is a global problem and needs to be addressed by everyone. Although not directly comparable, this is broadly in line with the findings of the

Eurobarometer Climate Change Report (2011), which stated that 89% of the Europeans saw climate change as a serious problem. On the other hand 15% of the respondents in both samples also agreed with the statement that the issue of climate change is exaggerated and doesn't need as much attention as it currently has been given (see Table 6.5 below for more details). These proportions are significantly lower than in the recently published survey of the general public Shuckburghet al. (2012), which reported that almost half (around 44%) of the respondents believed that the seriousness of climate change is exaggerated.

Table 6.4 Demographic and Household Profile

Category	**Experiment 1**	**Experiment 2**	**UK's Average**[25]
Demographic Profile			
Gender (Male share)	53%	54%	49%
Median age	49	51	40.2[26]
Share of sample over 65	9%	18%	16.1%
Average income	£35,800	£37,773	37,701[27]
Educated to a degree level	34%	23%	
Household Profile			
Affected by flooding or other climate change related impacts	14%	15%	
% of the sample that feel that their homes are well insulated	76%	78%	
% of the sample that own their homes	86%	90%	
% of the sample that already installed some type of micro-generation	5%	5%	
% of the sample that feel that they have space for micro-generation to be installed in their houses of gardens	46% (yes) (32% unsure)	53% (28% unsure)	

[25] Source: CIA World Factbook, 2012 (https://www.cia.gov/library/publications/the-world-factbook/geos/uk.html) and Office of National Statistics Database, 2010.
[26] The minimum age of the respondents in our sample is 21 (Experiment 1) and 19 (Experiment 2) hence higher median value than the UK's.
[27] Based on a ratio of an average gross disposable household income and an average size of household in the UK (source: Office of National Statistics, 2010)

Table 6.5 Comparison of Respondents' Attitudes towards Climate Change

Question	Experiment 1			Experiment 2		
	Agree	Unsure	Disagree	Agree	Unsure	Disagree
"Climate change is a global problem that needs to be addressed by everyone."	89%	5%	5%	84%	8%	7%
"The issue of climate change is exaggerated and doesn't need as much attention as it currently has been given."	15%	24%	60%	15%	32%	52%
"I believe that rather than trying to prevent climate change, we should learn to adapt to it."	43%	27%	28%	49%	20%	29%

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

The vast majority of the public felt that energy should be in the top three priority areas in the UK Government's budget. Public opinions split with regards to the right level of carbon reduction targets. In both cases, the majority of the sample (39% and 37%) felt that the "right level of reduction in carbon emissions by 2020" is a reduction by 34% compared to a 1990 level, i.e. the target set by the UK Government. Respondents' attitudes towards 20% and 42% targets on the other hand differed across the samples. A higher proportion of the sample (29%) in Experiment 1 believed that 20% is the right level of carbon reduction target in the UK and 21% felt that the level should be set at 42%, whereas in Experiment 2 27% of the sample felt that the level should be set at 42% with the 23% preferring the target set out by the EU of 20%. See Table 6.6 for a more detailed analysis of public preferences towards carbon targets.

Table 6.6 Comparison of Respondents' Attitudes towards Existing UK's Energy Policy

Question		Experiment 1			Experiment 2		
		Agree	Unsure	Disagree	Agree	Unsure	Disagree
I believe that energy should be in the top three priority areas in the Government's budget.		71%	18%	11%	75%	15%	8%
I believe that the right level of reduction in carbon emissions by 2020 (compared to 1990 level) is:	20%[28]	29%			23%		
	34%[29]	39%			37%		
	42%[30]	21%			27%		
	Other	12%			10%		

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

The cost of energy seems to be the topic that split public opinions within the samples the most. Roughly equal proportions of both samples (39% and 40% in Experiment 1) and (41% and 44% in Experiment 2) agreed and disagreed with the statement "I don't mind where my energy comes from as long as it is cheaper".

[28] Legally binding target set by the European Union.
[29] Target set by the UK Government.
[30] Target set by the Scottish Government.

6.4.3 Public Preferences towards Specific Micro-generation Technologies

The majority of the sampled population would like to generate their own energy (59% and 63% in Experiments 1 and 2 respectively) although fairly large proportion (25% and 22%) were unsure about this. 50% of the respondents in Experiment 2 and 45% in Experiment 1 were aware of Feed-in Tariffs introduced on the 1st April 2010 (see Table 6.7 for more details).

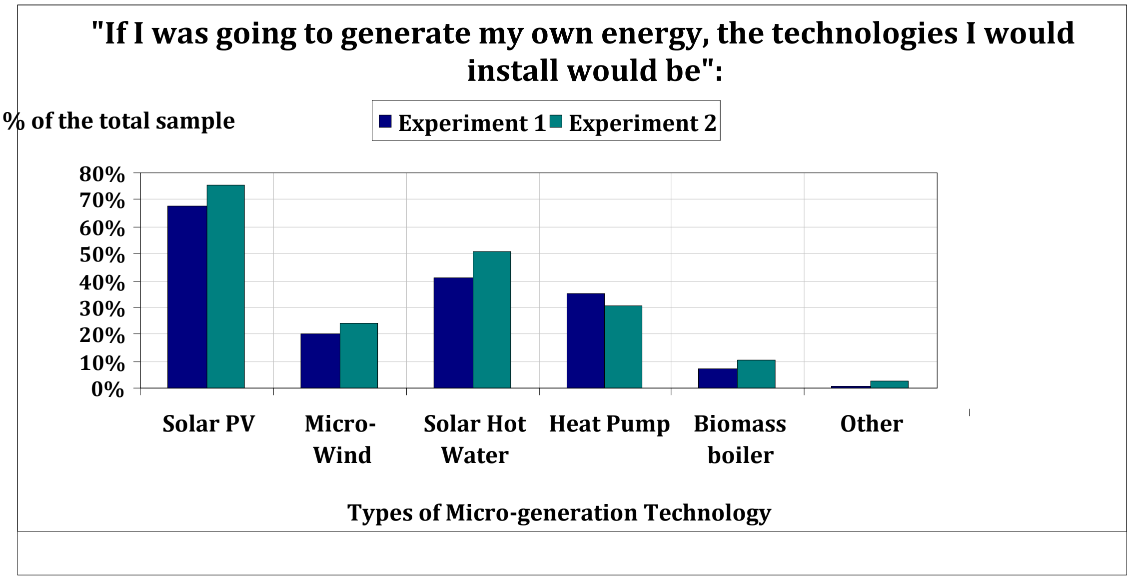
Respondents were consistent across the Experiments in displaying their attitudes towards specific micro-generation technologies. The majority of the sample in both Experiments identified Solar PV as a technology they would install (68% - Exp. 1 and 75% - Exp. 2) followed by solar thermal (hot water) (41% - Exp. 1 and 51% - Exp.2) and heat pumps (35% - Exp. 1 and 30% - Exp.2). Micro-wind and biomass boilers seem to be considered the least popular (or least practical) technologies amongst our samples. Around 1 in 5 respondents in both Experiments stated that they would install a micro-wind turbine and around 10% stated that they would install a biomass boiler (see Figure 6.1 for more details). These findings are consistent with those of Scarpa and Willis (2010) who also highlight higher public preferences for solar technologies in comparison with micro-wind. Given that the respondents were not presented with any information on the costs, advantages or disadvantages of any of the technologies, the reported results simply reflect public preferences based on their existing knowledge (or in some cases lack of) and subjective perceptions towards micro-generation.

Table 6.7 Comparison of Respondents' Attitudes towards Micro-generation

Question	Experiment 1			Experiment 2		
	Agree	Unsure	Disagree	Agree	Unsure	Disagree
I would like to be able to generate my own energy	59%	25%	14%	63%	22%	13%
I was aware that Feed-in Tariffs were introduced by the Government on the 1st April 2010.	45%	27%	25%	50%	25%	24%
I don't mind where my energy comes from as long as it is cheaper.	39%	19%	40%	41%	15%	44%

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

Figure 6.1 Attitudes towards specific types of Micro-generation Technologies



6.4.4 Comparison across Choice Experiments

The next section of the paper reports the results of Experiments 1 and 2 estimated using Random Parameters Model Specification (see Chapter 2 for more details on model specifications). The models were estimated using NLOGIT 4.0.4. Non-random parameters in Experiment 1 were: "spending on adaptation to climate change" and "increase in annual total household cost". Non-random parameters in Experiment 2 were: "Improvements in energy efficiency" and "increase in annual total household cost". The above parameters were tested for their "randomness", but were eventually included in the utility function as non-random due to insignificance of standard deviations associated with them. All random parameters were assigned normal distributions (although other distributions were investigated) and distribution simulations were based on 2000 draws for the maximum simulated likelihood estimation using Halton's method (see Hole, 2007).

Since the focus of this paper is to compare welfare estimates for a specific energy policy attribute, namely, increase in levels of micro-generation, thus testing the reliability of the method used, the model specification does not include any interactions with socio-economics factors or attitudinal characteristics. As highlighted by Campbell et al. (2006) and originally suggested by Louviere et al. (2003), the advantage of this approach is that it allows us to investigate trade-offs without complex relationships.

Table 6.8 Comparison of RPL Model Results for Experiments 1 and 2

Variable		Experiment 1			Experiment 2		
		Coeff.	**St. err.**	**t-stat.**	**Coeff.**	**St. err.**	**t-stat.**
Overlapping Random Parameters							
Increase in Level of Micro-generation (compared to current level, i.e. 1 out of 260 houses)	*1 out of 2 houses have micro-generation installed*	1.007***	0.35	2.89	3.093**	1.39	2.2
	1 out of 10 houses have micro-generation installed	0.93***	0.16	5.77	1.43***	0.48	2.9
	1 out of 50 houses have micro-generation installed	0.502**	0.21	2.33	0.578**	0.23	2.5
Overlapping Non-random Parameters							
Increase in an Annual Total Cost to a Household		-0.005***	0.00	-9.3	-0.011***	0.00	-7.1
Non-overlapping Random Parameters							
Increase in Large Scale Renewable Energy (compared to current level, i.e. 6.7%)	*10% of UK's energy*	0.919***	0.15	5.95			
	20% of UK's energy	1.111***	0.24	4.64			
	40% of UK's energy	1.402***	0.37	3.74			
Carbon reduction targets (compared to 20% level)	*30%*				0.438**	0.19	2.3
	40%				0.866***	0.2	4.4
	50%				0.644***	0.13	5.2

<table>
<tr><td colspan="8">Non-overlapping Non-random Parameters</td></tr>
<tr><td colspan="2">Adaptation – High
Represents much greater priority placed on adaptation measures compared to current levels.</td><td>0.406***</td><td>0.08</td><td>4.70</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Improvements in energy efficiency
(compared to improvements in private homes)</td><td>Service sector</td><td></td><td></td><td></td><td>-0.314**</td><td>0.13</td><td>-2.4</td></tr>
<tr><td>Public sector</td><td></td><td></td><td></td><td>0.062</td><td>0.14</td><td>0.4</td></tr>
<tr><td>Industrial sector</td><td></td><td></td><td></td><td>0.066</td><td>0.15</td><td>0.5</td></tr>
<tr><td colspan="8">Standard Deviations of Random Parameter Distributions</td></tr>
<tr><td rowspan="3">Increase in Level of Micro-generation
(compared to current level,
i.e. 1 out of 260 houses)</td><td>1 out of 2 houses have micro-generation installed</td><td>2.54**</td><td>1.2</td><td>2.1</td><td>5.188**</td><td>2.21</td><td>2.4</td></tr>
<tr><td>1 out of 10 houses have micro-generation installed</td><td>0.031</td><td>0.68</td><td>0.1</td><td>0.035</td><td>1.09</td><td>0.0</td></tr>
<tr><td>1 out of 50 houses have micro-generation installed</td><td>0.006</td><td>1.17</td><td>0.0</td><td>0.918</td><td>0.74</td><td>1.25</td></tr>
<tr><td rowspan="3">Increase in Large Scale Renewable Energy
(compared to current level, i.e. 6.7%)</td><td>10% of UK's energy</td><td>0.001</td><td>0.52</td><td>0.0</td><td></td><td></td><td></td></tr>
<tr><td>20% of UK's energy</td><td>1.648**</td><td>0.68</td><td>2.4</td><td></td><td></td><td></td></tr>
<tr><td>40% of UK's energy</td><td>0.399</td><td>1.74</td><td>0.2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Carbon reduction targets
(compared to 20% level)</td><td>30%</td><td></td><td></td><td></td><td>0.018</td><td>0.65</td><td>0.0</td></tr>
<tr><td>40%</td><td></td><td></td><td></td><td>0.766</td><td>0.61</td><td>1.3</td></tr>
<tr><td>50%</td><td></td><td></td><td></td><td>1.601**</td><td>0.68</td><td>2.3</td></tr>
<tr><td colspan="2">Number of Observations</td><td colspan="3">1416</td><td colspan="3">1552</td></tr>
<tr><td colspan="2">Log Likelihood Value</td><td colspan="3">-1431.29</td><td colspan="3">-1420.23</td></tr>
<tr><td colspan="2">AIC</td><td colspan="3">2.04</td><td colspan="3">1.86</td></tr>
<tr><td colspan="2">BIC</td><td colspan="3">2.09</td><td colspan="3">1.91</td></tr>
<tr><td colspan="2">R-squared</td><td colspan="3">0.08</td><td colspan="3">0.167</td></tr>
</table>

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

All of the estimated parameters came through as significant with the expected signs. Although different in scale, so not directly comparable, in both experiments coefficients associated with the overlapping attribute "increase in level of micro-generation" were highly significant and positive (at 1% and 5% levels), thus indicating that the public wants to see more micro-generation compared to current levels in the UK and that such preference is consistent across the two samples. In terms of standard deviations the same results are found as were presented in chapters 4 and 5 and as such we do not repeat these findings here.

