Can renewable energy be financed with higher electricity prices? Evidence from a Spanish region[#].

Azucena Gracia[1], Jesús Barreiro-Hurlé (*) [2] and Luis Pérez y Pérez[1].

Abstract: In this paper we estimate the willingness to pay for mix of renewable sources of electric power by means of a discrete choice experiment survey conducted in Spain in 2010. Two main categories of power supply attributes are explored: source of renewable power (wind, solar and biomass) and the origin of such power. The findings suggest that most consumers are not willing to pay a premium for increases in the shares of renewable in their electricity mix. For two of the three renewable sources considered (wind and biomass) an increase of the renewable mix would require a discount. Instead, we record positive willing to pay for increases in the share of both solar power and locally generated power. However, preferences for types of renewable (solar and wind) are found to be heterogeneous. By classifying respondents in two groups according to the implied importance of the share of renewable sources in their power mix we identify a market segment consisting of 20% of respondents that could promote renewable energy in the absence of subsidies. This is because such a segment shows willingness to pay higher than the current feed-in tariffs.

Keywords: Aragon, discrete choice experiment, consumer preferences, heterogeneity, willingness to pay

(*) Corresponding Author

[1] Unidad de Economía Agroalimentaria y de los Recursos Naturales. Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Gobierno de Aragón. Avda Montañana 930, 50059 Zaragoza, Spain. Phone: +34-976-716350. Fax:+34-976-716335. E-mail: agracia@aragon.es; lperez@aragon.es.

[2] Agricultural Development Economics Division. FAO-UN. Via delle Terme di Caracalla, 00153 Roma, Italia. Phone +39 06 5705 3923. E-mail: jesus.barreirohurle@fao.org

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Can renewable energy be financed with higher electricity prices? Evidence from a Spanish region.

1. Introduction

Climate change is considered to be one of the most serious threats to humankind as it will severely impact on growth and development in the mid and long term (Stern, 2007). Greenhouse gas (GHG) emissions have been identified as one of the main causes of climate change and the reduction thereof has been set as a global priority. In 2008, the European Union (EU) committed to reduce greenhouse gas emissions by 20% by 2020 as compared to 1990 levels and in 2009 adopted the so called climate and energy package. It is widely accepted that the power sector, which accounts for about one-third of Europe's total energy-related GHG emissions, must play an important role in the efforts to achieve the EU's GHG reductions goals. The use of renewable energy sources in the production of electricity is one the technological and societal means to achieve this goal. Moreover, renewable energy sources contribute to the diversification of energy supply, the promotion of local power generation and to reducing dependence on a limited number of energy sources (i.e. oil). Taking this into account, the EU, in its 2009 Directive on the promotion of the use of energy from renewable sources (EC, 2009), established mandatory targets for an overall 20% share of renewable energy source of all energy consumption by 2020[2].

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[2] The overall 20% target has been translated into individual targets for each Member State (e.g. 20% for Spain; 30% for Denmark).

Technological developments in the field of renewable energy and strong public support have led to a remarkable increase in their supply. Yet, the increases in the share of renewable sources in the electricity supply mix is limited, among other things, by the higher financial cost of production making many of the renewable sources economically unviable unless supported by public subsidies. Even the most price competitive renewable energy source in Spain (i.e. inland wind power) will not break even with existing electricity prices before 2017 assuming a 27% effective working rate (PER 2011-2020). However, as Stern (2007) pointed out, if the overall cost and risks of climate change were taken into account, the benefits of reducing GHG far outweigh the costs. Conventional energy production which emits GHG in the process has additional external costs that are not taken into account. If it were taken into account, the total cost of conventional energy production would be higher making renewable energy more competitive.

The percentage of electricity from renewable energy sources in gross electricity consumption in 2007 was 15.5% for the EU27 and 20% for Spain (European Commission, 2010), with figures for Spain showing that this share has risen to 32.3% in 2010 (MITYC, 2011). These figures reflect both the high potential of Spain to produce energy from renewable sources, mainly wind and solar power due to the country's geography and climatic conditions, and the success of the feed-in tariffs in place. In 2007 the average electricity price for households (all taxes included) was of 14.5 and 11.3 € cents per kWh in the EU-27 and in Spain respectively (Goerten and Ganea, 2010). Although Spain is on the path to reach the EU 2020 goals for renewable energy, further developments in renewable energy generation could be stimulated by using price as a financial incentive if a positive public attitude and a willingness to pay for higher renewable energy source in the electricity mix is in place. This is precisely the goal of this paper, to analyse consumer willingness to pay for renewable energy electricity in Spain.

Several studies have been conducted to analyze either attitudes towards renewable energy or the willingness to pay for renewable energy programs or investments (Hanley and Nevin, 1999; Bang *et al.,* 2000; Batley *et al.,* 2001; Alvarez-Farizo and Hanley, 2002; Rowlands *et al.,* 2003; Ek, 2005; Goosling *et al.,* 2005; Ladenburg and Dubgaard, 2007; Whitehead and Cherry, 2007; Bergmann *et al.,* 2008; Hansla *et al.,* 2008; Koundouri *et al.,* 2009; Dimitropoulos and Kontoleon, 2009; Scarpa and Willis, 2010; Meyerhoff *et al.,* 2010; Zografakis *et al.,* 2010; Krueger et al., 2011). However, a limited number of empirical studies have been carried out to study the willingness to pay for electricity from renewable sources. Most of them have found a positive WTP for renewable electricity, but while some of them explore WTP for generic renewable energy (Zarnikau, 2003; Nomura and Akai, 2004; Wiser, 2007; Bollino, 2009) or renewable energy from a specific source such as wind or forest biomass (Champs and Bishop, 2001; Soliño *et al.,* 2009a; Soliño *et al.,* 2009b; Soliño *et al.,* 2010; Soliño, 2010), few of them assess the WTP for renewable energy based on a broad scope of attributes and/or sources which may provide it (Goett *et al.,* 2000; Roe *et al.,* 2001; Bergmann *et al.,* 2006; Borchers *et al.,* 2007; Longo *et al.,* 2008)[3].

