Working Paper Series

No. 60

Annoyance and welfare costs from the presence of renewable energy power plants: an application of the contingent valuation method

Anabela Botelho

Lígia Pinto

Lina Lourenço-Gomes

Marieta Valente

Sara Sousa

November 2015

Núcleo de Investigação em Microeconomia Aplicada

Universidade do Minho

Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

Annoyance and welfare costs from the presence of renewable energy power plants: an application of the contingent valuation method

Anabela Botelho[1], Lígia M.C. Pinto[2]*, Lina Lourenço-Gomes[3], Marieta Valente[2], and Sara Sousa[4]

Abstract: Sustainability is frequently defined by its three pillars: economically viable, socially equitable, and environmentally bearable. Consequently the evaluation of the sustainability of any decision, public or private, requires information on these three dimensions. This paper focuses on social sustainability. In the context of renewable energy sources, the examination of social sustainability requires the analysis of not only the efficiency but also the equity of its welfare impacts. The present paper proposes and applies a methodology to generate the information necessary to do a proper welfare analysis of the social sustainability of renewable energy production facilities. This information is key both for an equity and an efficiency analysis. The analysis focuses on the case of investments in renewable energy electricity production facilities, where the impacts on local residents' welfare are often significantly different than the welfare effects on the general population. We apply the contingent valuation method to selected facilities across the different renewable energy power plants located in Portugal and conclude that local residents acknowledge differently the damage sustained by the type, location and operation of the plants. The results from these case studies attest to the need of acknowledging and quantifying the negative impacts on local communities when assessing the economic viability, social equity and environmental impact of renewable energy projects.

Keywords: Sustainability, Renewable Energy Sources, Contingent Valuation, Public Attitudes

[1] GOVCOPP, University of Aveiro, Aveiro, Portugal; e-mail: Anabela.botelhoua.pt
[2] NIMA and EEG, University of Minho, Campus de Gualtar, Braga, Portugal; e-mail: pintol@eeg.uminho.pt; mvalente@eeg.uminho.pt
[3] CETRAD and DESG, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal; lsofia@utad.pt
[4] ISCAC, Polytechnic Institute of Coimbra, Coimbra, Portugal; e-mail: ssousa@iscac.pt
* **Corresponding author:** pintol@eeg.uminho.pt; Tel: 00-351-253604510.

1. Introduction

The use of renewable energy sources (RES) in electricity generation is a key component of sustainable development, offering several benefits, namely: they generally cause less environmental impacts than other energy sources; they cannot be depleted; they are relatively independent of the cost of oil and other fossil fuels, thus are less price-volatile; and they are particularly advantageous in developing countries, representing a key contribution to better standards of living (Dincer and Rosen, 2005; Lund, 2007). However, the use of RES also raise some questions related to social sustainability. Social sustainability has two dimensions, according to Hassan and Lee (2015), social equity and sustainability of the community. Social equity indicators are consensual and involve access to facilities and amenities, education, quality of health, available housing, etc... Community sustainability is less consensual and involves the level of trust between community members, and the ability of local population to gather and discuss common issues and their ability to communicate with local authorities, among others.

RES are not entirely "environmentally benign” and can cause adverse impacts on the environment and local populations (OECD/IEA 1998). Important impacts of the installation of RES facilities are land occupation and interference with the social-economic realm (Bagliani *et al.*, 2010). Fragmentation of the countryside, change in land coverage, namely regarding forest, and specific impacts on local communities also raise questions regarding the subsidiary principle, whose implementation emphasises the need to make decisions “as close as possible” to the affected parties. As Bagliani *et al.* (2010, page 460) stresses “the local territory is not considered merely a de-articulation of an administrative activity regulated, however, by the same global type of logic in each territorial environment in which it is projected, but a structured and often conflicting set of meanings and attributions of meanings”. In addition, as Ariza-Montobbio *et al*. (2014) argue the exploration of RES for electricity production questions the prevalent distribution of production and consumption activities, originating social and demographic transformations that should be taken into consideration when planning the installation or expansion of RES facilities.

