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**The Internalization of Externalities  
in The Production of Electricity:  
Willingness to Pay for the  
Attributes of a Policy for  
Renewable Energy**

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# **The Internalization of Externalities in The Production of Electricity: Willingness to Pay for the Attributes of a Policy for Renewable Energy**

## **Summary**

This paper investigates the willingness to pay of a sample of residents of Bath, England, for a hypothetical program that promotes the production of renewable energy. Using choice experiments, we assess the preferences of respondents for a policy for the promotion of renewable energy that (i) contributes to the internalization of the external costs caused by fossil fuel technologies; (ii) affects the security of energy supply; (iii) has an impact on the employment in the energy sector; (iv) and leads to an increase in the electricity bill. Responses to the choice questions show that our respondents are in favour of a policy for renewable energy and that they attach a high value to a policy that brings private and public benefits in terms of climate change and energy security benefits. Our results therefore suggest that consumers are willing to pay a higher price for electricity in order to internalize the external costs in terms of energy security, climate change and air pollution caused by the production of electricity.

**Keywords:** Non Market Valuation, Choice Experiments, Willingness to Pay, Renewable Energy, Energy Security, Greenhouse Gases Emissions

**JEL Classification:** Q42, Q48, Q51

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## 1. Introduction and motivation

Over the last fifteen years there has been a significant research effort in measuring the external costs caused by electricity production (ExternE 1998; Friedrich and Bickel, 2001; Krewitt, 2002; European Commission, 2003; Markandya, 2003; NewExt, 2004; ExternEPol, 2005, European Commission, 2005). It is well established that air pollution, acid deposition, risk of accidents borne by the production of electricity have negative effects both on human health and on the environment. For example, human health is affected in terms of reduced life expectancy and respiratory hospital admissions, while the environment is affected through yield change of crops and global warming.

Using a bottom-up impact pathway approach,<sup>1</sup> the team of researchers of ExternE has quantified in monetary terms most of the damages to human health and the environment caused by different fuels and technologies that generate electricity. The external costs estimates are substantial; for example, ExternEPol (2005) has estimated that the external costs are in the range of 1.6 – 5.8 c€/kWh for current fossil systems, with figures at the lower end for gas based generation technologies and the upper end for traditional coal technologies. The results of the ExternE research also indicate the importance of the effects in terms of human health and global warming: at the end of the 90s ExternE identified that health impacts comprised 98% of the external costs from SO<sub>2</sub> and 100% of those from particulates (European Commission, 1999), with mortality impacts accounting for at least 80% of those health impacts. The costs associated specifically with global warming range widely and differ for fuel. The current phase of ExternE uses the *abatement cost* methodology for valuing the external costs of global warming because, according to ExternE, the current monetary

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<sup>1</sup> “The impact pathway assessment is a bottom-up-approach in which environmental benefits and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being expressed in monetary benefits and costs. The use of such a detailed bottom-up methodology – in contrast to earlier top-down approaches – is necessary, as external costs are highly site-dependent (cf. local effects of pollutants) and as marginal (and not average) costs have to be calculated” (European Commission, 2003, page 8).

valuations of global warming externalities have not yet been satisfactory. ExternE has chosen the value of 19 €/tCO<sub>2</sub> because that is the abatement cost in the EU implied by the commitment to the Kyoto protocol (European Commission, 2005).

Economists would suggest that when externalities are present, markets are not efficient as long as these external costs are not internalized and economic agents do not take into account these costs. The internalization of the externalities caused by the production of electricity should therefore target different fuels and technologies in different ways, according to the externalities caused: policy instruments, such as taxes, voluntary agreements, command and control measures or emission permits should target polluting fossil fuels, while subsidies could be used to stimulate the production of renewable energies that have a lower impact in terms of external costs, but are more expensive than traditional fossil fuels in terms of private costs. Subsidies to support the production of renewable energy have also been proposed by the recent ‘Community guidelines on State aid for environmental protection’ of the European Commission. The guidelines allow Member States to “grant operating aid [limited to a maximum of 5 c€/kWh] to new plants producing renewable energy that will be calculated on the basis of external costs avoided” (European Commission, 2001).

A second major reason to stimulate the production of renewable energy comes from the increasing demand for electricity, and moreover a demand for secure electricity. Already ten years ago, in the White Paper on Energy Policy, the European Commission identified the security of energy supply as one of the objectives on energy policies (European Commission, 1995). Two years later, with the White Paper for a Community Strategy and Action Plan – Energy for the future: Renewable Sources of Energy (European Commission, 1997) – the European Commission highlighted the goal of doubling the share of renewable energy from 6% to 12% in gross inland production by 2010 to cope with the increasing demand of energy. More recently, the Green Paper on Security of Energy Supply has tackled the growth in energy demand with measures to curb the growth in demand and manage the dependence on foreign

supply, by also fostering the development of less polluting energy sources (European Commission, 2000).

The current debate on the promotion of renewable energy has focussed on the identification of the policy instruments that are more effective in stimulating the production of renewable energy. Given that the private, or internal, costs of producing electricity are higher for renewable energy than for fossil fuel energy, governments need to identify effective instruments to promote the production of renewable energy. Policy instruments currently in use in the European Union are either investment focused, such as rebates, tax incentives, competitive bidding design, or generation based, such as feed-in-tariffs, rate based incentives and tradable green certificates.<sup>2</sup> Whatever instrument is chosen, it is clear that either consumers or the tax payer will have to pay for the extra cost of producing renewable energy.

The focus of this paper is on the characteristics of a policy for the promotion of renewable energy in the UK. In 2002, the share of renewable electricity production in the UK was only about 3% and the government aim is to increase the share of consumption of renewable energy to 10% of UK electricity in 2010 (DTI, 2003). Another major target for the UK energy policy is to comply with the commitment under the Kyoto Protocol that requires the UK to reduce the greenhouse gases emissions by 12.5% below the 1990 levels during the period 2008-2012. The increase in the production of renewable electricity is highlighted in the UK Energy White Paper that reckons that “renewable energy will also play an important part in reducing carbon emissions, while also strengthening energy security” (DTI, 2003, page 11).

The electricity supply industry has been liberalised in Great Britain in 1999 (Batley, 2001); today consumers have the opportunity to decide their supplier and the mix of energy, whether traditional or ‘green’ electricity. This means that the demand for specifically renewable electricity might contribute to an increase in its production. As Ek (2002) points out, if people’s willingness to pay for renewable is positive then we can expect that an increase

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<sup>2</sup> For a review of the policy instruments for the promotion of renewable energy see ENER, 2002; Haas et al, 2004; Haas, 2001; Menanteau et al, 2003.

in its production would be welcome. In particular, it is essential to understand what people think about these changes since they are the ones primarily affected. This change in the supply of electricity can have major effects on the structure of society. To give some examples, the employment in the energy sector might be affected as well as the electricity bill.