[3] See Menegaki (2008) and Johnson and Nemet (2010) for a comparative revision of renewable energy valuation studies

Bergmann *et al.* (2006) and Longo *et al.* (2008) assess WTP for environmental and social attributes of electricity from renewable sources (such as wildlife, pollution, GHG emissions, employment generated, etc.) in Scotland and England, respectively. In addition to environmental and social attributes of the electricity supply, Goett *et al.* (2000), Roe *et al.* (2001) and Borchers *et al.* (2007) added to the choice set other attributes such as contract terms, source mix, quantity generated by renewable energy, customer services or community base of the supplier, for an analysis carried out in the USA. Our work is similar to these last three studies but in addition provides an insight into consumer valuation of renewable energy sources in two different ways: First, we attempt to overcome the limitation pointed out by Roe *et al.* (2001) of their study, namely that of estimating WTP for changes in a single renewable or fossil fuel energy source. To address this we expand on the approach followed by Goett *et al.* (2000) and Borchers *et al.* (2007). These studies assess the WTP for different sources of renewable energy defining a single attribute for the type of source and one for the quantity of electrical usage generated by all of them together. Each of the individual energy sources (wind, solar, biomass, etc.) are taken as different levels of a "*type of source*" attribute. In our study, each individual renewable energy source (i.e. wind, solar and biomass) are considered as different attributes and their level is defined as the percentage of the total electrical use generated by the specific source. The *status quo* option corresponds with the current mix of renewable sources available for respondents in their electricity contract and therefore we can interpret WTP estimates as increases in the electricity bill, i.e. the premium a consumer will pay to increase the share of renewables in the overall electricity mix. This approach allows us to estimate the perceived value of each of the individual energy sources in relation to the overall value of the current electricity generation mix. Second, the study is conducted in a different geographical and regulatory setting, thus providing an additional insight on how to implement the transition to a low carbon energy mix.

For this purpose we use a choice experiment to elicit consumer WTP for electricity service attributes: the different renewable sources (wind, solar and biomass) combined with the regional origin of the electricity produced. The choice experiment was administered to a representative sample of electricity users in the city of Zaragoza (Spain) during July 2010. The paper is structured as follows: Section 2 directly below outlines the study methodology followed by a description of the survey and choice experiment design in section 3. In the following sections we describe data collection, the results and key findings and their economic implications, following which, in section 6, we look at the broader implications for the field.

2. Stated preference theory and discrete choice experiment

The theoretical model is based on the Lancastrian consumer theory of utility maximization (Lancaster, 1966), and consumers' preferences for attributes are modeled within a random utility framework (McFadden, 1974). Lancaster (1966) proposes that the total utility associated with the provision of a good can be broken down into separate utilities for their component characteristics or attributes. However, this utility is known to the individual but not to the researcher. The researcher observes some attributes of the alternatives but some components of the individual utility are unobservable and are treated as stochastic (Random Utility Theory). Thus, the utility is taken as a random variable where the utility from the n[th] individual facing a choice among *j* alternatives within choice set *J* in each of *t* choice occasions can be represented as,

$$U_{njt} = \beta'_n x_{njt} + \varepsilon_{njt} \quad (1)$$

where β_n is the vector of parameters which deviates from the population mean β by the deviation parameters η_n, x_{njt} is a vector of explanatory variables that are observed by the analyst in choice occasion *t* and ε_{njt} is an unobserved random term that is distributed following an extreme value type I (Gumbel) distribution, i.i.d. over alternatives and independent of $\beta_n^{'} x_{njt}$, that is known by the individual but unobserved and random from the researcher's perspective. Consumers are assumed to choose the alternative which provides the highest utility level from those available. Instead of assuming homogenous preferences, which results in the classic conditional logit model, we assume that preferences are heterogeneous, in other words, individuals differ from each other in terms of intensity of taste, and thus we seek to obtain estimates of the means and standard deviations of each random taste parameter. We then employed a Random Parameters Logit Model (RPL) considering a panel structure to take into account the fact that four choices were made by each individual (Train, 2003). From the population estimates obtained from the RPL model, posterior estimates of individual means and standard deviations can be obtained for each sample respondent. However, to specify models more in accordance with consumer preferences and with better statistical properties additional modeling issues need to be taken into account. In particular in this study correlations across utilities, across taste parameters and discontinuous preferences are investigated.

2.1. Correlation across utilities

In our application, the choice experiment design consists of two hypothetical alternatives and a *status quo* situation describing the current electricity mix. The *status quo* is actually experienced by the consumer while the experimental options are hypothetical and vary across choice tasks. Thus, the utilities of the hypothetical options are likely to be more correlated between them than with the *status quo* and have a higher variance than the utilities of the *status quo*. In effect, the experimental alternatives share an extra error component, which is missing in the utility of the *status quo* alternative (Scarpa *et al.,* 2007). To succinctly capture the extra variance of experimentally designed alternatives, Scarpa et al. (2005) suggested the inclusion of an additional error component in the mixed logit model (Error Component Mixed Logit) that has been used in several empirical applications (Campbell, 2007; Scarpa et al., 2007;, Hess and Rose, 2009; Scarpa et al., 2008; Hu et al., 2009; Jacobsen and Thorsen, 2010). This model has been very successful because it is parsimonious (it only requires one extra parameter) and has empirically been found to substantially improve model fit. Thus, we also estimate an Error Component Mixed Logit to test whether correlation across utilities exist.

2.2. Correlation across taste parameters

In the standard RPL taste parameters are assumed to be random but independently distributed. However, depending on the attributes under study, we can expect that some attributes may be inter-dependent. To take this into account, the correlation structure of β_n is assumed to follow a multivariate normal distribution (normal with vector mean μ and variance-covariance matrix Ω). If at least some of the estimates for elements of the Cholesky matrix C (where C'C= Ω) show statistical significance, then the data are supportive of dependence across tastes (Scarpa and Del Giudice, 2004).

