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R&D programs for wave energy in Spain: A contingent valuation application with multiple bounded uncertainty

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ABSTRACT

The development of wave energy is currently at the prototype stage, and it is possible that public funding may be required in order to facilitate its effective advancement. The majority of the general public shows a lack of knowledge regarding this specific offshore energy. This study employs a contingent valuation approach to assess the willingness of a representative sample of 2556 Spanish citizens to finance new research and development programs on wave energy. The results demonstrate a minimum willingness to pay (WTP) of €0.86 per month. Attending to different uncertainty considerations, there is a substantial variability in WTP estimates. Differences can be attributed to the limited knowledge surrounding this renewable energy source and the high uncertainty in WTP responses. There are also observed significant statistical differences depending on the manner in which the payment timeframe is presented. By employing the most conservative estimates as a reference point, the change in aggregate well-being could exceed 194 million euros per year. This figure provides a clear indication for policymakers on the social support for programs aimed at promoting and developing wave energy in Spain.

1. Introduction

The European Commission estimates the objective to have an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy, i.e. wave energy, tidal energy, ocean thermal energy, osmotic & salinity gradient, and others ([1]), by 2030 with a view to reach by 2050, 300 GW and 40 GW, respectively, of installed capacity ([2]). The global installed ocean energy capacity increased from 254.7 MW in 2012 to 508.1 MW in 2023. A half of the ocean energy installed capacity is the Republic of Korea, followed by 43 % in the European Union ([3]). In accordance with the International Renewable Energy Agency ([4]), the global ocean energy potential and deployment is the following: ocean thermal (44000 TWh), wave (29500 TWh); salinity gradient (1650 TWh) and tidal stream (1200 TWh). Tidal stream and wave energy converters are the most mature solutions applicable across different geographies. Tidal stream is now at pilot farm stage, whereas wave energy is at prototype stage, with several scaled and full-scale devices being tested in real sea conditions. In Northern Spain, the *Mutriku* wave plant is the first worldwide commercial project associated with the wave power sector. It produces approximately 300,000 kWh per year. It was launched in 2011 and in January 2024 reached cumulative electricity production of three million kWh.

The Spanish National Integrated Energy and Climate Plan (PNIEC) 2021–2030 establishes a framework for innovation and technological development of offshore energies, with special emphasis on offshore wind power. One of the measures is the development of innovative renewable energy facilities that make it possible to take advantage of renewable resources that have not yet been exploited, but which present a certain degree of technological, market or financial risk compared to more established renewable technologies. R&D programs can be likened to public goods in Spain, where traditionally low developed renewable technologies have been supported in order to accelerate their introduction into the market and meet the objectives and commitments set out in the energy plans. The PNIEC contributes to the development of offshore energy in Spain, including the tidal and wave energies. The roadmap for the development of offshore wind and ocean energy in Spain includes the following targets by 2030: a range between 1 GW and 3 GW of offshore wind and a range between 40 MW and 60 MW of ocean energy ([5]).

Offshore energies such as wind and tidal have been demonstrated as the less preferred renewable energies around the world ([6]). Offshore energy has been the subject of several contingent valuation studies,

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which have focused mainly on offshore wind, both to boost its market penetration and to prevent the development of this type of renewable energy. For example [7], estimate the willingness to pay (WTP) of Greek residents for electricity produced by an offshore wind farm, identifying that respondents' environmental awareness and their perception of climate change and renewable energy have a positive effect on their WTP, which is estimated at €120/year [8]. estimate the WTP in South Korea for offshore wind energy, finding that each household would be willing to pay on average 3600 KRW (3.1US$) per month as a surcharge in the electricity bill to replace coal-fired electricity with electricity produced by offshore wind. Other studies focus on analyzing preferences to prevent the installation of offshore wind power plants. For example [9], estimated the WTP for preserving a marine ecosystem in Nantucket Sound (USA), where there was a project to install an offshore wind farm, showing an individual WTP of $245.55 by the local population [10]. estimate the preferences for preserving the Estonian coast from wind farm construction, obtaining an average of €27/year for keeping the entire coastline free of wind turbines [11]. examines the WTP of households to preserve the natural beauty of the coast against the construction of offshore wind farms in the USA, obtaining a WTP of $56.71 per year for wind turbines not to be installed and a willingness to accept of $89.44 per year for them to be installed.

Marine renewables, such as tidal and wave energy, have been less studied, especially wave energy. For example [12], applied the contingent valuation method to obtain a preliminary assessment of the benefits of developing technology that commercializes ocean energy in South Korea. Their findings indicated a monthly WTP of US$0.9 per household [13]. estimate a WTP of $3.33 per month in the form of increased electricity bills for tidal energy R&D programs in Puget Sound (USA). Similarly [14], study the WTP in South Korea for tidal energy R&D, showing an average WTP of 4290 KRW (3.49US$) per household per year for 10 years through an increase in income taxes. Finally [15], study consumers' WTP for renewable energy development on the east coast of Malaysia, an area with high wind and wave energy potential, obtaining a WTP of RM4.9 (1.18US$) per month.

Meanwhile, there are also studies preventing for the installation of marine renewable infrastructures [16]. estimate an average WTP of £6.7 to conserve the marine area around St. David's (Pembrokeshire, United Kingdom), where a tidal turbine demonstration project was under development and a larger suite of renewable energy facilities, both tidal and wave, were planned. Similarly [17], discusses preferences for a tidal barrage in the UK, obtaining a WTP between £26.17 and £36.27 per year to secure a barrage design that would reduce the loss of coastal mudflats.

A diversity of methodological approaches has been adopted in other studies to analyze perceptions and/or preferences regarding marine energy. For instance Ref. [18], conducted a survey in 12 locations across the Mediterranean to ascertain citizens' perceptions and attitudes regarding blue energy. The findings of the study indicate that, although blue energy remains to a large extent unfamiliar to the general public (only 42 % of participants reported awareness of these technologies), there is a general willingness to host (70 %) such facilities in residential areas [19]. presented a quantitative investigation of public opinion on a wave energy test site that was under construction near the south-west coast of the United Kingdom. The results of the study indicate a general consensus in favor of wave energy as an economically viable method of electricity generation, with minimal adverse side effects [20]. undertook an evaluation of the principal factors that determine the social acceptance of marine renewable energy projects. The authors highlighted the pivotal role of individual preferences and the heterogeneity of these projects in shaping public opinion. In doing so, they have conducted a choice experiment in Chile with the objective of identifying the attributes that may hinder or favor the social acceptance of tidal energy projects. The findings of the study indicate significant heterogeneity in individual preferences, with energy generation, ecological impact, job creation, co-ownership and distributive justice identified as factors that influence project support [21]. conducted a qualitative empirical study comprising twelve in-depth interviews in order to analyze the acceptance of the coastal oscillating water column plant of *Mutriku* (Spain). The results of the study highlight the significance of effective and meaningful social participation in the successful promotion and dissemination of renewable energy infrastructures, such as wave power plants.

[22] conducted a survey of residents of Washington State (USA) in order to assess attitudes related to tidal energy, perceived benefits and risks, and beliefs about climate change. The findings of the study indicate that increased levels of perceived benefits and beliefs concerning climate change are associated with greater acceptability and support for tidal energy. Conversely, higher perceived risks are associated with reduced acceptability and support. Utilizing discrete choice experiments [23], conducted a study to analyze citizens' preferences for a tidal power plant project in Spain, thereby demonstrating that the general perception of the project is positive [24]. examined the willingness of South Korean households to financially support the environmental mitigation impacts of a tidal power plant [25]. conducted an empirical study of public beliefs and responses to tidal energy. This was achieved by conducting a survey of residents of two villages near a tidal energy converter in Northern Ireland. The results indicate a substantial degree of support for the project, stemming from the belief that it enhanced local distinctiveness by "putting the area on the map", was visually familiar and contributed to climate change mitigation. The prevailing positive beliefs concerning the project ultimately prevailed over the prevailing negative ones, which had asserted that it would engender only a negligible number of positive local economic outcomes and that it could potentially compromise local livelihoods and the local ecology.