In this paper we investigate the perception and the willingness to pay of UK energy users for different characteristics of energy policies that stimulate the production of renewable energy by using choice experiments (Louviere et al, 2000). In a choice experiments-based survey, respondents are asked to choose between hypothetical public programs or commodities described by a set of attributes (see Hanley et al. 2001); hypothetical programs of commodities differ by the level that two or more attributes take. Respondents trade off the levels of the attributes of the programs or goods, one of which is usually its cost to the respondent, allowing researchers to infer the willingness to pay for public goods or programs and the implicit value of each attribute (see Hanley et al, 1998).

In our survey, we query 300 respondents in the city of Bath, England, on their preferences for different hypothetical policies for the promotion of renewable energy that (i) contribute to the internalization of the external costs caused by fossil fuel technologies; (ii) affect the security of energy supply; (iii) have an impact on the employment in the energy sector; (iv) and lead to an increase in the electricity bill.

Past research has investigated consumers' willingness to pay (WTP) for renewables focusing on environmental effects (Roe et al, 2001; Ek, 2002; Alvarez-Farizo and Hanley, 2002; Bergmann et al, 2006), on health effects (Johnson and Desvousges, 1997; Bergmann et al, 2006), and on social aspects (Johnson and Desvousges, 1997; Bergmann et al, 2006). Other studies have focused on renewable energy without directly emphasizing the impacts on environment, health or social aspects in the valuation questions (Farhar and Houston, 1996; Farhar, 1999; Zarnikau, 2003; Menges et al, 2005). Finally, a group of studies has focused on the value of security of energy supply, even though these studies are not directly linked to the

promotion of renewable energy (Hartman et al, 1991; Beenstock et al, 1998; Goett et al, 2000; de Nooij et al, 2005; Baarsma et al, 2005). To our knowledge, our study is the first to investigate consumers' WTP for renewable energy that have an impact (i) on the internalization of the external costs of energy production in terms of reduced greenhouse gases emissions, (ii) on the security of energy supply, and (iii) on social aspects, such as the employment level in the energy sector. This paper is also novel in this literature because it assesses the willingness to pay of electricity users for a program that increases the production of renewable energy and brings positive effects in terms of both public benefits and personal, ancillary benefits. While other studies have only looked at public benefits of promoting renewable energy, this study also investigates private benefits, in terms of personal health, that the reduction of greenhouse gases emissions brings (see Table 1).

Table 1 should be approximately here

Surveying a sample of the population of Bath during the month of August 2005, we find that our respondents are willing to pay a higher price for electricity in order to promote the production of renewable energy. When we look at the attributes that describe a policy for the promotion of renewable energy, respondents are more sensitive to a policy that addresses climate change and internalizes the external costs by decreasing the emissions of greenhouse gases: our respondents are on average willing to pay, on a quarterly basis, £29.7 for a policy that, by increasing the production of renewable energy, contributes to decreasing the UK greenhouse gases emissions by 1% per year. Respondents are also willing to pay £0.36 for one minute of additional energy security per year and £0.02 for each additional employed in the electricity sector. Our results suggest that residents of Bath are quite sensitive to a program for the promotion of renewables and that they attach high value to a policy that brings high private and public benefits in terms of climate change and energy security. The results of our study



also highlight that our respondents have a significantly higher WTP, of about one order of magnitude, for abating emissions than previous studies have found, suggesting that ancillary benefits play an important role in calculating the benefits of a reduction in greenhouse gases emissions.

## **2. Literature review**

Several studies have looked at the willingness to pay for renewables in the US relying on Contingent Valuation (CV) questions (Mitchell and Carson, 1989). Farhar and Houston (1996) report a survey of more than 700 research polls on willingness to pay for renewables in the US carried out between 1973 and 1996 and conclude that about 40% to 70% of respondents have a positive willingness to pay for renewable energy. On a second survey of 14 different studies carried out between 1995 and 1997 in the US, Farhar (1999) finds that an average of 70% of respondents is willing to pay at least US\$5 per month more on electricity bill. Using a mail questionnaire, Farhar and Coburn (1999) survey 206 homeowners among the population of married couple with annual income of \$50,000 or higher in Colorado during the summer of 1998. Their WTP question asked the respondents to state what incremental monthly amount they were willing to pay among a set of five values plus the status quo. Only 21% said they were not willing to pay anything, while the median WTP fell between 2% and 5% increase in monthly electricity bill. Champ and Bishop (2001) use a mail questionnaire to elicit the WTP of 1,497 residents of Wisconsin for a voluntary pilot program to allow residents to purchase wind-generated electricity. Half of the sample that received a hypothetical WTP question that asked for a donation to support the program showed a mean WTP of US\$ 101 a year; the other half of the sample, that actually received a real offer of purchasing wind energy, showed a mean WTP of US\$ 59 a year. Wiser (2003) surveys 1,574 US residents who pay their own utility bill and finds that median WTP to switch to renewable energy is about US\$3 a month.

In the UK, using a market survey, Fouquet (1998) finds that 20% of respondents are willing to pay a premium for renewables and 5% are even willing to pay a premium higher than 20%. Batley et al. (2001) survey by mail 742 residents of Leicester and find that 34% of respondents are willing to pay more for electricity generated from renewable sources. They also find that respondents are on average willing to pay 16.6% extra for renewable energy. Hanley and Nevin (1999) apply the CVM to a sample of 45 residents of North Assynt Estate in Scotland, a small community of 130 households to investigate their willingness to pay for three projects for renewable energy. They find that respondents are on average willing to pay £52, £26 and £55 a year respectively for a wind farm, a biomass scheme and a small scale hydro scheme.

A second method widely used for assessing the WTP for renewable energy rely on choice modelling (Louviere et al, 2000; Hanley et al, 2001; Bateman et al, 2002). Roe et al. (2001) use choice experiments to survey 835 US residents in eight different cities and find that the median WTP across all population segments for an increase in renewable energy of 1% and a decrease of emissions of 1% ranges between US\$0.11 and US\$14.22 per year. The authors conclude that when such a reduction is achieved by substitution of renewable energy for fossil fuels, median WTP increases. Goett et al (2000) survey 1,205 electricity users in the US and find that, for hydro, customers are, on average, willing to pay 1.46 cents extra per kWh for a supplier that has 25% hydro power relative to a supplier with no renewables. Bergmann et al. (2006) analyse people's opinion over the effects of an increase in renewable energy in Scotland using a mail questionnaire that employs choice experiments. The attributes taken into account were measures to prevent effects on landscape, on wildlife, on air pollution, the potential gain in jobs and the increase in the price of hypothetical policies. Answers to 211 usable interviews indicate that households are willing to pay £14.40 a year to have renewable energy projects that have no increase in air pollution, but are not willing to pay anything for creating new long-term jobs related to renewable energy projects.