2.3. Discontinuous preferences

A basic assumption within the discrete choice experiment framework is that of substitutability between the attributes used to describe the alternatives in the choice set. This implies that respondents make trade-offs between all attributes across each of the alternatives, and are expected to choose their most preferred alternative without ignoring attributes in the choice set (Campbell *et al.,* 2008). Ignoring attributes in the choice set implies non-compensatory behaviour because no matter how much an attribute level is improved—if the attribute itself is ignored by the respondent—then such improvement will fail to compensate for worsening in the levels of other attributes (Spash 2000; Rekola 2003; Sælensminde 2002; Lockwood 1996). Therefore, without continuity, there is no trade-off between two different attributes, a key issue when computing the marginal rate of substitution between the attributes. With discontinuous preferences, the marginal rate of substitution can be derived from the estimated parameters at the sampled population level, but it is not computable for individual respondents who do not make trade-offs between the attributes.

Discontinuous preferences are likely to be an indication that there are some attributes within the choice set that are not relevant to certain respondents, i.e. these respondents are indifferent to the attributes in the choice set which they ignore[4]. Empirical evidence (Campbell *et al*., 2008; Hensher and Rose, 2009; Carlsson *et al*., 2010; Espinosa-Goded and Barreiro-Hurle, 2010) seems to corroborate that collecting information on attribute non-attendance is useful because it tends to improve statistical fit and provides a sensitivity analysis of welfare measure estimates. Attribute non-attendance can be either serial (i.e. not paying attention to an attribute during the full valuation process) or choice-task specific (i.e. not paying attention to some attributes in making a specific choice). In addition, non-attendance can be captured in two ways: respondent-reported non-attendance and analytical (or inferred) non-attendance (Scarpa *et* al. 2011). In our study respondents were asked at the end of all choice tasks to indicate which of the attributes they have taken into account when making their choices. Thus we consider attribute non-attendance as serial[5] and captured as respondent-reported. As there is some evidence regarding consistency between self-reported and inferred attribute non-attendance (Scarpa *et al*., 2010; Campbell and Lorimer, 2009; Espinosa-Goded and Barreiro-Hurle, 2010) we have considered a modeling strategy that allows for coefficients from individuals who

[4] There is a range of other factors that may give rise to discontinuous preferences in discrete choice experiments: *i)* the choice tasks require a significant cognitive effort; *ii)* cognitive ability of the respondent; *iii)* lack of knowledge; *iv)* fatigue; *v)* learning effects; vi) the strength of attitudes, beliefs, or dispositions that the respondent holds; and *vii)* other demographic, social and economic characteristics of the respondent.

[5] Scarpa *et al.* (2010) evaluate whether the introduction of information on choice task non-attendance in the choice modeling increase model fit comparing to the introduction of serial attribute non-attendance. They found that accounting for effects of choice task attribute non-attendance improves the statistical model performance. However, at the time of the questionnaire design we did not introduce a choice-task specific attribute non-attendance question.

declare attribute non-attendance to be different from zero. Discontinuous preferences are taken into account introducing additional variables in the specification of the utility function. A dummy variable based on the response to a follow-up question whether or not the attribute was considered by the respondent is added for each of the non-monetary attributes. This allows us to take into account serial non-attendance by including them as interaction terms with the attributes in the utility function.

3. Survey design

3.1. Questionnaire design

The questionnaire used in the study was developed based on information gathered from *i)* an interview with experts on energy matters; *ii)* two consumer focus groups; and *iii)* a pilot test involving 20 respondents. At the onset of our research, a total of ten experts on renewable energy participated in an interview to gain an understanding of the current trends and key issues related to renewable energy development. The interviews were conducted using a semi-structured questionnaire that included four blocks of open questions for discussion as follows: *i)* characteristics and current situation of electricity from renewable sources; *ii)* an estimate of the development of renewable energy sources in the future and possible degree of compliance with targets set by the European Union and Spain; *iii)* production costs of electricity from renewable sources and; *iv)* consumer attitudes towards renewable energy sources. These interviews were conducted with experts covering three geographical regions: the European Union, Spain and the region of Aragon; and three different economic agents: producers, distributors and operators (public and private). Results from these interviews were used to develop a group of questions included in the consumer questionnaire and to develop a first draft with both closed and opened-ended questions. A focus group of 14 individuals was used to refine both sets of questions and to establish the most important attributes of the electricity service. With this input, a second draft questionnaire was developed and tested with a new focus group of 15 consumers. This second focus group provided new information on the most important electricity service attributes. The resulting, refined questionnaire was then validated with a pilot survey of 20 consumers.

In the questionnaire, respondents were first asked a screening question on whether he or she was the responsible person for paying the electricity bill in his or her household. The interview was only conducted if a positive answer was provided to this question. Selected respondents were asked about their electricity provider and the current cost of their monthly electric service. They were also asked questions related to their knowledge of and attitudes to renewable energy, their concern with environmental issues, their socio-demographic characteristics (i.e. gender, family size and composition, age, educational level, income range) and lifestyle. The questionnaire includes the choice experiment question and the follow-up question for preference discontinuity which is defined in the next section.

3.2. Experimental design

The first step in implementing a choice experiment is to select the attributes and levels to be used. The selected attributes should be relevant to the problem under analysis, realistic, believable and easy to understand by the average respondent (Bateman *et al.,* 2002; Bergmann *et al.,* 2006). To meet these requirements, results from the expert interviews and consumer focus groups are highly relevant. In order to understand consumer demand for electricity, respondents in the interviews and focus groups were asked to indicate which characteristics of the electricity service they value the most. The characteristic mentioned by most people was price. The second most important characteristic was that of the renewable origin of the electricity and the third the geographic origin. Some respondents also mentioned the quality of the service but as many different issues were associated with this concept (regular supply, customer service, good information, etc.) it was impossible to identify a single attribute to capture all. Therefore, besides price, the selected attributes for the choice experiment are the different renewable electricity sources and the geographic origin of the electricity. Hyrdopower was discarded as a possible renewable source to be expanded in Aragon based on expert opinion that the capacity in the region is considered to already be very high, as well as the fact that consumers in the focus groups demonstrated strong concerns against additional hydropower projects[6]. Therefore the final attribute selection for renewable energy sources included wind, solar and biomass. All the attributes were defined using four levels, except for that of the geographic origin which has two levels. Table 1 shows the attributes and the levels used.