This research makes a significant contribution to the existing literature on the economic valuation of offshore renewables. To the best of our knowledge, this is the first published multi-bounded contingent valuation study in Europe that focuses exclusively on wave energy. As explained above, contingent valuation applications have been mainly conducted in Asia or America, and there are not many of those either. The renewable energy targets set for Europe are ambitious, and in order to achieve them, it will be necessary to expand the most developed renewable energies, as well as to research and develop less developed renewables that have great potential, such as wave energy. In Europe, several studies have been conducted to analyze preferences for wave energy using methods other than contingent valuation, and without obtaining WTP estimates. European studies that obtain WTP estimates focus on tidal energy rather than wave energy. This research does so by means of a novel contingent valuation case study on wave energy, incorporating an analysis of the effect of uncertainty of responses in the willingness to pay estimates. Furthermore, a distinguishing feature of this study is that the wave energy has hardly been implemented in Spain despite having the Mutriku wave plant (with an installed capacity of 296 KW) which is a pioneer and global benchmark. Consequently, the present study undertakes an ex-ante analysis, emphasizing the paramount importance of incorporating wave energy into Spain's long-term renewable energy planning strategies, through the implementation of R&D initiatives prior to its integration into the energy system.

For that purpose, a Contingent Valuation with Multiple Bounded Uncertainty (CV MBU) format ([28]) was applied. This methodological framework enables a systematic examination of the sensitivity of WTP with respect to the uncertainty inherent within responses. A variety of approaches were used to measure uncertainty in the contingent valuation literature. Examples of papers dealing with methodological and empirical issues related to uncertainty using the CV MBU include those by Refs. [29–31], and [32], to name a few. To the best of our knowledge, this is the first contingent valuation study that applies the MBU format to wave energy. Moreover, some studies have shown that the payment timeframe can affect responses ([26,27]) and a tentative approach is also presented in this regard. In this sense, payments were presented in three different ways: monthly payments, which correspond with the periodicity of the electricity bill; equivalent annual payments; and in the form of percentage increments.

2. Material and methods

2.1. The sample

An on-line survey was conducted between February and April of 2024 using the TickStat® website. The corresponding Ethical Committee approved the content of the survey (Internal code CSIC 254/2023). A total of 2556 Spanish inhabitants older than 18 years were randomly selected from an on-line database of consumers. Previously, the questionnaire was tested in a pilot survey to 83 random people considering the whole Spanish population. The questionnaire included a contingent valuation question with a multiple bounded uncertainty format. The participants were randomly allocated in three subsamples attending to the way of presentation of the bids (see the next section).

2.2. Contingent valuation with multiple bounded uncertainty

The CV MBU is a combination of a payment card and a polychotomous choice question that allows to express the degree of certainty that an individual would be willing to pay for a new environmental program using five categories: definitively yes (DY), probably yes (PY), not sure (UN), probably no (PN), and definitively no (DN). MBU enables to perform a sensitivity analysis of WTP taking into account the uncertainty in the responses ([34]). Individual responses can be recoded as yes/no decisions and analyzed following several approaches ([28,29,32]). In the MBU format, as the individual knows the full range of bid amounts, it is more likely that she may formulate an overall response strategy ([36]). Following [35], it is possible to bind the maximum WTP of an individual *i* from above by the lowest "no" bid (B_i^H); and from below by the highest "yes" amount (B_i^L):

$$B_i^L < WTP_i < B_i^H \tag{1}$$

We assume that the WTP is a linear function with a random component,

$$WTP = W + \varepsilon \tag{2}$$

where W is the systematic component of WTP, and ε is the random draws from the logistic distribution with the inverse scale of σ. Namely, $\eta=\varepsilon/\sigma$ follows a standard logistic distribution. Then the probability that the WTP lies between B^L and B^H can be expressed as:

$$\begin{aligned} &Pr\left(B^L < WTP < B^H\right) = \\ &= Pr\left(B^L < W+\varepsilon < B^H\right) = \\ &= Pr \setminus (BL < W+\eta\sigma < BH) = \\ &= Pr\ (BL/\sigma < W/\sigma+\eta < BH/\sigma) = \\ &= Pr\ (BL/\sigma - W/\sigma < \eta < BH/\sigma - W/\sigma) \end{aligned} \tag{3}$$

This probability can be expressed using the cumulative distribution function of the standard logistic distribution, i.e.

$$\Pr\left(\alpha+\beta B^L < \eta < \alpha+\beta B^H\right) = F\left(\alpha+\beta B^L\right) - F\left(\alpha+\beta B^H\right) \tag{4}$$

where F is the standard logistic distribution function. Therefore, the log-likelihood function is:

$$ln(L) = \sum_{i=1}^{n} ln\left[F\left(B_i^H\right) - F\left(B_i^L\right)\right] \tag{5}$$

where n is the number of individuals in the sample.

The analytical median (-α/β) can be estimated ([36]), where β represents the coefficient associated with the bid amount and α is the constant in the simple model, or the 'grand constant' in the expanded model, i.e. the sum of the products of the means of the explanatory variables times their associated coefficients. The 95 % confidence intervals were estimated using the [37] bootstrapping with 10,000 replications.

Wording, payment timeframe, temporal aggregation of payments, among other small changes in the definition of the payments, may influence the mean WTP estimates ([26,38–40]). Thus, three versions of the questionnaire were designed. The first one presented a percentage increment of the electricity bill ranging from 1 % to more than 15 %, following an exponential function for the bid design: {1 %, 2 %, 3 %, 6 %, 9 %, 15 %, more than 15 %}. The other two versions departed from the same percentage increments and consisted of presentations of annual and monthly bids calculated attending to a previous question where participants revealed their monthly expenditure of electricity. Participants were randomly assigned to one of the 3 versions. Note that the bids were equivalent between all the subsamples in percentage terms, and the only change between the three versions was the way of presentation of these increments in the electricity bill. An example of the MBU card for a household with electricity monthly expenditure of 100€ is shown in Fig. 1. Each individual is asked to indicate the extent (from definitively yes to definitively no) to which they would be willing to pay each of these increases in their electricity bill over the next 10 years.

According to the PNIEC, respondents are presented with the next contingent valuation scenario: "Some renewable energies are more developed than others. Despite their potential, marine renewable energies have not been well developed in Spain. It will take a long time before wave energy can compete with other renewable sources. In these circumstances, public support is particularly important in stimulating and guiding investments in the development of wave energy. It is therefore proposed that a fund be created to support the research and development programs for wave energy in Spain. This fund would be financed through a surcharge on household electricity bills. By law, the money raised for this fund could only be used for the research and development of wave energy". After the scenario was presented, respondents were asked to indicate their WTP as increases to their electricity bill over the next 10 years using the payment card shown in Fig. 1.

The usual follow-up questions to identify protest responses are included after the MBU card. There is not consensus in the previous literature about the treatment of protest responses. The analysis of protest responses using the MBU format is not straightforward [32]. proposed an integrative framework to deal with uncertainty, indifference and protest behaviors in MBU applications. In this case study, we include protest responses into the econometric analysis as it can avoid problems related to sample selection bias and post-hoc criteria about the weighting procedures of WTP.

3. Results

3.1. The sample

The total sample (n = 2556) is described below, distinguishing the results between the three subsamples in case of statistically significant differences at a 90 % confidence level. Appendix 1 presents the data for these three versions of the questionnaire (percentages, n = 850; annual, n = 848; monthly, n = 858). In relation to the socioeconomic characteristics of the participants, the percentage of women in the sample is 51.6 %, statistically equal to the percentage of the Spanish population aged 18 and older (p-value = 0.9467). The mean age of the participants was 49.7 years, statistically lower than the average age of the Spanish adult (>18 years old) population of 50.7 years (p-value = 0.0002). More than half of the sample (54.5 %) has university studies, with a significant difference (p-value<0.0001) in relation to the distribution by level of education of the Spanish population −41.4 % with university studies-, so that individuals with higher education are overrepresented. Furthermore, there is a statistically significant difference between the monthly and the percentage subsamples.

In relation to the employment situation, about half (49.7 %) of the

Increment of electricity bill*			Definitively no	Probably no	Not sure	Probably yes	Definitively yes
Percentage version	Monthly version	Annual version					
1%	0.81 €	9.67 €	☐	☐	☐	☐	☐
2%	1.61 €	19.34 €	☐	☐	☐	☐	☐
3%	2.42 €	29.02 €	☐	☐	☐	☐	☐
6%	4.84 €	58.03 €	☐	☐	☐	☐	☐
9%	7.25 €	87.05 €	☐	☐	☐	☐	☐
15%	12.09 €	145.08 €	☐	☐	☐	☐	☐
More than 15%	More than 12.09€	More than 145.08€	☐	☐	☐	☐	☐

Fig. 1. Example of MBU card for a household with electricity monthly expenditure of 80.60 € (* only one version is presented to each individual).

people surveyed were salaried, with a statistically significant difference (p-value<0.0001) in the distribution of the participants between different categories of employment situation, especially for students and retirees, where the sample shows percentages clearly lower than those observed for the whole of Spanish society (2.1 % vs. 8.0 % for students, and 16.7 % vs. 23.6 % for retirees). The net monthly household income of the respondents is mostly between €1500–5000, as is the case for Spain. However, there is a significant difference (p-value<0.0001) between the income distribution of the sample and that of the Spanish population, which could be due to the fact that about 20 % of the participants preferred not to declare their income.

