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Public perceptions of environmental friendliness of renewable energy power plants

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Abstract

Demanding EU targets for renewables create challenges for governmental decisions regarding energy sources and plant sitting. In this study we explore perceptions of the Portuguese general population regarding renewable energy power plants. In particular we study how these are affected by dimensions such as home distance to the power plant and its visibility, familiarity with the different energy sources, involvement in terms of employment, and socioeconomic characteristics. We find considerable differences in perception depending on familiarity and involvement with energy sources, environmental friendliness, and specific environmental impacts. Assessment of public perceptions of renewables should thus include these different dimensions.

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Keywords: social acceptance; environmental impacts; renewable energy sources; environmental preferences; eliciting perceptions.

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1. Introduction

The use of renewable energy sources (RES) and energy efficiency are issues that are central to the European Union (EU) energy policy, as RES contribute substantially to reducing CO_2 emissions, helping to meet EU's international commitments, either through curbing energy demand or by providing alternative carbon-free supplies. Furthermore, they improve energy security and can enhance competitiveness. The use of RES for electricity generation has become a cornerstone of EU energy policy promoting all three main energy policy goals: competitiveness, energy security and environment protection [1].

Despite the unquestionable advantages associated with the use of RES for electricity production, these are not free of negative impacts, affecting individuals' wellbeing, particularly those living in the vicinity of the different facilities. These facilities include solar photovoltaic panels, wind turbines, forest biomass fuelled plants and dams. Since each of these renewable energy technologies differs, the socioeconomic and environmental impacts of each technology may also vary [2]. The following negative effects associated with the activity of these facilities are common to all RES, namely the impact on landscape (e.g. [3]-[6]); the occupation of land and the opportunity cost of the area occupied (e.g. [7]-[9]); and the effects on fauna and flora (e.g. [6], [10]-[12]). There are other impacts more specific of each RES, as is the noise effect in the case of wind farms (e.g. [13]-[15]), and to a less extent dams (e.g. [16]); the glare effect (e.g. [6]) and the rise in soil temperature (e.g. [17]) are specific to photovoltaic farms. The installation of hydropower dams implies, in most cases, the destruction of natural or built heritage, which can have a significant social impact (e.g. [18], [19]). The public perception of these impacts, regardless of the proximity of the individual's home location in relation to the different facilities, may affect the value given to RES and the acceptability (or lack of it) regarding the construction of new power plant projects. As stressed by several studies (e.g., [20]-[23]), social acceptance is crucial for successful implementation of renewable energy technologies and thus should not be neglected in an efficient energy decision-making process.

This paper proposes to analyze how the perceptions of the general Portuguese population regarding the environmental friendliness of renewable energy power plants is affected by dimensions such as home location, visibility of power plants, familiarity with the different RES, potential involvement in terms of employment, and socioeconomic characteristics of respondents. We argue that these dimensions impact perceptions and thus any assessment of public perceptions should control for differences in these variables across respondents. For the empirical study, we collected a total of 1800 questionnaires among residents in mainland Portugal; the questionnaires were administered during the year of 2014 by a specialized survey firm on a national sample through personal interviews.

The remainder of this paper is organized as follows. In section 2 we discuss the social acceptance of renewables. Section 3 provides an overview of the main methodological issues. In section 4 we present and discuss the results. Finally, in section 5 the main conclusions of this paper are presented.

2. Social acceptance

Social acceptance as a decisive factor for renewables' implementation was extensively ignored in the 1980's when renewable energy policies became popular. As stressed by [20], most decision makers considered that implementation was not a problem, mainly because the first surveys on renewables' acceptance, in particular regarding wind energy source, revealed high levels of public support. However, more thorough studies analyzing the effective support of the different RES technologies showed that public support could not be taken for granted. Carlman [24], one of the first researchers to address this issue, carried out a study on the acceptance of wind power among decision makers and concluded that sitting wind turbines was closely related to important issues such as public, political, and regulatory acceptance. Other studies followed and raised other issues such as a low support from key stakeholders, low commitment and dedication from policy makers, lack of understanding of public attitudes regarding renewables, and underestimation of the importance and significance of impacts such as landscape intrusion ([20]).

The debate on social acceptance continues, mainly because there are several features of renewable energy innovation that constantly bring new aspects into consideration. One such feature concerns the scale of facilities given that renewable energy plants tend to be smaller than conventional power plants, increasing the number of location decisions to be made. Also, the energy sector as a whole generates widespread externalities, which means that for the acceptance of most renewable energy technologies a choice needs to be made between short-term costs and long-term benefits. Finally, resource extraction in particular in fossil fuels energy happens below the earth' surface and thus is invisible to most of the population, while in renewable plants the energy production is highly visible and closer to where the energy consumer lives: this is the so-called "backyard" ([20]).