[6] There are 101 functioning hydropower plants in Aragón (over 50% of total installations excluding solar) with a total capacity of 1,575 MW (23% of installed capacity). This shows a relative specialization in hydropower which only accounts for 17% of installed capacity.

Table 1. - Attributes and levels used in the choice design

Attributes	Levels	*Status quo*
Price (€ per kWh)	0.17; 0.21; 0.24 and 0.28	0.14
% of electricity from wind	16%; 18%; 21%; and 26%	13%
% of electricity from solar	6%; 10%; 14%; and 18%	2%
% of electricity from biomass	2%; 3%; 5%; and 6%	1%
Region of origin	Regional (Aragon) Unknown origin	Unknown origin

To address the primary goal of this paper, are consumers willing to pay for renewable, the payment vehicle selected was the price of kilowatt hour (kWh) in the electricity bill. At the time of the survey, the price per kWh in Spain for households was 0.14 €. The increments from this price were set using an increase of approximately 25% per level to reach the highest level with a price double that of the current one (0.17 €/kWh; 0.21 €/kWh; 0.24 €/kWh and 0.28 €/kWh[7]). To fix the levels of the different renewable electricity sources we started with the current Spanish electricity mix. The *status quo* in 2010 was that of 26% from renewable (13% from wind power; 10%, from hydro-electric; 2% from solar and 1% from biomass) and 74% from non-renewable sources. In addition to the *status quo*, four incremental levels were set based on the decarbonisation target scenarios of the of the

[7] Even when the upper level for the price vector doubles the current electricity price the focus groups did not discard it in their discussions. Moreover, we find that 27% of respondents choose at least once an option with this electricity price. These respondents show a significantly higher income level that the rest of the sample.

power sector outlined in the Roadmap 2050 (www.roadmap2050.eu) and the results obtained from the expert interviews described above. The Roadmap 2050 project provides an extensive technical, economic and political analysis of different scenarios for the production of electricity from renewable sources to achieve a low-carbon economy in Europe with the goal of reducing total greenhouse gas emissions by 90% in 2050. The different scenarios assume percentages of electricity from renewable source set at 40%, 60% and 80% of the total electricity mix. For wind energy, it is assumed that in the future the percentage in the mix of electricity will double; this sets the highest level of the attribute at 26%. Sequential increases representing approximately 20% of increment from the previous levels have been assumed to calculate the values for the different levels (16%; 18%; 21%; and 26%). For solar power, the Roadmap forecasts an increase to a maximum of 19% of total supply. In our study, we have set the highest level of the attribute at 18%. Intermediate levels have been set at 6%; 10%; 14%; and 18%. Finally, although the current share for biomass at EU level is 8% and projections show a share of up to 12%, the degree of uptake and its development prospects in Spain are less promising. Therefore, assumptions were based on statements collected from experts during the interview process which foresee a maximum contribution from biomass of 6% of the total electricity mix. The previous levels have been increased by approximately 50% in order to obtain the four levels of the attribute (2%; 3%; 5% and 6%). Finally, the attribute of geographic origin has two levels: one showing that electricity is produced in the region of Aragón and the other that of unknown origin of the electricity.

The choice set design was created following Street and Burgess (2007)[8]. As our goal was to estimate main effects only[9], the profiles in the first option were designed using an orthogonal main effect plan (OMEP) which results in an optimal choice set design (Street *et al.,* 2005). The orthogonal main effect plan has been calculated from SPSS orthoplan resulting in 32 profiles. The second option in the choice sets is then created adding one of the generators deriving from the suggested difference vector (1, 1, 1, 1, 1) by Street and Burgess (2007) for 5 attributes with 4, 4, ,4 ,4 and 2 levels, respectively, and two alternatives. We obtain 32 pairs and this design is 94.9% D-efficient compared with the optimal design[10]. To avoid fatigue effects associated with multiple scenario valuation tasks, the 32 choice sets were randomly split into 8 blocks of four choices. Thus, each respondent was asked to make four choices with 50 respondents per block.

A description of the choice experiment was presented to participants showing the selected attributes and levels for each of the electricity supply options. Our application uses what in Carson and Louviere´s terminology is defined as a generic discrete choice experiment with a multinomial choice sequence (Carson and Louviere, 2001). Interviewees face multiple choice sets which include three alternatives: two unlabeled alternatives consisting of the designed electricity supply

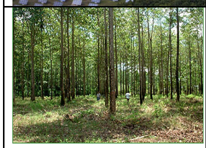
[8] Vermeulen *et al.* (2011) have proposed a Bayesian optimal design which leads to marginal WTP estimates that are substantially more accurate than those produced by other designs. However, at the time of undertaking this research we were not aware of such design.

[9] As a reviewer pointed out the origin attribute could be capturing some of the external effects of renewable energy sources. A design that allowed for the identification of two-way interactions could have allowed us to test this. We come back to this issue in the discussion of our results.

[10] To evaluate how the design performed given our data we compare the D-error from the Street and Burgess design (0.0013) with the D-error from our data (0.0042). The latter has been calculated using the asymptotic variance and covariance matrix from the basic MNL model (Scarpa and Rose, 2008).

options and the *status quo* corresponding to the actual price per kWh, electricity mix and geographic origin. The choice sets were presented using graphical aids as shown in Figure 1.