The average monthly expenditure on electricity is €80.6 for the sample, statistically equal (p-value = 0.3435) to the average for Spanish households, which stands at €76.51 per month. More than two-thirds of respondents prefer new renewable power plants to be installed throughout Spain, although 13 % prefer such plants to be located far from the area in which they live, although there is a statistically significant difference between the annual subsample and the monthly subsample.

With regard to wave energy, more than 63 % of the participants had not heard of it before. 17.06 % of the respondents were not willing to accept any increase in the electricity bill to finance the research and development of this type of ocean renewable energy in Spain (appointing a statistically significant difference between the percentage of the annual and monthly subsamples). The main reasons were related to an increase in the electricity bill and that they considered that this cost should be borne by electric companies, although there is a significant difference between the annual and monthly subsamples.

For the remaining variables, which are described below, we do not have information to compare with the Spanish population. Respondents have a high level of environmental concern, with marine pollution, water pollution in rivers and lakes, waste generation, climate change and biodiversity conservation being the issues with the highest level of concern. With respect to other environmentally-related claims, more than half of the sample strongly agree that climate change is a reality, and more than three-quarters of participants agree or strongly agree. Likewise, more than two-thirds of the participants believe that Spain should carry out significant reductions in CO_2 emissions immediately. In addition, more than 60 % of the sample agrees or strongly agrees that protecting the environment stimulates economic growth and would be willing to change their lifestyle for the benefit of the environment, although 57.6 % of the participants believe that environmental policies should not cost them more money. Finally, most of the participants are not sure that environmental problems will be solved thanks to technological progress. In any case, there are statistical differences between the annual and the percentage subsample with respect to the statement that environmental policies should not cost more money, as well as between the monthly and the percentage subsample with respect to the statement that environmental problems are often exaggerated.

In relation to the implementation of environmental actions related to consumption habits, the participants mainly separate waste, save water and consume local products. Likewise, 6.1 % are members of an environmental organization. The percentage of participants who carry out each of the actions considered is, in general, statistically equivalent in all subsamples, except for the consumption of fair-trade products and water saving, where differences emerge between the annual and the monthly subsample, and for concern about the origin of energy between the monthly and the other two samples. With regard to carrying out actions to reduce energy consumption in the home, the participants mainly turn off the lights when leaving the room, replace traditional light with energy-saving bulbs, and air dry their clothes. Disconnecting the standby mode of electronic devices is the action they carry out the least, although almost 50 % do it. The percentage of participants who carry out each of these actions is also statistically equivalent for all subsamples, except for replacing light bulbs, where a statistically higher percentage is observed in the annual subsample.

3.2. *Contingent valuation*

Based on the data collected on consumption habits, energy saving, opinions about energy, etc., an exploratory analysis of the statistical individual significance of these variables has been carried out. Then, we selected a set of explanatory variables statistically significant at a level of 90 % in the lower bound (DY) model for the full sample. The explanatory variables included in the expanded models are described in Table 1. We observe that samples are quite similar considering a significance level of 5 %. There is insufficient statistical evidence to conclude that there is a significant difference between the percentages of the samples for all the variables listed in Table 1, except for *GovPay* between the percentage and annual samples (p = 0.0031). The expected sign for all the variables is positive, except the lack of knowledge about the wave energy ([41]), to agree that environmental programs should not cost money to consumers, and living in the Northwest Spain because of the conflicts between the small-scale fisheries and the offshore wind industry.

Table 2 presents the results for the simple and expanded models attending to differentiate levels of uncertainty, from the DY lower bound, where only definitively yes responses are coded as it, to the higher bound DY-PY-UN-PN models where the probably yes, unsure and probably no responses are also coded as yes responses. It is also presented a model for each version of the survey (percentage - %, annual -A and monthly -M) and an aggregate model including all the responses

Table 1
Description of explanatory variables.

Variable	Description	Expected sign	Version			
			All: Full sample	%: Percentage	A: Annual	M: Monthly
Income	Monthly net income over €2000	+	0.4593 (0.4984)	0.4682 (0.4993)	0.4611 (0.4988)	0.4487 (0.4977)
NorthWest	Living in Northwest Spain	−	0.2492 (0.4326)	0.2671 (0.4427)	0.2441 (0.4298)	0.2366 (0.4252)
CCProblem	To consider climate change to be a very important environmental problem	+	0.4863 (0.4999)	0.4859 (0.5001)	0.4965 (0.5003)	0.4767 (0.4997)
Never	I had never heard of wave energy before	−	0.6311 (0.4826)	0.6059 (0.4889)	0.6368 (0.4812)	0.6503 (0.4771)
EnvOwn	Disagree or strongly disagree with the statement “I'm not willing to do anything for the environment if other people do not do the same"	+	0.6811 (0.4661)	0.6824 (0.4658)	0.6804 (0.4666)	0.6807 (0.4665)
LifeStyle	Agree or strongly agree with the statement “I am willing to change my lifestyle for the benefit of the environment"	+	0.6240 (0.4845)	0.6329 (0.4823)	0.6274 (0.4838)	0.6119 (0.4876)
GovPay	Agree or strongly agree with the statement “Government policies to address environmental issues should not cost me money"	−	0.5759 (0.4943)	0.5482 (0.4980)	0.6191 (0.4859)	0.5606 (0.4966)
EnvEcon	Agree or strongly agree with the statement “Protecting the environment is a way to stimulate economic growth"	+	0.6272 (0.4837)	0.6353 (0.4816)	0.6450 (0.4788)	0.6014 (0.4899)
Sample size (n)			2556	850	848	858

Note: Mean values per sample (Standard deviation in parenthesis).

(All). All the bids were coded as percentages to perform the comparisons between the samples. On the basis of the [37] bootstraps, the median WTP are statistically different at a 95 % confidence level for all the versions presented in Table 2 (p-value<0.05), except for the case of ‘Probably Yes All’ for the simple and expanded models, where the null hypothesis is not rejected (p-value = 0.188).

The results of the expanded models show that the explanatory variables have different effects depending on the uncertainty model and version of the questionnaire. Thus, all the variables (Table 1) are statistically significant at 90 % level and confirm the expected sign for the models lower bound (DY) and Probably Yes (DY-PY). People most likely to agree to pay for this R&D program are those with monthly net income over €2000 (*Income*); those who consider climate change to be a very important environmental problem (*CCProblem*); people which disagree or strongly disagree with the statement ‘I'm not willing to do anything for the environment if other people do not do the same’ (*EnvOwn*); or agree or strongly agree with the statement ‘I am willing to change my lifestyle for the benefit of the environment’ (*LifeStyle*), people who agree or strongly agree with the statement ‘Protecting the environment is a way to stimulate economic growth’ (*EnvEcon*). On contrary, those living in the Northwest Spain are more reluctant to finance the program (*NorthWest*), and people that had never heard of wave energy before (*Never*) are most likely to do not pay for the R&D Program. When the models incorporate a higher degree of uncertainty (*Not sure* and *Higher bound*), some of these variables are not statistically significant. But apart from the *Constant* and the *Bid*, the variable *GovPay* is also statistically significant for all the models, i.e. people that agree or strongly agree with the statement ‘Government policies to address environmental issues should not cost me money’ have a lesser probability to pay for the R&D program on wave energy.

As expected, the estimated median WTP is sensitive to the degree of uncertainty taken into consideration, as the ratio of yes/no responses changes. Higher WTP values are estimated from the lower bound to the higher bound models. We can estimate a conservative WTP of 1.13 % from the current average electricity expenditure per household to promote R&D programs for the wave energy. In monetary terms, this increment represents a surcharge of 0.86€ per month in the average Spanish household electricity bill. According to the last data from the Spanish Institute of Statistics, 18.75 million of households were in Spain in 2020. Thus, that surcharge would represent a total of 194 million euros per year for R&D programs on wave energy. This figure represents the aggregate gain in social wellbeing due to the investment in R&D for this new and lesser pollutant energy source in Spain.