The next section reports comparison of implicit prices or marginal 'willingness to pay' (WTP) values for Experiments 1 and Experiments 2. These represent monetary values that respondents place on a change in a given attribute. WTP was calculated using WALD function in NLogit, which allows the confidence intervals associated with the WTP to be simultaneously calculated. As described in Chapter 2, WTP estimates are not subject to scaling effect, so their values are directly comparable.

6.4.4.2 Non-overlapping Attributes

Our results confirm that the public wants more renewable energy in the UK. This is reflected in positive and significant values for WTP coefficients both for large scale renewable energy and for micro-generation. In addition to mitigation measures mentioned earlier (i.e. renewable energy generation – both micro and macro), respondents also displayed positive and significant WTP for an increase in adaptation to climate change measures as part of the future energy policy of the UK. They also prefer to see higher carbon reduction targets than those set out by the EU, but respondents' average WTP does not follow a linear relationship and declines from 40% to 50%. Compared to private sector, public willingness to pay for energy efficiency improvements in other sectors of the economy is negative and significant at 5% and 1% with the least preferred being the service sector. For a detailed analysis, values and policy implications of non-overlapping attributes see chapters 4 and 5 of this dissertation.

6.4.4.3 Willingness to Pay for Micro-generation in the UK and Reliability Testing

The publics' WTP for an increase in levels of micro-generation in the UK is positive and significant across both Experiments (1 and 2). Compared to current levels, respondents are willing to pay on average £102.3 per year and £52.1 per year to see some type of micro-generation installed in 1 out of 50 houses in the UK respectively. They are willing to pay even more to see micro-generation installed in 1 out of 20 houses in the UK (£189.7 per year – Experiment 1 and £128.9 per year – Experiment 2) and for micro-generation to be installed in every second house in the UK, the public is willing to pay on average £205.3 and £278.8 per year in Experiments 1 and 2 respectively. See Table 6.9 for more details.

Table 6.9 WTP Estimates for an Increase in Level of Micro-generation in the UK (an overlapping attribute)

Variable		Experiment 1			Experiment 2		
		WTP	St. error	t-stat	WTP	St. error	t-stat
Increase in level of micro-generation (compared to current level, i.e. 1 out of 260 houses)	1 out of 2 houses have micro-generation installed	£205.3*** (£78.1-£332.5)	64.88	3.16	£278.8** (£40.8-£516.7)	121.4	2.3
	1 out of 10 houses have micro-generation installed	£189.7*** (£130.2-£249.2)	30.38	6.24	£128.9*** (£49.4-£208.4)	40.58	3.18
	1 out of 50 houses have micro-generation installed	£102.3*** (£26.6-£177.9)	38.6	2.65	£52.1*** (£12.8-£91.3)	20.02	2.6

Comparing willingness to pay values between two choice experiments, we note that the WTP in Experiment 1 is more closely bounded than in Experiment 2 with less divergence between the three levels of the attribute. Having reported that, we identify some level of equality in the WTP for micro-generation estimates between the two experiments. To formally test this claim, Welch's T-test was used to test the hypothesis of means equality for two populations with different sample sizes and unequal variance (i.e. Experiment 1 and 2). Based on the results of the test (see Appendix 6), the hypothesis of the means equality between the populations cannot be rejected and we can conclude that the WTP between the choice experiments is not statistically different. Overlapping confidence intervals also support this claim.

As we do not disprove the existence of equality (or the absence of heterogeneity) between estimates this result advocates the theoretical robustness of CE method and its reliability for use in policy making. Although the mean WTP in experiment

1 for 1 in 50 households being twice that of the result in experiment 2 suggests caveats regarding the use of absolute levels.

Difference in average WTP may be attributed to the framing of the attributes. As described earlier in the paper: Experiment 1 contained attributes that represented direct measures for dealing with climate change, whereas Experiment 2 contained more general attributes including focus and goals. As can be seen by the lower coefficient associated with the price attribute in Experiment 1 compared to Experiment 2, individuals in Experiment 2 were focussing more on the price of the scenarios they were presented with. This suggests that the overall policy in Experiment 1 was more attractive to the public. Choice experiments identify the relative importance of the attributes of a policy or good – however, the overall utility associated with the bundle of goods may be seen to impact upon the final WTP as identified by the interaction of the attributes for price with the other attributes. Even efficient designs may fail to account for this – ideally the price attribute for each experiment would have been derived from extensive piloting to account for this divergence but such analysis was out with the scope of this research. The other explanation could of course be due to socio-demographic differences between the two samples.

6.5 Scale Parameter Investigation between the Two Models – Extensions to the Modelling Framework

6.5.1 Modelling Approach

In order to further test the relationships between the two experiments reported in Chapters 4 and 5 it was necessary to investigate the differences in scale parameter between the experiments. To directly compare coefficient estimates across different choice models it is necessary to take account of differences in scale as the estimated parameters in each treatment are confounded with an unknown scale parameter which is inversely proportional to the error variability of the respondents' choices in a particular experiment (Colombo et al 2007, p. 137).

The use of WTP is not confounded with scale, in essence the scale of the attributes and cost cancel out when WTP is calculated (Scarpa et al 2008). However, in order to extend the analysis and identify which attributes contribute most to the differences between experiments it is necessary to look beyond WTP. Below we present the results of a pooled model where we fix the scale parameter of the first experiment to one and allow the scale parameters of the other experiment to vary.

In conducting this analysis certain issues had to be faced, the experiments shared certain variables in terms of micro-generation and cost. However, there were also non overlapping variables that only appeared in one experiment. In terms of adopting the same specification as those presented earlier in this chapter for the two experiments it was found that the General Mixed Logit model with which scale is calculated was unable to optimise due to insufficient variability where these non overlapping variables were dummy coded, that is where they were assumed to be non-linear in nature. As such a simplifying assumption was required, allowing for these non overlapping attributes to be coded as continuous variables, i.e. to assume a linear relationship for the attributes: Increase in Levels of Large Scale Renewable Energy and Carbon Reduction Targets. Such attributes as Adaptation and Energy Efficiency were coded as single dummies as such, unlike the previously presented analyses, the following analyses consider the preference for a move away from investment in energy efficiency in private households. Whilst these models are somewhat constrained they allowed the scale parameter to be considered.

6.5.2 Results and Discussion

In the first instance we present the results of the un-pooled models using the specification detailed above, then present the pooled model run using the GMX specification which allows the scale parameter to be identified. Using this scale parameter we can begin to compare the coefficients between the experiments. We then discuss the differences in coefficients identified. We then aim to identify the relaxations of the constrained model (pooled model) by allowing certain variables to vary between the experiments to identify the model which comes closest to the level of fit of the un-pooled models. By introducing additional observations the significance of the shared variables in the model is expected to improve. We relax the constraints on shared attributes in various combinations to test whether the model is improved by applying log-likelihood ratio tests (see

Chapter 2). In order to identify the best fitting models a random parameters specification was adopted, with analysis of scale using the GMX model only conducted for the best fitting models. This methodology was adopted due to the significant processing time required for the GMX analyses.

6.5.2.1 Model Results and Analysis of Scale using a Fully Constrained model.

Firstly we present the results of the un-pooled models adopting the new specifications, the constrained pooled model analysed using both RPL and GMX specifications. By constrained model we mean the model in which all shared variables are held constant across the two treatments.

As can be seen from the table below, including scale in the analysis results in very similar coefficients for different levels of micro-generation suggesting that the price attribute is driving differences in scale.

Table 6.10 – Simple RPL Models, Pooled Constrained RPL Model, GMX model

Variable	RPL Model Exp. 1	RPL Model Exp. 2	RPL Model Pooled	GMX Model Pooled
Random Parameters in Utility Functions				
Increase in Level of Micro-generation *1 out of 2 houses have microgen. installed*	0.804*** (0.18)	0.89*** (0.23)	0.759*** (0.13)	0.235** (0.09)
Increase in Level of Micro-generation *1 out of 10 houses have microgen. installed*	0.742*** (0.13)	0.57** (0.24)	0.651*** (0.11)	0.236** (0.09)
Increase in Level of Micro-generation *1 out of 50 houses have microgen. installed*	0.643** (0.14)	0.30** (0.15)	0.502*** (0.09)	0.221** (0.08)

Non-Random Parameters in Utility Functions				
Adaptation – High	0.174*** (0.07)		0.141** (0.07)	0.116* (0.06)
Increase in Large Scale Renewable Energy	2.459*** (0.45)		2.707*** (0.41)	2.573*** (0.43)
Increase in an Annual Total Cost to a Household	-0.005*** (0.00)	-0.008*** (0.00)	- 0.006*** (0.00)	-0.006*** (0.00)
Improvements in Energy Efficiency in the Private Sector		0.071 (0.07)	0.087 (0.07)	0.083 (0.07)
Carbon Reduction Targets (compared to 2020 level)		1.807*** (0.27)	1.763*** (0.25)	1.568*** (0.25)
Derived Standard Deviations of Parameter Distributions				
Increase in Level of Micro-generation *1 out of 2 houses have micro-generation installed*	1.49*** (0.18)	2.073*** (0.30)	1.585*** (0.15)	1.23** (0.55)
Increase in Level of Micro-generation *1 out of 10 houses have micro-generation installed*	0.89*** (0.16)	1.893*** (0.29)	1.11*** (0.14)	0.233 (1.42)
Increase in Level of Micro-generation *1 out of 50 houses have micro-generation installed*	0.53*** (0.25)	1.195*** (0.26)	0.857*** (0.13)	0.422 (10.01)
R squared	0.08	1.83	0.1	0.1
AIC	2.04	0.17	1.95	1.98
Number of Observations	1416	1552	2968	2968
Log Likelihood Value	-1432.71	-1410.6	-2876.9	-2918.5
Scale Parameter				1.203*** (0.42)

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

Table 6.11 - Impact of Scale on Shared Parameter Estimates

Variable	RPL Model Exp. 1	RPL Model Exp. 2	RPL Model Exp. 2 –Adj. for Scale
Increase in Level of Micro-generation *1 out of 2 houses have microgen. installed*	0.804***	0.89***	0.739***
Increase in Level of Micro-generation *1 out of 10 houses have microgen. installed*	0.7428***	0.57**	0.474**
Increase in Level of Micro-generation *1 out of 50 houses have microgen. installed*	0.643**	0.3**	0.249**
Increase in an Annual Total Cost to a Household	-0.005***	-0.008***	-0.0067***

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

6.5.2.2 Discussion of Coefficients in Model / Scale.

Table 6.10 reports the results of the RPL models both pooled and un-pooled and the calculation of scale. Table 6.11 takes scale into consideration for those attributes which are shared. The results of the analysis are broadly similar to those reported earlier in this chapter (although constraining the non shared attributes to be linear has some impact). As can be seen including the scale parameter in the analysis (dividing the coefficients of experiment 2 by the calculated scale holding the scale equal to one in experiment one) has the impact of making the coefficients for micro-generation in every 10 and every 50 houses further apart. However, it results in the cost parameter becoming more similar between experiments. Thus it is indicative that the cost attribute may be more important in determining scale than the other shared attributes. This is investigated further in the following section.

6.5.2.3 Relaxation of the Constraints

In this section we present the results of relaxing certain constraints for which a series of models were run. Firstly the micro-generation attributes were relaxed (that is allowed to vary between experiments) in turn, then in various combinations. Then we relaxed the cost attribute and then tested relaxation of the cost attribute in combination with those micro-generation attributes we found to most improve the model. The full list of relaxations that were investigated in current analysis is presented below:

- *Relaxed Cost Attribute*
- *Relaxed Micro 1 in 2 attribute*
- *Relaxed Micro 1 in 10 attribute*
- *Relaxed Micro 1 in 50 attribute*
- *Relaxed Micro 1 in 2 and 1 in 10 attributes*
- *Relaxed Micro 1in 2 and Micro 1 in 50 attributes*
- *Relaxed Micro 1 in 2, Micro 1 in 10 and Micro 1 in 50 attributes*
- *Relaxed Micro 1 in 2 and cost attributes*
- *Relaxed Micro 1 in 10 and cost attributes*
- *Relaxed Micro 1 in 50 and cost attributes*
- *Relaxed Micro 1 in 2 and 1 in 10 and cost attributes*
- *Relaxed Micro 1 in 10 and 1 in 50 and cost attributes*
- *Relaxed Micro 1 in 2 and 1 in 50 and cost attributes*

The models found to provide the log likelihood closest to zero all relaxed the cost attribute alone or in combination with some level or relaxation of the micro-generation attributes: taking into account the impact on the degrees of freedom of these relaxation of 'cost' and relaxation of 'cost' and 'micin50' were found to most improve the log likelihood. These models are presented in Table 6.12 below.

Table 6.12 - Parameter estimates for RPL pooled constrained model, RPL pooled model with relaxed cost parameter and RPL pooled model with relaxed Micro 1 in 50 attribute and a Cost parameter.