Although the existing research shows that renewable energies are generally supported by public opinion, when deciding the location of specific renewable energy projects these often face resistance from the local population. This local resistance towards renewable energy developments is often explained by the Not-In-My-Backyard (NIMBY) syndrome. However, this concept has been questioned for example by Wolsink [25]-[28] who studied the validity of the NIMBYism for the specific case of wind power. According to Wolsink, the NIMBY explanation is too simplistic and considers at most a secondary issue for people opposing local renewable energy projects. Instead, Wolsink considers that institutional factors are highly important and that open collaborative approaches with the involved actors are crucial for the development of renewable energy technologies. In another study, Bell *et al.* argue that "the NIMBY concept has rightly been criticized on the grounds that it fails to reflect the complexity of human motives and their interaction with social and political institutions" [29, p. 460]. Studies have concluded that the NIMBY concept is inadequate, but few have proposed alternative solutions. A notable exception is Devine-Wright [30]'s work in explaining NIMBY responses as "place-protective actions". This new "psychological framework" reframes the issue stating that "so-called 'NIMBY' responses should be re-conceived as place-protective actions, which are founded upon processes of place attachment and place identity. This enables a deeper understanding of the social and psychological aspects of change arising from the siting of energy technologies in specific locations" ([30], p. 432). Therefore, one could hardly expect a confined acronym such as NIMBY to fully capture oppositional attitudes towards RES.

There is no doubt about the complexity around the social acceptance of renewable energy innovations. According to Wüstenhagen *et al.* [20], the concept of social acceptance of renewable energy innovations is multi-dimensional, including socio-political acceptance, community acceptance and market acceptance.

Socio-political acceptance is "social acceptance on the broadest, most general level" ([20], p. 2684). It refers to the role of citizens. It is primarily manifested through general support for a renewable-based technology or for policies supporting its development. This is often measured through opinion polls that represent the individuals' aggregated attitudes ([23], [31], [32]). Socio-political acceptance helps establish conductive conditions for implementing innovations. It is about the willingness among actors (general public, key stakeholders and policymakers) to generate institutional changes and policies that create favourable conditions for new technologies ([33]).

Community acceptance refers to the role of consumers as voluntary or involuntary users of technology. It plays an important role in the cases where the adoption of an innovation affects groups of agents, such as the sitting decisions for renewable energy installations ([23]). An efficient community approach is essential to renewables deployment. Studies on this subject show that some factors seem to be crucial for successful renewable energy projects, such as a collaborative decision-making process, employing effective forms of community involvement; effective involvement of the community in the sitting process or in the management/ ownership, which allows the community to identify with the project; the perception of how well the new system fits into the identity of the community; the fact that the decision-making process is perceived as being fair; and the existence of mutual trust between community members and the investors and owners of the infrastructure ([33]-[36]).

Finally, there is market acceptance, or the process of market adoption of an innovation. One of the main problems associated with green power marketing (and trading) is the separation between (physical) supply and demand. In the renewable energy market, consumers have the opportunity to switch to renewable energy supply without being actually involved in the physical generation. However, if consumers demand increasing amounts of green power, there still need to be sitting processes for power plants to meet this demand. In the context of market acceptance, the actors (incumbents, investors, new firms and consumers) have an important role and their willingness-to-pay (WTP) or to invest in renewable energy projects is crucial ([33]).

This model of analysis has the merit of clarifying the complex concept of social acceptance through its different components. In this paper we focus on socio-political acceptance as an aggregate of the individual attitudes of citizens and control for several dimensions that are likely to impact social acceptance.

3. Survey design and implementation

With the aim of understanding public perceptions regarding the use of RES for electricity generation in Portugal, we designed a questionnaire to survey the general population. The questionnaire was developed in an interactive process using focus group discussions and think-aloud sessions to improve it ([37]). The generic questionnaire is divided into three sections. The first section focuses on respondents' knowledge, opinions and preferences over renewable energy sources and the third section addresses socio-demographic characteristics. The focus of the present paper is on the first section of the questionnaire, complemented with respondents' characteristics from the third section[a]. The survey was conducted through personal interviews during the first semester of 2014. A total of 1800 questionnaires were collected, of which 1523 were complete.

4. Results

The sample corresponds to the 1523 complete questionnaires and is characterized by respondents with mean age of 49 years old (with a minimum and maximum of 18 and 91 years old, respectively); most respondents are married (64%) or single (24%). Regarding their employment situation, most respondents are employed or retired (46% and 24% respectively), and have either completed secondary or higher education (29% and 32%); however approximately 14% have only completed primary school level education.[b]

Due to high non-response rate regarding the income variable (only 36% of the respondents answered the question), the value of the monthly electricity bill is used as a proxy for the income level for comparison purposes. It is assumed that a higher electricity bill is related to more electrical appliances and thus higher income. The average electricity bill in the sample is 66 Euros.

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[a] The questionnaire included a second section eliciting respondents' economic valuation regarding the effects of RES on the environment and which differed according to the specific RES. There were five alternative variants for the second section, specifically concerning solar photovoltaics, hydro power, wind farms, forest biomass and one variant for all renewables. This section is not the focus of the present paper. Both the first and third section, which are the object of analysis of the present paper, are similar in all questionnaires.

[b] Relative to the national population, the sample is relatively older (average age is 41.8 years in 2011); the unemployment rate is similar (in 2015 unemployment rate was 12.4%); the sample has an over-representation of married individuals (national average is 46% in 2011); and respondents are more educated than the national average (25% of Portuguese population has primary schooling, and 13% has completed secondary education in 2011). Data collected from INE (www.ine.pt) and PORDATA (www.pordata.pt).