4. Discussion

There is a lack of awareness among the Spanish population regarding wave energy. Despite this, it is shown that there is a positive WTP for developing this type of marine energy. Specifically, the population consulted was willing to pay for a R&D program in support of wave energy in Spain. It is observed that, at least, they would be willing to pay €0.93 per month in the average Spanish household electricity bill. This finding indicates that the interviewed population is in favor of redesigning the system of surcharges on the electricity bill for the promotion of renewables. This approach would be similar to the one previously implemented in Spain for wind and solar energy, which have since become well-established in the territory [41]. examined the social perceptions of wave energy on the west coast of North America and also found a majority of respondents held positive attitudes to wave energy, but respondents also had low familiarity, with a quarter of respondents lacking sufficient information to form an opinion.

A number of studies have investigated WTP for wave energy; however, the preceding literature on this particular marine renewable is limited. Taking the most conservative measure obtained from a contingent valuation with MBU format, our results show an average annual WTP €10.37/year per household for wave energy R&D programs in Spain, reaching €103/year per household at the maximum level of uncertainty. The estimated WTP range is broad, but it is a logical consequence of the MBU format. In this sense, the substantial variability in WTP estimates can be attributed to the limited knowledge surrounding this renewable energy source, resulting in high uncertainty in responses.

We proposed an R&D program and not the installation of plants, since this technology has not yet reached a level of maturity for its large-scale implementation in the market. If we compare our results with contingent valuation studies focused on other offshore energies, we observe that for wind energy the values are much higher: €120/year in Ref. [7], $89.44/year in Ref. [11], or $37.2/year in Ref. [8]. [15] estimate the WTP for offshore renewable energy in Malaysia, with high wind and wave energy potential, obtaining a WTP of 14.16$/year, a figure near to our conservative WTP estimate. Similarly [13], estimate a WTP of 39.96$/year for tidal energy R&D programs in Puget Sound (USA) [14]. obtain a lower WTP in South Korea for R&D programs on tidal energy, showing an average WTP of 3.49US$ per household per year for 10 years. Should the most reliable WTP measure be considered, that is to say, the one with lower uncertainty, then the results obtained serve to reinforce the idea that R&D programs on wave energy, which

Table 2
MBU results.

	Lower bound (DY)				Probably yes (DY-PY)				Not sure (DY-PY-UN)				Higher bound (DY-PY-UN-PN)			
	All	%	A	M	All	%	A	M	All	%	A	M	All	%	A	M
Simple model																
Constant	1.114***	1.176***	1.175***	1.085***	1.309***	1.356***	1.260***	1.368***	1.371***	1.399***	1.234***	1.499***	1.643***	1.696***	1.472***	1.791***
	(0.063)	(0.105)	(0.111)	(0.111)	(0.063)	(0.106)	(0.111)	(0.111)	(0.077)	(0.134)	(0.134)	(0.132)	(0.085)	(0.140)	(0.152)	(0.149)
Bid	−0.951***	−1.093***	−1.193***	−0.722***	−0.468***	−0.513***	−0.557***	−0.386***	−0.242***	−0.242***	−0.269***	−0.225***	−0.173***	−0.182***	−0.180***	−0.163***
	(0.009)	(0.017)	(0.018)	(0.014)	(0.006)	(0.001)	(0.012)	(0.010)	(0.005)	(0.009)	(0.009)	(0.008)	(0.005)	(0.009)	(0.009)	(0.009)
Log likelihood	−5223.846	−1634.490	−1600.230	−1907.803	−6114.703	−1979.306	−1983.577	−2094.169	−6659.516	−2183.408	−2275.051	−2178.557	−6468.719	−2097.680	−2235.834	−2117.008
AIC/n	4.089	3.851	3.779	4.452	4.786	4.662	4.683	4.886	5.212	5.142	5.370	5.083	5.063	4.940	5.278	4.939
Median	1.17***	1.08***	0.98***	1.50***	2.80***	2.65***	2.26***	3.54***	5.67***	5.78***	4.59***	6.65***	9.48***	9.31***	8.17***	10.98***
WTP *(% increase)*	(0.059)	(0.085)	(0.084)	(0.133)	(0.107)	(0.165)	(0.162)	(0.220)	(0.221)	(0.386)	(0.372)	(0.382)	(0.256)	(0.413)	(0.487)	(0.421)
	[0.92; 1.43]	[0.71; 1.39]	[0.63; 1.30]	[0.95; 1.97]	[2.35,3.20]	[1.93,3.29]	[1.64,2.93]	[2.59,4.33]	[4.87,6.53]	[4.27,7.10]	[3.13,6.04]	[5.16,7.90]	[8.42,10.42]	[7.60,10.94]	[5.81,9.71]	[9.27,12.32]
Expanded model																
Constant	1.075***	1.133***	1.296***	0.880***	1.359***	1.427***	1.409***	1.256***	2.060***	2.071***	1.955***	2.148***	2.392***	2.482***	2.240***	2.445***
	(0.172)	(0.282)	(0.318)	(0.302)	(0.139)	(0.233)	(0.254)	(0.243)	(0.132)	(0.228)	(0.234)	(0.230)	(0.130)	(0.220)	(0.234)	(0.227)
Bid	−0.991***	−1.133***	−1.249***	−0.758***	−0.508***	−0.552***	−0.606***	−0.424***	−0.261***	−0.257***	−0.292***	−0.247***	−0.193***	−0.200***	−0.199***	−0.184***
	(0.009)	(0.017)	(0.018)	(0.014)	(0.006)	(0.012)	(0.012)	(0.010)	(0.005)	(0.009)	(0.009)	(0.009)	(0.005)	(0.009)	(0.009)	(0.009)
Income	0.214**	0.179	0.239	0.258*	0.273***	0.221	0.272*	0.369***	0.103	−0.010	0.221	0.122	0.142**	0.038	0.164	0.244**
	(0.089)	(0.152)	(0.164)	(0.147)	(0.080)	(0.140)	(0.145)	(0.135)	(0.075)	(0.132)	(0.135)	(0.127)	(0.069)	(0.121)	(0.123)	(0.119)
NorthWest	−0.197*	−0.122	−0.355*	−0.125	−0.258***	−0.162	−0.317*	−0.301*	−0.291***	−0.255	−0.236	−0.397**	−0.319***	−0.378***	−0.209	−0.357**
	(0.108)	(0.177)	(0.211)	(0.184)	(0.096)	(0.163)	(0.170)	(0.173)	(0.090)	(0.157)	(0.156)	(0.155)	(0.081)	(0.144)	(0.139)	(0.142)
CCProblem	0.224**	0.354**	0.150	0.210	0.191**	0.249*	0.133	0.226	0.035	0.082	−0.023	0.083	0.030	0.046	0.042	0.037 (0.126)
	(0.094)	(0.168)	(0.169)	(0.157)	(0.085)	(0.148)	(0.151)	(0.144)	(0.080)	(0.140)	(0.142)	(0.137)	(0.073)	(0.128)	(0.126)	
Never	−0.184**	−0.261*	−0.253	−0.096	−0.137*	−0.210	−0.251*	−0.004	0.033	0.040	−0.058	0.094	0.124*	0.131	0.024	0.194 (0.127)
	(0.090)	(0.154)	(0.165)	(0.153)	(0.082)	(0.142)	(0.146)	(0.141)	(0.078)	(0.137)	(0.139)	(0.133)	(0.073)	(0.126)	(0.128)	
EnvOwn	0.242*	0.128	0.237	0.350*	0.240**	0.091	0.292	0.319*	0.005	−0.034	−0.006	0.041	0.005	0.048	−0.035	−0.015
	(0.123)	(0.218)	(0.217)	(0.208)	(0.099)	(0.174)	(0.178)	(0.169)	(0.088)	(0.152)	(0.162)	(0.148)	(0.080)	(0.140)	(0.143)	(0.138)
LifeStyle	0.196*	0.105	0.202	0.258	0.268***	0.224	0.301*	0.267*	0.124	−0.004	0.189	0.159	0.184**	0.119	0.135	0.270**
	(0.110)	(0.191)	(0.211)	(0.177)	(0.096)	(0.170)	(0.180)	(0.157)	(0.089)	(0.157)	(0.163)	(0.146)	(0.082)	(0.145)	(0.147)	(0.136)
GovPay	−0.571***	−0.520***	−0.613***	−0.560***	−0.888***	−0.842***	−0.902***	−0.871***	−1.220***	−1.074***	−1.266***	−1.276***	−1.461***	−1.390***	−1.442***	−1.504***
	(0.092)	(0.163)	(0.166)	(0.153)	(0.082)	(0.146)	(0.147)	(0.139)	(0.077)	(0.135)	(0.137)	(0.128)	(0.069)	(0.122)	(0.122)	(0.118)
EnvEcon	0.217**	0.336*	0.221	0.170	0.360***	0.463***	0.368**	0.325**	0.108	0.105	0.173	0.092	0.173**	0.083	0.299**	0.184 (0.129)
	(0.105)	(0.191)	(0.196)	(0.166)	(0.092)	(0.171)	(0.169)	(0.149)	(0.085)	(0.155)	(0.157)	(0.138)	(0.079)	(0.139)	(0.146)	
Log likelihood	−5118.513	−1600.239	−1562.634	−1867.748	−5933.039	−1923.051	−1919.325	−2026.871	−6490.720	−2140.078	−2213.742	−2112.786	−6247.882	−2030.332	−2165.919	−2033.085
AIC/n	4.013	3.789	3.709	4.377	4.650	4.548	4.550	4.748	5.087	5.059	5.245	4.948	4.897	4.801	5.132	4.762
Median	1.22***	1.13***	1.03***	1.57***	2.90***	2.75***	2.36***	3.64***	5.81***	5.89***	4.78***	6.80***	9.63***	9.49***	8.36***	11.05***
WTP *(% increase)*	(0.060)	(0.089)	(0.087)	(0.133)	(0.101)	(0.157)	(0.151)	(0.205)	(0.208)	(0.371)	(0.344)	(0.356)	(0.234)	(0.377)	(0.445)	(0.387)
	[1.11; 1.33]	[0.55; 1.40]	[0.61; 1.50]	[0.50; 1.87]	[2.71,3.09]	[1.90,3.28]	[1.57,3.03]	[2.01,4.02]	[5.40,6.21]	[5.28,9.43]	[4.36,7.95]	[6.34,9.97]	[9.17,10.10]	[8.95,13.93]	[7.68,12.88]	[10.47,14.93]