Variable	RPL Model Pooled (constr.)	RPL Model Pooled (Cost relaxed)	RPL Model Pooled (Cost and Micro 1 in 50 relaxed)
Random Parameters in Utility Functions			
Increase in Level of Micro-generation (*1 out of 2 houses have micro-generation installed)*	0.759*** (0.13)	0.768*** (0.13)	0.774*** (0.14)
Increase in Level of Micro-generation (*1 out of 10 houses have micro-generation installed)*	0.651*** (0.11)	0.709*** (0.11)	0.702*** (0.11)
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed)*	0.502*** (0.09)	0.454*** (0.09)	
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed (relaxed)* – **Experiment 1**)			0.648*** (0.14)
Increase in Level of Micro-generation **(***1 out of 50 houses have micro-generation installed (relaxed)* – **Experiment 2**)			0.333*** (0.12)
Non-Random Parameters in Utility Functions			
Adaptation – High	0.141** (0.07)	0.187*** (0.07)	0.174*** (0.07)
Increase in Large Scale Renewable Energy	2.707*** (0.41)	2.405*** (0.41)	2.475*** (0.41)
Increase in an Annual Total Cost to a Household	-0.006*** (0.00)		

Increase in an Annual Total Cost to a Household (relaxed) – **Exp 1**		-0.004*** (0.00)	-0.005*** (0.00)
Increase in an Annual Total Cost to a Household (relaxed) – **Exp 2**		-0.009*** (0.00)	-0.009*** (0.00)
Improvements in Energy Efficiency in the Private Sector	0.087 (0.07)	0.054 (0.07)	0.069 (0.07)
Carbon Reduction Targets (compared to 2020 level)	1.763*** (0.25)	1.669*** (0.26)	1.719*** (0.07)
Derived Standard Deviations of Parameter Distributions			
Increase in Level of Micro-generation (*1 out of 2 houses have micro-generation installed)*	1.585*** (0.15)	1.663*** (0.36)	1.647*** (0.16)
Increase in Level of Micro-generation (*1 out of 10 houses have micro-generation installed)*	1.11*** (0.14)	1.101*** (0.14)	1.111*** (0.15)
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed)*	0.857*** (0.13)	0.825*** (0.14)	
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed (relaxed)* – **Experiment 1**)			0.651*** (0.19)
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed (relaxed)* – **Experiment 2**)			0.938*** (0.18)
R squared	0.1	0.13	0.13
AIC	1.95	1.93	1.93
Number of Observations	2968	2968	2968
Log Likelihood Value	-2876.9	-2852.2	-2849.7

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

6.5.2.4 Analysis of Log-Likelihood Ratio Test.

As can be seen relaxing both the cost and micro-generation in 1 in 50 households brings the Log-Likelihood closest to zero, and whilst the Log-Likelihood ratio test shows that the value of 4.8 (2 times the difference in Log-likelihood) is greater than the critical value of 3.84 at the 5% significance level it is not greater than the 6.63 at the 1% significance level. As such we have reported both models to demonstrate the importance of the cost attribute to the improvement of fit of the model.

These results indicate that cost seems to be the key driver of difference between the experiments with the relaxation of the cost attribute having the greatest impact upon the level of fit of the pooled model. This implies that respondents' marginal utility of income when facing a set of choices was impacted by the framing of the experiment. That is that there is a smaller cost coefficient associated with Experiment 1 than with Experiment 2. Noting that Experiment 1 looked at direct policy measures (so renewable energy and adaptation in addition to micro-generation) this suggest that this framing lead individuals to place less weight upon the cost attribute relative to the other attributes in the experiment. However, in the second experiment where a more general framing in terms of potential future policy was adopted individuals place more weight upon the cost attribute.

6.5.2.5 Analysis of Scale Adopting Best Fitting Models.

The scale parameter for the model with relaxed 'Cost' and 'Micro 1 in 50' attributes is closer to zero than the cost only relaxed model but the 1 in 50 does not come through as significant. Whilst this is a significant improvement over the 1 in 260 households this result suggests that the 1 in 50 level is not statistically preferred over the 1 in 260 and that perhaps further analysis omitting this variable would be warranted given sufficient time. As can be seen from the Table 6.12 below, the inclusion of this variable has little impact on the scale parameter and the results of this model do not significantly impact on the results discussed above.

Taking the model with cost only relaxed and analysing the scale, the striking difference is the change in the scale parameter by taking variation in costs into account. That is the scale parameter rather than moving the micro-generation variables further apart between experiments moves them closer together (with the exception of Micro 1 in 2). All the standard deviations of the random parameters loose significance suggesting that what heterogeneity there was in the population sampled is taken into account by relaxing the cost attribute and allowing for the scale parameter. Also in the previous analysis of scale the micro-generation coefficients were found to be almost identical between levels as a result of the inclusion of a scale parameter, this was likely due to the relative importance of price to the differences in scale. Now that the price constraints have been relaxed the variation in coefficients and relative weights attached to each attribute return to the expected levels. It would appear from the cost coefficients that the framing of a scenario is important to the price individuals are willingness to pay.

Table 6.12 Parameter estimates for a GMX Pooled Model with Relaxed Cost Parameter and a GMX Pooled Model with Relaxed Cost and Micro 1 in 50 Parameters.

Variable	GMX Model Pooled Cost Relaxed	GMX Model Cost and Micro 1 in 50 Relaxed
Random Parameters in Utility Functions		
Increase in Level of Microgen (*1 out of 2 houses have micro-generation installed)*	0.408*** (0.09)	0.466*** (0.09)
Increase in Level of Microgen (*1 out of 10 houses have micro-generation installed)*	0.377*** (0.1)	0.409*** (0.1)
Increase in Level of Microgen (*1 out of 50 houses have micro-generation installed)*	0.292*** (0.13)	
Increase in Level of Microgen. (*1 out of 50 houses have micro-generation installed (relaxed)* – **Exp. 1**)		0.336* (0.17)
Increase in Level of Microgen. (*1 out of 50 houses have micro-generation installed (relaxed)* – **Exp. 2**)		0.199 (0.12)
Non-Random Parameters in Utility Functions		
Adaptation – High	0.136***	0.155*** (0.04)
Increase in Large Scale Renewable Energy	2.658***	2.803*** (0.39)
Increase in an Annual Total Cost to a Household		
Increase in an Annual Total Cost to a Household (relaxed) – **Exp 1**	-0.005*** (0.00)	-0.005*** (0.00)
Increase in an Annual Total Cost to a Household (relaxed) – **Exp 2**	-0.007*** (0.00)	-0.008*** (0.00)
Improvements in Energy Efficiency in the Private Sector	0.028 (0.06)	-0.01 (0.06)
Carbon Reduction Targets (compared to 2020 level)	1.744*** (0.19)	1.718*** (0.19)

Derived Standard Deviations of Parameter Distributions		
Increase in Level of Micro-generation *1 out of 2 houses have micro-generation installed*	0.152 (0.2)	0.304** (0.13)
Increase in Level of Micro-generation (*1 out of 10 houses have micro-generation installed)*	0.074 (0.56)	0.176 (3.82)
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed)*	0.165 (0.78)	
Increase in Level of Micro-generation *(1 out of 50 houses have micro-generation installed (relaxed)* – **Experiment 1**)		0.436 (0.35)
Increase in Level of Micro-generation (*1 out of 50 houses have micro-generation installed (relaxed)* – **Experiment 2**)		0.269 (2.53)
R squared	0.11	0.11
AIC	1.967	1.969
Number of Observations	2968	2968
Log Likelihood Value	-2901.14	-2899.72
Scale Factor	0.69*** (0.26)	0.64*** (0.25)

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

6.6 Conclusions and Future Research

This chapter aimed to achieve the following goals:

- To analyse public preferences towards different levels of increase in micro-generation in the UK framed alongside other areas of the UK's future energy policy.
- To investigate the issue of reliability over attribute tasks by comparing marginal willingness to pay estimates obtained from two independently run choice experiments each containing "an increase in level of micro-generation" and "increase in annual total household cost" as overlapping attributes.
- To further extend the model and investigate the impact of scale on the estimated parameters.

The results indicate that the public wants to see more micro-generation in the UK and consistently identified it as a priority area in terms of future Government spending on energy related issues. It is reflected by the marginal willingness to pay for this attribute, which was positive and significant for all levels of an increase in micro-generation rising with scale.

As mentioned earlier in this Chapter, the financial incentives to install micro-generation technologies are currently provided by the Government in the form of Feed-in tariffs, costs of which are passed on to the UK consumer via energy bills (REF, 2012). According to REF (2012), DECC has predicted that the Feed-in Tariff will cost electricity consumers £570 million a year in 2020, which will add approximately £22 a year to every household's electricity bill. In addition to that Renewable Heat Incentive financed through taxation and aimed at promoting heat generating micro-generation technologies is estimated to cost the consumer around £860 million in 2014/15 (cap introduced as a result of the Government's Spending Review). Combined with the evidence that whilst only 5% of the sampled respondents have micro-generation installed but 59% (Experiment 1) and 61% (Experiment 2) would like to, this result may imply that additional investment / subsidisation or other policies to promote the uptake of micro-generation may be warranted.

When it comes to comparing the results, it is apparent that no statistical differences in marginal willingness to pay for an increase in level of micro-generation in the UK were found between the two experiments. It is also clear that there is scope for additional research to further investigate some of the issues raised above. Of course our results do not claim 'that we are able to show beyond doubt that theory is right' (or in this case the 'theories' supporting stated preference valuation). However, our results by no means disprove the theories. From the outputs derived it can be seen that a policy maker who uses the results in a cautious and sensible manner to identify a range of values and the relative weights placed upon attributes could be reassured that the results of choice experiments are reliable and robust enough to support such a use. However, those who wish to identify a single value irrespective of the framing used, are likely to under or over represent the importance of an attribute to the public, an issue with every form of stated preference valuation.

Chapter 7 Discussion and Conclusion

The key objective of this dissertation is to produce policy relevant and theoretically sound research in relation to energy and climate change issues in the UK. It aims to provide insights into public perceptions of the key policy areas that can help to bridge the gap between industry, policy makers and the public when it comes to designing successful and effective future energy and climate change policy of the country. A consistent methodological approach, namely Choice Experiment, was employed throughout this dissertation that allowed for greater comparability of the results as well as for robustness and reliability testing of the method itself.

This final chapter begins with a brief summary of the dissertation; section 7.2 follows a chapter by chapter approach to report on key results and policy implications; section 7.4 outlines limitations and opportunities for future research and section 7.5 concludes.

7.1 Summary

The impending closure of almost one fifth of the today's generation capacity combined with growing electricity demand presents the major challenge that is facing policy-makers in the UK in the decade to come. Policy decisions to address these issues will have to be weighed against their ability to meet the strict climate change targets that the UK is committed to. The country will have to reduce its carbon emissions by 34% by 2020 compared to 1990 levels (a legally binding target set out by the Climate Change Act 2008). This implies a combination of low-carbon policies and measures that need to be put in place to ensure secure supply of energy as well as the ability to meet customer's demand. These policies, however, will come at a cost. According to DECC (2011) estimates, the UK's energy sector requires an investment of at least £200 billion to meet decarbonsation targets by 2020. The impact of such changes has already been felt by consumers in the form of rising energy bills and consumer prices. Energy and climate change policies already form a significant proportion of UK domestic energy bills (12% of electricity and 4% of gas bills) (DECC, 2010).

Impacts of changing climate have already being felt across the country. According to the Met Office (2009), temperature across the UK has constantly risen over the last three decades: Central England temperature has risen by about 1 degree Celsius since 1970s and temperatures in Scotland and Northern Ireland have risen by about 0.8 degree Celsius since 1960s; severe windstorms have become more frequent across the country and there has been an increase in winter rainfall from heavy precipitation events over the last 45 years. As discussed above the key future climate change impacts that the UK will potentially be faced with include: sea level rise, droughts, floods, overheating, an increase in extreme weather events and impacts on public health (Metoffice, 2011, UKCIP, 2009). All these changes will have associated economic and social impacts that need to be accounted and planned for. Adapting to climate change therefore is another area that forms a key part of the UK's future energy and climate change policy alongside the actions on mitigation.

Research conducted in this dissertation aimed to understand public preferences towards key policy areas that form UK climate change and energy policy. The UK Government acts "on behalf of people and in the interests of people" (UK Parliament, 2012) and, therefore it is imperative that public preferences lie at the foundation of any policy that is implemented by the Government including climate change and energy policies.

One way of eliciting public preferences is through choice experiments, the method employed in this dissertation. As identified in Chapter 2, Choice experiment was particularly suited to this study as it allowed the investigation of future policy and given its ability to handle a multiple number of attributes and therefore higher levels of uncertainty, a key advantage over alternative stated preference techniques, e.g. Contingent Valuation. Another advantage of applying one consistent approach was to be able to compare and test the reliability of the method itself thus providing a contribution to the theoretical field of stated preference valuation.

The empirical work was carried out in two stages. Chapter 3 is a study of public preferences towards different low-carbon energy generating options in Scotland. Chapters 4, 5 and 6 investigated public preferences across key areas of the future energy and climate change policy of the UK. Policy areas analysed in Chapter 4 contained direct measures for dealing with climate change, whereas attributes analysed in Chapter 5 were more general in terms of identifying the potential focus and aims of future policy. Each of the experiments contained two overlapping attributes: increase in level of micro-generation and an increase in total household cost which are further investigated in chapter 6. The next section reports on the key findings and policy implications of this dissertation.

7.2 Key results and Policy Implications

7.2.1 "Preferences for Energy Futures in Scotland"

This part of the dissertation was concerned with investigation of public preferences towards future low-carbon energy generating options in Scotland. We employed a labelled choice experiment that framed each technology: wind, biomass, nuclear and existing energy mix (status quo) in terms of five attributes. The attributes were: distance from respondent's home, carbon emissions reductions, local biodiversity impacts, land requirements and an annual electricity bill increase. We also investigated heterogeneity in public preferences depending on their geographical location and addressed the presence of non-compensatory behaviour in our sample. To the author's knowledge this is the first choice experiment study that identified public preferences towards low-carbon technologies and included a nuclear option as part of the overall generation mix in Scotland.

Our results confirmed that Scottish public has strong preference towards wind power over the current energy mix. We also found positive and significant public preference towards nuclear energy in Scotland. The policy relevance of this result is backed by the recent decision (4th December, 2012) of EDF Energy to extend the life of Hunterston B nuclear power station until 2023 (previously scheduled to close in 2011). The decision to keep the station open has also been supported by a

Scottish Government that is against any new build nuclear plants in Scotland. One could argue that this is the first step that Scottish Government made to re-examine it's "no nuclear" policy. It is evident that nuclear power is back on the political agenda of the country and as such our results are of relevance to policy makers as they can provide an insight and help to quantify public preferences towards two low-carbon energy generating sources (renewable and nuclear energy), both of which have a potential to form part of Scotland's future generation portfolio.