To understand the social acceptability of RES power plants it is important to characterize attitudes towards environmental issues. When asked about the major environmental problems in Portugal, respondents consider water and air pollution the most significant (51% and 50% respectively), followed by waste management (48%) and climate change (46%). Most respondents are familiar with RES, however the least familiar sources are wave-energy, geothermal and forest biomass. Wave energy is just exploratory in Portugal, thus respondents' unfamiliarity is expected, and the same is true for the case of geothermic energy which is not present in mainland Portugal (only in the archipelago of Açores). Forest biomass, however, is present in Portugal, although with a significantly lower penetration rate, so it is therefore somewhat surprising that only 54% of the respondents indicate knowledge of this particular energy source. Also, 27% of the respondents see some RES power plant in their daily lives, and of those the most frequent (72%) are wind farms (WF), while 35% see solar photovoltaic farms (SPV), 13% hydropower (HP), and only 3% state seeing forest biomass power plants (FB). Most frequently the power plants are visible from either respondents' homes or during their daily commute (Table 1).

Table 1. Descriptive statistics

Variable	Description	Mean/frequency	Variable	Description	frequency
Age	Age of respondent	49.1 (16.6)	*Knowledge*	Wind	98.6%
Employment situation	Unemployed	12.7%		Solar	95.3%
	Unpaid family worker	3.0%		Forest biomass	53.6%
	Student	3.7%		Geothermal	56.5%
	Retired	24.2%		Hydropower	94.9%
	Self-Employed	10.0%		Wave energy	70.8%
	Employed	46.3%	*Respondent sees RES power plant*		27.0%
Marital status	Married	64.0%	*If yes,*	sees WF	72.2%
	Divorced	6.3%	*If yes,*	sees FB	2.9%
	Single	23.9%	*If yes,*	sees HP	12.7%
	Widower	5.8%	*If yes,*	sees SPV	34.6%
Schooling	Primary school (years 1-4)	13.6%	*If yes,*	from residence	50.9%
	Preparatory school (years 5-6)	4.9%	*If yes,*	from work	11.7%
	Secondary school (years 7-9)	13.6%	*If yes,*	during daily commute	54.7%
	Post-secondary (years 10-12)	28.8%	*Environmental problems*	Air pollution	50.9%
	Undergraduate degree	32.5%		Water pollution	51.5%
	Master degree	5.2%		Over-exploitation of natural resourc.	9.1%
	PhD	0.9%		Decreased biodiversity	16.9%
	Other	0.4%		Climate change	46.0%
Electricity bill	Monthly electricity bill €	66.5 (63.6)		Waste	48.2%
				Other	3.3%

(Standard deviations in parentheses)

There, however, are important regional variations, reflecting the geographic distribution of RES power plants. In the districts of Viana do Castelo, Portalegre and Guarda, more than 60% of the respondents see some RES power plant; while less than 20% see one in the districts of Beja, Braga, Porto, Setúbal and Évora. Regarding wind farms, in Bragança, Guarda, Leiria, Lisboa, Portalegre, Santarém, Viana do Castelo, Vila Real, and Viseu, more than 60% of respondents see a wind farm from their homes or work location, or during their daily commutes; while Évora is the only district where respondents do not see a wind farm from their homes or in daily commutes. Respondents from Beja and Portalegre are the ones that see hydropower plants with highest frequency. In most districts the percentage of respondents that state seeing a hydropower plant is lower than 10%, which is expected given the location of dams in Portugal. Respondents' answers regarding solar-photovoltaic farms is not reliable as in most districts respondents state they see these farms daily, while the only solar-photovoltaic farms in Portugal are located in Beja and Évora. We interpret these results as respondents referring to individual solar panels in buildings or in some industrial facility, rather than to actual farms. In 11 districts no respondent states seeing a forest biomass power plant; in the others the percentage stating seeing a forest biomass power plant is lower than 10%, and again there are some responses in the data which probably are not accurate because of lack of information or familiarity with this RES in particular (Table 2).

Table 2. Descriptive statistics by district – visibility of power plant (in %)

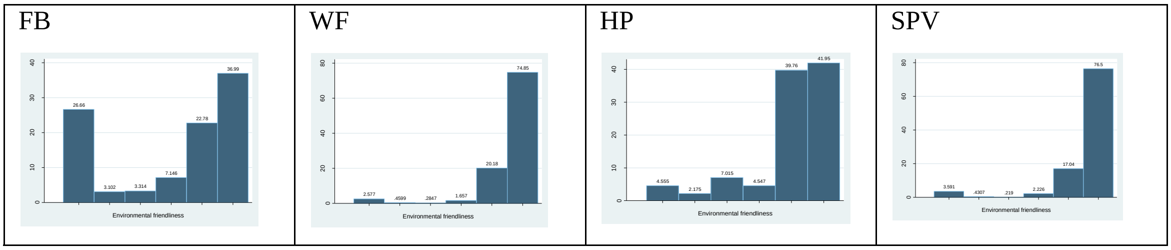
District	RES is visible	WF is visible	FB is visible	HP is visible	SPV is visible
Aveiro	24.1	55.2	0.0	3.5	58.6
Beja	28.6	100.0	0.0	50.0	50.0
Braga	20.1	60.7	3.6	10.7	50.0
Bragança	47.4	88.9	0.0	11.1	33.3
Castelo Branco	35.7	80.0	0.0	10.0	40.0
Coimbra	41.5	77.8	3.7	11.1	33.3
Évora	4.0	0.0	0.0	0.0	100.0
Faro	30.3	80.0	0.0	20.0	25.0
Guarda	64.0	93.8	6.3	25.0	6.3
Leiria	43.3	78.6	0.0	4.8	33.3
Lisboa	21.7	82.4	0.0	1.5	35.3
Portalegre	52.6	90.0	0.0	30.0	0.0
Porto	16.7	33.3	4.4	35.6	44.4
Santarém	31.9	69.6	4.4	8.7	39.1
Setúbal	14.4	52.4	23.8	14.3	42.9
Viana Castelo	67.6	100.0	4.0	8.0	4.0
Vila Real	33.3	90.0	0.0	10.0	10.0
Viseu	45.1	77.3	0.0	13.6	36.4