Figure 1. Sample choice set (translated as original is in Spanish)

	1 – Block # 1	Option A	Option B	Status Quo
€	Price per kWh	0,21 €	0,24 €	Actual price 0,14 €
	% electricity generated from WIND	18%	21%	13%
	% electricity generated from SOLAR	6%	10%	2%
	% electricity generated from BIOMASS	5%	6%	1%
	Place were renewable electricity is generated	Aragón	Not specified	Not specified
	I would choose:	Option A ☐	Option B ☐	Neither option A or B ☐

As mentioned this study also considers preference discontinuity and thus a follow-up question was introduced to test whether respondents considered all attributes or just a sub-set. In order to address this, at the end of all choice tasks, respondents were asked to indicate which attributes they had taken into account when making their choices in the experiment.

4. Data Collection

Data was collected from a survey conducted in Zaragoza, a medium-sized town located in northwest Spain (Aragon region), during July 2010. Zaragoza is a town widely used by food marketers and market research consulting companies as the socio-demographics are representative of the Spanish Census of Population (Annex I). Target respondents were adults who receive and are responsible for paying an electricity bill as this is the payment vehicle of the experiment. The questionnaire was administered face-to-face by a single interviewer who also attended the focus groups and was extensively briefed by the research team. Weekly follow-up meetings were arranged in order to identify any problems with the survey, however no major problems were detected and the process was maintained throughout the whole interview period. A stratified random sample of consumers was made on the basis of district and age. Sample size was set at 400, resulting in a sampling error of ±5%, and a confidence level of 95.5% when estimating the proportion of individuals choosing one of the hypothetical options (p=q=0.5; k=2). The interviewer selected and approached individuals randomly, asking them one screening question: whether they are the responsible for paying an electricity bill. In the case of a negative response, interviewers randomly selected another customer belonging to a given age group, until they obtained a positive response to the question. Although the individuals that declined to participate in the questionnaire were not recorded, non-response was never highlighted as an issue during the weekly debriefs.

Summary statistics for the characteristics of the sample are presented in table 2. About half of the respondents were female (53%) with an average age of 46 years and a mean household size of 3. Approximately 30% of respondents stated that their household monthly net income was between € 1,500 and € 2,500 and half of the respondents had university degrees. 11% of households had children under the age of 6, and 20% of households included elderly individuals. As shown in table 2 our sample differs from the general population for age and education level. However as shown below these socio-demographics do not affect segment characterization and thus results can be considered representative of the overall population.

Table 2. Sample characterization (*% unless stated otherwise)*

Variable	*Sample*	*Population*	*Test (h0 = values equal)*
Gender[1]			0.25
Male	47.3	49.9	
Female	52.8	50.1	
Age[1] (Average from total sample)	46.7	49.9	-4.25
Education of respondent[1]			28.39
Elementary School (1)	18.5	34.1	
High School (2)	29.8	41.4	
University (3)	51.8	24.4	
Average Household monthly net Income[2,3]			
Below 600 € (750 €)	4.3	12.0	
Between 600 and 1,500 € (750 and 1,167 €)	15.8	10.9	
Between 1,501 and 2,500 € (1,168 and 1,583 €)	29.5	15.1	
Between 2,501 and 3,500 € (1,584 and 2,083 €)	17.8	15.6	
Between 3,501 and 4,500 € (2,084 and 2,917 €)	11.8	21.4	
More than 4,500 € (More than 2,917 €)	21.0	25.0	
Household Size (Average from total sample)	3.1	Na	
Household with children less than 6 years old (1=Yes)	11.0	Na	
Household with adults more than 65 years old (1=Yes)	20.0	Na	

[1] Population information from IAEST (2010)
[2] Population information from INE (2008)
[3] Test for differences in average household cannot be undertaken due to different cut-off values in sample and population.
Chi-square test for gender and education and t-test for age
Na: not available

5. Results

5.1 Estimated utility parameters and willingness to pay

In the final specification of the utility function in addition to the attributes, an alternative-specific constant associated with the *status quo* (ASC_{sq}) was introduced. The utility function is then specified as follows:

$$U_{njt} = ASC_{sq} + \beta_1 PRICE_{njt} + \beta_2 WIND_{njt} + \beta_3 SOLAR_{njt} + \beta_4 BIOMASS_{njt} + \beta_5 REGION_{njt} + \varepsilon_{njt}$$

where, *J* denotes each of the three options available in the choice set and ASC_{sq} is a dummy variable describing the *status quo* alternative. The price variable represents the kWh price levels given to consumers for each electricity supply option. The variable representing the different renewable sources (WIND, SOLAR and BIOMASS) are the different percentage levels of contribution to the electricity mix given to consumers (Table 1). The geographic origin is an effect-coded variable (REGION). As we assume that renewable energy electricity is considered a desired good by consumers it is expected that the ASC_{sq} would be negative and significant, indicating that consumers will obtain greater utility from the designed alternatives (A and B) than from the *status quo*[11]. All coefficients, except for that of price are allowed to be random following a normal distribution, but only those with significant standard deviation are maintained random in the presented results. Price is expected to have a negative impact on utility while the effects of the other variables are the focus of interest here. All estimations were conducted using NLOGIT 4.0.

[11] All options have higher levels of renewable sources in the energy mix than the *status quo*.

Table 3. Results for different model specifications of the choice experiment.