To investigate regional preferences across Scotland, we split the total sample into three regions: Central, Southern and Highlands and Islands. We found that public preferences vary depending on where they live. More specifically, a sub-sample of respondents that live in Highlands and Islands identified increase in biodiversity as the most important attribute, valuing it more than the distance from the power plant or reduction in carbon emissions. On the other hand, respondents living in the Southern region (which includes Glasgow and Edinburgh, the two most populated cities in Scotland) identified distance and reduction in carbon emissions as the most important to them. Although somewhat lacking statistical significance due to small sample size, nonetheless, the results are of direct relevance to Scottish energy policy, especially when it comes to planning and locating future power generating plants.

Another important finding of this section concerns the presence of non-compensatory behaviour in our sample. We found that a substantial proportion of our sample consistently chose one energy option over the others. Although not consistent with random utility theory, such non-compensating behaviour can also be a fully rational process as was shown by such authors as Payne et al. 1993, Kahnemann et al., 2002, Arana, 2009). If significant, however, such behaviour may affect the way the results are interpreted and cause biased estimates. Although in our case we found little impact on the overall results, the underlying reasons for such behaviour need to be further investigated and understood.

7.2.2 "Public Preferences towards Adaptation to and Mitigation of Climate Change in the UK"

The key objective of this chapter was to investigate public opinions and WTP for priority placed on adaptation measures framed alongside such energy policy areas as increase in large scale renewable energy, increase in level of micro-generation and increase in total household cost. We aimed to identify public trade-offs in prioritising mitigation and adaptation measures as part of the Government's overall energy and climate change spending.

The results show the existence of positive utility derived by the public towards increase in levels of renewable technologies both on a macro and micro scale. These findings are consistent with previous studies that incorporated renewable energy as one of the attributes of the overall policy (e.g. Longo et al. (2008) and Greenberg (2009). Although difference in overall willingness to pay between the levels wasn't statistically significant due to overlapping confidence intervals, the average willingness to pay for renewable and micro generation does go up as the levels increase. Another key finding that is of a particular policy relevance is the similarity in public willingness to pay for large scale renewable energy and micro-generation, which suggests that when it comes to a trade-off between generation of renewable energy on a large or a micro scale, the public wants to see both but are relatively indifferent between them. In particular this indicates that the measures introduced as part of the UK Energy Bill 2012 to encourage investment in renewable energy are likely to be popular with the general public and that further investment in terms of support for adoption of micro-generation may be warranted.

We also show that the public wants to see an increased priority placed on adaptation measures in the Government's overall energy and climate change spending. We find that willingness to pay of an average respondent whose house has already been affected by climate change is twice as high as that of an average respondent whose house isn't (£110.5 per year versus £54.9 per year). Results of the latent class modelling revealed existence of two distinct classes within the sample, that were split in terms of positive and negative preferences towards increased priority placed on adaptation measures. At the same time both classes of respondents displayed positive and significant preferences towards increase in levels of large scale renewable energy and micro-generation.

With recent flooding and the failure of defences across the country, whether the floods of November 2012 are identified to be a result of climate change or not, it is clear that further adaptation to the possible impacts of climate change may reach the top of the policy agenda in the near future. It also suggests that additional effort to protect people and property from future impacts of climate change is justified. As was mentioned earlier in this thesis, no studies to date were found in the literature that attempted to estimate public preferences towards adaptation measures as part of an overall climate change and energy policy of the UK. No estimates of the impacts of adaptation measures on consumer bills were found either. Therefore it is hoped that this study could provide a starting point in understanding public preferences towards policies of adaptation to climate change.

7.2.3 "Carbon Reduction Targets and Improvements in Energy Efficiency from the UK Publics' Perspective"

This Chapter aimed to reveal public preferences for levels of carbon reduction targets and to identify which sectors of the economy according to the public need support of the Government in terms of energy efficiency improvements.

We show that the respondents in our sample in general support the provision of energy efficiency improvements, although income may impact upon this result. We find negative and significant relationship between income of the respondents and their willingness to support Government's spending on energy efficiency in the private sector. The public's willingness to support Government spending in other sectors of the economy was negative compared to the private sector with the industrial sector being least preferred.

Policy relevance of these results has been demonstrated by the recently published consultation of the UK Government (DECC, 2012) that seeks to introduce a range of financial measures aimed to encourage businesses and industry to be more energy efficient. It is apparent that public is not as willing to support Government subsidies in other sectors of the economy and if such measures are to be introduced, Government needs to ensure that they are introduced at a minimal or no cost to the consumer.

Another area covered in this Chapter is public preference towards various levels of carbon reduction targets for 2020. Perhaps one of the most interesting results is that public support significant levels of carbon reduction targets, but that there seems to be a tipping point beyond which their willingness to pay decreases. The public prefer all alternatives which set targets beyond the 20%, legally binding commitment set by the EU. Their willingness to pay for the increase in targets, however, does not follow a linear pattern and goes down at some point after 40%. More specifically, respondents are willing to pay £76.90 per year for carbon reduction targets set at 40% and £35.50 and £59.90 per year for 30% and 50% accordingly. Due to overlapping confidence intervals it can not be claimed that these values vary significantly from each other, however, the results indicate that the levels set by the UK of 34% and Scotland of 42% reduction in carbon emissions by 2020 lie in the optimal region. As one of the headline pledges within the manifesto's of political parties this result may suggest that the public may hold similar negative views to those recently displayed in the media regarding the choice of the current UK government to delay a decision upon targets for 2030 until 2016 after the next election.

7.2.4 “Willingness to Pay for Micro-Generation in the UK. Evidence from Two Comparative Discrete Choice Experiments.”

The dominant focus of this chapter was to analyse public preferences towards the scale of micro-generation development in the UK. It also compared results of two choice experiments previously reported in Chapters 4 and 5, both of which contained increase in levels of micro-generation as an overlapping attribute.
We find that majority of the sampled respondents would like to generate their own energy, but only 5% of them have some type of micro-generation already installed in their homes. Amongst the technologies they would install, the majority of both samples named solar PV as the preferred technology followed by solar thermal (solar hot water). Biomass boilers and micro-wind were the least preferred technologies. These findings are consistent with those of Scarpa and Willis (2010) who also showed higher preference of their sample towards solar technologies.

Overall we find strong preference amongst the population towards an increase in scale of micro-generation in the UK. Although the context in which this policy area was framed did affect the magnitude of the WTP values, the difference between them was not statistically significant hence supporting reliability of the results and the use of choice experiments as a methodology.

In addition in this chapter we conducted an analysis of scale and the framing of the experiment. It was shown that cost was the most significant factor in determining differences in scale between the two treatments of micro-generation preference in the UK. This result suggests that the policy framing of a choice task can have significant impact upon the marginal utility of income of individuals whilst participating in choice experiments. In particular it was shown that a firmer framing in specific adaptations to current policy lead people to consider the attributes to a higher degree relative to the cost attribute than when framed against possible future policy scenarios. It should be noted that individuals were being faced with hypothetical scenarios and no actual payment was made which may in part explain this variation of marginal utility of income.

The framing of policy scenarios has previously been shown to impact upon stated preference analysis Kemp and Maxwell (1993) showed this finding a value of $85 when valuing treatment of oil spills of the coast of Alaska alone but a value of only 29 cents when considered in combination with other public goods. It would appear from the results presented, that Choice Experiments may not be immune to this framing impact, however, that is not to say that respondents were not behaving rationally but rather the anticipation of the overall impact of a policy framing and the rational expectation of the scale of positive outcomes across the entire policy scenario may impact on the level of payment likely to be selected in individual choices.

7.3 Policy Relevance of Carried out Research

In summary, as this research has come to the end, its policy relevance has been demonstrated by the several major announcements and changes to energy policy of the UK:

- On the 29th November 2012 the Coalition Government announced that it will postpone setting further carbon reduction targets for 2030 until 2016 (Energy Bill 2012).

- It also increased the level of low-carbon spend allowed by the Levy Control Framework (LCF) for 2020/21 from £2.35 billion to £7.6 billion in real terms (Energy Bill 2012), essentially tripling the amount that can be passed on to a consumer by energy companies.

- Alongside the Energy Bill 2012, the UK Government launched a consultation on electricity demand reduction across all sectors of the economy (DECC, 2012). It seeks to introduce a range of financial measures aimed to encourage businesses and industry to improve energy efficiency.

- The Green Deal was officially launched on the 1st October 2012, but as of the 16th of November 2012, according to Greg Barker the Climate Change Minister, "no assessments have yet been lodged on the Governments official register by homeowners", or in other words nobody has applied for it yet.

- On the 4th December EDF Energy announced that it will extend operation of one of the two remaining nuclear power stations in Scotland, Hunterston B until 2023 (EDF Energy Press release, 2012). The decision to keep the station in operation has also been backed by the Scottish Government.

It is clear that energy and climate policy in the UK is in transition and as such, this dissertation provides some of the first pieces of research aimed at identifying optimal future policy from the perspective of the public rather than merely trying to identify public preference for existing policy.

7.5 Future research and limitations

The following section highlights some limitations experienced in the process of this work and discusses potential extensions to the research.

7.5.1 Limitations

Perhaps the main limitation of this work was the limited budget which constrained the selection of the method of distribution and limited our sample to 1000 households in each experiment. Had the budget allowed, the sample size would ideally have been much higher.

Postal distribution of surveys was again selected as the best available alternative subject to our budget constraint. Although this method avoids presence of such biases as "interviewer" bias[31] or an "internet" sampling bias[32], it is also subject to a self-selection and non-response biases that we have to allow for. Comparing socio-demographic characteristics of our samples to the general population, we found that generally all of our samples were a good representation of the overall population, although some areas, such as for example gender for the Experiment described in Chapter 4 and age for the Experiment described in Chapter 5 were slightly misrepresented. In terms of self-selection bias, given that the policy framing of our choice experiments in Chapters 4 and 5 didn't allow for inclusion of

[31] "Interviewer" bias is where an interviewer can influence the responses or level of participation in an interview.

[32] Access to internet and computer is not available to every household, and therefore creates a potential sampling bias which is especially significant when it comes to the surveys that cover the population in general (Kaplowitz et al. 2004, Olsen, 2009).

status quo alternative, there may have been an under representation of those who didn't agree with any of the alternatives offered in the choice sets.

There are various opinions regarding the inclusion of a status quo or no purchase alternative in choice experiments. General consensus in the field of non-market valuation is that where practical a status quo should be included (e.g. Louviere (2010), Hanley (2001), Bateman (2002)). However, as Louviere points out "of course, some contexts may not have a status quo option equivalent to no purchase". This may be considered to be particularly true in terms of future policy in particular for issues such as climate change where costs will be passed on to consumers no matter what approach is adopted to deal with arising issues. It was considered in the case of this research that policy relevance was the most important element, and inclusion of the status quo option would have been unrealistic.

As such it is accepted that without further investigation of the forced choice the results of this research should be used to compare between relative preferences for attributes rather than to identify absolute values. Given the above it is essential to note at this stage that the aim of the choice experiments in Chapters 4 and 5 was not to compare public willingness to pay for the Government policy but to merely identify trade-offs and the priority that public places on the separate attributes.

7.5.2 Future Research

One interesting extension to this dissertation would be to investigate the impact of information about the total costs associated with climate and energy policies on resulting willingness to pay. A split sample approach could be employed where half of the respondents were presented with the information about breakdown categories of their bills and half weren't to test if this information impacts on stated WTP.

In terms of outputs it would be of an interest both from the empirical and theoretical perspectives to test if the WTP amounts derived from the choice experiment are considered appropriate by the individuals who responded to the experiments. Theoretically this could also be done with a different sample as long as it is representative of the same overall population.

Complexity of the policy areas to be investigated in answering the thesis of this dissertation was accounted for by splitting the attributes into two overlapping choice experiments. This presented many advantages such as ability to compare between the results and to test reliability of the estimates. One alternative method of accounting for a large number of attributes is the blocking approach undertaken by Willis and Scarpa (2005), when the attributes are split into several blocks with an overlapping cost attribute. Adopting this approach in combination with the approach of the current research could provide further comparison and reliability testing between the estimates.

As mentioned earlier in this Chapter, the Scottish Government has recently supported the life extension of the nuclear power station Hunterston B, previously scheduled to close in 2011 and later extended to 2016. The new closure date is 2023. The results of the first choice experiment carried out in this dissertation showed that Scottish public generally supports nuclear power in Scotland despite the "no nuclear" policy of the Scottish Government. This, however, implied new build nuclear power plants and not extending the life of old ones. Therefore it would be interesting to further investigate if there is any divergence in public preferences depending on the source of nuclear power and if that affects their relative preference towards alternative technologies.

Another recent development in the UK energy sector is the emergence of a relatively low cost energy source, shale gas. According to the IoD's (2012) assessment of shale gas potential in the UK, alongside lower energy prices and energy security benefits, shale gas may play some role in achieving carbon reduction targets of the UK and could save up to 45 million tonnes of CO2, 8% of the UK's annual carbon emissions by replacing existing coal generation. In addition shale gas can also provide much needed generation backup for expanding renewable energy at times when most needed. The UK Government views shale gas as a key element in the overall UK's decarbonisation policy. Public preferences towards this source, however, are yet to be understood and represent the scope for future research.

7.5.3 Key Outputs

This research produced a number of policy relevant outputs with results being either published or being prepared for submission to selected journals:

- E. Tinch, Nick Hanley, Preferences for Energy Futures in Scotland, Special Edition of Fraser Allander Economic Commentary on Energy and Pollution, Jan. 2011;
- Public Preferences towards Adaptation to and Mitigation of Climate Change in the UK – *being prepared for submission*;
- Carbon Reduction Targets from the UK Publics' Perspective – *being prepared for submission;*
- Willingness to Pay for Micro-Generation in the UK: Evidence from Two Comparative Discrete Choice Experiments – *being prepared for submission.*

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APPENDIX 1

UNIVERSITY OF STIRLING

Imperial College London

QUESTIONNAIRE SURVEY

What is this survey about…

This survey is part of a PhD research project conducted jointly by the University of Stirling and Imperial College London.

This survey was originally carried out in England. We, however, feel that people in Scotland may have different attitudes towards future UK policies regarding placement and types of energy generating options. Your opinion is therefore very important to us and we appreciate your time spent completing this questionnaire.