Regarding respondents' knowledge with respect to the different RES, wind, solar-photovoltaic and hydropower are known to most respondents in all districts. The energy source that is less familiar is forest biomass. Residents in Beja and Castelo Branco are the least familiar with this RES. The most familiar respondents live in Guarda (Table 3).

Table 3. Descriptive statistics by district – knowledge about the different RES (in %)

District	WF is known	FB is known	HP is known	SPV is known
Aveiro	93.1	58.89	95.3	98.1
Beja	100.0	21.4	100.0	100.0
Braga	97.8	56.8	90.7	95.0
Bragança	100.0	57.9	100.0	84.2
Castelo Branco	89.3	35.7	89.3	92.89
Coimbra	96.9	64.6	93.9	98.5
Évora	100.0	44.0	80.0	84.0
Faro	98.5	43.9	97.0	97.0
Guarda	100.0	68.0	88.0	88.0
Leiria	97.9	60.8	93.8	92.8
Lisboa	99.4	49.2	97.8	96.8
Portalegre	94.7	47.4	94.7	94.7
Porto	98.9	53.7	95.6	94.8
Santarém	100.0	62.0	98.6	100.0
Setúbal	99.3	53.8	93.8	92.5
Viana Castelo	97.3	46.0	97.3	94.6
Vila Real	10	46.7	90.0	96.7
Viseu	98.0	58.8	96.1	98.0

To understand the perception by respondents of the degree of environmental friendliness of RES, they were asked to rate each RES on a 5 point scale. Overall, more than 5% find all four RES as somewhat or environmentally friendly. However there is some variation across sources (Figure 1); in the case of forest biomass there is a significant percentage of respondents that are not familiar with the source and consequently are unable to rate it with respect to its environmental friendliness. Concerning hydropower and forest biomass plants, a non-trivial percentage of respondents find them not friendly (respectively 9.2% and 6.4%). Results on the four RES considered reveal significant regional differences between respondents' opinion of the degree of environmental friendliness of RES.



Legend: 0 don't know; 1 not friendly; 2 somewhat not friendly; 3 indifferent; 4 somewhat friendly, 5 very friendly
Fig. 1. Perception of environmental friendliness by source

To explain the perception of environmental friendliness of RES, and to analyse the regional variability in respondents' preferences, an ordered probit model is specified. The ordered probit model is adequate when the dependent variable is categorical and has more than two possible outcomes, and these are ordered from lowest to highest ([38]-[40]). In this case, the dependent variable is the degree of perceived friendliness varying between 1 and 5, respectively. The error term u_j is assumed to be normally distributed and *i* is the number of possible outcomes, in this case 5. Finally $\beta_1,...,\beta_k$ are the coefficients associated with the explanatory variables.

$$\Pr\left(outcome_j = i\right) = \Pr\left(k_{i-1} < \beta_1 x_{1j} + \beta_2 x_{2j} + ... + \beta_k x_{kj} + u_j \le k_i\right)$$

In the estimated model, the explanatory variables are district of residence, age and gender of the respondent, whether the respondent buys environmentally friendly products (to proxy for environmental preferences), a variable relating to the involvement of the respondent with the RES, a binary variable taking the value 1 if the respondent sees a RES power plant daily, and finally the amount of respondents' electricity bill (as a proxy for income, as the variable income had many missing observations).

Tables 4.1-4.4 report the average marginal effects for each outcome (degree of friendliness from 1 to 5) computed after the estimation of the ordered probit.[c] Results in Table 4.1-4-4 reveal consistency across RES. Visibility has a significant effect for hydropower but not in other cases. The effect is positive for unfriendliness levels but negative for upper friendliness level, indicating a dislike for the view. Respondents involved with the RES are more likely to consider the RES environmentally friendly, as expected. Involvement has a significant negative effect on probability of unfriendliness, but a significant positive effect for the friendliness level, indicating that interest increases the positive attitude towards the RES.

Also noteworthy are the regional variations in results. Residents in Lisbon, except for biomass, indicate a more positive attitude towards all energy sources higher than the reference location for friendliness level (Aveiro), but significantly lower for unfriendliness levels. Residents in Setúbal

[c] Results were obtained using Stata12 ®.

consistently show the same behavior, except for forest biomass, while the remaining districts do not show consistent statistically significant differences.

The most likely degree of friendliness is five, the highest, for all energy sources, although the likelihood is higher for SPV, followed by wind farms. Considering degrees four and five together, these two energy sources are very similar.