Choice experiments have also been used to assess the WTP for energy security. Using a mail survey of 12,409 households, Baarsma et al (2005) find that Dutch households are willing to pay €5 to avoid one outage of one hour per year. Goett et al (2000) find that customers are on average willing to pay 1.21 cents extra per kWh to reduce outages of one hour (from four 30 minutes outages to two such outages) per year. Hartman et al (1991) use both CV and choice experiments to survey 1,500 US customers. From the CV part of the mail questionnaire they find that respondents are willing to pay a range of 1.64-2.95 US\$ a month to avoid a one hour shortage a year. From the choice experiment section of the questionnaire, the authors assess that respondents are willing to pay \$3.32 a month to improve the security of supply by four hours a year. Beenstock et al (1998) sample almost 3,000 Israeli households by using different mail questionnaires that employ contingent valuation and choice modelling. They find that the aggregate cost of unsupplied electricity to a household is about \$7 per kWh in 1990 prices.<sup>3</sup>

### **3. Structure of the questionnaire and survey administration**

#### *A. Selection of the Attributes and conjoint choice questions*

In our choice experiments, the hypothetical policies for the promotion of renewable energy are described by four attributes:<sup>4</sup> (i) annual percentage reduction in greenhouse gases (GHG), (ii) length of shortages of energy supply, (iii) variation in the number of employed in the energy sector, (iv) and increase in the electricity bill. We focused on these four attributes because we were interested in understanding the trade-off between (i) the internalization of external costs causing damages to human health and the environment, (ii) the need of electricity for day to day activities, (iii) a social element always important in political

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<sup>3</sup> The total consumption of electricity in Israel in 2003 was 39,976 billion kWh.

<sup>4</sup> Bateman et al. (2002) suggest that not more than 4-5 attributes, including price, should be presented in a choice experiments-based questionnaire.

decisions, such as jobs creation/loss (iv) and finally the cost of the policy to understand the willingness to pay for renewable energy.

In a choice experiments-based survey it is essential to present a realistic and clear description of the hypothetical program or good that the respondents are asked to value. This means that the attributes chosen to describe the policy for the promotion of renewable energy presented in the choice sets and their levels have to be realistic and consistent with the government policies, as well as relevant and understandable to respondents.

In choosing the first attribute, the percentage reduction in GHG emissions, we were interested in selecting an attribute that would consider both the long term climate change impacts as well as internalize some of the associated external costs of local pollutants that cause damages to human health and the environment.<sup>5</sup> At first we wanted to use two separate attributes, one for human health effects of local air pollutants, and one for damages to the environment. However, after focus groups and one-on-one interviews, we decided to use only one attribute because participants felt that the two effects, on environment and on human health, were correlated. Unfortunately this makes it difficult to separate the local pollution valuation of individuals from that of broader climate change benefits, except on the basis of the share of damages associated with each when GHG emissions are reduced by a given amount.

The decision to use the annual percentage change in GHG emissions matches with the recent UK Energy White Paper (DTI, 2003) description of the potential benefits that renewable sources might bring to the internalization of the external costs. The UK set the target to decrease GHG emissions by 60% below the levels of 1990 by 2050. In order to reach this target, the UK need to reduce the emission of CO<sub>2</sub> by at least 15 or 25 MtC before 2020 (DTI,

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<sup>5</sup> Local air pollution reduction associated with reductions in GHGs is called an ancillary benefit. Studies for the UK and other countries show that such benefits are very policy and location specific, and vary between £2 and £334 per ton of carbon reduced, (DEFRA, 2002), and according to the OECD they could be as much as twice the climate change benefits (OECD, 2000).

2003). An increase in the share of renewable sources in the production of energy could bring a reduction of CO<sub>2</sub> emissions of 3-5 MtC. This means that renewable energy can contribute to cut GHG emissions by 1% per year.<sup>6</sup> Therefore, the levels chosen for this attribute in the questionnaire are: 1%, 2% or 3% reduction in GHG emissions per year in the UK.<sup>7, 8</sup>

The second attribute presented is energy security. Insecurity of energy supply, in the form of sudden physical shortages, can disrupt the economic performance and social welfare of the country in the event of supply interruptions and/or large, unexpected short-term price increases (JESS, 2003). According to the UK Energy White Paper (DTI, 2003), the UK production of oil and gas will strongly decline in the next years and the UK will become a net importer of these resources. As a consequence, the UK will be more vulnerable to price fluctuations and interruption of supply. DTI (2005b) reports that over the year April 2004 to March 2005 the total number of customer interruptions in the UK was around 22 million, for a total number of customer minutes lost of 2,668.5 million. In 2001/02, UK customers suffered on average 85.5 minutes of power cuts during the year (JESS, 2003). These figures, combined with previous works on energy security (Hartman, 1991; Beenstock, 1998; Goett, 2000) and focus groups indications, suggested us to set the levels for energy security as follows: 30, 60, 120 minutes black-out per year, being the business as usual scenario 90 minutes per year.<sup>9</sup>

The third attribute presented in the questionnaire is the one related to employment. As Bergmann et al. (2006) claim, employment is an essential aspect about changes in the structure

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<sup>6</sup> On the basis of UK current policies, including the full impact of the Climate Change Programme, UK carbon dioxide emissions might amount to some 135 MtC in 2020. A reduction of carbon emissions of 15-25 MtC by 2020 would put the UK on course to reduce its carbon dioxide emissions by some 60% by about 2050. Renewable energy, by contributing to a 3-5MtC cut in emissions by 2020, would therefore help in cutting emissions by 20%. This suggests that renewable energy might actually contribute to about 1% reduction in GHG emissions per year (DTI, 2003).

<sup>7</sup> Even though 3% might be a well too optimistic scenario, we felt it was necessary to have such a variation among the levels of this attribute so that respondents could better appreciate the different contribution of different hypothetical policies to GHG reductions.

<sup>8</sup> In preparing the questionnaire we were worried whether respondents would understand the differences between GHG reductions of 1, 2, and 3 percent, but in our focus groups we found that people did understand these differences.

<sup>9</sup> People may attach different values to energy shortages whether shortages are announced or not (Beenstock et al, 1998; Baarsma et al, 2005.) Our questionnaire focuses on unannounced energy shortages, as in the UK the public has generally not been informed of forthcoming electricity black-outs.

of society due to new energy policies. In our study, we assume that the increasing demand for renewable energy might increase the number of jobs in renewable energy sectors, but might decrease the number of jobs in the fossil fuel energy sectors. Moreover, being the private cost of renewable energy more expensive than fossil fuel energy, an increase of renewable energy might have macroeconomic consequences in the industry resulting in a total loss of jobs.<sup>10</sup> Focus groups discussions suggested to set the following levels for the attribute “employment”: +1000 new jobs, -1000 jobs, and no new jobs in the energy sector in the UK. The values were calculated by assuming a hypothetical variation of about 0.5% of the total number of employees in the energy sector.<sup>11</sup>

In a choice experiment exercise, when the focus is on the marginal price of attributes and the willingness to pay for a hypothetical program or good, it is necessary to include a payment vehicle among the attributes. Following the literature (Fahar, 1999; Goett, 2000; Bergmann, 2006), we used the electricity bill as a payment mechanism for the policy to promote renewables. The levels of the electricity bill chosen are an increase by £6, £16, £25 and £38 on the quarterly electricity bill paid by the respondents. These correspond to an increase by 10%, 25%, 40%, and 60% from the average electricity bill in the UK.<sup>12</sup>

In our choice experiments we included the ‘status quo’ or ‘do nothing’ option in each choice set to compare the stated preferences of our respondents with the current situation. Such a comparison is necessary when researchers want to compute the value (WTP) of each alternative policy (Hanley et al, 2001). Table 2 summarizes the attributes and their levels for the present study.