In the specific case of Portugal, it is a country which has good conditions in terms of sun exposure, wind speed, river resources and an extensive forest area, which favour the use of renewables for electricity generation. The use of RES for power generation has several advantages: it diversifies the sources of energy generation, reduces the external dependency, and decreases the stress on non-renewable energy sources. In addition, from an environmental perspective, it may contribute to reducing emissions of greenhouse gases if used in substitution of fossil fuels. However, RES are not free of negative impacts and, although the public attitude towards them is generally positive, local people may react differently to some specific projects, creating discussion over the social sustainability of some projects. The absence of consensus is justified by the adverse environmental impacts caused by the activity of the power pants. As common negative effects of renewables are the impact on landscape (e.g. Ouyang *et al.,* 2010; Dockerty *et al*., 2012; Gordon, 2001; Chiabrando *et al.,* 2009); the occupation of land and the opportunity cost of the area occupied (e.g. Denholm *et al.*, 2009; Sarlos *et al*., 2003; Rashad and Ismail, 2000); and the effects on fauna and flora (e.g. Travassos *et* al., 2005; Wang and Chen, 2013; Jonsell, 2007; Chiabrando et al., 2009). More specific to each source is the noise effect in the case of wind power (e.g. Pederson *et al.,* 2009; Van den Berg, 2005, 2006), and to a less extent hydropower (e.g. JKA, 2010); specific to photovoltaic solar energy is the glare effect (e.g. Chiabrando *et al*., 2009) and the rise in soil temperature (e.g. Gunerhan *et al*., 2009). Hydropower dam installation implies, in most cases, the destruction of some heritage, which may represent a significant social impact (e.g. Bakken *et al.*, 2012; Ferreiro *et al*., 2013).

These impacts are particularly difficult to quantify and are likely to be case-specific. Nevertheless, any efficient economic assessment for a sustainable growth of the use of the RES should attempt to incorporate the value of all environmental impacts, both positive and negative. The final aim of this analysis is to develop RES in an efficient and sustainable way, which means maximizing the positive impacts, including the environmental ones, and, at the same time, minimising the costs, without neglecting those only experienced by the local communities. To this end we develop a contingent valuation (CV) questionnaire to elicit local populations' welfare change caused by the environmental impacts of particular forest biomass power plants, wind farms, solar photovoltaic power plants and hydropower. Information regarding local residents´ perceived annoyance by impact category is also collected. In this fashion we are able to (1) compute the amount of compensation due to local populations and (2) characterize local residents' perception of the annoyance caused by the nearby presence and activity of the selected power plants. Jointly, (1) and (2), contribute to a better design of the facilities siting decisions as they provide relevant information on the impacts that are most relevant for local populations in addition to computing the monetary value of the welfare cost imposed.

The remainder of this paper is organized as follows. The next section provides an overview of the main methodological issues, in which we present the valuation method, the selected case studies and the questionnaire design. Then we present and discuss the main results. Finally, the main conclusions of this paper are exposed, alongside policy implications.

2. Methodology

The valuation of non-economic environmental impacts of RES facilities operation requires the use of non-market valuation methodologies. The objective is to compute what would be the monetary amount to compensate the residents in the facilities' vicinity. This elicitation requires the application of economic non-market valuation methods, which can rely on stated preference methods or revealed preferences. In this application, the stated preference method, the contingent valuation (CV) method, was chosen as it allows the estimation of the compensation amount. Alternative non-market valuation methods are not applicable in circumstances, where the objective is to compute the total economic value, not related to any particular use or type of impact. CV method is a questionnaire-based method that asks a sample of the relevant population what would be the maximum amount they would be willing to pay for a proposed hypothetical environmental change, or, alternatively, what is the minimum amount of compensation that would be demanded to accept a proposed environmental change (Adamowicz *et al*., 1994; Hanley *et al*., 2001). One crucial step in any CV study is the design of the questionnaire. The CV questionnaire must have incentive-compatible characteristics, so that respondents answer the questionnaire as if it was a real situation (not hypothetical). In addition, it should contain a set of questions to analyse the internal consistency of the respondents' answers and detect any strategic behaviour, such as hypothetical bias or an excessive number of zeros. Hypothetical bias consists in respondents expressing a valuation which does not correspond to their true preference, because the scenario under valuation is hypothetical. Inclusion of a cheap talk argument as suggested by Carlsson and Martinssom (2006) contributes to ameliorate the potential problem, and a careful data analysis might also help to detect hypothetical bias and other strategic behaviours. The excessive number of zeros can be dealt with during the model specification phase.

2.1. Case Studies

The renewable energy sources considered were currently those present in mainland Portugal: forest biomass, wind farms, solar photovoltaic farms and hydropower. In electricity production within RES, hydropower and wind energy are the most significant, followed by solar and forest biomass. According to APREN (www.apren.pt), in 2014, RES were responsible for 55% of the electricity produced in Portugal, big hydropower plants and wind parks were responsible for approximately 40% each (within RES); solar photovoltaic and forest biomass have a residual contribution. Literature has suggested that environmental impacts of RES facilities are case and energy specific (see for example Borchers *et al.*, 2007), hence the selection of the sites was guided by two principles: representativeness by source, and location.