In summary, respondents depending on their residence district have different opinions regarding each RES, and their opinion is not independent of the particular RES under consideration. WF and SPV are more likely considered environmentally friendly than other sources. If we consider the probability of being classified as somewhat friendly or friendly, WF and SPV have a probability of 98% and 97%, respectively, while HP has a probability of 85% and FB has 83%. All four renewable energy sources considered in this study are objectively environmentally friendly. However, the perception of the degree of friendliness varies between sources and between districts of residence. Moreover, it should be stressed that there is a considerable and statistically significant, although small, percentage of respondents that consider RES not friendly. This is the case of 0.7% for WF, 10% for HP, 0.7% for SPV, and 9% for FB.

Table 4.1. Ordered probit estimated average marginal effects –WF

	Prob(degree=1)	Prob(degree=2)	Prob(degree=3)	Prob(degree=4)	Prob(degree=5)
Age	1.08E-05 (2.25E-05)	9.44E-06 (1.96E-05)	3.54E-05 (7.21E-05)	2.43E-04 (4.93E-04)	-2.98E-04 (6.06E-04)
Male	1.09E-04 (7.32E-04)	9.52E-05 (6.40E-04)	3.58E-04 (2.40E-03)	2.45E-03 (0.02)	-3.01E-03 (0.02)
Electricity bill	-6.94E-06 (6.50E-06)	-6.05E-06 (6.15E-06)	-2.27E-05 (2.06E-05)	-1.55E-04 (1.39E-04)	1.91E-04 (1.71E-04)
Env. Products	-1.44E-03 (1.13E-03)	-1.25E-03 (9.27E-04)	-4.71E-03 (3.37E-03)	-0.03 (0.02)	0.04 (0.03)
RES is visible	-1.42E-03 (1.02E-03)	-1.24E-03 (9.65E-04)	-4.64E-03 (2.90E-03)	-0.03* (0.02)	0.04* (0.02)
Involvement	-2.38E-03* (1.49E-03)	2.08E-03 (1.35E-03)	-7.81E-03** (3.71E-03)	-0.05** (0.02)	0.07** (0.03)
District$^{\alpha}$					
Beja	2.35E-02 (0.02)	0.02 (0.01)	0.05 (0.03)	0.17*** (0.07)	-0.26** (0.13)
Braga	7.11E-04 (2,55E-03)	6.09E-04 (2.16E-03)	2.20E-03 (7.88E-03)	0.01 (0.04)	-0.02 (0.06)
Bragança	1.70E-03 (5.21E-03)	1.43E-03 (4.29E-03)	5.10E-03 (0.01)	0.03 (0.08)	-0.04 (0.10)
Castelo Branco	4.73E-03 (6.34E-03)	3.81E-03 (4.86E-03)	0.01 (0.02)	0.06 (0.07)	-0.09 (0.09)
Coimbra	4.08E-03 (4.55E-03)	3.32E-04 (3.46E-03)	0.01 (0.01)	0.06 (0.05)	-0.08 (0.07)
Évora	-3.84E-03 (2.43E-03)	-3.69E-03 (2.54E-03)	-0.01** (7.78E-03)	-0.11* (0.06)	0.13* (0.07)
Faro	-3.83E-04 (2,73E-03)	-3.34E-04 (2.38E-03)	-1.23E-03 (8.78E-03)	-7.19E-03 (0.05)	9.13E-03 (0.07)
Guarda	-1.61E-03 (3.83E-03)	-1.45E-03 (3.73E-03)	-5.45E-03 (0.01)	-0.03 (0.09)	0.04 (0.12)
Leiria	-2.71E-03 (2.20E-03)	-2.51E-03 (2.07E-03)	-9.67E-03 (6.87E-03)	-0.07 (0.05)	0.08 (0.06)
Lisboa	-4.23E-03* (2,32E-03)	-4.14E-03* (2.42E-03)	-0.02*** (5.81E-03)	-0.14*** (0.04)	0.16*** (0.04)
Portalegre	-2.35E-03 (3.34E-03)	-2.15E-03 (3.24E-03)	-8.21E-03 (0.01)	-0.05 (0.09)	0.07 (0.11)
Porto	-2.73E-03 (2.00E-03)	-2.53E-03 (1.98E-03)	-9.75E-03* (5.94E-03)	-0.07* (0.04)	0.08* (0.04)
Santarém	-2.50E-03 (2.23E-03)	-2.30E-03 (2.17E-03)	-8.81E-03 (7.18E-03)	-0.06 (0.05)	0.07 (0.06)

Setúbal	-4.27E-03* (2.34E-03)	-4.19E-03* (2.45E-03)	-0.02*** (6.06E-03)	-0.14*** (0.04)	0.16*** (0.05)
Viana Castelo	0.01 (7.23E-03)	7.75E-03 (5.40E-03)	0.03* (0.01)	0.11** (0.05)	-0.15** (0.08)
Vila Real	3.18E-03 (4.98E-03)	2.63E-03 (3.96E-03)	9.17E-03 (0.01)	0.05 (0.06)	-0.06 (0.08)
Viseu	-7.81E-04 (2.76E-03)	-6.89E-04 (2.48E-03)	-2.55E-03 (9.02E-03)	-0.02 (0.05)	0.02 (0.07)
Predicted probabilities	3.48E-03** (1.48E-03)	3.55E-03** (1.56E-03)	0.02*** (3.23E-03)	0.19*** (9.84E-03)	0.79*** (0.01)
N	1484				
Wald-chi2	80.21***				

$^{\alpha}$ reference category is Aveiro. *significant at 10%; **significant at 5%, ***significant at 1%. Robust standard errors in parentheses.