In our conjoint choice questions, respondents are asked to indicate which they prefer between policy A and B and the status quo. To create the pairs of alternative hypothetical

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<sup>10</sup> Firms might face higher prices. This could lead to an increase in wages in such a way that the unemployment rate would need to increase to balance the effect.

<sup>11</sup> According to the Office for National Statistics (2005), the total number of employees in the Energy and Water Industry Sector in the UK during the second quarter of 2005 was 177,000.

<sup>12</sup> The average annual electricity bill in the UK according to the National Statistics is equal to £251 (DTI, 2005a; Table 2.2.2). The electricity consumption in 2003 was equal to 337.443 billion kWh (IEA, 2003).

policies, we first created the full factorial design, i.e., all of the possible combinations of attribute levels. This gave a total of 108 possible combinations of hypothetical policies. To reduce the number of possible combinations, we opted for a fractional factorial design (Louviere et al, 2000). We then randomly selected two of these alternatives, but discarded pairs containing dominated or identical alternatives.<sup>13</sup> At the end we prepared six different versions of the questionnaire with six choice experiments each. An example of choice experiment is shown on figure 1.

Table 2 should be approximately here

Figure 1 should be approximately here

### *B. Structure of the Questionnaire and Survey Administration*

The questionnaire starts by presenting the topic of the survey: people's opinions on hypothetical renewable energy policies. In the first part of the questionnaire, respondents face a group of warm-up questions aimed to investigate the level of knowledge of respondents on the friendliness of energy fuels. The second part prepares the respondents with the hypothetical policies: here we describe the four attributes that define the possible impacts of a policy for the promotion of renewables. Respondents are asked to focus only on the four attributes we consider and not to think of other elements that might characterize the impacts of a policy for renewable energy. The next section is the central part of the questionnaire with the six choice experiments. The fourth section presents some debriefing questions to verify whether the respondents considered all the attributes in their choices, or only one. The fifth part of the questionnaire collects the usual socio-demographic characteristics of respondents. At the end,

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<sup>13</sup> A dominated alternative is one that should obviously be less preferred to the other. For instance, if two projects are created that are identical in every respect except for the price, the project with the higher cost is dominated by the other.

the interviewers took note whether respondents seemed annoyed by the interview or seemed to not understand the choice exercise.

The survey was administered in person to 300 respondents intercepted in shopping areas, public parks and other central areas of Bath, England, in July and August 2005 by professional interviewers who were instructed to interview an even number of men and women and to ensure given proportions of respondents in various age groups. To mitigate possible biases in the sample, interviewers were instructed to follow the common practice of stopping potential respondents every 7<sup>th</sup> person passing by. We chose to interview people through in-person interviews to guarantee a high quality in the answers. The budget constraint of this study limited our analysis to sample residents of Bath and North East Somerset. The results presented in this study should therefore be interpreted with caution: they are not representative of the UK population, but of the residents of a quite wealthy medium sized town of the South of the UK.

#### 4. Economic Model and Econometric Model

##### *A. The willingness to pay for a policy for renewable energy*

Our statistical analysis of the responses to the choice questions is based on the random utility model (RUM). We posit that in each of the choice questions the respondent selects the alternative with the highest indirect utility. We assume that the indirect utility function is linear in parameters:

$$(1) \quad V_{ik} = \beta_{0k} + \mathbf{x}_{ik}\boldsymbol{\beta} + \varepsilon_{ik} ,$$

where  $i$  denotes the respondent,  $\beta_0$  is an alternative specific constant,<sup>14</sup>  $k$  denotes the alternative, and  $\mathbf{x}$  is a  $1 \times 4$  vector comprised of the four attributes: the annual GHG emissions

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<sup>14</sup> We add an alternative-A specific to model (1) to pick any effect not explained by the levels of the attributes that explains why respondents selected either the alternative on the left (for example, policy A) or the alternative on



reductions, the yearly minutes of energy shortages, the permanent impact on the energy job market, and the increase in the quarterly electricity bill.  $\beta$  is a vector of unknown coefficients.

If the error terms  $\varepsilon$  are independent and identically distributed and follow the type I extreme value distribution, the probability that the hypothetical policy  $k$  is selected out of  $K$  policies is:

$$(2) \quad \Pi_{ik} = \Pr(\text{resp. } i \text{ chooses } k) = \exp(\mu V_{ik}) / \sum_{j=1}^K \exp(\mu V_{ij}),$$

where  $\mu$  is the scale parameter which is inversely proportional to the standard deviation of the error terms. Equation (2) is the contribution to the likelihood in a conditional logit model. In our questionnaire,  $K=3$ . The log likelihood function of the conditional logit model is:

$$(3) \quad \ln L = \sum_{i=1}^n \sum_{k=1}^K y_{ik} \cdot \ln \pi_{ik},$$

where  $y_{ik}$  takes on a value of 1 if the respondent chooses  $k$ , 0 otherwise. The coefficients are estimated using a Maximum Likelihood Estimation Method. The model described by (2) and (3) allows us to estimate the trade off between any two attributes and the willingness to pay for different policies. The marginal price of attribute  $k$  is given by:

$$(4) \quad MP_k = -\frac{\hat{\beta}_k}{\hat{\beta}_c},$$

where  $\hat{\beta}_k$  is the utility from an extra unit of  $k$ . Divided by the price coefficient,  $\hat{\beta}_c$ , it gives us the monetary value of the utility coming from an extra unit of  $k$ .

Finally we can derive the willingness to pay for a certain policy, formally:

$$(5) \quad WTP_{ik} = -\frac{x_{ik} \hat{\beta}}{\hat{\beta}_c}$$

Where  $x$  is the vector of the levels of attributes of policy  $k$  given to individual  $i$ .

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the right (for example, policy B). See for example Louviere et al, 2000, Alberini et al, 2003, Bergland et al, in press.

We will use model (1) to test the findings by Bergman et al (in press) that in choosing a policy for the promotion of renewable energy, the impact on the job market does not matter (Hypothesis I). An insignificant sign of the coefficient of (JOBS) would accept Hypothesis I.

The second hypothesis (Hypothesis II) of our model is that respondents value more the externalities on human health and the environment than energy disruptions. We claim that people are willing to pay more to avoid damages to human health and the environment than to avoid energy disruptions because past research on external costs of energy production has not given much attention to energy disruptions.<sup>15</sup> To test this hypothesis we will compare how much our respondents are willing to pay to avoid energy shortages, considering the average length of energy shortages of 90 minutes per year, with how much they are willing to pay to decrease GHG emissions from promoting renewables to comply with the DTI (2003) targets of reducing emissions by 60% below the levels of 1990 by 2050, which is roughly given by a GHG reduction of 1% a year.