	Model [1]	Model [2]	Model [3]
Mean Values			
ASC_{sq}	-2.8417	-1.9651	-2.0799
	(-8.52)	(-4.04)	(-4.23)
PRICE	-26.1670	-22.004	-21.7189
	(-11.72)	(-11.56)	(-11.19)
WIND	-0.0753	-0.0426	-0.0771
	(-2.80)	(-1.97)	(-2.99)
$WIND*DCON_W$			0.1556
			(3.18)
SOLAR	-0.0192	0.0760	0.0654
	(-0.72)	(4.72)	(3.64)
$SOLAR*DCON_S$			0.0754
			(1.93)
BIOMASS	-0.1519	-0.0870	-0.0956
	(-2.52)	(-2.18)	(-2.25)
$BIOMASS*DCON_B$			N.S.
REGION	0.5069	0.4228	0.1616
	(6.58)	(6.72)	(2.12)
$REGION*DCON_R$			0.5741
			(5.14)
Standard deviations of parameter distributions			
WIND	0.2030	0.1363	0.1322
	(5.71)	(4.07)	(3.92)
SOLAR	0.3320	0.0866	0.0810
	(10.56)	(2.90)	(2.86)
BIOMASS	0.4400	N.S.	N.S.
	(5.04)		
REGION	0.8032	0.5384	0.4571
	(7.17)	(6.39)	(4.92)
Standard deviation of the latent random effect			
Σ		5.62	5.26
		(9.55)	(9.22)
N	4,800	4,800	4,800
Log likelihood	-1,270	-1,199	-1,176
χ^2	974.28	1,117	1,162
Pseudo R^2	0.275	0.315	0.328

t-values in parenthesis

Three models have been estimated to select the one that best fits our data. The first model presented (Table 3, Model [1]) is a Random Parameters Logit Model (RPL) using a panel data structure to take into account the fact that each individual made four choices (Train 2003). For the estimation of the RPL model, we used 500 Halton draws rather than pseudo-random draws since the former provides a more accurate simulation for the RPL (Train, 1999; Train, 2003).

The results of the RPL model provide estimated parameters for each individual in the sample, reflecting the fact that consumers have heterogeneous preferences. However, they do not take into account the fact that the design alternatives have larger utility variance than the *status quo* alternative, which is succinctly captured here by a shared error component that is missing in the utility of the *status quo*. This error component random parameter model is represented here by model 2[12] (Table 3). In addition, to test whether taste parameters are correlated, we have also estimated a model assuming that the correlation structure of β_n follows a multivariate normal distribution (normal with vector mean μ and variance-covariance matrix Ω). However, only one diagonal value in the Cholesky matrix was statistically significant different from zero indicating that random parameters are not correlated.

To test which of the different assumed specifications is preferred, first, we look at the log-likelihood and the pseudo R^2 values. The log-likelihood value at convergence and the pseudo R^2 reach their best value in model [2] compared to model [1]. Moreover, we observe that σ_ε for the error associated with alternatives different from the *status quo* is statistically significant, corroborating that an error component model must be specified. Thus, model [2] is the one used for further analysis because all the

[12] Because, the Wald statistic for the standard deviation for the BIOMASS parameter indicates that the dispersion around the mean estimate is not statistically different from zero, we assume that the BIOMASS has a fixed coefficient.

estimated parameters are statistically significant. This last model is then modified because some respondents stated that they ignore specific attributes when they make choices in the experiment. Model [3] is then a ECRPL with the addition of four dummy variables, one per non-monetary attribute, which take value one if the respondent took this attribute into account when making their choice and zero, otherwise. This a very relevant issue as the percentage of respondents that ignore each of the attributes is 18.3% for price; 84.3% for wind; 87% for solar; 95.8% for biomass and 65.3% for region[13]. Both models are statistically significant taking into account the χ^2. The log-likelihood function is -1,199 for model [2] and -1,176 for model [3], indicating a better model fit for the model that takes into account the discontinuous preferences.

Results are discussed with reference to models [2] and [3]. The *status quo* alternative specific constant was found to be negative and significant in both models indicating that the respondents found the "current situation" less desirable than the designed alternatives. The estimated coefficient for PRICE is, as expected, negative for both models and of similar value. The estimated coefficients in model [3] for the interaction terms with the dummy variables are statistically significant different from zero for all the attributes except for BIOMASS. The equality to zero of the estimated coefficient for the interaction term for BIOMASS indicates that the value of this attribute is the same for those respondents who take the attribute into account as well as for those who ignore it. This is further confirmed by the fact that respondents

[13] We have also calculated the percentage of respondent who ignore the four non-monetary attributes that accounts for 52% of the sample. Moreover, the percentages of respondents who ignore three, two and one of the non-monetary attributes account for 35.5%, 7.25% and 5.25 %, respectively.

present homogenous preferences towards the BIOMASS attribute. On the other hand, respondents' valuation of the rest of attributes differs between the two groups and they present heterogeneous preferences. For WIND, while the utility for respondents who ignore the attribute is negative (-0.0771), it is positive for those respondents who do take it into account (0.0785) [14]. For SOLAR, utility for both groups of respondents is positive but the value attached to this attribute is higher for those who take it into account (0.1408). The same is seen for the REGION attribute, the utility for respondents who consider the attribute is higher (0.7357) than for those who ignore it (0.1616).

The best way to interpret these differences is through the analysis of the willingness to pay for the attributes. Table 4 shows the marginal WTP estimates derived from model [3]. Mean WTP and the statistical significance are calculated by dividing the parameters for the non-monetary attribute over price and multiplied by minus one[15]. We have also calculated the percentage in relation to the current price, 0.14 € per kWh and the monthly estimates based on an average usage of 344kWh which is the sample average[16]. In addition, we can derive the WTP for each additional renewable kWh consumed by the individuals from this data. The payment vehicle used was an increase in the kWh price in the bill irrespective of source. Total WTP for the

[14] The estimated parameter for the isolate attribute (WIND, SOLAR, BIOMASS) corresponds to the value for the respondent who ignores the attribute. To calculate the one for the respondent who considers the attribute we add the estimated parameter for the interaction with the dummy for the discontinuous preferences ($WIND*DCON_W$ and $SOLAR*DCON_S$, respectively).

[15] For the REGION effect code variable, WTP estimates are calculated by dividing the parameter over the price and multiplied by minus two (Lusk *et al.,* 2003).

[16] We asked for monthly expenditure on electricity and obtained an average of 69.29 Euros per household (65% item response rate). This was converted into kWh considering taxes and other concepts included in the electricity bill (i.e. equipment rental and power charges).

increase in renewable energy is WTP multiplied by total consumption (344 kWh). As the payment would cover a 1% increase of the renewable component (i.e. 3.44 kWh), WTP for each additional renewable kWh is total WTP divided by 3.44.