Table 4.2. Ordered probit estimated average marginal effects –HP

	Prob(degree=1)	Prob(degree=2)	Prob(degree=3)	Prob(degree=4)	Prob(degree=5)
Age	-6.65E-05 (1.05E-04)	-1.24E-04 (1.95E-04)	-5.96E-05 (9.36E-05)	-1.91E-04 (2.99E-04)	4.42E-04 (6.90E-04)
Male	-2.20E-03 (3.54E-03)	-4.10E-03 (6.61E-03)	-1.97E-03 (3.17E-03)	-6.31E-03 (0.01)	0.01 (0.02)
Electricity bill	-2.70E-05 (3.80E-05)	-5.05E-05 (7.17E-05)	-2.42E-05 (3.44E-05)	-7.77E-05 (1.10E-04)	1.80E-04 (2.54E-04)
Env. Products	-4.76E-03 (4.75E-03)	-8.90E-03 (8.77E-03)	-4.27E-03 (4.30E-03)	-0.01 (0.01)	0.03 (0.03)
RES is visible	9.75E-03** (4.20E-03)	0.02** (7.71E-03)	8.75E-03** (3.78E-03)	0.03** (0.01)	-0.06** (0.03)
Involvement	-7.42E-03 (5.30E-03)	-0.01 (0.01)	-6.65E-03 (4.80E-03)	-0.02 (0.02)	0.05 (0.04)
District$^{\alpha}$					
Beja	8.44E-03 (0.02)	1.43E-03 (0.03)	6.33E-04 (0.01)	1.46E-03 (0.03)	-4.37E-03 (0.10)
Braga	-7.17E-03 (0.01)	-0.01 (0.02)	-5.93E-03 (8.10E-03)	-0.02 (0.02)	0.04 (0.06)
Bragança	-0.01 (0.01)	-0.02 (0.03)	-0.01 (0.01)	-0.03 (0.04)	0.08 (0.09)
Castelo Branco	0.03 (0.02)	0.04 (0.03)	0.02 (0.01)	0.02 (0.01)	-0.12 (0.07)
Coimbra	-4.86E-03 (0.01)	-8.57E-03 (0.02)	-3.91E-03 (9.16E-03)	-0.01 (0.02)	0.03 (0.06)
Évora	-0.02** (0.01)	-0.05** (0.02)	-0.02* (0.01)	-0.09 (0.06)	0.18* (0.11)
Faro	-5.70E-03 (0.01)	-0.01 (0.02)	-4.63E-03 (9.33E-03)	-0.01 (0.02)	0.03 (0.07)
Guarda	0.02 (0.03)	0.03 (0.04)	0.01 (0.02)	0.02 (0.02)	-0.09 (0.11)
Leiria	-0.02* (9.76E-03)	-0.04** (0.02)	-0.02** (8.78E-03)	-0.06** (0.03)	0.13** (0.06)
Lisboa	-0.02* (8.96E-03)	-0.03** (0.02)	-0.02** (7.27E-03)	-0.05** (0.02)	0.11** (0.05)
Portalegre	-0.02* (0.01)	-0.04* (0.02)	-0.02* (0.01)	-0.07 (0.05)	0.15 (0.09)
Porto	4.12E-03 (9.80E-03)	6.81E-03 (0.02)	2.98E-03 (7.26e-03)	6.5E-03 (0.02)	-0.02 (0.05)
Santarém	-8.49E-03 (0.01)	-0.02 (0.02)	-7.15E-03 (9.97E-03)	-0.02 (0.03)	0.05 (0.07)
Setúbal	-0.02** (9.38E-03)	-0.04*** (0.02)	-0.02*** (8.72E-03)	-0.08*** (0.03)	0.17*** (0.06)
Viana Castelo	-7.37E-03 (0.01)	-0.01 (0.02)	-6.12E-03 (0.01)	-0.02 (0.03)	0.04 (0.08)

Vila Real	-6.40E-03 (0.01)	-0.01 (0.03)	-5.24E-03 (0.01)	-0.01 (0.03)	0.04 (0.08)
Viseu	-2.17E-05 (0.01)	-3.70E-05 (0.02)	-1.65E-05 (9.83E-03)	-3.87E-5 (0.02)	1.14E-04 (0.07)
Predicted probabilities	0.03*** (4.10E-03)	0.07*** (6.78E-03)	0.05*** (5.41E-03)	0.40*** (0.01)	0.46*** (0.01)
N	1448				
Wald-chi2	43.38***				

[α] reference category is Aveiro. *significant at 10%; **significant at 5%, ***significant at 1%. Robust standard errors in parentheses.