What we ask you to do….

Please take a few minutes to complete this survey. There are no "right" or "wrong" answers. We are very interested in your views.

Any information you provide will be kept strictly confidential.

To return the questionnaire…

Please return the completed questionnaire using the stamped return envelope ***by the 1st June 2008***.

Prize draw...

If you would like to be entered into the prize draw to win £100, please enter your details on the last page of the questionnaire.

If you have any questions, please contact…

Elena Tinch;
Economics Department, University of Stirling
Stirling, FK9 4LA, Scotland
Tel: 01786 467482; E-mail: Elena.Tinch@stir.ac.uk

Thank you very much for helping us with our survey!

A. ENERGY & THE ENVIRONMENT

Q1. Which of the following low-carbon energy sources have you heard of? (Low-carbon energy sources have much lower CO_2 (carbon dioxide) emissions than traditional electricity sources like coal and gas.)

PLEASE TICK ALL THAT APPLY

☐ Wind	☐ Biomass	☐ Solar	☐ Wave	☐ Tidal
☐ Geothermal	☐ Hydro	☐ Nuclear	☐ Micro-Generation	☐ None

Q2. How much do you know about the following energy sources?

PLEASE TICK AS APPROPRIATE

	No knowledge at all				A lot of knowledge
	1	2	3	4	5
Wind Power	☐	☐	☐	☐	☐
Biomass	☐	☐	☐	☐	☐
Nuclear Power	☐	☐	☐	☐	☐

Q3. How would you describe the information about these different energy sources, from sources like TV or the newspapers, that you have come across so far:

PLEASE TICK AS APPROPRIATE

	Negative (i.e. mostly bad news)		Neutral (neither good nor bad)		Positive (i.e. mostly good news)
	1	2	3	4	5
Wind Power	☐	☐	☐	☐	☐
Biomass	☐	☐	☐	☐	☐
Nuclear Power	☐	☐	☐	☐	☐

Q4. Using the scale below please indicate what you think about the following statements.

For example if you "Strongly agree" with the sentence, put number "5" next to it. If you "Strongly Disagree" put number "1" next to it.

1	2	3	4	5
Strongly disagree	**Disagree**	**Unsure**	**Agree**	**Strongly agree**

PLEASE INSERT THE NUMBER THAT DESCRIBES BEST YOUR FEELINGS

Statements	Number
Solving environmental problems should be one of the top 3 priorities for public spending in the UK.	
Environmental problems, such as climate change and air pollution have been exaggerated.	
Developed (industrialized) countries are the main contributors to global warming.	
The UK should invest more in renewable energy sources as a way to tackle climate change.	
The UK should invest more in nuclear power stations as a way to tackle climate change.	
Climate change is a global problem that needs to be addressed internationally by all countries.	
We all have to substantially change our behaviour in order to help tackle climate change.	

➡ **NOW GO TO SECTION B**

B. ENERGY OPTIONS

In view of the environmental challenges caused by climate change, the UK government has recognised that the UK should try to reduce its CO2 (carbon dioxide) emissions by 2020. One way to work towards this reduction (**along with other measures**) would be **to generate 20% of total UK electricity from low-carbon energy sources by 2020.**

In this part of the survey you are presented with **four options capable of generating 20% of total UK electricity by 2020** (the other 80% will be generated using the current energy mix).

Option 1 uses **On-shore Wind Power (on land)**;
Option 2 uses **Biomass**;
Option 3 uses **Nuclear Power**;
Option 4 uses the **Current Energy Mix** which relies mainly on coal and natural gas and to a lesser extent on nuclear power and renewable sources.

Below you can find a short description of the energy options:

Description of Energy Options

Wind turbines capture the wind's energy with two or three propeller-like blades, which are mounted on a rotor, to generate electricity. The turbines sit high atop towers, taking advantage of the stronger and less turbulent wind. Currently most of the UK's wind farms are located on-shore (on-land) with off-shore (sea) being more expensive and therefore less common.

Biomass is derived from agricultural and forestry residues; energy crops; landfill gas and biodegradable components of waste. One of the common ways to produce electricity from biomass is mix it with fossil fuels, such as coal.

Nuclear power is the controlled use of nuclear reactions to release energy, including the generation of electricity. Nuclear energy is produced by a controlled nuclear chain reaction and creates heat—which is used to boil water, produce steam, and drive a steam turbine. The turbine can be used to generate electricity.

We would like to find out which options you prefer for generating 20% of total electricity in the UK by 2020 using the choice cards that follow.

- Each choice card includes all four energy options (wind, biomass, nuclear, current energy mix). We would like you to choose the ONE option that you prefer the most in EACH CHOICE CARD

- **Each energy option is described in terms of FIVE characteristics**:

1) **Distance** from your home to newly built energy generation sites (e.g. wind farm, biomass plant, nuclear power station etc.)
2) **Local biodiversity:** impacts on local number of species of birds, mammals, insects or plants.
3) **CO2 (Carbon) emissions from electricity generation**: Choosing different options for future energy generation can produce a range of reductions in emissions. ***This relates only to 20% of the UK's electricity generation.*** *Overall reduction in CO2 will require other measures*.
4) **Total land** occupied by the energy option all over the UK ***in order to produce 20% of total UK's electricity***. For example, making considerable use of biomass could mean the UK devoting a lot of its land area to growing plants for energy production.
5) **Annual increase in household electricity bill**: your electricity bill will increase per year by the amount stated in each option.

Here is an example of a completed choice card. After considering all the options and their characteristics, the person has decided that they prefer Option 2 (Biomass) for future electricity production. Therefore they have ticked this option.

Now, look through the next 5 choice cards, and think about which option you would prefer in each case. Put a tick underneath that preferred option.

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	☐	☑	☐	☐

Below you can find example pictures of a **typical** wind farm, biomass plant, nuclear power station and coal power station:

On-shore Wind farm

Biomass plant & Energy crop

Nuclear power station

Coal power station

A removable card presenting the characteristics in detail and the above photos is attached to the survey.

A few things to consider when completing the choice cards:

- Please consider **<u>each choice card separately</u>**.
- **<u>All choice cards are different</u>**. This means that the impacts for each energy option will change from one choice card to another, representing different technological possibilities.
- Choosing an option will **<u>cost money to your household</u>** since your annual electricity bill will increase. Therefore, please **<u>consider your household budget</u>** and remember that **<u>there may be other things that you would like to spend your money on</u>**.

Thank you very much for your help with our survey!

Please look at the energy options in Card 1 below and choose the ONE option that you prefer the most

Card 1				
Characteristics	**Option 1** Electricity from **WIND**	**Option 2** Electricity from **BIOMASS**	**Option 3** Electricity from **NUCLEAR**	**Option 4** **Current Energy Mix**
Distance from Home	10 miles *[16km]*	6 miles *[10km]*	0.25 miles *[400m]*	18 miles *[29km]*
Local Biodiversity	No change	Less	No change	Less
Carbon Emissions for producing 20% of UK electricity	Reduction by 97%	Reduction by 90%	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	**£67**	**£143**	**£20**	**£0**
Please tick your preferred option	☐	☐	☐	☐

Please look at the energy options in Card 2 below and choose the ONE option that you prefer the most.

Card 2				
Characteristics	**Option 1** **Electricity from WIND**	**Option 2** **Electricity from BIOMASS**	**Option 3** **Electricity from NUCLEAR**	**Option 4** **Current Energy Mix**
Distance from Home	1 mile *[1.6km]*	6 miles *[10km]*	10 miles *[16km]*	18 miles *[29km]*
Local Biodiversity	No change	More	Less	Less
Carbon Emissions for producing 20% of UK electricity	Reduction by 99%	Reduction by 50%	Reduction by 99%	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	**£40**	**£90**	**£67**	**£0**
Please tick your preferred option	☐	☐	☐	☐

Please look at the energy options in Card 3 below and choose the ONE option that you prefer the most.

Card 3				
Characteristics	**Option 1** Electricity from **WIND**	**Option 2** Electricity from **BIOMASS**	**Option 3** Electricity from **NUCLEAR**	**Option 4** **Current Energy Mix**
Distance from Home	10 miles *[16km]*	1 mile *[1.6km]*	6 miles *[10km]*	18 miles *[29km]*
Local Biodiversity	No change	Less	Less	Less
Carbon Emissions for producing 20% of UK electricity	Reduction by 97%	Reduction by 50%	Reduction by 99%	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**	**£67**	**£67**	**£0**
Please tick your preferred option	☐	☐	☐	☐

Please look at the energy options in Card 4 below and choose the ONE option that you prefer the most.

Card 4				
Characteristics	**Option 1** Electricity from **WIND**	**Option 2** Electricity from **BIOMASS**	**Option 3** Electricity from **NUCLEAR**	**Option 4** **Current Energy Mix**
Distance from Home	0.25 miles *[400m]*	6 miles *[10km]*	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 90%	Reduction by 99%	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	**£40**	**£20**	**£40**	**£0**
Please tick your preferred option	☐	☐	☐	☐

Please look at the energy options in Card 5 below and choose the ONE option that you prefer the most.

Card 5				
Characteristics	**Option 1** Electricity from **WIND**	**Option 2** Electricity from **BIOMASS**	**Option 3** Electricity from **NUCLEAR**	**Option 4** **Current Energy Mix**
Distance from Home	10 miles *[16km]*	1 mile *[1.6km]*	6 miles *[10km]*	18 miles *[29km]*
Local Biodiversity	No change	More	Less	Less
Carbon Emissions for producing 20% of UK electricity	Reduction by 99%	Reduction by 90%	Reduction by 99%	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	**£90**	**£67**	**£20**	**£0**
Please tick your preferred option	☐	☐	☐	☐

Q5. Which of the characteristics did you think was most important to you in making your choices?

PLEASE TICK ALL THAT APPLY

☐ Technology / Label	☐ Distance	☐ Local Biodiversity	☐ All Characteristics
☐ Total Land	☐ Carbon Emissions	☐ Cost	

Q6. When looking at the characteristic ‘Distance’, did you consider:

PLEASE TICK ALL THAT APPLY

The visual effect of the energy option	☐
The possible health effects of the energy option, such as chronic illnesses	☐
The possible safety issues with the energy option, such as a possible incident	☐
Other issues *(Please specify)*: ………………………………………………………………………………..	☐

Q7. If you chose Option 4 ‘Current Energy Mix’ 3 or more times, why was this the case?

Q8. If you always chose a specific energy option (e.g. Wind power) in all choice cards, why was this the case?

Q9. There is also the possibility that wind farms are located off-shore (at sea) instead of on land. They would therefore not occupy land and be less visible, but this option would also be more costly to develop.

Using the scale below please indicate how far you disagree or agree with the following statements.

1	2	3	4	5
Strongly disagree	**Disagree**	**Unsure**	**Agree**	**Strongly agree**

PLEASE INSERT THE NUMBER AS APPORPRIATE

Statements	Number
I am indifferent between on-shore and off-shore wind farms.	
In general, I would prefer the cheapest option for me.	
I would prefer off-shore wind farms as long as it does not cost me more.	
I would be prepared to pay more to have off-shore wind farms	
In general, on-shore wind farms do not affect me.	
I dislike wind farms whether on-shore or off-shore.	

Q10. Have you ever seen or lived near one of the following?

PLEASE TICK ALL THAT APPLY

	I have seen	I have lived near
On-shore wind farm (on land)	☐	☐
Off-shore wind farm (at sea)	☐	☐
Biomass power station	☐	☐
Nuclear power station	☐	☐
Coal power station	☐	☐
Gas power station	☐	☐
None	☐	☐

Q11. If you were given an option of installing a micro-generation technology (e.g. a small-windmill or solar panels) in your house/community – would you prefer it to large scale energy options?

PLEASE TICK AS APPROPRIATE:

☐ **YES** ☐ **NO** ☐ **NOT SURE**

Q12. Would you be prepared to pay more for micro-generation?

PLEASE TICK AS APPROPRIATE:

☐ **YES** ☐ **NO** ☐ **NOT SURE**

Q13. In the future we will be conducting a separate survey looking at public opinions towards micro-generation. Would you be interested in taking part?

PLEASE TICK AS APPROPRIATE:

☐ **YES** ☐ **NO**

➡ **NOW GO TO SECTION C**

C. RESPONDENT/HOUSEHOLD PROFILE

Please spend a few minutes completing this section. This section is <u>important</u> for our research; it will help us understand the profile of the respondents to our survey. The information provided will be used for <u>statistical purposes</u> only and will remain <u>strictly confidential</u>.

1. Are you:

☐ Male ☐ Female

2. What is your age?

☐ Under 20 years	☐ 20–29 years	☐ 30–39 years	☐ 40–49 years
☐ 50–59 years	☐ 60–69 years	☐ 70–75 years	☐ Over 75 years

3. What is your highest educational level or qualification?

PLEASE TICK AS APPROPRIATE

Primary education	☐
O level/GCSE/GCE or equivalent	☐
A level/HNC/HND/BTEC or equivalent	☐
College/University degree	☐
Higher degree (Diploma, Master's, Doctorate)	☐
Professional qualification	☐
Other: *(Please specify)*:..	☐

4. Which of the following describes best your current work status?

PLEASE TICK AS APPROPRIATE

Self-employed	☐
Employed full-time (>30hrs/week)	☐
Employed part-time (<30hrs/week)	☐
Looking after home full-time	☐
Unemployed	☐
Student	☐
Retired	☐
Unable to work	☐

5. How many children under the age of 16 live in your household?

Please insert your answer _______________.

6. Which of the following describes best your total annual household income <u>before tax</u>?

PLEASE TICK AS APPROPRIATE

£0 – 14,999	☐
£15,000 – 19,999	☐
£20,000 – 29,999	☐
£30,000 – 39,999	☐
£40,000 – 49,999	☐
£50,000 – 59,999	☐
£60,000 – 79,999	☐
£80,000 – 99,999	☐
£100,000 or more	☐

7. Do any of the following apply to you?

PLEASE TICK ALL THAT APPLY

You are member of an environmental or conservation organization (e.g. Greenpeace, WWF, Friends of the Earth, RSPB).	☐
You have made a donation to an environmental or conservation organization.	☐
None of the above	☐

This information is for <u>statistical purposes</u> only and will be kept <u>strictly confidential</u>.