Forest Biomass case studies:

The use of forest biomass in electricity production in Portugal is still residual. Most installations are located in the centre of Portugal. Two plants were selected: Mortágua and Constância, which are located in the districts of Viseu and Santarém, respectively. Mortágua power plant was installed in 1999 and has 9 MW (10 MVA) of installed capacity, while Constância was installed in 2009 and has 13.5 MW (14.5 MVA) of installed capacity.

Wind power case studies:

Most wind farms are located in the North of Portugal, although some are also present in the centre. The wind farms selected are located in Caminha and Vila Pouca de Aguiar, in the north and Lousã in the centre of Portugal. The Arga wind farm, in Caminha, was installed in 2006 and has 36 MW of installed capacity; the Lousã wind farm operates since 2008 with 50 MW of installed capacity; and the farms in Vila Pouca de Aguiar, Negrelo & Guilhado farms, began operating in 2009 with an installed capacity of 20 MW, but since 2011, an additional wind turbine of 2.3 MW was added.

Solar photovoltaic case studies:

Solar photovoltaic farms are located exclusively in the south of Portugal, a region characterized by a considerable high number of hours of sun exposure. The three PVFs selected are located in the villages of Brinches (Hércules PVF), Amareleja and Ferreira do Alentejo. The Hércules photovoltaic farm operates since 2007 with an installed capacity of 11 MWp; the Amareleja photovoltaic farm was installed in 2008 and has an installed power capacity of 45.78 MWp; Ferreira do Alentejo hosts more than one PVFs built and owned by distinct companies, operate since 2009 they have an installed capacity of 1.8 MWp, 10 MWp and 12 MWp, respectively.

Hydropower case studies:

Most hydropower facilities of high electric potential are located in the north and centre of Portugal (Botelho et al, 2015) and they have some distinguishing characteristics with respect to year of construction and the morphology of the territory. Three dams were selected, Aguieira, Alqueva and Douro International (composed by Picote and Bemposta dams that have similar characteristics and are at a distance of 21km from each other). The dams are located in the districts of Coimbra, Évora and Bragança, respectively. The Aguieira hydropower plant has an installed power of 336 MW and operates since 1981; the Alqueva hydropower plant, operating since 2002 with an installed power of 260 MW, has been subject to a power reinforcement operation and, since 2012, a new central, known as Alqueva II, is operating with 260 MW of additional power; the Picote hydropower plant, operates since 1958 with an installed power of 195 MW, but in 2011 has been subject to a power reinforcement operation with the construction of a new underground plant with 246 MW, known as Picote II; the Bemposta hydropower plant began operating in 1964 with 240 MW and in 2011 a new investment was made in strengthening the installed power with the construction of a new central of 191 MW, known as Bemposta II.

2.2. Questionnaire Design

For each renewable, a CV questionnaire was designed to elicit the minimum amount of compensation that residents in the vicinity of the facilities require (or their willingness to accept - WTA) to be compensated for the inconveniences caused by the specific facility located near them. Following Whitehead (2006), each questionnaire is composed of four sections. After an introductory section with general questions on the renewables, section 2 presents several questions on the production of electricity from each renewable facility, of which we highlight here, for its relevance, the valuation question and the question on respondent’s certainty regarding the stated WTA. Due to the fact that we had no prior information on the distribution of respondents' valuation for choosing the thresholds for a discrete-choice format, the valuation question was formulated as an open question and the payment vehicle chosen was a return in the monthly electricity bill, as follows:

Taking into account your income and your usual expenses, answer the following question:

What is the minimum amount that you would be willing to receive as compensation for the inconvenience that the presence of the facility causes you? The amount would be credited to your monthly electricity bill.

You would be willing to receive _______________ *Euros per month.*

Prior to the valuation question, respondents were asked how annoyed they felt by the presence of the facility in general and with respect to specific environmental impacts. Section 3 contains additional questions on respondents' preferences and opinions on renewable and non-renewable energies. Finally socio-demographic questions are included in section 4. The relevant population for each case study is the residents in the vicinity of the RES power facilities. The population present in the selected villages is scarce, mostly elderly and less educated than the national average. Accordingly, the sample was recruited among the residents present in public places (outside and in shops) who were willing to participate in the study. Questionnaires were then administered through personal interview in a private place. All data was collected between May and October 2014.