Table 4. Mean estimates WTP (€/kWh)

	WTP	t-test	WTP as % of current kWh price	Monthly WTP (€)[a]	Implicit WTP for additional renewable kWh (€/kWh)
Respondents who ignore the attribute					
Wind	-0.0036	-3.33**	-2.5	-1.24	-0.36
Solar	0.0030	3.69**	2.2	1.03	0.30
Biomass	-0.0044	-2.43**	-3.1	-1.51	-0.44
Region	0.0148	2.14**	10.6	5.09	n.a.
Respondents who consider the attribute					
Wind	0.0036	1.93*	2.6	1.24	0.36
Solar	0.0065	3.91**	4.6	2.24	0.65
Biomass	-0.0044	-2.43**	-3.1	-1.51	-0.44
Region	0.0677	8.50**	48.4	23.29	n.a.

[a] Assuming a monthly consumption of 344 kWh
** (*) Statistically significant at 5% (10%) level.

Although a majority of the respondents declared that they did not consider one or more of the attributes of the electricity supply options, results show that they are indeed making choices that do take into account these attributes (i.e. the coefficient for the isolated attribute is significantly different from zero). Thus modeling preference discontinuity by setting the parameters to zero is not adequate and may lead to the wrong conclusions[17]. Besides this methodological insight, the most significant finding is that a majority of consumers are not willing to pay additional costs for increases in the renewable component of their electricity mix. Moreover,

[17] These estimates have been conducted but are not presented here. For example, the coefficient for BIOMASS is positive but not significant and that for WIND is only marginally significant (90%) and positive. Thus this alternative modeling provides more information on who and how values renewable energy in their electricity mix.

they would only accept an increase of the renewable mix at a discount for two of the three renewable sources considered (wind and biomass). On the contrary people are indeed willing to pay for an increase in the share of solar energy in the electricity mix of their supplier and for generating electricity within their region rather than importing it from farther afield.

However, these results do not preclude that some ancillary benefits (i.e. less forest fires due to biomass use) or costs (i.e. higher noise associated with wind power) of renewable energy could be captured by the attribute related to origin. As mentioned above our choice set design does not allow for estimating a model with attribute interactions, which would address this issue. Moreover, we did not provide descriptions of the potential benefits and costs associated with the different renewable electricity sources to avoid biased responses. From other questions included in the questionnaire we can conclude that individuals associate renewable energy primarily with environmental friendliness and climate change mitigation and less with the impact on employment. We can thus assume that the origin attribute captures the overall economic benefit of energy production while the energy source ones capture environmental effects.

5.2. Who values renewable energy electricity?

These results do not mean that there is no niche market for the finance increase in renewable energy via higher electricity prices. The first niche market is that of solar energy. For this energy source even consumers that claim not to take into account the amount of solar energy in the energy mix in making their decisions would be willing to pay an increase of 2.2% in the price per kWh for an increase in the share of solar in the supply energy mix. This percentage more than doubles in the case of those that do. The second niche market is that of consumers who look at the presence of wind source in the electricity mix of their supply. Although small in number (around 15% of the total population) they show a significant WTP for the wind renewable origin of their electricity (2.6% of current price). For this reason it would be important to profile both groups of respondents for policy analysis and the industry as the second group would be a more interesting target segment. As the group which pays attention to the attributes shows a greater WTP, this segmentation profiling would provide information on the best marketing strategy to finance renewable energy via higher electricity prices in Spain. Thus we turn to examining who these consumers are.

To achieve this, we grouped the respondents into two segments according to whether or not they took into account at least one of the renewable sources attributes (wind, solar or biomass) when making decisions in the choice experiment: the lower willingness to pay segment and the higher willingness to pay segment. Then we looked at whether there were differences between the segments based on personal characteristics: socio-demographic and economic, environmental concern, attitudes towards renewable electricity, intention to use renewable electricity, environmentally friendly behavior and involvement.

Environmental concerns were measured asking respondents to rank their concern using a five-point scale for different environmental issues: air pollution, generation of municipal waste, water pollution and climate change. Attitudes towards renewable electricity were also measured using a five-point scale to rank degree of agreement with different characteristics of renewable energy: impact on waste generation, decreasing oil dependency and greenhouse gas emissions. Respondent were also asked whether they probably or definitely would use renewable electricity, even if electricity prices would increase. In order to understand environmental friendly behavior, respondents were asked if they undertook any of a number of actions that would result in decreased energy consumption. These include reducing car use, substituting common light bulbs with energy-savings bulbs, insulating their house, efficient use of air-conditioning and heating and buying low consumption appliances. Respondents were also asked whether they participate in an environmental organization, separated the garbage, saved water, avoided buying products that damage the environment, consumed organic products or participated in environmental conservation practices in order to assess environmental involvement.

To check whether differences between the two segments exist t-test or Pearson chi-square tests were used. Table 5 presents the mean/percentage for both segments and the corresponding t-test or chi-square test along with the p-values for the personal characteristics found statistically different between the two segments.

Table 5. Segments characterization

Characteristics	Segment Lower willingness to pay (80.8 %)	Segment Higher willingness to pay (19.2%)	t-test/chi-square (p-value)
Enviromental concerns			
Air pollution	3.69	3.88	-1.76 (0.077)
Generation of municipal waste	3.56	3.78	-1.77 (0.076)
Water polution	3.77	4.39	-5.11 (0.000)

Climate change	3.73	4.14	-2.82 (0.005)
Attitudes towards renewable energy			
Generates waste that needs special treatment	2.14	2.47	-2.72 (0.007)
Diminishes the dependence from fossil fuels	3.69	3.87	-1.55 (0.12)
Reduces Greenhouse Gas Emissions	1.98	2.41	-3.85 (0.000)
Intention to use renewable electricity even at higher prices	48.6%	64.9%	6.64 (0.010)
Environmentally friendly behavior			
Efficient use of air-conditioning heating	74.3%	85.7%	4.5 (0.034)
Insulating their house	49.2%	70.1%	10.9 (0.001)
Environmental involvement			
Membership in environmental organizations	5.7%	13.0%	4.97 (0.026)
Dispose waste taking into account recycling	76.5%	90.9%	7.88 (0.005)
Avoid buying products with high environmental impact	29.1%	39.0%	2.82 (0.093)
Consume organic products	15.5%	29.9%	8.63 (0.003)
Participate in environmental conservation practices	34.4%	53.3%	9.41 (0.002)