#### *B. Heterogeneity among respondents and specific hypothesis*

The conditional logit model described by equations (2)-(3) is easily amended to allow for heterogeneity among the respondents. Specifically, one can form interaction terms between individual characteristics, such as age, gender, education, etc., and all or some of the attributes, and enter these interactions in the indirect utility function to test other specific hypotheses.<sup>16</sup>

Our Hypothesis III aims to investigate the internal validity of our responses. Therefore we add interaction terms between respondents' income (INCOME) and the reduction of GHG emissions (GHGREduc) and between (INCOME) and the length of energy shortages (BLACKOUT).

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<sup>15</sup> As reported in the introduction, ExternE has previously found that health impacts comprised 98% of the external costs from SO<sub>2</sub> and 100% of those from particulates (European Commission (1999)), with mortality impacts accounting for at least 80% of those health impacts. Researchers of the ExternE team have only recently moved their attention also to energy shortages.

<sup>16</sup> Since respondents' characteristics do not vary across alternative hypothetical policies, socio-demographic characteristics must be introduced as interaction terms with the attributes or the alternative specific constants.

In the literature on non-market valuation, researchers usually try to disentangle the components of the good being estimated into its use and non-use value components (see Freeman, 2003). For our good, a policy for the promotion of renewable energy, is quite difficult to identify the use value component. This would be related to the direct benefits that respondents receive by the policy, such as the improvement in their own health status, the conservation of the natural environment that they do visit, and especially the reduction in energy shortages in their own dwellings. Non-use components also seem likely to be very important for such a policy, given that most benefits will emerge in the long run. For example, future generations will be more likely to experience the benefits in terms of health and global warming of the cuts in GHG emissions. If the share of ancillary benefits from GHG reduction are of the order of 10% (OECD, 2000) then we can say, roughly, that 10% of the willingness to pay for renewables is partly for personal benefits (although even here others also gain from the reduction) and 90% is for the longer term benefits of future generations.

Our fourth Hypothesis is therefore that respondents that have children are more willing to accept the policy for the promotion of renewables and are willing to pay more than those without children. To test this hypothesis, we add an interaction term between (GHGREduc) and a dummy variable that takes on a value of one if a respondents has children, and 0 otherwise (CHILD). To further test whether respondents that care for future generations have a higher willingness to pay for renewables, we add an interaction term between (BLACKOUT) and (CHILD).

Finally, we wish to see whether the level of schooling or the membership in an environmental organization influence the WTP for renewables. We therefore expect both characteristics, being a member of an environmental organization (ENV\_MEMBER) and having a college degree (COLLEGE), to positively affect WTP. Our Hypothesis V is that the coefficients of the interaction terms between (ENV\_MEMBER)\*(GHGREduc) and

(COLLEGE)\*(GHGREduc) to be positive and significant. Table 3 summarizes the hypotheses.

Table 3 should be approximately here

To further accommodate for variation in taste among individuals and relaxing the IIA<sup>17</sup> hypothesis implicit in the conditional logit model, we also estimate a more complex variant of model (2), which allows for the coefficients  $\beta$  to be random variables and to vary over the population with density  $f(\beta)$ . In the random-parameter logit model (Train, 2003), the utility function of equation (1) is augmented by a vector of parameters  $\theta$  that takes into account of individual's preference deviations with respect to the mean preference values expressed by the vector  $\beta$ :

$$(6) \quad V_{ik} = \beta_0 + \mathbf{x}_{ik}\boldsymbol{\beta} + \mathbf{x}_{ik}\boldsymbol{\theta} + \varepsilon_{ik},$$

where  $\theta$  is a vector of deviations from the mean  $\beta$  parameters estimated. Clearly, estimation of the likelihood function based on (6) requires that assumptions be made about which coefficients are random, and about the joint distribution of these coefficients.

## 5. Results

### *A. Description of the data*

Table 4 reports descriptive statistics for our sample and compares them with those for the population of Bath and North East Somerset, showing that the socio-demographics of our sample are for the most part very similar to those of the population of Bath and North East Somerset. Our sample tends to be slightly richer and younger than the population of Bath and North East Somerset.

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<sup>17</sup> The Independence of Irrelevant Alternatives (IIA) states that the relative probability of choosing between any two alternatives is independent of all other alternatives (Haab and McConnell, 2002).

Table 4 should be approximately here

Our average respondent is 35 years old, has an annual gross household income of about £37,000, and pays £70 per quarter on electricity bill. The sample is well balanced in terms of gender, with about one quarter of our respondents having one or more children. About 22% of our respondents are members of an environmental organization, and almost 31% have electric heating.

Our first order of business when analysing the data was to look at the first set of questions (warm up questions) where respondents were asked to state whether the different electricity fuels presented were environmental friendly or not. Results are reported in table 5. Eight different sources were presented. The results can be viewed in the light of the broad qualitative conclusions of ExternE (2003). The two sources with more uncertain answers are biomass and gas, probably due to a lack of knowledge of the sources itself, especially for biomass. Despite the quite positive consideration of nuclear power by ExternE, our respondents consider this source of energy highly hazardous for human health and the environment. The explanation we received the most was related to the risk of accidents and the problems with the wastes.

Table 5 should be approximately here

The opinion over the other sources, oil, natural gas and wind power are confirmed by the external costs estimated by ExternE (2003). Hydro, solar and wind are generally considered environmentally friendly by our respondents, while oil and coal are deemed dangerous to human health and the environment by more than 90% of the respondents.

Before running our conditional logit model, we checked the quality of the responses. In a debriefing question, most respondents considered the choice experiments as easy: on a 1 to 5 likert scale, where 1 mean very difficult and 5 very easy, the average value given by respondents is 4.16. To further check the quality of the responses, at the end of the questionnaire interviewers noted whether they thought that respondents understood the choice exercise or were annoyed during the interview. Only a few respondents seemed annoyed by the questionnaire, and only 13 respondents did not understand the choice experiments. We also check the percentages of respondents who always choose the alternative displayed on the left-hand side of the card (alternative A hereafter), or the alternative displayed on the right-hand side of the card (alternative B hereafter), which may signal the presence of abnormal response patterns (Viscusi et al., 1991). Only 1 respondent selected alternative A for all of the six choice questions included in the questionnaire, and no one selected always either alternative B or the status quo for all of the six choice questions. These preliminary observations suggest that the choice tasks were not prohibitive and were accepted by our respondents.

### *B. Results from the Discrete Choice Models*

In this section, we report the results of the random parameter logit models and of the conditional logit models estimated by dropping the observations of 13 respondents who did not understand the choice exercises.