2.3. Sample Description

To conduct the welfare analysis of residents in the vicinity of the 12 power plants analyzed in this study we collected, during the year of 2014, a total of 219 CV questionnaires: 48 questionnaires in the vicinity of Constância and Mortágua FBPPs;; 57 questionnaires in the vicinity of Arga, Lousã and Negrelo & Guilhado WFs; and 64 questionnaires near Amareleja, Hércules and Ferreira do Alentejo solar PVFs; and 50 questionnaires in the vicinity of Bemposta & Picote, Alqueva and Aguieira dams. As already mentioned, in the CV questionnaires respondents were presented with several questions besides the valuation question on the WTA amount, allowing us to gather important information on the local respondents' sample, namely on their opinion concerning the main environmental problems currently affecting Portugal, the degree of the respondents' familiarity with RES, whether the facility is visible from the respondents` residence/ work place/daily commute; and the opinion on the use of RES for electricity generation. Moreover, socio-demographic questions were collected. This information is summarized in Table 1.

Table 1: Local Residents' Samples – Descriptive Statistics: Relative Frequencies and Means

	Forest Biomass	**Wind**	**Photovoltaic**	**Hydropower**
Environmental problems				
Climate change	0.5435	0.2542	0.5075	0.6600
Air pollution	0.7609	0.5763	0.6119	0.7000
Water pollution	0.7826	0.6780	0.5970	0.6400
Overexploitation of Natural Resources	0.2391	0.0847	0.0896	0.0800
Lower biodiversity	0.4348	0.2542	0.2388	0.2200
Waste	0.4348	0.7288	0.5373	0.3400
Familiarity with RES				
Wind	0.9565	1.000	0.9104	0.9000
Solar photovoltaic	0.8261	0.7458	0.9701	0.7800
Forrest biomass	0.9565	0.3051	0.3433	0.3600
Hydropower	0.9348	0.9492	0.9403	0.9000
Visibility				
Hydropower	0.9778	0.8136	0.8955	0.9200
Wind	0.8696	0.9492	0.4154	0.5200
Solar photovoltaic	0.7333	0.1864	0.8333	0.5333
Forest biomass	0.9333	0.0339	0.1061	0.3556
Visible from home	0.7609	0.9492	0.7165	0.7600
Self-interest	0.5435	0.2373	0.4030	0.4800
Electricity bill (€/month)	59.84 (25.90)	71.55 (68.08)	76.32 (58.62)	67.63 (64.02)
Opinion on RES(agreement)				
Portugal has good conditions	1.000	0.9808	0.9692	0.9778
Benefits population	1.000	0.8000	0.8657	0.8542
Renewable source	0.6304	0.2727	0.3793	0.5854
Importance of RES	0.3478	0.6034	0.7313	0.6531
Non polluting emissions	0.7391	0.3409	0.5345	0.7561
Climate Change Reduction	0.6522	0.2955	0.4655	0.7073
Creates employment	0.2826	0.4546	0.4828	0.3659
Lower external dependency	0.1522	0.5000	0.5862	0.3659
WTA (€/month)	16.74 (24.43)	35.96 (40.69)	27.34 (48.05)	20.42 (71.90)
Socio-demographic				
Male	0.4783	0.4915	0.5522	0.7000
Age (in years)	55.0435 (16.7584)	59.8305 (16.2206)	52.0597 (17.7456)	50.7200 (17.6844)
Income per capita (€/month)	449.06 (380.86)	251.88 (162.15)	429.59 (301.70)	374.40 (318.77)
Primary education	0.4348	0.6271	0.2388	0.3800

Note: standard deviations are presented in parentheses.

The local residents' average age varies between 51 years old in the hydropower sample and approximately 60 years in the wind sample. The samples also differ in terms of education and income (the highest proportion of residents with lowest education level and the lowest income occur in wind power sample). For respondents, the most important environmental problem in Portugal nowadays is water pollution, followed by waste and air pollution (though the frequency varies between RES subsamples). Regarding the respondents' familiarity and opinion of RES, the least familiar energy source is forest biomass, across all samples; the most familiar are wind energy and hydropower. Also concerning the familiarity with RES, respondents were asked if they see a RES power plant daily, and in fact between 72% (in the case of PVFs) and 95% (in the case of wind farms) of the respondents see the power plant from their residence.