This is the end of the survey!

Thank you very much for your time!

If you wish to be entered in a prize draw, please fill in your details in a detachable sheet overleaf.

If you wish to be entered into the prize draw to win £100 (see front page) please provide your contact details below:

……………………………………………………………………………………………

……………………………………………………………………………………………

<u>TO RETURN THE COMPLETED QUESTIONNAIRE:</u>

PLEASE RETURN THE COMPLETED QUESTIONNAIRE USING THE STAMPED RETURN ENVELOPE BY

<u>1st JUNE 2008</u>

It would be a great help if you could return the questionnaire as soon as possible!

If you would like to add any further comments please use the space below:

APPENDIX 2

UNIVERSITY OF STIRLING

Survey of Public Preferences Towards Future Energy Policy of the UK

What is the survey about:
This survey is being conducted by the University of Stirling Economics Division. Our research is aimed at identifying public attitudes towards future energy policy in the UK. By doing so we aim to investigate public awareness of current energy issues and identify areas that people in the UK value most and want to see as part of their energy future.

What we ask you to do:
You will be presented with a set of questions and a set of 8 choice cards, each of which will contain three possible scenarios. We ask you to consider all the attributes associated with each of these scenarios and choose the option that you prefer most.

The survey should take no longer than 10-15 minutes to complete. Please try and answer as many questions as you can and remember that each opinion can make a difference.

ALL ANSWERS WILL BE KEPT STRICTLY CONFIDENTIAL and NO information will be passed on to any third party.

How you were chosen:
You were chosen randomly as part of the representative sample of 2000 individuals across the UK.

To return the questionnaire:
Please return the completed questionnaire in the attached postage paid envelope. Alternatively just post it to:

Elena Tinch, Economics Department, University of Stirling, Stirling, FK9 4LA

Contact:

If you have any questions regarding the survey, have feedback or just want to find out more about our research, please write, call or e-mail to:

Contact: Elena Tinch
Address: Economics Department, University of Stirling, Stirling, FK9 4LA
Telephone: 01786 466408; Mobile: 07793600891; E-mail: Elena.Tinch@stir.ac.uk

THANK YOU AND HOPE YOU ENJOY THE SURVEY!

Background to the Research:

Future Government energy policy in the UK is at a crossroads. Climate change is an issue that is globally recognized and tackling it has become a vital challenge for most countries worldwide.

As part of its effort the UK is committed to reducing its carbon emissions by 34% by 2020 (compared to 1990 levels). There are various ways of achieving this: by increasing the fleet of renewable generation (building more large scale on-shore and offshore wind farms, investing in tidal and wave energy etc.); another way is by improving insulation of buildings; alternatively it might be achieved by decentralization of energy generation (i.e. micro-generation – where energy is generated in people's homes or via community schemes).

An alternative way of coping with climate change is adapting to it. For example by building flood defences and reinforcing homes, we can try and ensure that any impacts of climate change can be accounted for.

Each of these solutions will have a cost associated with it and our aim is identify what areas the public believe should be prioritized when it comes to planning future energy budget.

The key questions we are trying to address are:

- Are the carbon reduction targets set at a reasonable level?

- Should the Government not only think about trying to reduce carbon emissions but also focus on adapting to climate change?

- Is large-scale renewable generation the main answer to reducing carbon emissions or would the public prefer to see an increased share of micro-generation technologies in the UK's generating portfolio?

Whatever solution the Government will come up with, it is the public who will end up paying for it. It is therefore important that public opinion and preferences should be taken into account when designing any future energy policy and we hope that our research will help in doing so.

Part 1: General public attitudes.

In this part you will be presented with a set of questions aimed at finding out general public attitudes towards climate change, renewable generation and UK's energy policy. Please answer as many questions as you can. All you need to do is to tick the answer depending whether you agree, are unsure of or disagree with the statement. Please remember that there are no right or wrong answers and that each opinion is equally important.

Section 1.1: Attitudes towards climate change

1. **Climate change is a global problem that needs to be addressed by everyone.** (*Please tick your answer)*

   ☐ Agree ☐ Unsure ☐ Disagree

2. **The issue of climate change is exaggerated and doesn't need as much attention as it currently has been given.** (*Please tick your answer)*

   ☐ Agree ☐ Unsure ☐ Disagree

3. **I believe that rather than trying to prevent climate change, we should learn to adapt to it (for example by building flood defences, reinforcing buildings, insulating homes etc.).** (*Please tick your answer)*

   ☐ Agree ☐ Unsure ☐ Disagree

Section 1.2: Attitudes Towards Existing Energy Policy of the UK

4. **I believe that energy should be in the top three priority areas in the Government's budget.** (*Please tick your answer)*

   ☐ Agree ☐ Unsure ☐ Disagree

5. **I believe that the right level of reduction in carbon emissions (compared to 1990) is:** (*Please tick your answer).*

   ☐ 20% reduction by 2020 - *Legally binding target set by the European Union.*
   ☐ 34% reduction by 2020 - *Target set by the UK Government.*
   ☐ 42% reduction by 2020 - *Target set by the Scottish Government*.
   ☐ Other (please specify): ___________________________________

Section 1.3: Attitudes Towards Renewable Energy and Microgeneration

6. **I would like to be able to generate my own energy.** (*Please tick your answer).*

   ☐ Agree ☐ Unsure ☐ Disagree

7. **If I was going to generate my own energy, the technologies that I would install would be** *(Please tick all that apply)*:

   ☐ Solar panels ☐ Wind turbine ☐ Solar hot water ☐ Ground source heat pump

   ☐ Biomass boiler ☐ Other (please specify): ______________________________

8. **I was aware that Feed-in Tariffs were introduced by the Government on the 1st April 2010.** (*Please tick your answer).*

   ☐ Agree ☐ Unsure ☐ Disagree

9. **I don't mind where my energy comes from as long as its cheaper.** (*Please tick your answer).*

   ☐ Agree ☐ Unsure ☐ Disagree

Part 2: CHOICE CARDS / Explanation of Attributes

In this part you will be presented with a set of eight choice cards. Each of the choice cards will contain three possible scenarios. Each of these scenarios will contain a mixture of different levels of attributes (adaptation to climate change, level of large scale renewable generation, level of micro-generation and annual cost to a household).

The next two pages provide more information about each of the attributes.

Attribute 1

Spending on Adaptation to Climate Change

(flood defences, building reinforcements etc.)

Adapting to climate change means preparing for changes in climate by building flood defences in areas with a higher potential risk of flooding, reinforcing homes where required, improving buildings insulation etc.

Each scenario in a choice card will contain one of 2 possible levels:

High – adaptation measures, such as building flood defences, reinforcing homes and improving insulation, are given much greater priority and attention compared to current levels.

Low – adaptation measures, such as building flood defences, reinforcing homes and improving insulation, are given no or very little attention.

Attribute 2

Increase in Large Scale Renewable Energy

(onshore and offshore wind, tidal etc.)

The UK Government has made a commitment to generate 20% of its energy from renewable sources in line with the EU's renewable targets.

In the UK the most common way of generating renewable energy is from wind (on-shore and off-shore wind farms). Hydro schemes are relatively common as well. There are also other methods of renewable energy generation such as wave and tidal, biomass and solar.

Below are the pictures of the most commonly used renewable technologies:

Off-shore windfarm

Onshore windfarm

Hydroelectric plant

Wave energy

Tidal energy

Biomass plant

To give you an idea of scale, the UK currently generates 6.7% of its energy from renewables mostly from wind and hydro.

Each scenario in a choice card will contain one of 4 levels of large-scale renewable generation:

Large - 40% of total UK's energy generated form large-scale renewable sources.

Medium - 20% of total UK's energy generated form large-scale renewable sources.

Slight - 10% of total UK's energy generated from large-scale renewable sources.

No change - 6.7% of total UK's energy generated from large-scale renewable sources.

Attribute 3
Increase in Level of Micro-generation

Micro-generation is a way of generating clean energy on a small scale where it is needed.

Below are the examples of types of micro-generation technologies that you might expect to see:

Solar panel

Wind turbine

Solar hot water

Micro-hydro

Ground source heat pump

In the UK there are currently approx. 100,000 micro-generation units installed out of potential millions. To give you an idea – this roughly means that only 1 out of 260 households has some type of micro-generation installed at the moment.

To provide 40% of total UK energy needs, pretty much every house will have some sort of micro-generation technology installed.

We ask you to consider 4 possible levels of micro-generation uptake in the UK:

Large - every second household will have a micro-generation unit installed in their homes.

Medium - 1 in 10 households will have a micro-generation unit installed in their homes.

Slight - 1 in 50 households will have a micro-generation unit installed in their homes.

No change - 1 in 260 households will have a micro-generation unit installed in their homes.

Attribute 4
Increase in Annual Total Cost to a Household

Achieving a reduction in carbon emissions and switching to renewable generation implies additional costs to the consumers, which will result in the increase in total cost to the households. Experts' estimates vary, but it can range from £40 to £260 pounds depending on the policy chosen.

We ask you to consider 4 possible levels of annual increase in total household's cost:

- **£40** - your total expenditures will go up by £40 a year.
- **£80** - your total expenditures will go up by £80 a year.
- **£160** - your total expenditures will go up by £160 a year.
- **£260** - your total expenditures will go up by £260 a year.

Example of a Choice Card:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	Large *(40% of total UK's energy)*	Medium *(20% of total UK's energy)*	No change *(6.7% of total UK's energy*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Medium *(1 out of 10 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*	Slight *(1 out of 50 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£160	£260	£40
PLEASE TICK ONE SCENARIO YOU PREFER:			

Please complete each of the 8 choice cards that follow by ticking the one scenario per card that you prefer.

A few things to remember when completing the choice cards:

- Each choice card is different and contains different combination of attributes.
- Some of the scenarios might seem unrealistic, please don't be put off and try and choose one anyway.
- It is important that you complete ALL choice cards.
- There are no right or wrong answers.

CHOICE CARDS

(Please complete all 8 cards that follow)

Choice Card 1:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	Large *(40% of total UK's energy)*	Large *(40% of total UK's energy)*	Large *(40% of total UK's energy)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Medium *(1 out of 10 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£260	£40	£80
PLEASE TICK <u>ONE</u> SCENARIO YOU PREFER:			

Choice Card 2:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	Low *(adaptation measures are given no or very little attention)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	No change *(6.7% of total UK's energy*	No change *(6.7% of total UK's energy*	No change *(6.7% of total UK's energy*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Large *(1 out of 2 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£40	£40	£260
PLEASE TICK <u>ONE</u> SCENARIO YOU PREFER:			

Choice Card 3:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*	High *(much greater priority compared to current levels)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	Slight *(10% of total UK's energy)*	Medium *(20% of total UK's energy)*	No change *(6.7% of total UK's energy*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Large *(1 out of 2 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£260	£40	£40
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 4:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	No change *(6.7% of total UK's energy*	Slight *(10% of total UK's energy)*	Slight *(10% of total UK's energy)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	No change *(1 out of 260 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£40	£160	£80
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 5:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	No change *(6.7% of total UK's energy*	Medium *(20% of total UK's energy)*	Medium *(20% of total UK's energy)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	No change *(1 out of 260 houses have microgeneration installed)*	Slight *(1 out of 50 houses have microgeneration installed)*	Slight *(1 out of 50 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£80	£260	£40
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 6:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	Low *(adaptation measures are given no or very little attention)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	Large *(40% of total UK's energy)*	Large *(40% of total UK's energy)*	Slight *(10% of total UK's energy*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£40	£260	£160
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 7:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	High *(much greater priority compared to current levels)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	Slight *(10% of total UK's energy)*	No change *(6.7% of total UK's energy*	Slight *(10% of total UK's energy)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	No change *(1 out of 260 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£80	£80	£260
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 8:

Level:	**Option A**	**Option B**	**Option C**
Spending on Adaptation to Climate Change *(flood defences, building reinforcements etc.)*	High *(much greater priority compared to current levels)*	Low *(adaptation measures are given no or very little attention)*	Low *(adaptation measures are given no or very little attention)*
Increase in Large Scale Renewable Energy *(onshore and offshore wind, tidal etc.)*	Large *(40% of total UK's energy)*	Slight *(10% of total UK's energy)*	Large *(40% of total UK's energy)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	No change *(1 out of 260 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£260	£80	£160
PLEASE TICK ONE SCENARIO YOU PREFER:			

In making your choices which of the attributes in the choice cards did you consider to be important or unimportant? (*Please tick the relevant answers.)*

Attribute	Important	Quite Important	Not Important at All
Spending on Adaptation to Climate Change			
Increase in Large Scale Renewable Energy			
Increase in Level of Micro-generation			
Increase in Annual Total Cost to a Household			

Two other issues that future energy policy of the UK will also have to address are: 1. Levels of Carbon Reduction Targets adopted by the UK and 2. Improvements in Energy Efficiency.

Do you feel that these attributes would be more important to you than the ones in the choice cards above?

Attribute	YES	UNSURE	NO
Levels of Carbon Reduction Targets (e.g. 20%, 30% and etc.)			
Improvements in Energy Efficiency (e.g. in individual houses, public buildings and industrial sector)			

Part 3: RESPONDENTS / HOUSEHOLD PROFILE

In this last section (thank you for making it so far!) we ask you a few questions about yourself and your household. This information will help us identify how representative our sample of respondents of total UK's population. Please note that we do not ask for your name, address or anything that may compromise your confidentiality. Although important for our research, if there is any question you will feel uncomfortable to answer – just leave it and move on.

As already mentioned – all answers will be kept strictly confidential and NO information will be passed on to a third party.