We began with random-coefficient models, but found no evidence that coefficients are random, and subsequently ran conditional logits.<sup>18</sup> Therefore, we present here the results from the conditional logit model. The first specification of the model uses only the four attributes as independent variables and the alternative specific constants to take into account of the status quo effect (see Holmes and Adamowicz, 2003). Model 1 of table 6 shows that all coefficients

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<sup>18</sup> We experimented with log-normal distributions for all the coefficients. Since the coefficients on price and on blackout should be negative, we specified a lognormal distribution for the negative of this coefficient (Train, 2003). In all cases the standard deviation of the coefficient was very small relative to the mean of the coefficient, was insignificant, and the model reduced to a conditional logit.

are significant at the 1% level and have the correct sign. The positive sign in GHGREDUCT and JOBS implies that our respondents are more likely to favour a policy that reduces the emissions of GHG and support the creation of new jobs. Model 1 allows us to reject Hypothesis I: Contrary to the findings by Bergmann et al (2006), our respondents are not indifferent to a policy for the promotion of renewables that affects the number of jobs in the energy market. The negative sign in BLACKOUT means that our respondents shy away from policies that have longer electricity shortages, and the negative sign on PRICE also suggest that our respondents do not like a policy that entails higher energy prices, with all other characteristics of the policy remaining constant. The positive sign of the alternative specific constants suggests that our respondents do prefer a new policy for the promotion of renewable energy in comparison with the status quo. A Wald test of equality of coefficients for the two alternative specific constants does not reject the null hypothesis of equality of coefficients (Chi-squared=1.79) and confirms that our respondents did not systematically prefer alternative A over alternative B, or vice versa.

Model 2 of table 6 controls for socio-demographic characteristics of the respondents by controlling for age, income, level of education, membership in environmental organizations, and whether the respondent has children or not. A Likelihood ratio test shows that Model 2 outperforms Model 1 at the conventional levels (LR test = 76.244). When considering the level of income, we find that respondents with higher income are willing to pay more for the reduction in GHG emissions, as well as for decreasing the shortages of energy. These considerations provide us with reasons to not reject Hypothesis III: Our model is internally valid, being WTP increasing with income, while (AGE) is negatively associated with the number of jobs created in the energy market, but is not significant.

Model 2 also provides evidence in support of Hypothesis IV: respondents with children have a higher WTP for a policy that stimulates the promotion of renewable energy. The interaction term between (CHILD) and (GHGREDUCTION) shows that respondents with

children are more responsive to a policy that internalize a higher percentage of GHG emissions; and the interaction between (CHILD) and (BLACKOUT) suggests that this group of respondents is willing to pay more than respondents without children for a policy that minimizes the minutes of energy shortages. These results suggest that our respondents do recognize the importance of a policy for the promotion for renewable energy and are willing to pay for the benefits that such a policy will entail also to future generations.

Table 6 should be approximately here

Model 2 provides little support in favour of Hypothesis V: having a college degree negatively affects the probability of choosing a policy that internalizes a higher percentage of GHG, while members of environmental organizations are more likely to select a policy that internalizes a higher percentage of GHG.

Finally, to evaluate Hypothesis II, we need to look at the marginal prices of the attributes, as we do in the next section.

### *C. Marginal Prices and Willingness to Pay*

Table 7 reports the implicit prices of the attributes used in the choice experiments. The standard errors are calculated using the Delta method. The second column presents the implicit prices for the model without interaction terms, Model 1, while the third column presents the implicit prices derived from Model 2, calculated at the mean values of the socio-demographic characteristics of the respondents. As in the previous section we saw that Model 2 outperforms Model 1, our attention is for the results of Model 2. This model shows that respondents are on average willing to pay in addition to their electricity bill: (i) £29.65 to decrease the GHG



emissions by 1% a year; (ii) £0.36 to decrease the shortages of energy by 1 minute a year; (iii) £0.02 to increase the permanent number of jobs in the energy sector by 1.

Table 7 should be approximately here

Model 2 can also be used to assess the marginal prices for different groups of respondents, according to their socio-demographic characteristics. For example, respondents with a college degree, with children and a membership in an environmental organization are willing to pay £45.54 (st. er. 10.49) in addition to their electricity bill for a policy that decreases the GHG emissions by 1%, while respondents with a college degree, no children and no membership in any environmental organization are willing to pay £9.77 (st. er. 3.96) for the same policy. Model 2 can also be used to study the impact of having children in valuing energy shortages: a respondent with children is willing to pay £0.52 (st. er. 0.13) in addition to his electricity bill for a policy that decreases energy shortages by 1 minute per year, while a respondent without children is willing to pay only £0.31 (st. er. 0.07) for the same policy.

Results from Model 2 can also be used to estimate the WTP for the effects of specific policies for the promotion of renewable energy. Table 8 reports the WTP for five different policies characterized by different effects on the reduction of GHG emissions, blackouts and employment in the energy sector. For example, our respondents are on average willing to pay about £32 for a policy for the promotion of renewables that reduces GHG emissions by 0.5% a year, limits energy shortages to 45 minutes per year and maintains the current level of employment in the energy sector.

Table 8 should be approximately here

Comparing Policy D and Policy E helps to investigate whether our respondents consider more important to internalize external costs affecting human health and the environment than guaranteeing energy security (Hypothesis II). Policy D gives more importance to energy security, keeping the current level of reduction of GHG emissions, while Policy E gives more importance to the reduction of GHG emissions, keeping the current level of energy shortages; both policies keep the number of jobs in the energy sector constant. Our respondents are willing to pay about £22 for a policy that, even though does not improve on GHG emissions reductions, limits energy shortages to 30 minutes a year, while are willing to pay about £15 for a policy that decreases GHG emissions by 0.5% per year, but maintain the current level of energy shortages. This result seem to suggest that our respondents do consider energy security as an important externality and value an average reduction in energy shortages of one hour per year more about 50% more than a decrease of 0.5% in GHG emissions.

It is also interesting to note that the prices of £22.11 for policy D and of £14.82 for policy E are the prices that make our respondents indifferent in a choice set that entails the two policies D, E and the status quo. By using equation (2) we can further calculate the probability of selecting policy D, if this was offered at £14.82. In this case, the probability of selecting policy D would become 37.4%, while both the status quo and policy E would be chosen with probability equal to 31.3%. We can further see that by rising the minutes of blackout of policy D to 50, brings back the probabilities of selecting D, E or the status quo to 33.33% each. This suggests that our respondents would be indifferent to (i) paying £14.82 for a policy that would not cut the GHG emissions but would limits energy shortages to 50 minutes per year, (ii) paying £14.82 for a policy that would cut GHG emissions by 0.5% per year, but would make no efforts in reducing energy shortages, (iii) not paying any additional electricity bill increase

for maintaining the status quo. This simple example shows how Model 2 can be used for simulating policy scenarios.

## **6. Discussion and conclusions**

It is of considerable interest to policy makers to know how much more individuals are willing to pay for renewable energy than for fossil fuel energy. It is also of interest to know what they are paying for – whether it is a public good or whether there is an element of personal benefit associated with it. A number of studies in the UK and US have tried to elicit the additional value of renewable energy and have come up with figures ranging from one dollar a month to as much as \$6.98 (2005US\$). Translating this into reductions in carbon is an approximate exercise and comes up with estimates of \$170 to \$848 (2005US\$) per year per country per ton. Details are given in Table 9 below. In our study we find a willingness to pay equal to \$5,162 for a ton of carbon. This value represents how much *society* in the UK is willing to pay every year for reducing carbon emissions by one ton of CO<sub>2</sub>. These payments have to be seen as a payment for a public good if individuals make the ‘Cournot Nash’ assumption that only they are making the payment. In that case the additional benefits at the personal level are insignificant and the WTP is a gesture of social goodwill. This assumption may, however, be suspect. Perhaps individuals are assuming that the programs of shifting to renewable energy apply to society, in which case there could be important local pollution reduction benefits.