Std.Err. in parenthesis. K&R 95 % Confidence interval in brackets. ***, **, * Significance at 1 %, 5 %, 10 % level.

can be likened to a public good, should be promoted by Spanish public agencies.

In addition, in this article a methodological test was carried out on the effects of the presentation of bids in an MBU format on WTP estimates. The results show that monthly payments could be associated with higher WTP values than the annual or percentage versions if the discount rate was neglectable. The differences between annual and monthly versions could be explained because the annual amounts represent an apparent big share of the electricity bill comparing with the monthly ones [26]. The median WTP values obtained in the percentage version are situated between those yielded by the monthly and annual versions. It can be reasonably assumed that the percentage version is more neutral than the other approaches, and less susceptible to potential bias due to the periodicity of payments. In any case, taking into account different payment timeframes (monthly and annual) generates complexity related to the discount factor used by respondents in the interviews ([33,42,43]). The influence of discount rates in choices could be further examined to calculate the present value of the different approaches [44]. This is a limitation of the study but, at the same time, an opportunity for future research.

5. Conclusions

The previous literature on the economic valuation of renewable energies has focused on inland energies and, among offshore energies, on wind energy. There are few studies on tidal energy and even fewer on wave energy. This article contributes to reducing this gap by analyzing the preferences of a sample of residents in Spain for wave energy. The sample is not representative of the whole population, and thus we cannot argue that our results are representative of the whole Spanish society. First of all, it should be noted that this energy is unknown to almost two-thirds of the 2556 residents in Spain who have participated in this study. Despite this lack of knowledge, respondents show a positive WTP for R&D programs that should allow wave energy to reach the state of maturity necessary to be implemented on a national scale. Therefore, it can be concluded that this ocean energy would be accepted by Spanish society, which would experience a positive wellbeing change due to the greater presence of this renewable energy in the electricity mix. The novel empirical evidence presented herewith can inform the design of incentives to accelerate the development of wave energy. Furthermore, the understanding of the technological restrictions and social preferences regarding wave energy is a keystone to contribute to the fulfilment of the European policies regarding renewable energy.

Although our study does not make any methodological contributions regarding the MBU format, it does offer a novel empirical contribution to the contingent valuation literature on marine renewables. We applied the well-established MBU elicitation format to wave energy in Spain, a low-explored marine energy source. Furthermore, we compared different payment timeframes as an indicator of reliability, thereby contributing to the discussion on how timeframes can affect WTP estimates. Small changes to the payment definition may influence mean WTP estimates, and this paper provides new evidence on this issue, opening up new avenues for future research.

Finally, a straightforward extension of this study is to use other stated preference methods, such as Discrete Choice Experiments, to examine the trade-offs between different benefits or disbenefits from wave energy, to analyze the preferences of the wave energy compared to other marine energy renewables, and to better understand why people should pay more for wave energy.

CRediT authorship contribution statement

Emilio Cerdá: Writing – review & editing, Writing – original draft, Supervision, Resources, Investigation, Funding acquisition, Conceptualization. **Xiral López-Otero:** Writing – review & editing, Writing – original draft, Resources, Investigation, Data curation, Conceptualization. **Sonia Quiroga:** Writing – review & editing, Validation, Investigation, Conceptualization. **Mario Soliño:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Comparison of subsamples

Table A1
Sample descriptions

		Sample size	Mean	Std. Deviation	Min.	Max.	Statistical tests		
							Annual vs Monthly	Annual vs Percentage	Monthly vs Percentage
Gender (woman: 1; man: 0)	Annual	848	0.5236	0.4997	0	1	*t*-test p-value: 0.6222	*t*-test p-value: 0.6262	*t*-test p-value: 0.9964
	Monthly	858	0.5117	0.5002	0	1			
	Percentage	850	0.5118	0.5002	0	1			
Age	Annual	848	50.3019	13.7226	24	92	Kolmogorov-Smirnov test p-value: 0.278	Kolmogorov-Smirnov test p-value: 0.309	Kolmogorov-Smirnov test p-value: 0.639
	Monthly	858	49.2506	13.7258	24	87			
	Percentage	850	49.4765	13.9398	24	91			
Household - number of members	Annual	848	2.7252	1.3453	1	20	Fisher test p-value: 0.694	Fisher test p-value: 0.076*	Fisher test p-value: 0.045**
	Monthly	858	2.7494	1.7671	1	42			
	Percentage	849	2.5830	1.0796	1	6			
Household - number of childs (<18 years old)	Annual	847	0.6588	0.9775	0	5	Fisher test p-value: 0.938	Fisher test p-value: 0.892	Fisher test p-value: 0.972
	Monthly	858	0.6737	1.0229	0	9			

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Table A1 (*continued*)

		Sample size	Mean	Std. Deviation	Min.	Max.	Statistical tests		
							Annual vs Monthly	Annual vs Percentage	Monthly vs Percentage
	Percentage	850	0.6753	1.0055	0	5			
Residence area (rural: 1, urban: 0)	Annual	848	0.1745	0.3798	0	1	*t*-test p-value: 0.1197	*t*-test p-value: 0.9163	*t*-test p-value: 0.0965*
	Monthly	858	0.1469	0.3542	0	1			
	Percentage	850	0.1765	0.3814	0	1			
Municipality of residence (coast = 1; inner: 0)	Annual	848	0.5849	0.4930	0	1	*t*-test p-value: 0.7021	*t*-test p-value: 0.2567	*t*-test p-value: 0.4504
	Monthly	858	0.5758	0.4945	0	1			
	Percentage	850	0.5565	0.4970	0	1			
Electricity monthly expenditure	Annual	848	73.8625	104.8930	15	2500	Kolmogorov-Smirnov test p-value: 0.848	Kolmogorov-Smirnov test p-value: 0.999	Kolmogorov-Smirnov test p-value: 0.898
	Monthly	858	96.7911	358.9849	15	9000.12			
	Percentage	850	71.1634	79.3692	15	2000			