1. Are you: ☐ Male ☐ Female

2. What is your age? ___________________

3. What is your highest educational level or qualification?
(Please tick the relevant answer).

☐ School ☐ College

☐ Undergraduate University Degree ☐ Postgraduate University Degree

☐ Professional qualification ☐ Other (please specify): __________

5. How many children under the age of 16 live in your household?

Please insert your answer ______________.

6. Which of the following describes best your total annual household income <u>before tax</u>?

(Please tick the relevant answer)

£0 – £14,999	☐
£15,000 – £19,999	☐
£20,000 – £29,999	☐
£30,000 – £39,999	☐
£40,000 – £49,999	☐
£50,000 – £59,999	☐
£60,000 – £79,999	☐
£80,000 – £99,999	☐
£100,000 or more	☐

7. **What is your postcode: ____________**

8. **Do you live in the area affected by flooding or any other climate change related impacts** (please tick all that relevant)**:**

   ☐ Flooding ☐ None ☐ Other (please specify):________________

9. **Is your home well insulated?**

   ☐ Yes ☐ No ☐ Unsure

10. **Do you have any micro-generation technologies already installed in your house?**

    ☐ Yes (please specify): ____

    ☐ No

11. **How do you currently heat your home?** *(Please tick all the relevant answers)*

    ☐ Oil ☐ Gas ☐ Electricity ☐ Woodburning stove

    ☐ Groundsource heatpump ☐ Biomass boiler

    ☐ Other (please specify): ____________________________________

12. **Do you own or rent your house?**

    ☐ Own

    ☐ Rent

13. **Do you feel you have the space in your current house and garden to install micro-generation technologies?**

    ☐ Yes ☐ No ☐ Unsure

This is the end of the survey!
Thank you very much for your time!
If you wish to be entered in a prize draw, please fill in your details in a detachable sheet overleaf.

If you wish to be entered into the prize draw to win one of the 4 prizes of £25 (see front page) please provide your contact details below:

……………………………………………………………………………………………

……………………………………………………………………………………………

<u>TO RETURN THE COMPLETED QUESTIONNAIRE:</u>

PLEASE RETURN THE COMPLETED QUESTIONNAIRE USING THE ATTACHED RETURN ENVELOPE BY

<u>1st September 2011</u>

If you would like to add any further comments please use the space below:

Block 1

APPENDIX 3

Attributes and Choice Cards for Experiment 2

Background information and attitudinal and socio-economic profiling questions in Experiment 2 are identical to those in Experiment 1 and can, therefore, be found in Appendix 2.

Attribute 1
Carbon Reduction Targets

As part of the EU directive, the UK is legally committed to reducing carbon emissions by 20% by 2020 (compared to 1990 levels). UK's internal target is 34% reduction and Scotland's target is 42% reduction in carbon emissions compared to 1990 levels.

Reduction in carbon emissions can be achieved in a number of different ways: renewable generation, use of non-fossil fuels, switching to electric cars, improvement in energy efficiency etc.

As such each scenario in the choice card will contain one of 4 levels of reductions in carbon emissions (compared to 1990 levels):

- **20%** carbon reduction target (by 2020) – *legally binding target for the UK set out by the European Union.*
- **30%** carbon reduction target (by 2020)
- **40%** carbon reduction target (by 2020)
- **50%** carbon reduction target (by 2020)

Attribute 2
Improvements in Energy Efficiency

Improvements in energy efficiency can play a major role in reducing carbon emissions. The Government has put in place various measures designed to encourage the public to make their homes more energy efficient. This again will carry some underlying costs which will be passed on to the consumer. By introducing this attribute we would like to test public preferences towards location and scale of energy efficiency improvements.

Please consider 3 possible levels:

- Private homes - focus on energy efficiency improvement in private houses.

- Public buildings – energy efficiency measures will be implemented in public and community buildings (village halls, schools etc.).

- Service Sector – energy efficiency measures will be implemented in industrial and service sector (pubs, shops etc.).

- Industrial Sector - energy efficiency measures will be implemented in industrial sector (factories, offices etc.).

Attribute 3
Increase in Level of Micro-generation

Micro-generation is a way of generating clean energy on a small scale where it is needed.

Below are the examples of types of microgeneration technologies that you might expect to see:

Solar panel heat pump

Wind turbine

Solar hot water

Micro-hydro

Ground source

In the UK there are currently approx. 100,000 micro-generation units installed out of potential millions. To give you an idea – this roughly means that only 1 out of 260 households has some type of micro-generation installed at the moment.

To provide 40% of total UK energy needs, pretty much every house will have some sort of micro-generation technology installed.

We ask you to consider 4 possible levels of micro-generation uptake in the UK:

- Large - every second household will have a microgeneration unit installed in their homes.

- Medium - 1 in 10 households will have a microgeneration unit installed in their homes.

- Slight - 1 in 50 households will have a microgeneration unit installed in their homes.

- No change - 1 in 260 households will have a microgeneration unit installed in their homes.

Attribute 4
Increase in Annual Total Cost to a Household

Achieving a reduction in carbon emissions and switching to renewable generation implies additional costs to the consumers, which will result in the increase in total cost to the households. Experts' estimates vary, but it can range from £40 to £260 pounds depending on the policy chosen.

We ask you to consider 4 possible levels of annual increase in total household's cost:

- **£40** - your total expenditures will go up by £40 a year.
- **£80** - your total expenditures will go up by £80 a year.
- **£160** - your total expenditures will go up by £160 a year.
- **£260** - your total expenditures will go up by £260 a year.

CHOICE CARDS
(Please complete all 8 cards that follow)

Choice Card 1:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	20%	40%	40%
Improvements in Energy Efficiency	Public Buildings *(schools, village halls etc.)*	Private homes	Private homes
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Large *(1 out of 2 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£40	£80	£260
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 2:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	20%	50%	30%
Improvements in Energy Efficiency	Industrial Sector *(i.e. factories, offices etc.)*	Private homes	Service Sector *(pubs, shops etc.)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£80	£80	£160
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 3:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	40%	40%	30%
Improvements in Energy Efficiency	Industrial Sector *(factories, offices, etc.)*	Public Buildings *(schools, village halls etc.)*	Service Sector *(pubs, shops, etc.)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Large *(1 out of 2 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£80	£160	£260
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 4:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	50%	20%	30%
Improvements in Energy Efficiency	Industrial Sector *(factories, offices, etc.)*	Service Sector *(pubs, shops, etc.)*	Private homes
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Slight *(1 out of 50 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£260	£80	£40
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 5:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	30%	40%	40%
Improvements in Energy Efficiency	Private homes	Service Sector *(pubs, shops, etc.)*	Industrial Sector *(factories, offices, etc.)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Large *(1 out of 2 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£80	£160	£80
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 6:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	20%	30%	50%
Improvements in Energy Efficiency	Private homes	Public Buildings *(schools, village halls etc.)*	Industrial Sector *(factories, offices, etc.)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Slight *(1 out of 50 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*	No change *(1 out of 260 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£160	£260	£40
PLEASE TICK ONE SCENARIO YOU PREFER:			

Choice Card 7:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	50%	50%	20%
Improvements in Energy Efficiency	Service Sector *(pubs, shops, etc.)*	Public Buildings *(schools, village halls etc.)*	Industrial Sector *(factories, offices, etc.)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*	Medium *(1 out of 10 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£260	£80	£80
PLEASE TICK <u>ONE</u> SCENARIO YOU PREFER:			

Choice Card 8:

Level:	**Option A**	**Option B**	**Option C**
Carbon Reduction Targets	30%	20%	50%
Improvements in Energy Efficiency	Industrial Sector *(factories, offices, etc.)*	Service Sector *(pubs, shops, etc.)*	Public Buildings *(schools, village halls etc.)*
Increase in Level of Microgeneration *(e.g. small wind turbines, solar panels etc.)*	Slight *(1 out of 50 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*	Large *(1 out of 2 houses have microgeneration installed)*
Increase in Annual Total Cost to Household	£160	£160	£160
PLEASE TICK <u>ONE</u> SCENARIO YOU PREFER:			

In making your choices which of the attributes in the choice cards did you consider to be important or unimportant? (*Please tick the relevant answers.)*

Attribute	Important	Quite Important	Not Important at All
Increase in level of Micro-generation			
Carbon Reduction Targets			
Improvements in Energy Efficiency			
Increase in annual total cost to a household			

Two other issues that future energy policy of the UK will also have to address are: 1. Adaptation to Climate Change Measures (e.g. flood defences, building reinforcements etc.) and 2. Share of Large Scale Renewable Energy (onshore and offshore wind, tidal etc.) in the future UK energy portfolio.

Would you rather see these options in the choice cards above?

Attribute	YES	UNSURE	NO
Adaptation to Climate Change Measures (e.g. flood defences, building reinforcements etc.)			
Share of Large Scale Renewable Energy (onshore and offshore wind, tidal etc.)			

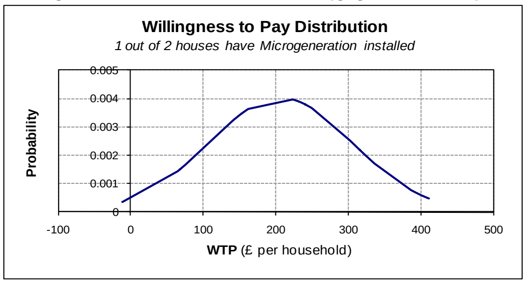
Appendix 4. Total Welfare Estimates (Chapter 3)

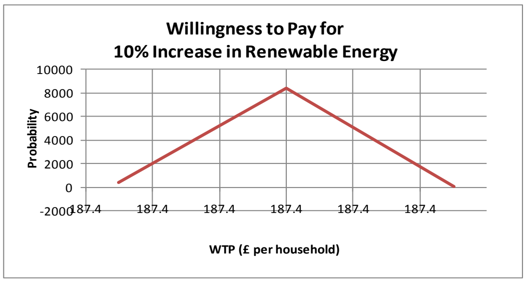
Scenarios – Move from Current Energy Mix	Compensating Surplus
Wind scenario 1 – (18 miles, Increase in Biodiversity, 98% CO2 reduction)	474.65 (£ per household per year)
Wind scenario 2 – (10 miles, Increase in biodiversity, 95% CO2 reduction)	440.86 (£ per household per year)
Wind Scenario 3 – (5 mile, Increase in Biodiversity, 90% CO2 reduction)	416.21 (£ per household per year)
Biomass Scenario 1 – (18 miles, Increase in Biodiversity, 90% CO2 reduction)	217.61 (£ per household per year)
Biomass Scenario 2 - (10 miles, Increase in Biodiversity, 50% CO2 reduction)	142.01 (£ per household per year)
Biomass Scenario 3 – (5 miles, increase in biodiversity, 50% CO2 reduction)	123.01 (£ per household per year)
Nuclear Scenario 1 – (18 miles, increase in biodiversity, 98% CO2 reduction)	418.65 (£ per household per year)
Nuclear scenario 2 – (10 miles, increase in biodiversity, 95% CO2 reduction)	384.85 (£ per household per year)
Nuclear scenario 3 – (5 miles, increase in biodiversity, 90% CO2 reduction)	360.2 (£ per household per year)

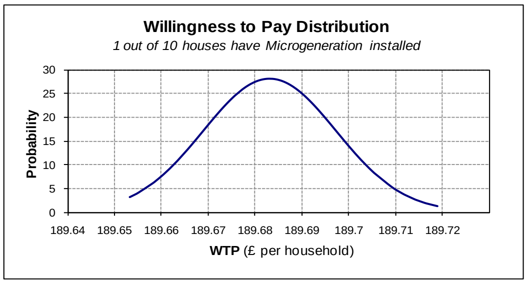
Appendix 5.

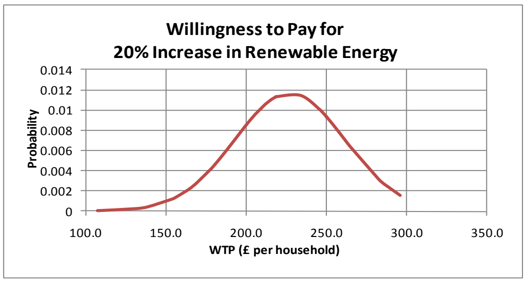
Distributions of WTP Estimates Suggested by Random Parameters

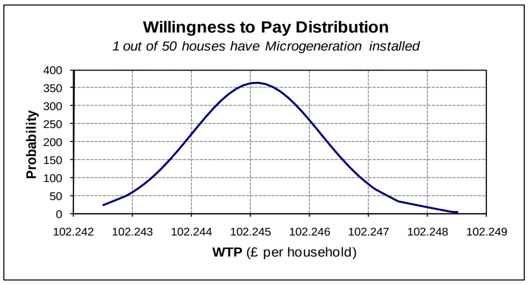
Chapter 4 RPL model (pp.96-97)

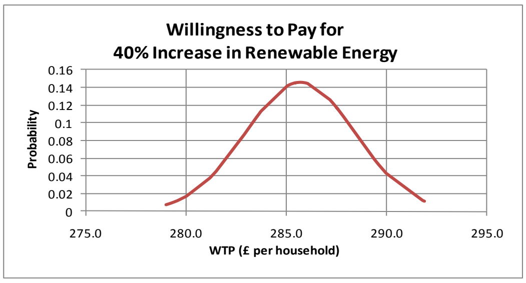










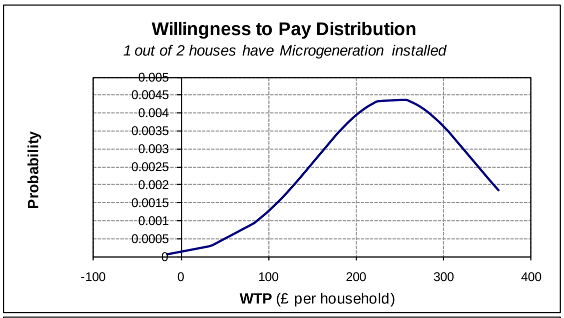


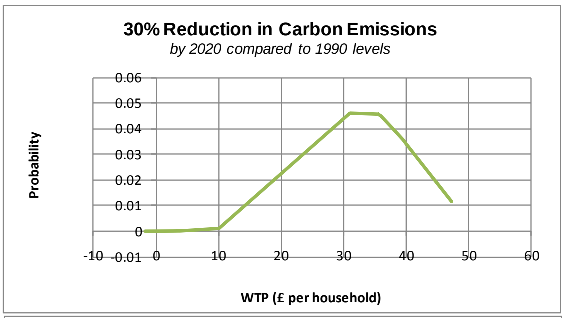
Variable	Significance of Standard Deviations suggested by Random Parameters *(see Table 4.6)*
WTP for Microgeneration (1 in 2 houses)	Significant at 5%
WTP for Microgeneration (1 in 10 houses)	-
WTP for Microgeneration (1 in 50 houses)	-
WTP for 30% increase in renewable energy	-
WTP for 40% increase in renewable energy	Significant at 5%
WTP for 50% increase in renewable energy	-