Table 4.3. Ordered probit estimated average marginal effects –SPV

	Prob(degree=1)	Prob(degree=2)	Prob(degree=3)	Prob(degree=4)	Prob(degree=5)
Age	1.97E-05 (3.15E-05)	7.36E-06 (1.2E-05)	6,23E-05 (9.73E-05)	2.85E-04 (4.44E-04)	-3.74E-0 (5.83E-04)
Male	5.88E-04 (1.03E-03)	2.20E-04 (4.00E-04)	1.86E-03 (3.26E-03)	8.49E-03 (0.01)	-0.01 (0.02)
Electricity bill	-4.54E-06 (8.06E-06)	-1.70E-06 (3.20E-06)	-1.44E-05 (2.55E-05)	-6.56E-05 (1.16E-04)	8.62E-05 (1.52E-04)
Env. Products	-2.08E-03 (1.45E-03)	-7.77E-04 (6.31E-04)	-6.57E-03 (4.69E-03)	-0.03 (0.02)	0.04 (0.03)
RES is visible	-1.89E-03 (1.39E-03)	-7.05E-04 (6.30E-04)	-5.97E-03 (2.80E-03)	-0.03 (0.02)	0.04 (0.02)
Involvement	-4.03E-03* (2.10E-03)	-1.50E-03 (1.06E-03)	-0.01 (5.08E-03)	-0.06*** (0.02)	0.08*** (0.03)
District[α]					
Beja	0.03 (0.03)	9.74E-03 (8.05E-03)	0.07* (0.04)	0.16*** (0.06)	-0.27** (0.12)
Braga	-2.97E-03 (2.66E-03)	-1.18E-03 (1.29E-03)	-0.01 (8.47E-03)	-0.05 (0.04)	0.06 (0.05)
Bragança	6.15E-03 (9.18E-03)	2.17E-03 (3.20E-03)	0.02 (0.02)	0.06 (0.07)	-0.08 (0.10)
Castelo Branco	0.01 (0.01)	3.84E-03 (3.73E-03)	0.03 (0.02)	0.09 (0.06)	-0.13 (0.10)
Coimbra	4.80E-03 (5.12E-03)	1.72E-03 (1.89E-03)	0.01 (0.01)	0.05 (0.04)	-0.07 (0.06)
Évora	-3.82E-03 (3.46E-03)	-1.54E-03 (1.67E-03)	-0.01*** (0.01)	-0.06 (0.06)	0.08 (0.08)
Faro	4.02E-03 (5.20E-03)	1.45E-03 (1.97E-03)	0.01 (0.01)	0.04 (0.05)	-0.06 (0.07)
Guarda	2.63E-03 (8.32E-03)	9.63E-04 (2.92E-03)	7.74E-03 (0.02)	0.03 (0.08)	-0.04 (0.11)
Leiria	-8.67E-04 (3.10E-03)	-3.31E-04 (1.19E-03)	-2.78E-03 (9.90E-03)	-0.01 (0.04)	0.02 (0.06)
Lisboa	-4.85E-03* (2.64E-03)	-2.00E-03 (1.52E-03)	-0.02*** (7.22E-03)	-0.09*** (0.03)	0.12*** (0.04)
Portalegre	-1.86E-03 (6.80E-03)	-7.21E-04 (2,81E-03)	-6.15E-03 (0.02)	-0.03 (0.11)	0.04 (0.14)
Porto	3.76E-03 (2.56E-03)	-1.51E-03 (1.33E-03)	-0.01* (7.45E-03)	-0.06** (0.03)	0.08* (0.04)
Santarém	-4.13E-03 (2.76E-03)	-1.67E-03) (1.45E-03)	-0.01* (8.68E-03)	-0.07* (0.04)	0.09* (0.05)
Setúbal	-5.25E-03* (2.77E-03)	-2.19E-03 (1.62E-03)	-0.02*** (7.52E-03)	-0.11*** (0.04)	0.13*** (0.05)
Viana Castelo	0.02 (0.01)	5.32E-03 (4.01E-03)	0.03* (0.02)	0.11** (0.05)	-0.17** (0.08)
Vila Real	5.45E-03 (8.30E-03)	1.93E-03 (2.82E-03)	0.01 (0.02)	0.05 (0.06)	-0.08 (0.09)
Viseu	-2.59E-04 (2.84E-03)	-9.80E-05 (1.46E-03)	-8.15E-04 (0.01)	-3.30E-03 (0.05)	4.47E-03 (0.07)
Predicted probabilities	4.96E-03***	2.13E-03*	0.02***	0.16***	0.81***

	(1.78E-03)	(1.22E-03)	(3.74E-03)	(9.32E-03)	(9.91E-03)
N	1467				
Wald-chi2	77.01***				

[α] reference category is Aveiro. *significant at 10%; **significant at 5%, ***significant at 1%. Robust standard deviations in parentheses.