** Statistical significative difference at 5 % level; **statistical significative difference at 10 % level.

Table A2
Sample characteristics

Variable	Annual	Monthly	Percentage	Statistical tests		
				Annual vs Monthly	Annual vs Percentage	Monthly vs Percentage
Education level				Fisher test p-value: 0.970	Fisher test p-value: 0.222	Fisher test p-value: 0.070*
Without studies	0.12 %	0.00 %	0.35 %			
Primary	2.59 %	2.80 %	2.94 %			
Secondary	7.67 %	7.23 %	5.06 %			
Old secondary	12.74 %	12.35 %	13.29 %			
Professional training	23.47 %	24.71 %	21.18 %			
University	50.47 %	50.47 %	53.53 %			
Doctorate	2.95 %	2.45 %	3.65 %			
Employment status				Fisher test p-value: 0.215	Fisher test p-value: 0.173	Fisher test p-value: 0.589
Salaried	49.88 %	49.88 %	49.29 %			
Autonomous	7.67 %	7.93 %	9.18 %			
Unemployed	11.44 %	11.89 %	9.65 %			
Student	1.18 %	2.68 %	2.47 %			
Public employee	8.49 %	9.56 %	10.24 %			
Retired	18.28 %	15.03 %	16.82 %			
Other	3.07 %	3.03 %	2.35 %			
Household monthly net income				Chi-square test p-value: 0.590	Chi-square test p-value: 0.112	Chi-square test p-value: 0.634
No income	0.94 %	0.47 %	0.59 %			
<500 €	1.89 %	1.05 %	0.59 %			
500-1000 €	6.37 %	5.24 %	4.94 %			
1000-1500 €	12.85 %	14.10 %	11.65 %			
1500-2000 €	12.97 %	15.15 %	14.00 %			
2000-2500 €	13.56 %	14.34 %	12.47 %			
2500-3000 €	11.56 %	11.77 %	13.18 %			
3000-5000 €	16.63 %	15.15 %	17.53 %			
5000-7000 €	3.66 %	2.68 %	2.35 %			
7000-9000 €	0.59 %	0.58 %	0.71 %			
>9000 €	0.12 %	0.35 %	0.59 %			
Prefers not to answer	18.87 %	19.11 %	21.41 %			
Holidays in coastal area				Fisher test p-value: 0.905	Fisher test p-value: 0.695	Fisher test p-value: 0.991
No	22.17 %	20.75 %	20.94 %			
Yes, because she leaves in a coastal area	38.92 %	38.11 %	37.29 %			
Yes, she usually visits coastal areas for vacations	18.87 %	19.46 %	19.18 %			
Yes, she usually makes trips to coastal areas	11.44 %	13.05 %	13.65 %			
Yes, both on vacations and getaways	8.14 %	8.04 %	8.12 %			
Prefers not to answer	0.47 %	0.58 %	0.82 %			
Degree of concern for environmental issues *a. Air pollution*	*3.8962*	*3.9266*	*3.9329*	Fisher test p-value: 0.800	Fisher test p-value: 0.904	Fisher test p-value: 0.602
Mean	*0.9663*	*0.9855*	*0.9381*			
Std. Error	1.77 %	2.21 %	1.29 %	Fisher test p-value: 0.732	Fisher test p-value: 0.879	Fisher test p-value: 0.416
1. Nothing worrying	6.25 %	5.94 %	5.88 %			

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Table A2 (*continued*)

Variable	Annual	Monthly	Percentage	Statistical tests		
				Annual vs Monthly	Annual vs Percentage	Monthly vs Percentage
2. Little worrying	23.00	21.33 %	22.12 %	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
3. Something worrying	%	38.00 %	39.65 %	0.695	0.762	0.797
4. Quite worrying	38.56	32.52 %	31.06 %	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
5. Very worrying ***b. Pollution of water in rivers and lakes***	%	*4.1818*	*4.2200*	0.901	0.884	0.867
Mean	30.42	*0.9061*	*0.8627*	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
Std. Error	%	1.28 %	0.82 %	0.737	0.688	0.570
1. Nothing worrying	*4.2205*	3.96 %	2.71 %	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
2. Little worrying	*0.8664*	13.99 %	15.53 %	0.260	0.216	0.452
3. Something worrying	0.71 %	36.83 %	35.53 %	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
4. Quite worrying	3.42 %	43.94 %	45.41 %	0.424	0.660	0.460
5. Very worrying ***c. Marine pollution***	14.39	*4.2331*	*4.2588*	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
Mean	%	*0.8785*	*0.8498*	0.652	0.980	0.554
Std. Error	36.08	1.05 %	0.59 %			
1. Nothing worrying	%	2.80 %	3.06 %			
2. Little worrying	45.40	14.92 %	13.76 %			
3. Something worrying	%	34.27 %	35.06 %			
4. Quite worrying	*4.2736*	46.97 %	47.53 %			
5. Very worrying ***d. Waste generation***	*0.8683*	*4.1352*	*4.1518*			
Mean	1.06 %	*0.9027*	*0.8800*			
Std. Error	2.95 %	1.17 %	0.82 %			
1. Nothing worrying	12.50	3.85 %	3.29 %			
2. Little worrying	%	16.32 %	17.41 %			
3. Something worrying	34.55	37.65 %	36.82 %			
4. Quite worrying	%	41.03 %	41.65 %			
5. Very worrying ***e. Climate change***	48.94	*4.0723*	*4.1376*			
Mean	%	*1.1223*	*1.0628*			
Std. Error	*4.1592*	4.31 %	3.65 %			
1. Nothing worrying	*0.8824*	6.18 %	4.71 %			
2. Little worrying	1.18 %	15.15 %	14.47 %			
3. Something worrying	2.95 %	26.69 %	28.59 %			
4. Quite worrying	16.27	47.67 %	48.59 %			
5. Very worrying ***f. Overexploitation of renewable natural***	%	*3.9126*	*3.9424*			
resources	37.97	*1.0476*	*0.9900*			
Mean	%	2.45 %	1.53 %			
Std. Error	41.63	8.04 %	6.71 %			
1. Nothing worrying	%	20.75 %	22.71 %			
2. Little worrying	*4.1203*	33.33 %	34.12 %			
3. Something worrying	*1.1133*	35.43 %	34.94 %			
4. Quite worrying	4.48 %	*3.8497*	*3.9400*			
5. Very worrying ***g. Depletion of energy resources***	5.54 %	*1.0604*	*1.0088*			
Mean	13.09	3.15 %	2.12 %			
Std. Error	%	7.93 %	6.82 %			
1. Nothing worrying	27.24	22.14 %	20.82 %			
2. Little worrying	%	34.38 %	35.41 %			
3. Something worrying	49.65	32.40 %	34.82 %			
4. Quite worrying	%	*4.0886*	*4.1200*			
5. Very worrying ***h. Threatened species and biodiversity***	*3.9717*	*0.9801*	*0.9510*			
Mean	*1.0119*	1.52 %	1.41 %			
Std. Error	2.71 %	5.24 %	4.94 %			
1. Nothing worrying	5.42 %	19.11 %	16.59 %			
2. Little worrying	20.05	31.12 %	34.35 %			
3. Something worrying	%	43.01 %	42.71 %			
4. Quite worrying	35.61					
5. Very worrying	%					
	36.20					
	%					
	3.9340					
	1.0570					
	2.83 %					
	7.55 %					
	19.69					
	%					
	33.25					
	%					
	36.67					
	%					
	4.1073					
	0.9579					
	1.65 %					
	4.60 %					
	17.33					
	%					
	34.20					

(*continued on next page*)

Table A2 (*continued*)