In our study we explicitly assumed that the reduction being paid for was at the national level. Hence there is a public good benefit as well as some personal health benefit. If emissions of GHGs are reduced by one percent, so will associated particles and other health related pollutants and the individual will benefit. Of course, even here, as in the case of the previous studies, there is the potential for free-riding – to state a zero or very low WTP because a large

part of the benefits go to others. Notwithstanding this possibility, the figures of WTP in both sets of studies appear to be significant. Hence the extent of free riding behaviour appears to be limited.

Table 9 should be approximately here

How can these results be reconciled? There are a number of possible explanations. First, our study includes private health benefits, which could be of considerable importance. Studies of ancillary benefits suggest that such benefits are very policy and location specific, and vary between £2 and £334 per ton of carbon reduced, (DEFRA, 2002), and according to the OECD they could be as much as twice the climate change benefits (OECD, 2000). In that event half of the WTP could be for private health benefits of the GHG reductions. Second, our study took place about more than four years after the latest of the earlier studies. In that time awareness of the climate problem has grown and WTP may have risen considerably. Third, our estimates come from a sample of residents of Bath, a quite wealthy area in the UK and may overstate the WTP of the UK population. Fourth, the higher willingness to pay for abating emissions in the UK compared to the results from the US studies might further be explained by the different preferences of the two societies for renewable energy programs and for the internalization of the GHG emissions, a result that mirrors the positions of the two national governments in climate change negotiations.

Finally, it is interesting to see that our estimates for the value of 1 ton of CO<sub>2</sub> abatement are considerably higher than the values found in studies that employ the *abatement cost* method. Most of the results in the abatement cost literature are in the range of 5 to 125 US\$/tCO<sub>2</sub>, but they are also subject to high uncertainty (Tol, 2005). For the UK, in 2002, the Government Economic Service recommended an illustrative estimate for the social costs of carbon of £70/tCO<sub>2</sub>, within a range of £35 to £140/tCO<sub>2</sub>, for use in policy appraisal across Government. A

recent review by DEFRA (2004) suggests to update the estimates range at £12 - £260/tCO<sub>2</sub> for emissions abated in 2010, but it also states that the current modelling reveals that estimates of the social cost of carbon span at least three orders of magnitude, from 0 to over 1000 £/tCO<sub>2</sub>, reflecting uncertainties in climate and impacts, coverage of sectors and extremes, and choices of decision variables. Our results, and the results presented on Table 9, indicate that studies that employ the WTP methodology find estimates for the values of CO<sub>2</sub> emissions much higher than those based on the abatement cost method, suggesting that the benefits to society are substantial, especially when ancillary benefits are considered, as in our study.

Other major results of interest from our study are the following:

- People are ready to pay little extra in order to increase renewable energy through policies that increase employment. Regarding this attribute, it seems that people are more concerned with the loss of jobs than with the gain of new ones. Interventions should, therefore, be careful with losing jobs. We also note that this result is at odds with previous studies (see e.g. Bergmann et al, 2006).
- The WTP to avoid blackouts is in the range of £22 per hour (£0.37 per minute) and is much higher than previous studies that have figures in the range of £1-3 per hour. We need to investigate further the reasons for this high value.

Even though the results from this study have some interesting characteristics, the work was constrained by a lack of budget and was limited to a sample of residents of the city of Bath. Therefore, it would be necessary to undertake wider research in order to understand public opinion over the issue and to promote policies generally accepted by society at a higher level.

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Table 1. Categories of benefits covered by the program for the promotion of renewable energy

	<b>Personal Health</b>	<b>Public Health</b>	<b>Personal Climate Change</b>	<b>Public Climate Change</b>
Roe et al, 2001	No	Yes	No	Yes
Wiser, 2003	No	Yes	No	Yes
Goett et al, 2001	No	Yes	No	Yes
Batley et al, 2001	No	Yes	No	Yes
This study	Yes	Yes	No	Yes

Table 2. Attributes and their levels for the choice experiments

<b>Attribute</b>	<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Level 4</b>	<b>Status quo</b>
Annual reduction in GHG emissions due to renewable energy increase (3 levels)	1%	2%	3%	-	no additional greenhouse gases emissions reduction
Annual length of electricity shortages in minutes (3 levels)	30	60	120	-	current level of black-outs
Change in number of employees in the electricity sector (3 levels)	+1000	-1000	0	-	no employment change in the energy sector
Increase in electricity bill in £ (4 levels)	6	16	25	38	no price increase in the electricity bill

Table 3. Hypothesis tested with our model.

<b>Hypothesis</b>	<b>Description</b>
I	In a policy for the promotion of renewable energy, the number of jobs created or lost does not matter.
II	It is more important to internalize external costs affecting human health and the environment than guaranteeing energy security.
III	Test the internal validity of the responses: WTP increases with income.
IV	WTP is higher for respondents with children.
V	Members of environmental organizations and a college degree positively affect the WTP for a policy for renewable energy

Table 4. Descriptive statistics

Variable (acronym used in regressions)	Sample average or percent (Standard deviation)	Bath and North East Somerset
<i>Individual characteristics</i>		
Age	35.75 (12.52)	38.4 <sup>a</sup>
Annual Income (in £) (INC)	37687.29 (26528.63)	31,000 <sup>b</sup>
Male	51.33%	48% <sup>a</sup>
Have a college degree	22.66%	25.90% <sup>a</sup>
Have children	25.66%	
Member of environmental organizations	22.29%	
Electricity bill (in £)	70.86 (38.78)	
Electric heating	30.33%	
<i>Choice experiments</i>		
Ranking of the attributes		
GHG reduction ranked as 1 <sup>st</sup>	68.33%	
Number of jobs created/lost ranked as 1 <sup>st</sup>	16.67%	
Energy shortages ranked as 1 <sup>st</sup>	6.33%	
Electricity bill increase ranked as 1 <sup>st</sup>	8.67%	
Found the choice experiments difficult (1=very difficult; 5=very easy)	4.166 (0.88)	
Considered all attributes in the choice questions	69.67%	
Attribute mostly considered...		
GHG reductions	21.67%	
Number of jobs created/lost	4.66%	
Energy shortages	1.67%	
Electricity bill increase	2.33%	
<i>Interviewer debriefing questions</i>		
Understood the choice questions	95.66%	
Annoyed by the questionnaire (1= very annoyed; 5=not annoyed at all)	4.47 (0.68)	

<sup>a</sup> Source: National Neighbourhood Statistics - [http://neighbourhood.statistics.gov.uk/dissemination/home.do?\\$ph=60](http://neighbourhood.statistics.gov.uk/dissemination/home.do?$ph=60)

<sup>b</sup> Gross annual household income in the UK. Source: HMRC CACI Paycheck Model 2005.

Table 5. Are the following electricity sources environmentally friendly?