Table 4.4. Ordered probit estimated average marginal effects –FB

	Prob(degree=1)	Prob(degree=2)	Prob(degree=3)	Prob(degree=4)	Prob(degree=5)
Age	-1.31E-04 (1.85E-04)	-1.10E-04 (1.55E-04)	-1.39E-04 (1.96E-04)	-2.15E-04 (3.04E-04)	5.95E-04 (8.39E-04)
Male	0.01** (6.20E-03)	0.01** (5.17E-03)	0.01** (6.39E-03)	0.02** (9.75E-03)	-0.06** (0.03)
Electricity bill	-7.86E-05 (5.44E-05)	-6.60E-05 (4.53E-05)	-8.37E-05 (5.74E-05)	-1.29E-04 (8.88E-05)	3.58E-04 (2.43E-04)
Env. Products	-6.44E-03 (8.09E-03)	-5.40E-03 (6.82E-03)	-6.85E-03 (8.70E-03)	-0.01 (0.01)	0.03 (0.04)
RES is visible	7.95E-03 (6.58E-03)	6.67E-03 (5-56E-03)	8.46E-03 (7.00E-03)	0.01 (0.01)	-0.04 (0.03)
Involvement	-0.02** (8.56E-03)	-0.02** (7.28E-03)	-0.02** (9.07E-03)	-0.03** (0.01)	0.09** (0.04)
District[α]					
Beja	0.041** (0.17)	0.10*** (0.02)	0.05 (0.03)	-0.13 (0.09)	-0.44*** (0.07)
Braga	-9.05E-03 (0.02)	-7.69E-03 (0.01)	-9.66E-03 (0.02)	-0.01 (0.02)	0.04 (0.07)
Bragança	0.03 (0.04)	0.02 (0.03)	0.03 (0.03)	0.03 (0.02)	-0.11 (0.12)
Castelo Branco	0.02 (0.03)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	-0.07 (0.10)
Coimbra	-5.55E-04 (0.02)	-4.52E-04 (0.01)	-5.51E-04 (0.02)	-7.38E-04 (0.02)	2.30E-03 (0.07)
Évora	-0.04*** (0.01)	-0.04*** (0.01)	-0.06*** (0.02)	-0.15*** (0.06)	0.30*** (0.10)
Faro	-0.02 (0.02)	-0.01 (0.02)	-0.02 (0.02)	-0.03 (0.03)	0.07 (0.08)
Guarda	-0.02 (0.02)	-0.02 (0.02)	-0.02 (0.03)	-0.03 (0.06)	0.09 (0.14)
Leiria	-6.04E-03 (0.02)	-5.05E-03 (0.01)	-6.28E-03 (0,02)	-8.92E-03 (0.02)	0.03 (0.07)
Lisboa	-7.91E-03 (0.01)	-6.68E-03 (0.01)	-8.37E-03 (0,01)	-0.01 (0.02)	0.04 (0.06)
Portalegre	-0.03 (0.02)	-0.03 (0.03)	-0.04 (0,04)	-0.08 (0.10)	0.18 (0.19)
Porto	-5.21E-03 (0.01)	-4.35E-03 (0.01)	-5.39E-03 (0.01)	-7.58E-03 (0.02)	0.02 (0.06)
Santarém	-0.03** (0.01)	-0.03** (0,01)	-0.04** (0.02)	-0.08** (0.03)	0.18** (0.07)
Setúbal	-4.09E-03 (0.02)	-3.39E-03 (0.01)	-4.18E-03 (0.02)	-5.82E-03 (0.02)	0.02 (0.07)
Viana Castelo	0.02 (0.03)	0.01 (0.02)	0.01 (0.02)	0.02 (0.02)	-0.06 (0.10)
Vila Real	0.01 (0.03)	0.01 (0.02)	0.01 (0.03)	0.01 (0.03)	-0.05 (0.11)
Viseu	-0.01 (0.02)	-9.95E-03 (0.01)	-0.01 (0.02)	-0.02 (0.03)	0.05 (0.08)
Predicted probabilities	0.04*** (5.84E-03)	0.05*** (6.38E-03)	0.08*** (8.18E-03)	0.30*** (0.01)	0.53*** (0.015)
N	1117				
Wald-chi2	45.90***				

[α] reference category is Aveiro. *significant at 10%; **significant at 5%, ***significant at 1%. Robust standard errors in parentheses.

5. Discussion and Conclusions

Renewable energy sources have become popular in the context of climate change policies. The EU has set increasingly more stringent targets for greenhouse gas emissions, whose attainment relies heavily on a more intensive use of renewable energy sources. The intensification of use of RES requires the installation of new WF and SPV, HP and FB plants, which then requires sitting decisions for these facilities. As argued, these decisions are multidimensional and affect a multitude of stakeholders. Botelho et al. [41] find significant effects of the installation of RES facilities on residents living nearby. Moreover, the welfare effects are location and energy source specific, thus requiring a site/ energy source specific evaluation. The results obtained in the present study support the general claim that renewable energy sources are perceived as environmentally friendly, and consequently socially acceptable. However, the results also support the hypothesis that the acceptability of renewable energy sources varies across sources and locations. Moreover, the degree of environmental friendliness varies not only by district of residence, but also with socio-demographic characteristics of the respondents and their relationship with the environment and the RES in particular. Additionally, the effect of visibility of RES power plants on the social acceptability is supported by the results presented and reinforces the plausibility of the NIMBYism effect reported in Devine-Wright [30], for example.

While the results are in line with previous literature, showing a general social acceptance of RES, the present paper adds some qualifications to this general result. First, there are considerable differences between respondents’ perception of specific RES. In particular wind and solar energy are considered the friendliest, followed by hydropower and forest biomass. Second, there is a small but non-negligible fraction of the population that consider RES not environmentally friendly (particularly HP and FB). In addition, we observe regional and socio-demographic variations which suggest preferences depend on the experience and familiarity with specific energy sources. Therefore a more nuanced and detailed analysis of the social acceptance of the different RES is called for when discussing and developing renewable energy power plants.

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