Variable	Annual	Monthly	Percentage	Statistical tests: Annual vs Monthly	Statistical tests: Annual vs Percentage	Statistical tests: Monthly vs Percentage
	% 42.22 %					
Thinking that Spain should carry out significant reductions in CO2 emissions				Fisher test p-value: 0.918	Fisher test p-value: 0.429	Fisher test p-value: 0.130
No	7.19 %	7.23 %	6.00 %			
Yes, immediately	68.16 %	67.02 %	68.35 %			
Yes, but not right now	13.33 %	14.69 %	12.71 %			
Don't know	10.38 %	10.37 %	11.06 %			
Prefers not to answer	0.94 %	0.70 %	1.88 %			
Where would they prefer new renewable power plants to be installed in Spain?				Fisher test p-value: 0.098*	Fisher test p-value: 0.315	Fisher test p-value: 0.817
Distributed throughout the territory	68.99 %	68.07 %	69.76 %			
In the area where you live	2.24 %	3.38 %	2.47 %			
Far from the area where you live	11.32 %	14.10 %	13.41 %			
Indifferent	16.04 %	12.82 %	12.82 %			
Prefers not to answer	1.42 %	1.63 %	1.53 %			
Considers that the population residing near where a renewable power plant is installed should be compensated				Fisher test p-value: 0.453	Fisher test p-value: 0.665	Fisher test p-value: 0.337
No	12.97 %	14.57 %	12.24 %			
Yes	67.45 %	65.50 %	65.88 %			
Don't know	18.99 %	18.76 %	21.06 %			
Prefers not to answer	0.59 %	1.17 %	0.82 %			
I had heard about wave energy before				Fisher test p-value: 0.082*	Fisher test p-value: 0.308	Fisher test p-value: 0.056*
No	63.68 %	65.03 %	60.59 %			
Yes	35.50 %	32.98 %	38.12 %			
Prefers not to answer	0.83 %	1.98 %	1.29 %			
He is against paying for R&D in wave energy				*t*-test p-value: 0.0291**	*t*-test p-value: 0.5561	*t*-test p-value: 0.1109
Yes	18.75 %	14.80 %	17.65 %			
No	81.25 %	85.20 %	82.35 %			
Main reason to be against paying for R&D in wave energy				Fisher test p-value: 0.052*	Fisher test p-value: 0.695	Fisher test p-value: 0.632
Against renewables in general	1.26 %	7.09 %	4.00 %			
Against the waves in particular	1.26 %	1.57 %	2.00 %			
Your budget does not allow you to afford an additional payment	10.69 %	6.30 %	10.00 %			
This cost must be assumed by companies	25.16 %	22.83 %	25.33 %			
This cost should be assumed by the government	20.13 %	15.75 %	15.33 %			
Other countries will develop wave technology before Spain	0.00 %	2.36 %	0.00 %			
Disagree with an increase in the electricity bill	29.56 %	25.98 %	28.00 %			
No enough information	4.40 %	4.72 %	4.00 %			
Other	7.55 %	13.39 %	11.33 %			
Degree of agreement with statements related to the environment				Fisher test p-value: 0.938 Fisher test p-value: 0.605 Fisher test p-value: 0.900 Fisher test p-value: 0.780 Fisher test p-value: 0.156 Fisher test p-value: 0.701 Fisher test p-value: 0.292 Fisher test p-value: 0.473	Fisher test p-value: 0.416 Fisher test p-value: 0.649 Fisher test p-value: 0.904 Fisher test p-value: 0.495 Fisher test p-value: 0.014** Fisher test p-value: 0.908 Fisher test p-value: 0.836 Fisher test p-value: 0.856	Fisher test p-value: 0.407 Fisher test p-value: 0.086* Fisher test p-value: 0.394 Fisher test p-value: 0.449 Fisher test p-value: 0.199 Fisher test p-value: 0.612 Fisher test p-value: 0.517 Fisher test p-value: 0.841
a. You are not willing to do anything for the environment if others do not do the same						
Mean	*2.2123*	*2.2040*	*2.1565*			
Std. Error	*1.0689*	*1.0690*	*1.0297*			
1. Strongly disagree	7.59 %	27.97 %	29.76 %			
2. Disagree	40.45 %	40.09 %	38.47 %			
3. Neither agree nor disagree	19.34 %	20.05 %	21.06 %			
4. Agree	8.37 %	7.34 %	7.76 %			
5. Strongly agree	4.25 %	4.55 %	2.94 %			
b. Environmental problems are often exaggerated						
Mean	*2.2795*	*2.3170*	*2.2165*			
Std. Error	*1.2268*	*1.1960*	*1.2115*			
1. Strongly disagree	33.73 %	30.42 %	36.47 %			
2. Disagree	29.48 %	31.59 %	28.47 %			
3. Neither agree nor disagree	18.40 %	19.93 %	17.29 %			
4. Agree	11.91 %	12.00 %	12.47 %			
5. Strongly agree	6.49 %	6.06 %	5.29 %			
c. Environmental issues should primarily be addressed by future generations						
Mean	1.9092	1.9277	1.8835			
Std. Error	0.9584	0.9791	0.9383			
1. Strongly disagree	40.45 %	39.63 %	41.76 %			
2. Disagree	36.44	37.53 %	35.18 %			
3. Neither agree nor disagree		15.85 %	17.65 %			
4. Agree		4.43 %	3.76 %			
5. Strongly agree		2.56 %	1.65 %			
d. You are willing to change your lifestyle to						
		3.6096	*3.6482*			
		0.9615	*0.8948*			
		4.20 %	3.06 %			
		6.76 %	5.88 %			

(*continued on next page*)

Table A2 (*continued*)

Variable	Annual	Monthly	Percentage	Statistical tests		
				Annual vs Monthly	Annual vs Percentage	Monthly vs Percentage
benefit the environment	%	27.86 %	27.76 %			
Mean	16.98	46.27 %	49.76 %			
Std. Error	%	14.92 %	13.53 %			
1. Strongly disagree	4.01 %	*3.6783*	*3.6059*			
2. Disagree	2.12 %	*1.0711*	*1.0494*			
3. Neither agree nor disagree	*3.6380*	2.68 %	2.71 %			
4. Agree	*0.9409*	10.61 %	11.88 %			
5. Strongly agree ***e. Government policies to address environmental***	3.30 %	30.65 %	30.59 %			
issues shouldn't cost you money	7.55 %	28.32 %	31.76 %			
Mean	26.42	27.74 %	23.06 %			
Std. Error	%	*3.1107*	*3.1247*			
1. Strongly disagree	47.52	*1.0182*	*0.9772*			
2. Disagree	%	6.88 %	5.65 %			
3. Neither agree nor disagree	15.21	17.83 %	18.24 %			
4. Agree	%	41.03 %	41.18 %			
5. Strongly agree ***f. Environmental problems will be solved thanks***	*3.7783*	25.87 %	27.88 %			
to technological progress	*1.0413*	8.39 %	7.06 %			
Mean	2.00 %	*3.6865*	*3.7294*			
Std. Error	9.79 %	*0.9471*	*0.9497*			
1. Strongly disagree	26.30	2.68 %	3.18 %			
2. Disagree	%	6.06 %	4.94 %			
3. Neither agree nor disagree	32.19	31.12 %	28.35 %			
4. Agree	%	40.21 %	42.82 %			
5. Strongly agree ***g. Protecting the environment is a way to***	29.72	19.93 %	20.71 %			
stimulate economic growth	%	*4.1818*	*4.2212*			
Mean	*3.1179*	*1.0865*	*1.0502*			
Std. Error	*0.9744*	4.55 %	4.00 %			
1. Strongly disagree	5.42 %	3.61 %	2.82 %			
2. Disagree	18.40	13.40 %	14.00 %			
3. Neither agree nor disagree	%	25.99 %	25.41 %			
4. Agree	42.69	52.45 %	53.76 %			
5. Strongly agree ***h. Climate change is a reality***	%					
Mean	25.94					
Std. Error	%					
1. Strongly disagree	7.55 %					
2. Disagree	*3.7370*					
3. Neither agree nor disagree	*0.9145*					
4. Agree	2.59 %					
5. Strongly agree	4.95 %					
	27.95					
	%					
	45.17					
	%					
	19.34					
	%					
	4.2429					
	1.0308					
	3.30 %					
	3.18 %					
	14.50					
	%					
	23.94					
	%					
	55.07					
	%					
Level of connection with nature	*3.5896*	*3.5862*	*3.5706*	Fisher test p-value:	Fisher test p-value:	Fisher test p-value:
Mean	*0.9480*	*0.9064*	*0.8832*	0.617	0.249	0.712
Std. Error	3.18 %	2.10 %	2.24 %			
1. Nothing connected	6.96 %	7.34 %	6.12 %			
2. Little connected	33.84	35.66 %	37.88 %			
3. Moderately connected	%	39.63 %	39.88 %			
4. Quite connected	39.74	15.27 %	13.88 %			
5. Very connected	%					
	16.27					
	%					
Carrying out actions related to consumption habits a. I avoid	49,70	50,59 %	51,60 %	*t*-test	*t*-test	*t*-test
buying products that harm the environment	%	71,24 %	73,02 %	p-value: 0.7163	p-value: 0.4366	p-value: 0.6773
b. I consume local products	72,54	24,77 %	27,10 %	p-value: 0.5516	p-value: 0.8271	p-value: 0.4155
c. I consume organic products	%	26,06 %	25,56 %	p-value: 0.5857	p-value: 0.5818	p-value: 0.2726
d. I consume fair trade products	25,92	25,94 %	27,93 %	p-value: 0.0762*	p-value: 0.1240	p-value: 0.8162
e. I consume cooperative products	%	26,41 %	32,07 %	p-value: 0.6264	p-value: 0.6630	p-value: 0.3558
f. I am concerned with the origin of the energy	22,37	5,63 %	6,39 %	p-value: 0.0319**	p-value: 0.6757	p-value: 0.0103**
g. I am a member of an environmental organization	%			p-value: 0.5786	p-value: 0.9205	p-value: 0.5123

(*continued on next page*)

Table A2 (*continued*)