3. WTA Results

Although the questionnaires between sources are comparable in terms of design, given the specificity of the environmental impacts to the RES used, we modelled four separate valuation functions. One common characteristic of contingent valuation data is an excessive number of zeros, and there might be over-dispersion of the data. In addition, data on the amount residents are WTA as compensation is discrete, as only integer amounts were accepted. When deciding the amount of compensation, we can assume that local residents perform a two-stage process whereby they first decide whether they are entitled to compensation and then, if they admit to a compensation, what is the minimum amount (in integer numbers) they require as compensation. These two decisions may result from distinct processes, which calls for the use of mixture models in the data analysis. The first decision is translated into a binary yes/no variable while the second is translated into an integer, positive number. To accommodate these specificities of the data collected we use a zero-inflated negative binomial model in the econometric analyses of the WTA decisions. The selection for the explanatory variables for the two part model was guided by previous studies and in certain circumstances by data limitations. Explanatory variables include location-specific dummies, level of annoyance in general or specific to the source and socio-demographic characteristics. Individual source results are presented in Tables 2 through 5.

i) Forest Biomass Power Plants Impacts

Local residents' valuation of the annoyance felt and the amount of compensation required to offset the nuisances were estimated considering that location and socio-economic variables were the determinants of the decision to be compensated, while the amount of compensation was assumed to be explained by the socio-demographic characteristics, location, annoyance and whether the respondent had any involvement in the power plant.

Table 2: Zero-inflated negative binomial model – forest biomass power plants

Dependent Variables	Explanatory Variables	Coefficient	(Robust Standard error)
WTA (yes/no)	Mortágua	1.7765**	(0.8134)
	Retired	0.6322	(0.9636)
	Male	-1.2895	(0.8154)
	Age	0.0335	(0.0265)
	Constant	-2.5734	(1.6474)
WTA (amount)	Mortágua	0.4102	(0.3389)
	Involvement	-0.2920	(0.1856)
	Annoyance	0.3918***	(0.1093)
	Retired	-0.2987	(0.2592)
	Male	-0.1800	(0.1924)
	Age	0.0106	(0.0084)
	Constant	1.9408***	(0.7570)
	Ln(alpha)	-1.7424***	(0.1962)
Number of observations: 46; Non-zero: 23; Zero: 23; Wald chi2(6) 38.19***			

Note: *Significance level of 10%; ** 5%; *** 1%; Constância is the omitted location category in both equations; Annoyance measures the level of annoyance felt by the respondents, taking the value 0 if the respondent does not feel annoyed by the presence of the power plant, up to 5 corresponding to the maximum annoyance; Involvement, is a binary variable taking the value 1 if the respondent works or has worked or has friends or family members who do or did.

According to the results in Table 2, location is an important determinant of the decision to receive compensation, with residents close to the FBPP in Mortágua being more likely to demand compensation than residents in Constância. With respect to the amount of compensation demanded, people feeling more annoyed with the presence of the FBPP demand significantly higher amounts, on average, as expected. Based on the regression model we predict that the amount of compensation would be on average 17.8 Euros per month. By power plant predicted WTA is 31. 6 Euros in Constância and 8.9 Euros in Mortágua, matching the size of the power plant. In sum, populations feel annoyed by the presence of the FBPP which influences their decisions; the amount of compensation demanded is location specific; and, annoyance plays some role in explaining the amount of compensation demanded.

ii) Wind Farms Impacts

The valuation function estimated for the case of wind farms is reported in Table 3. In addition to location, the binary variable *annoyance_yn* was selected to explain the decision to receive compensation. Perfect collinearity and/or perfect prediction of the outcome variable precluded the inclusion of other considered explanatory variables. Moreover, although this sample only had 3 zero observations, we decided to maintain the model specification for consistency with the analysis regarding other RES. The explanation of the amount of compensation demanded (reported in the second panel) relies on socio-demographic variables, location and also the degree of noise-annoyance.

According to Table 3, the locations are a significant determinant of the decision to be compensated, with residents in Vila Pouca de Aguiar and Lousã being less likely to demand compensation than residents in Arga (Caminha). Concerning the amount of compensation, the results show that older respondents demand, on average, lower amounts than younger respondents, a result that can be interpreted as a sign that older residents are more resigned to not being compensated for damages sustained. Location is again a statistically significant determinant of the amount of compensation, with residents in Vila Pouca demanding significantly higher amounts than residents in Lousã and Arga. The wind farm in Vila Pouca de Aguiar is smaller than the other two considered, but houses are located much closer than in the other parks which might explain the higher amounts of compensation demanded.

Table 3: Zero-inflated negative binomial model – wind farms

Dependent Variables	**Explanatory Variables**	**Coefficient**	**(Robust Standard error)**
WTA (yes/no)	Lousã	-18.7171***	(1.2931)
	Vila Pouca Aguiar	-18.4871***	(0.9139)
	Noise Annoyance_yn	0.1828	(0.4971)
	Constant	-2.4670*	(1.3606)
WTA (amount)	Lousã	-0.0618	(0.4339)
	Vila Pouca Aguiar	0.5239*	(0.2749)
	Noise Annoyance	0.0280	(0.0855)
	Age	-0.0160*	(0.0094)
	Incomepc	-0.0007	(0.0006)
	Constant	4.4622	(0.5669)
	Ln(alpha)	-0.6028***	(0.1804)
Number of observations: 57; Non-zero: 54; Zero: 3; Wald chi2(5) 9.85*			

Note: *Significance level of 10%; ** 5%; *** 1%; Arga is the omitted location category in both equations; Noise annoyance_yn is a binary variable, taking the value 1 if the respondent feels annoyed by the noise produced by the WF, and 0 otherwise; Incomepc, measures the household per capita income; Noise Annoyance measures the degree of annoyance felt by the respondent by the noise produced by the WF. It takes the value 0 if the respondent feels no annoyance up to 5 which corresponds to the maximum level of annoyance.