[1] the null hypothesis is the no existence of differences

Results indicate that the socio-demographic and economic characteristics of the consumer are not statistically different between segments. On the other hand, several other characteristics related to environmental concerns and involvement, attitudes towards renewable energy, intention to use renewable energy and environmentally friendly behavior have been found statistically significant. In general, the higher willingness to pay segment shows higher environmental concerns; has a more positive attitude towards renewable energy; follows more environmental friendly behavior and is more involved in environmental friendly practices. Moreover, they show higher intention to use renewable electricity, even at higher prices, which is confirmed by their higher WTP. We did see that although traditional socio-demographic and economic characteristics do not differ between the two segments, personal characteristics related to environmental issues are important when profiling. The more environmentally conscious individual pays more attention to the renewable energy origin of electricity when making choices. This characterization is also relevant to attribute non-attendance as the groups were created taking into account this variable. However, we were not able to find significant differences between energy sources.

6. Conclusions

This study presents the results of a choice experiment which elicits individuals' willingness-to-pay for different renewable sources in the electricity generation mix. In summary the results show that, with the exception of solar energy, further support to increase renewable share in electricity by means of an increase in electricity price is not the best way forward. Yet we have also seen that a niche market to obtain additional revenue from green energy does exist, although restricted in size, for both wind and biomass. Solar energy is the exception where higher prices can be obtained without having to target consumers. Moreover this premium would cover current renewable energy feed-in tariffs in Spain for solar energy. Consumers who take into account the attribute show a WTP much higher than current premia (maximum of 44 euro cents per kWh), while those who do not would only be willing to pay for the premium for PV with installed capacity above 10MW and solar thermal. Thus the costs of increasing solar energy in the electricity mix could be financed via market prices.

However for wind and biomass the comparison of WTP for additional supply of renewable electricity with current feeding tariff premia existing in Spain (BOE, 2007) is less favourable. WTP for wind power for those who consider the attribute is well above the existing premium (7.3 euro cents per kWh) but only 15% of the total population would be willing to pay for it. As biomass exhibits a negative WTP not even the lowest biomass generation premium (11,8 euro cents per kWh) would be considered by consumers. Considering that the average premium paid for renewable energy production in Spain stood at 8.9 Euro cents per kWh in 2010[18], based on the above we can conclude that the full sample surveyed would be willing to pay that amount for solar energy, 15% for wind and nothing for biomass.

Our study is, to our knowledge, the first to demonstrate that increases in renewable energy in the electricity mix might not be valued by consumers. The literature review showed more or less positive WTP for renewable energy whilst the findings here show zero or even negative WTP for some renewable energy sources. Individuals would be willing to accept less renewable energy in their electricity mix if that implied a decrease in price. When attribute non-attendance is taken into consideration positive WTP are obtained for some renewable sources. Positive values in prior studies might be due to an increased awareness and access to additional information provided by the survey. Additional research is needed in order to compare results of valuation scenarios that provide more information on renewable energy with those which do not but instead ask for preexisting knowledge of renewable energy. Moreover, it seems that renewable sources do matter when eliciting preferences. As all sources are good substitutes in so far as the final product is concerned (i.e.

[18] This value is obtained by dividing total premia payments for renewable energy (5.3 billion Euros) by the total renewable energy production (59,342 gWh) provided by the Spanish National Commission for Energy (CNE).

electricity in the grid) this trade-off needs to be included when valuing renewable energy.

With regards to possible policy implications, raising awareness would be one of the first steps to increase the potential to finance renewable energy via higher electricity prices. When consumers take into account the renewable origin attribute in the choice experiment their WTP increases. However as the percentages of people considering the attributes is still very low, this might only happen to a limited extent. Thus, in order to finance the additional costs of renewable energy public administration and private agents should consider other alternatives. Private agents might consider promoting only a specific renewable source instead of a more general description of renewable energy or coupling renewable energy with regional origin to capture higher premia to compensate the additional financial costs of renewable energy production. Public administration should avoid relating electricity price increases to the promotion of renewable energy as this would not increase support. Alternative revenue sources to support renewable energy development should be sought.

One should consider these results with some caution. Some specific characteristics of the study region make our results not directly transposable to other settings. Our study has not included hydro power which might well be a highly valued renewable energy source in other areas. Moreover, Aragón is a region with a high presence of wind energy both in production and consumption (nearly half of the renewable energy electricity is generated by wind) and this might explain some of the negative preference for further increases. Furthermore, there is a lack of knowledge regarding biomass as a source of electricity generation and therefore preferences should be treated with caution. Finally, the survey was conducted at a time of fierce political discussion concerning increases in electricity prices (a price increase of 10% was finally agreed and implemented as of January 2011). Therefore, these results cannot be said to show that people do not want renewable energy, but that they are not willing to undergo additional price increases to promote it. One should consider that consumers may support using part of their current energy bill to pay for renewable rather than for nuclear and/or coal, and that consumers would be willing to reduce overall consumption whilst maintaining expenditure constant to promote renewable energy. These are important questions requiring further research.

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Annex I. Population in Spain and Zaragoza

Table A1. Population by sex and age in Spain and Zaragoza (%)

		Sex		Age				
	Total	Female	Male	0-19	20-34	35-54	55-64	More than 64
Spain	46,148,605	50.99	49.01	19.88	20.80	31.10	11.05	17.14
Zaragoza	952,383	50.90	49.10	18.46	19.63	30.83	11.64	19.42

Source: Spanish Census of Population, 2011. www.ine.es