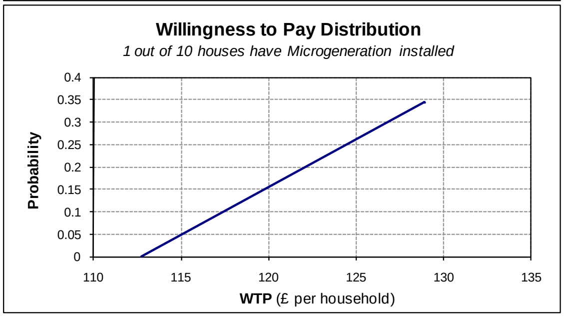
The above plots show distributions of willingness to pay for increase in microgeneration levels and increase in renewable energy attributes suggested by random parameters. As can be seen from the Table above, the estimated standard deviations for such attributes, as an Increase in level of Microgeneration (1 in 2 houses) and a 40% increase in renewable energy, came through as significant at 5%. This suggests the presence of heterogeneity within the sampled population for these attributes. Once plotted, it can also be observed that the willingness to pay for an increase in level of microgeneration (1 in 2 houses) is mainly positive with a very small proportion of observations falling below zero. On the other hand all of the repondents seem to be willing to pay extra to see a 40% increase in renewable energy.

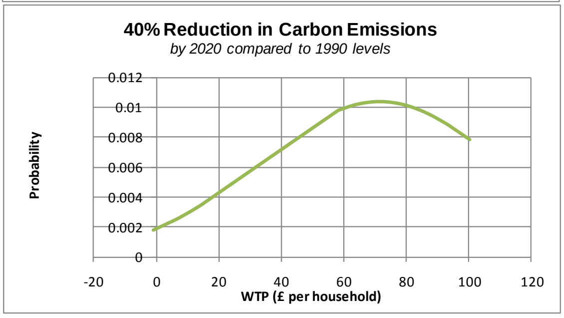
Chapter 5

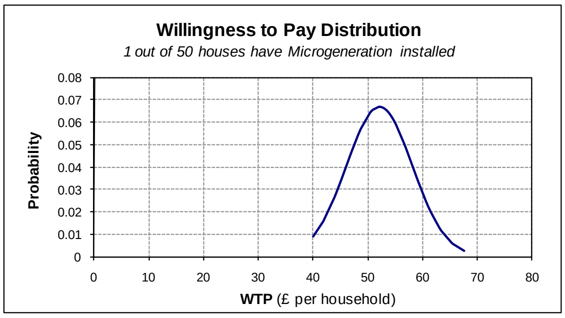
RPL extended model (pp.130-133)

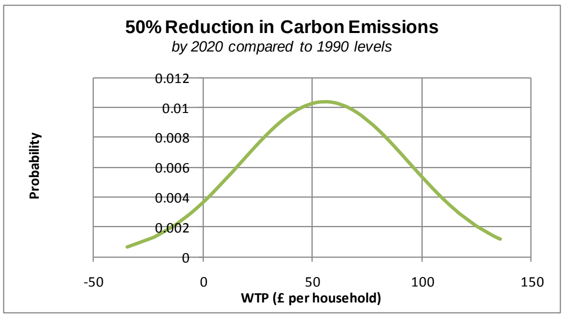












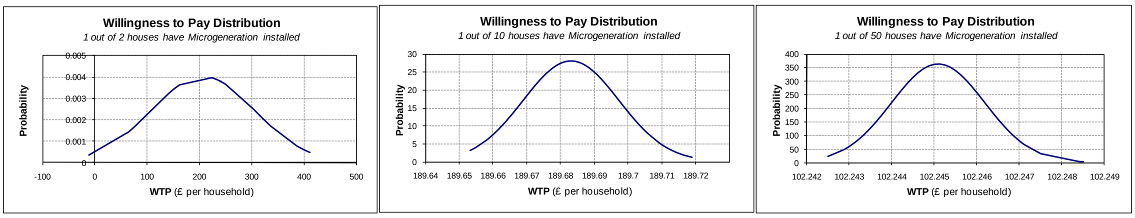
Variable	Significance of Standard Deviations suggested by Random Parameters *(see Table 5.6)*
WTP for Microgeneration (1 in 2 houses)	Significant at 5%
WTP for Microgeneration (1 in 10 houses)	-
WTP for Microgeneration (1 in 50 houses)	Significant at 10%
WTP for 30% carbon reduction target	-
WTP for 40% carbon reduction target	-
WTP for 50% carbon reduction target	Significant at 5%

Although graphs were plotted for all of the attributes, the distributions were significant only for three of those, i.e. Increase in Microgeneration (1 in 2 houses), Incerase in Microgeneration (1 in 50 houses) a 50% Carbon Reduction Target. We note that the WTP for "Micro 1 in 2 houses" is mainly positive with only a small proportion of respondents having negative WTP. WTP for 'Micro 1 in 50' houses is a tighter spread indicating higher consistency in repsondents WTP towards this attribute. In its turn, WTP for a 50% Carbon reduction target is wide with significantly higher proportion of respondents having negative WTP for this attribute. Possible explanations of such heterogeneity is discussed in more details in Chapter 6.

Chapter 6

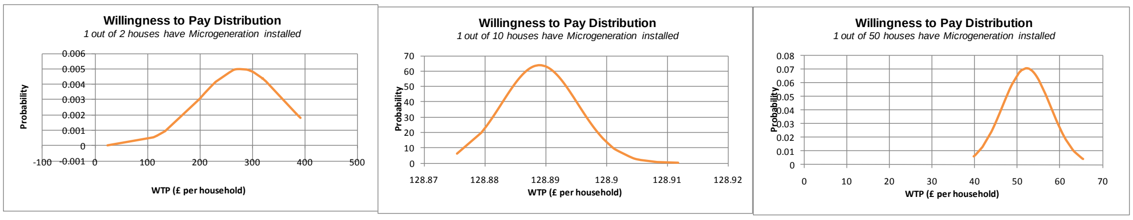
Comparison of Micro-generation distribution estimates suggested by Random Parameters

Experiment 1



Variable	Significance of Standard Deviations suggested by Random Parameters *(see Table 6.8)*
WTP for Microgeneration (1 in 2 houses)	Significant at 5%
WTP for Microgeneration (1 in 10 houses)	-
WTP for Microgeneration (1 in 50 houses)	-

Experiment 2



Variable	Significance of Standard Deviations suggested by Random Parameters *(see Table 6.8)*
WTP for Microgeneration (1 in 2 houses)	Significant at 5%
WTP for Microgeneration (1 in 10 houses)	-
WTP for Microgeneration (1 in 50 houses)	-

Heterogeneity in WTP amongst sampled respondents for increase in micro-generation in 1 out of 2 houses came through as significant at 5% in both experiments. We note that WTPs in Experiment 1 and Experiment 2 have broadly similar shape with a small proportion of values falling below zero in Experiment 1, whereas WTPs in Experiment 2 are all positive.

Appendix 6
Results of the Welch's T-test – Two Sample Test Assuming Unequal Variances

Chapter 4 – Results for 10%, 20% and 40% Increase in Renewable Energy

	ren10	*ren40*	*ren10*	*ren20*	*ren20*	*ren40*
Mean	187.419	285.6498	187.419	226.7068	226.7068	285.649786
Variance	1.95E-09	7.313775	1.95E-09	1150.57	1150.57	7.31377502
Observations	175	175	175	175	175	175
Hypot. Mean Difference	0		0		0	
df	174		174		174	
t Stat	-480.508		-15.3222		-24.7724	
P(T<=t) one-tail	5.8E-274		2.13E-34		3.02E-59	
t Critical one-tail	1.653658		1.653658		1.653658	
P(T<=t) two-tail	1.2E-273		4.25E-34		6.03E-59	
t Critical two-tail	1.973691		1.973691		1.973691	

Null Hypothesis: Mean difference is equal to zero.

	Ren 10	Ren 20	Ren40
Ren 10	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected
Ren 20	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected

Chapter 4 - Comparison between a 40% Increase in Renewable Energy and an Increase in Level of Micro-generation 1 in 2 houses (RPL model)

	Renew 40%	*Micro 1 in 2*
Mean	285.6497864	205.3287421
Variance	7.313775023	9562.676725
Observations	175	175
Hypot. Mean Difference	0	
df	174	
t Stat	10.86157031	
P(T<=t) one-tail	1.30648E-21	
t Critical one-tail	1.653658017	
P(T<=t) two-tail	2.61296E-21	
t Critical two-tail	1.9736914	

Null Hypothesis: Mean difference is equal to zero.

	Ren 10
Micro 1 in 2	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected

Chapter 5 – Results for 30%, 40% and 50% Carbon Reduction Target

	30% target	*40% target*	*30% target*	*50% target*	*40% target*	*50% target*
Mean	35.49868	76.86464	35.49868	59.87743	76.86464	59.87743
Variance	64.27642	313.8183	64.27642	1441.663	313.8183	1441.663
Observations	193	193	193	193	193	193
Hypot. Mean Difference	0		0		0	
df	267		209		272	
t Stat	-27.411		-8.15464		5.168314	
P(T<=t) one-tail	6.87E-80		1.61E-14		2.29E-07	
t Critical one-tail	1.650581		1.652177		1.650475	
P(T<=t) two-tail	1.37E-79		3.21E-14		4.58E-07	
t Critical two-tail	1.968889		1.971379		1.968724	

Null Hypothesis: Mean difference is equal to zero.

	30% target	40% target	50% target
30% target	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected
40% target	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected

Chapter 6 – Results for Increase in Levels of Micro-generation for Experiment 1 (Ch.4) and Experiment 2 (Ch.5) – between and within estimates

Experiment 1

	mic2	*mic10*	*mic2*	*mic50*	*mic10*	*mic50*
Mean	205.3287	189.6829	205.3287	102.2451	189.6829	102.245071
Variance	9562.677	0.000196	9562.677	1.14E-06	0.000196	1.1412E-06
Observations	175	175	175	175	175	175
Hypot. Mean Difference	0		0		0	
df	174		174		174	
t Stat	2.116838		13.94517		89321.06	
P(T<=t) one-tail	0.017848		1.85E-30		0	
t Critical one-tail	1.653658		1.653658		1.653658	
P(T<=t) two-tail	0.035695		3.7E-30		0	
t Critical two-tail	1.973691		1.973691		1.973691	

Null Hypothesis: Mean difference is equal to zero.

	Micro (1 in 2 houses)	Micro (1 in 10 houses)	Micro (1 in 50 houses)
Micro (1 in 2 houses)	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected
Micro (1 in 10 houses)	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected

Experiment 2

	mic2	mic10	mic2	mic50	mic10	mic50
Mean	279.9715	128.8889	279.9715	52.15832	128.8889	52.15832
Variance	6209.074	4.07E-05	6209.074	35.15248	4.07E-05	35.15248
Observations	193	193	193	193	193	193
Hypot. Mean Difference	0		0		0	
df	192		192		192	
t Stat	26.63849		43.08049		179.9794	
P(T<=t) one-tail	1.06E-66		6.2E-101		2.6E-216	
t Critical one-tail	1.652829		1.652829		1.652829	
P(T<=t) two-tail	2.12E-66		1.2E-100		5.1E-216	
t Critical two-tail	1.972396		1.972396		1.972396	

Null Hypothesis: Mean difference is equal to zero.

	Micro (1 in 2 houses)	Micro (1 in 10 houses)	Micro (1 in 50 houses)
Micro (1 in 2 houses)	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected
Micro (1 in 10 houses)	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected	NA	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected

Comparison between Experiment 1 and Experiment 2

	Experiment 1	Experiment 2	Experiment 1	Experiment 2	Experiment 1	Experiment 2
	Micro2	Micro 2	Micro10	Micro 10	Micro 50	Micro 50
Mean	205.3287421	279.9715066	189.6829393	128.8890382	102.2450714	52.1978619
Variance	9562.676725	6064.362576	0.000196134	3.83967E-05	1.14124E-06	31.23633385
Observations	175	193	175	193	175	193
Hypot. Mean Difference	0		0		0	
df	332		235		192	
t Stat	-8.064105454		52920.08861		124.4023217	
P(T<=t) one-tail	6.77256E-15		0		8.6522E-186	
t Critical one-tail	1.649456205		1.651363544		1.65282859	
P(T<=t) two-tail	1.35451E-14		0		1.7304E-185	
t Critical two-tail	1.967134988		1.970110009		1.972396447	

Null Hypothesis: Mean difference is equal to zero.

	Micro (1 in 2 houses) – Experiment 2	Micro (1 in 10 houses) – Experiment 2	Micro (1 in 50 houses) – Experiment 2
Micro (1 in 2 houses) – Experiment 1	Absolute t-stat > 1.97, therefore hypothesis cannot be rejected		
Micro (1 in 10 houses) – Experiment 1		t-stat > 1.97, therefore hypothesis cannot be rejected	
Micro (1 in 50 houses) – Experiment 1			t-stat > 1.97, therefore hypothesis cannot be rejected