Based on the regression model we predict that the amount of compensation would be on average 35.0 Euros per month, 27.1 Euros in Arga, 34.9 Euros in Lousã II and 44.9 Euros in Vila Pouca Aguiar. The reduced size of the sample collected, resulting from the fact that the villages near wind farms have few residents, requires some caution in interpreting the results but it does not preclude us from drawing important implications from the analysis, namely that the decision to be entitled to compensation is site-specific, the amount of compensation demanded is also site- specific, and finally that socio-demographic characteristics play a role on the amount of compensation demanded.

iii) Photovoltaic Farms Impacts

To explain the decision to receive compensation or not, we include some socio-demographic variables and the location of the farm where Amareleja is the omitted location. The explanation of the amount rests on the degree of annoyance caused by the glare effect, on socio-demographic variables and on location.

According to Table 4, location is the most important determinant of the decision to receive compensation: relative to residents in Amareleja, residents in Ferreira do Alentejo are more likely to demand compensation. Socio-demographic characteristics are not statistically significant but for retired variable which is negative. Regarding the amount of compensation decision, results show that retired and younger respondents demand, on average, higher amounts; residents who feel more annoyed by the glare effect also demand significantly higher amounts than those that do feel less annoyed. On the other hand, residents living close to Ferreira do Alentejo and Hércules PVFs demand, on average, lower amounts of compensation. This might be justified by the differences in the size of the PVFs: Amareleja plant is the biggest (250 ha), followed by Ferreira Alentejo (58+31+5 = 94 ha) and Hércules (60 ha) plants.

Table 4: Zero-inflated negative binomial model - photovoltaic farms

Dependent Variables	Explanatory Variables	Coefficient	(Robust Standard error)
WTA (yes/no)	Hércules	-1.3711	(2.2204)
	Ferreira Alentejo	2.2752***	(0.7415)
	Retired	-2.0605*	(1.2414)
	Male	-0.6328	(0.9549)
	Age	0.0174	(0.0333)
	Constant	-1.3567	(1.4445)
WTA (amount)	Hércules	-0.8678***	(0.3282)
	Ferreira Alentejo	-0.7588**	(0.3162)
	Glare Annoyance	0.3598***	(0.1293)
	Retired	0.7778*	(0.4259)
	Male	-0.2237	(0.3374)
	Age	-0.0336***	(0.0104)
	Constant	5.2386***	(0.5722)
	Ln(alpha)	-0.5883*	(0.3614)
Number of observations: 64; Non-zero: 39; Zero: 25; Wald chi2(6) 31.96***			

Note: *Significance level of 10%; ** 5%; *** 1%; Amareleja is the omitted location category in both equations; Glare Annoyance measures the degree of annoyance felt by the respondents due to the glare produced by the presence of the PP. It takes the value 0 if the respondent does not feel any glare annoyance, up to 5, which corresponds to the maximum level of annoyance.

Based on the regression model, we predict that the amount of compensation would be on average 30.1 Euros per month, being 56.3 Euros in Amareleja, 21.5 Euros in Hércules and 10.1 Euros in Ferreira Alentejo. The results allow us to conclude that compensation amounts are clearly site-specific; socio-demographic characteristics also influence the respondents' decision on the amount to be compensated; and, finally, local populations feel annoyed by the presence of the PVF, particularly due to its glare effect, demanding higher amounts of compensation.

iv) Hydropower plants Impacts

The valuation function estimated for the hydropower plants considers as an explanation for the decision in the first stage, whether or not the respondent feels annoyance with the presence of the hydropower plant and location. For the decision in the second stage, in addition to socio-demographic variables, annoyance and location are included as explanatory variables of the amount of compensation.