	Our survey			ExternE (2003)
	YES	NO	Don't Know	
Biomass	38.00%	36.33%	24.67%	“There are dozens of different biomass technologies, and depending on the care given on gas cleaning technologies, the biomass options can range from low to high external costs.”
Nuclear	20.33%	70.33%	9.33%	“Nuclear power in general generates low external costs, although the very low probability of accidents with very high consequences and the fuel cycle impacts are included. It is also a technology with very low greenhouse gas emissions.”
Gas	31.00%	52.00%	17.00%	“Gas-fired technologies are quite clean, with respect to classical pollutants, but their impact on climate change depends strongly on the efficiency of the technology.”
Hydro	93.67%	3.00%	3.33%	Hydropower exhibits low external costs of all systems, but they may increase on sites where higher direct emission of GHG from the surface of reservoir occurs (ExternE-Pol, 2005).
Oil	3.33%	90.33%	6.33%	Oil has high external costs due to air pollution with impacts on global warming and human health. Introduction of advanced technology (Combined Cycle) substantially reduces the external costs of fossil systems (ExternE-Pol, 2005).
Solar	99.00%	0.67%	0.33%	“Photovoltaics is a very clean technology at the use stage, but has considerable life cycle impacts.”
Wind	96.33%	3.33%	0.33%	“Wind technologies are very environmental friendly with respect to emissions of "classical" pollutants (SO <sub>2</sub> , NO <sub>x</sub> , dust particles) and with respect to greenhouse gas emissions.”
Coal	3.67%	92.67%	3.67%	“Coal technologies carry the burden of their very high CO <sub>2</sub> emissions, even for new, more efficient technologies, and in addition cause quite high impacts due to the primary-secondary aerosols.”

Table 6. Conditional logit model estimates

	Model 1		Model 2	
	Coeff.	t-stat	Coeff.	t-stat
A_Alt.1	2.0498	12.90	2.1290	13.12
A_Alt.2	1.9786	12.77	2.0488	12.95
GHGREDUCTION	0.6804	7.29	0.4437	3.78
BLACKOUT	-0.0088	-7.45	-0.0055	-3.09
JOBS	0.0006	6.69	0.0007	4.98
PRICE	-0.0224	-3.34	-0.0244	-3.58
AGE*JOBS			-0.0046 <sup>a</sup>	-1.33
INCOME*BLACKOUT			-0.0006 <sup>b</sup>	-1.70
INCOME*GHGREDUCTION			0.0453 <sup>b</sup>	2.84
ENV_MEMBER*GHGREDUCTION			0.4872	4.83
COLLEGE*GHGREDUCTION			-0.3755	-4.02
CHILD*GHGREDUCTION			0.3380	3.30
CHILD*BLACKOUT			-0.0050	-2.38
Loglikelihood	-1358.72		-1297.47	
Observations	1722		1692	

a The coefficient of (AGE\*JOBS) has been multiplied by 1,000.

b The coefficients of (INCOME\*BLACKOUT) and (INCOME\*GHGREDUCTION) have been multiplied by 10,000.

Table 7. Implicit Prices in British Pounds (standard error in parenthesis)

	Model 1	Model 2 <sup>a</sup>
GHGREDUCTION	30.39*** (6.10)	29.65*** (5.50)
BLACKOUT	-0.39*** (0.09)	-0.36*** (0.08)
JOBS	0.02*** (0.00)	0.02*** (0.00)

\*\*\* significant at the 1% level

<sup>a</sup> calculated at the mean values of the socio-demographic characteristics of the respondents

Table 8. Willingness to pay for selected hypothetical policies in British Pounds

	Policy A	Policy B	Policy C	Policy D	Policy E
GHGREDUCTION	0.5%	No improvement	0.5%	No improvement	0.5%
BLACKOUT	45min	60min	30min	30min	90min
JOBS	const	+ 1,000	- 1,000	const	const
WTP	32.19***	34.78***	13.21***	22.11***	14.82***
(standard error)	(6.29)	(6.47)	(4.00)	(4.76)	(2.75)

Table 9. Implied society's WTP for reducing emissions by one ton of CO<sub>2</sub> per year (all the prices are in 2005 US\$).

Study	Country	Year of the survey	Program	Households' WTP	Total WTP/year <sup>c</sup>	MTons of CO <sub>2</sub> reduction/year <sup>d</sup>	Implied WTP per ton CO <sub>2</sub> per year per country (in 2005 US\$)
Roe et al, 2001	USA	1997	WTP for 1% air emissions reduction	\$0.99 per month <sup>a</sup>	\$1,365.3 Million	8.02	\$170.15
Wiser, 2003	USA	2001	WTP for renewable sources	\$3.31 per month	\$4,552.6 Million	17.77	\$256.10
Goett et al, 2001	USA	2000	WTP for 25% of energy is renewable coming from wind and hydro	\$6.98 per month	\$9,597.2 Million	17.77	\$539.87
Batley et al, 2001	UK	1997	WTP for renewable sources	\$3.69 per month <sup>b</sup>	\$2,645.4 Million	3.12	\$847.93
Longo, Markandya and Petrucci, 2006	UK	2005	WTP for 1% GHG emissions reduction	\$17.21 per month	\$5,368 Million	1.04	\$5,162

<sup>a</sup> WTP for the median respondent leaving in the Northeast of the US, with high school degree and no environmental organization membership

<sup>b</sup> WTP calculated as 16.6% increase in the electricity bill (DTI, 2003a).

<sup>c</sup> Total WTP was calculated as (Households' WTP)/(number of persons in a household)\*(population of the country)

<sup>d</sup> We calculated the MTons of CO<sub>2</sub> reductions by year in the following way:

for Roe et al, we considered a 1% reduction in US Mtons emissions from the 2001 levels: 5,500Mtons\*0.01

for Wiser et al, and Goett et al, we assumed that the proposed program would bring an increase of renewable energy of 2% *per year*, which is consistent with government programs of stimulation of renewable energy. The figure of 17.7 Mtons comes from the CO<sub>2</sub> contribution of one kWh of energy (0.00606) multiplied by the average kWh consumed in the US by each person (4922) multiplied by the number of citizens living in the US (298M), multiplied by 2%, the increase in annual renewable energy (see <http://www.carbonfund.org/assumptions.php>).

for Batley et al, we assumed that the increase in renewable energy would lead to a 3% decrease in the 2001 levels of UK emissions: 104Mtons\*0.03 (DTI, 2005)

in our study, the total emissions reductions was calculated as: 104Mtons\*0.01

Figure 1. Example of choice experiments question.

<b>Characteristics</b>	<b>Policy A</b>	<b>Policy B</b>	<b>Neither</b>
Greenhouse Gases emissions	3% reduction per year	1% reduction per year	no additional greenhouse gases emissions reduction
Black-outs	30 min per year	60 min per year	current level of black-outs
Employment	0 new jobs	-1,000 jobs	no employment change in the energy sector
Price	£25 per quarter	£6.5 per quarter	no price increase in the electricity bill

Which policy would you choose?

☐
☐
☐



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