Table 5: Zero-inflated negative binomial model – hydropower plants

Dependent Variables	Explanatory Variables	Coefficient	(Robust Standard error)
WTA (yes/no)	Alqueva	-0.3817	(0.7618)
	Douro International	-3.2866**	(1.4160)
	Annoyance_yn	0.6932	(0.9816)
	Constant	-0.7871	(0.5448)
WTA (amount)	Alqueva	0.5601	(0.4298)
	Douro International	-1.4265***	(0.3110)
	Annoyance_yn	1.0244	(0.9391)
	Retired	0.1466	(0.7332)
	Male	0.7439**	(0.3207)
	Age	-1.0186	(0.0261)
	Constant	3.6782***	(1.2378)
	Ln(alpha)	-1.4477***	(0.3759)
Number of observations: 50; Non-zero: 23; Zero: 27; Wald chi2(6) 135.87***			

Notes: *Significance level of 10%; ** 5%; *** 1%; Aguieira is the omitted location category; Annoyance_yn is a dummy variable taking the value 1 if the respondent feels annoyed by the presence of the PP, and zero otherwise.

According to Table 5, location is the most significant variable explaining the decision to be compensated. Residents near Douro international are less likely to demand compensation than residents near Alqueva or Aguieira. Regarding the amount of compensation, location is statistically significant with residents in Alqueva demanding amounts of compensation not significantly different than residents near Aguieira, while residents in Douro International demand lower amounts, relative to residents in Aguieira. This result might be explained by the morphology of the area, as Douro International´s dams are in deeper and narrower valleys than those of Aguieira and Alqueva. Moreover, it is important to highlight that the construction of the Alqueva II plant led to the submersion and consequent translocation of an entire village, leaving the local population very dissatisfied. Socio-demographic characteristics are not significant except for male which is positive and statistically significant. Based on the regression model we predict that the amount of compensation would be on average 17.7 Euros per month, being 7.1 Euros in Aguieira, 30.4 Euros in Alqueva and 6.3 Euros in Douro International.

4. Conclusions

In this paper, we used a CV approach to estimate the environmental impacts caused by the activity of dams, PVF, WF and FBPP. These are particularly felt by the residents of the local communities who, most of the times, do not receive any compensation for their welfare loss. Our results show that the CV method is adequate to elicit the amount of compensation demanded, given that the estimates differ across RES and across locations. Furthermore, the CV method allows us to identify the most significant determinants of the amount and of the decision to receive compensation. With this research and the application of this method, we have given a voice, and a value, to the complaints of the local communities near some facilities in Portugal and concluded that residents feel negatively affected by their presence and consequently state a positive willingness to accept corresponding to an adequate monetary amount as compensation for their welfare loss. These values can be interpreted on the one hand as a sign that the affected residents should be indeed entitled to compensation, as a consequence of the damage sustained. On the other hand, these positive WTA values testify to the non-trivial economic value of those damages. More than focusing on the actual values estimated for the specific power plants, we highlight the power of these types of studies in addressing social sustainability of RES for electricity production.

Based on the estimated results, it is clear that public decision-makers need a better understanding of this equity asymmetry problem, when deciding the construction and location of new developments. The results clearly show that the installation of RES facilities close to communities, even if small, raises issues concerning social sustainability. In addition it provides decision-makers with a metric to evaluate the seriousness of the sustainability challenge. Also relevant is the role that socio-demographic variables play in explaining the welfare impacts. With this study, we expect to have contributed to a more thorough and sustainable decision-making process for RES development in the future.

Acknowledgments: The authors gratefully acknowledge the financial support from FCT Fundação para a Ciência e Tecnologia with grant number PTDC/EGE-ECO/122402/2010.

References

Adamowicz, W., Louviere, J., and Williams, M. (1994). Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities. *Journal of Environmental Economics and Management 26*, 271-279.

Ariza-Montobbio, P., Farrell, K.N., Gamboa, G., and Ramos-Martim, J. (2014). Integrating energy and land-use planning: socio-metabolic profiles along the rural-urban continuum in Catalonia (Spain). *Environment Development and Sustainability, 16,* 925-956.

Bagliani, M., Dansero, E., and Puttilli, M. (2010). Territory and energy sustainability: the challenge of renewable energy sources. *Journal of Environmental Planning and Management, 53 (4),* 457-472.

Bakken, T., Sundt, H., Ruud, A., and Harby, A. (2012). Development of small versus large hydropower in Norway - comparison of environmental impacts. *Energy Procedia 20,* 185-199.

Borchers, A, Duke, J., and Parsons, G. (2007). Does willingness to pay for green energy differ by source? *Energy Policy 35*, 3327–3334

Botelho, A., Lourenço-Gomes, L., M.C.Pinto, L., Sousa, P., Sousa, S., and Valente, M. (2015). Using choice experiments to assess environmental impacts of dams in Portugal. *AIMS-Energy, 3(3),* 316-325.

Carlsson, F. and Martinssom, P. (2006). Do Experience and Cheap Talk influence Willingness to Pay in an Open-Ended Contingent Valuation Survey? *Working Papers in Economics 190,* University of Gothenburg, Department of Economics.

Chiabrando, R., Fabrizio, E., and Garnero, G. (2009). The territorial and landscape impacts of photovoltaic systems: Definition of impacts and assessment of the glare risk. *Renewable and Sustainable Energy Reviews 13,* 2441-2451.

Denholm, P., Hand, M., Jackson, and M., Ong, S. (2009). Land-use requirements of modern wind power plants in the United States. *Golden, CO: National Renewable Energy Laboratory*.

Dincer, I. and Rosen, M.A. (2005). Thermodynamic Aspects of Renewables and Sustainable Development. *Renewable and Sustainable Energy Reviews 9*, 169-189.

Dockerty, T.; Appleton, K. and Lovett, A., (2012). Public opinion on energy crops in the landscape: considerations for the expansion of renewable energy from biomass. *Journal of Environmental Planning and Management 55 (9),* 1134-1158.

Ferreiro, M.F., Gonçalves, M.E., and Costa, A. (2013). Conflicting values and public decision: The Foz Côa case. *Ecological Economics 86*, 129-135.

Gordon, Jr. (2001). Wind, energy, landscape: reconciling nature and technology. *Philosophy & Geography, Vol. 4 (2),* 169-184.

Gunerhan, H., Hepbasli, A., and Giresunlu, U. (2009). Environmental Impacts from the Solar Energy Systems. *Energy Sources, Part A, 31*, 131-139.

Hanley, N., Mourato, S., and Wright, R.E. (2001). Choice Modelling Approaches: A Superior Alternative for Environmental Valuation? *Journal of Economic Surveys, Vol. 15 (3),* 435-462.

Hassan, A. M. and Lee, H. (forthcoming). *The paradox of the sustainable city: definitions and examples*. *Environment, Development and Sustainability.*

Jonsell, M. (2007). Effects on biodiversity of forest fuel extraction, governed by processes working on a large scale. *Biomass and Bioenergy 31,* 726-732.

JKA (2010) - Jongens Keet Associates, Noise Impact Assessment. In: *Groot Letaba River Water Development Project – Environmental Impact Assessment. Department of Water Affairs, Republic of South Africa*.

Lund, H. (2007). Renewable energy strategies for sustainable development. *Energy 32*, 912-919.

OECD/IEA (1998). *Benign energy? The environmental implications of renewables.* Organization for Economic Co-operation and Development and International Energy Agency

Ouyang, W., Hao, F., Zhao, C., and Lin, C. (2010). Vegetation response to 30 years hydropower cascade exploitation in upper stream of Yellow River. *Commun Nonlinear Sci Numer Simulat 15*, 1928-1941.

Pearce, D., Atkinson, G., and Mourato, S. (2006). *Cost-Benefit Analysis and the Environment: Recent Developments,* OECD.

Pedersen, E., Van den Berg, F., Bakker, R., and Bouma, J. (2009). Response to noise from modern wind farms in The Netherlands. *Journal of Acoustical Society of America 126 (2),* 634-643.

Rashad, S. and Ismail, M. (2000). Environmental-impact assessment of hydro-power in Egypt. *Applied Energy 65,* 285-302.

Sarlos, G., Haldi, P.A., and Verstraete, P. (2003). *Systèmes énergétiques. Offre et demande d`Energie: méthodes d'analyse.* Lausanne: Presses Polytechnique set Universitaires Romandes.

Travassos, P., Costa, H.M., Saraiva, T., Tomé, R., Armelin, M., Ramírez, F.I., and Neves, J. (2005). *A energia eólica e a conservação da avifauna em Portugal.* SPEA (Sociedade Portuguesa para o Estudo das Aves), Lisboa.

Van den Berg, F.G.P. (2005). The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines. *Low Frequency Noise, Vibration and Active Control Vol.24 (1),* 1–24.

Van den Berg, F.G.P. (2006). *The sounds of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise.* Doctoral thesis, Rijksuniversiteit Groningen, Groningen, The Netherlands.

Wang, K. and Chen, D. (2013). Impacts of the Three Gorges Dam on Fishery Resources in the Yangtze River. In: *After Three Gorges Dam Symposium Proceedings,* Appendix C: Submitted Papers. July, 2013, 1-9.

Whitehead, J.C. (2006). A Practitioner`s Primer on Contingent Valuation Method. In Alberini, A., Kahn, J.R. (Eds): *Handbook on Contingent Valuation,* Edward Elgar, Cheltenham, UK, 66-91.