Variable	Annual	Monthly	Percentage	Statistical tests		
				Annual vs Monthly	Annual vs Percentage	Monthly vs Percentage
h. I separate waste (glass, packaging, cardboard)	26,98 %	87,44 %	87,46 %	p-value: 0.9342	p-value: 0.9414	p-value: 0.9929
i. I save water	31,12 %	82,04 %	83,79 %	p-value: 0.0296**	p-value: 0.2222	p-value: 0.3400
	6,27 %					
	87,57 %					
	85,92 %					
Taking actions to reduce home energy consumption				*t*-test	*t*-test	*t*-test
a. Replacing normal light bulbs with low consumption bulbs	90,90 %	88,43 %	86,93 %	p-value: 0.0952*	p-value: 0.0092**	p-value: 0.3435
b. Reduction in car use	58,16 %	59,70 %	59,48 %	p-value: 0.5187	p-value: 0.5795	p-value: 0.9281
c. Efficient use of air conditioning and heating	71,28 %	68,57 %	70,67 %	p-value: 0.2245	p-value: 0.7839	p-value: 0.3469
d. Turn off the lights when leaving the room	94,44 %	93,46 %	93,99 %	p-value: 0.3937	p-value: 0.6907	p-value: 0.6490
e. Only use full loads in washing machines or dishwashers	79,31 %	78,97 %	78,45 %	p-value: 0.8621	p-value: 0.6613	p-value: 0.7907
f. Wash clothes in cold water instead of hot water	72,70 %	69,51 %	71,02 %	p-value: 0.1474	p-value: 0.4448	p-value: 0.4940
g. Disconnect the standby mode of electronic devices	46,10 %	47,55 %	46,53 %	p-value: 0.5499	p-value: 0.8605	p-value: 0.6729
h. Air dry clothes instead of using a dryer	84,28 %	82,59 %	81,74 %	p-value: 0.3500	p-value: 0.1648	p-value: 0.6468
Opinion on the time spent filling out the questionnaire a. Very long	3,66 %	3,85 %	3,41 %	Fisher test p-value: 0.921	Fisher test p-value: 0.723	Fisher test p-value: 0.306
b. Long	16,98 %	17,95 %	17,76 %			
c. Appropriate	76,30 %	74,59 %	76,59 %			
d. Short	1,89 %	2,56 %	1,29 %			
e. very short	0,47 %	0,47 %	0,12 %			
f. Don't know/prefers not to answer	0,71 %	0,58 %	0,82 %			

** Statistical significative difference at 5 % level; **statistical significative difference at 10 % level.

References

[1] T. Bradford, The Energy System. Technology, Economics, Markets and Policy, The MIT Press, Cambridge, Massachusetts, 2018.

[2] European Commission, An EU Strategy to Harness the Potential of Offshore Renewable Energy for a Climate Neutral Future, COM, 2020, 2020) 741 final.

[3] IRENA, Ocean energy data. Electricity Capacity Trends, International Renewable Energy Agency, Abu Dhabi, 2024. https://www.irena.org/Energy-Transition/Technology/Wind-energy. (Accessed 27 October 2024).

[4] IRENA, Innovation Outlook: Ocean Energy Technologies, International Renewable Energy Agency, Abu Dhabi, 2020.

[5] Ministerio para la Transición Ecológica y el Reto Demográfico, Hoja de Ruta Eólica Marina y Energías del Mar en España. Ministerio Para La Transición Ecológica Y El Reto Demográfico, 2021. Madrid.

[6] E. Cerdá, X. López-Otero, S. Quiroga, M. Soliño, Willingness to pay for renewables: insights from a meta-analysis of choice experiments, Energy Econ. 130 (2024) 107301, https://doi.org/10.1016/j.eneco.2024.107301.

[7] I. Georgiou, F.J. Areal, Economic valuation of an offshore wind farm in Greece: the role of individual's base-state influences and beliefs in the value formation process, Renew. Sustain. Energy Rev. 523 (2015) 717–724, https://doi.org/10.1016/j.rser.2015.07.178.

[8] M.-K. Lee, J. Nam, M. Kim, Valuing the public preference for offshore wind energy: the case study in South Korea, Energy 263 (2023) 125827, https://doi.org/10.1016/j.energy.2022.125827.

[9] J. Haughton, D. Giuffre, J. Barrett, D.G. Tuerck, An Economic Analysis of a Wind Farm in Nantucket Sound, The Beacon Hill Institute at Suffolk University, Boston, Massachusetts, 2004.

[10] M. Müürsepp, Ü. Ehrlich, Conflicting interest in the production of wind energy: public demand for shores without wind turbines, Estonian Discus. Econ. Policy 20 (2) (2012) 126–143, https://doi.org/10.15157/tpep.v20i2.834.

[11] N. Nepal, E. Steltzer, A.K. Bohara, K. Cullen, Public values on offshore wind farm, Environ. Econ. Pol. Stud. 20 (2018) 225–240, https://doi.org/10.1007/s10018-017-0191-8.

[12] S.Y. Kwak, S.H. Yoo, The public's value for developing ocean energy technology in the Republic of Korea: a contingent valuation study, Renew. Sustain. Energy Rev. 43 (2015) 432–439, https://doi.org/10.1016/j.rser.2014.11.036.

[13] H.J. Polis, S.J. Dreyer, L.D. Jenkins, Public willingness to pay and policy preferences for tidal energy research and development: a study of households in Washington state, Ecol. Econ. 136 (2017) 213–225, https://doi.org/10.1016/j.ecolecon.2017.01.024.

[14] K.-R. Choi, J.-H. Kim, S.-H. Yoo, The public willingness to pay for research and demonstration of tidal stream energy in South Korea, Mar. Pol. 138 (2022) 104981, https://doi.org/10.1016/j.marpol.2022.104981.

[15] A.A. Azlina, S.A. Bakar, M. Kamaludin, A.N. Ghani, Willingness to pay for renewable energy: evidence from high wind and wave energy potential areas, Jurnal Ekonomi Malaysia 56 (1) (2022) 59–70, https://doi.org/10.17576/JEM-2022-5601-05.

[16] M. Voke, I. Fairley, M. Willis, I. Masters, Economic evaluation of the recreational value of the coastal environment in a marine renewables deployment area, Ocean Coast Manag. 78 (2013) 77–87, https://doi.org/10.1016/j.ocecoaman.2013.03.013.

[17] T. Hooper, Evaluating the Costs and Benefits of Tidal Range Energy Generation, Doctoral Thesis, University of Bath, 2014.

[18] G. Betti, G.P. Cervellera, F. Gagliardi, C. Gioia, N. Patrizi, S. Bastianoni, Perceptions and attitudes toward blue energy and technologies in the mediterranean area: ASKYOURCITIZENSONBE, Front. Energy Res. 10 (2022) 973952, https://doi.org/10.3389/fenrg.2022.973952.

[19] I. Bailey, J. West, I. Whitehead, Out of sight but not out of mind? Public perceptions of wave energy, J. Environ. Pol. Plann. 13 (2) (2011) 139–157, https://doi.org/10.1080/1523908X.2011.573632.

[20] R.D. Ponce Oliva, M. Estay, M. Barrientos, R.A. Estevez, S. Gelcich, F. Vásquez-Lavín, Emerging energy sources' social acceptability: evidence from marine-based energy projects, Renew. Sustain. Energy Rev. 198 (2024) 114429, https://doi.org/10.1016/j.rser.2024.114429.

[21] I. Heras-Saizarbitoria, I. Zamanillo, I. Laskurain, Social acceptance of ocean wave energy: a case study of an OWC shoreline plant, Renew. Sustain. Energy Rev. 27 (2013) 515–524, https://doi.org/10.1016/j.rser.2013.07.032.

[22] S.J. Dreyer, H.J. Polis, L.D. Jenkins, Changing tides: acceptability, support, and perceptions of tidal energy in the United States, Energy Res. Social Sci. 29 (2017) 72–83, https://doi.org/10.1016/j.erss.2017.04.013.

[23] A. Vazquez, G. Iglesias, Public perceptions and externalities in tidal stream energy: a valuation for policy making, Ocean Coast Manag. 105 (2015) 15–24, https://doi.org/10.1016/j.ocecoaman.2014.12.017.

[24] J.-K. Lee, S.-H. Yoo, Measuring the environmental costs of tidal power plant construction: a choice experiment study, Energy Policy 37 (12) (2009) 5069–5074, https://doi.org/10.1016/j.enpol.2009.07.015.

[25] P. Devine-Wright, Enhancing local distinctiveness fosters public acceptance of tidal energy: a UK case study, Energy Policy 39 (1) (2011) 83–93, https://doi.org/10.1016/j.enpol.2010.09.012.

[26] M. Soliño, B.A. Farizo, M. Vázquez, A. Prada, Generating electricity with forest biomass: consistency and payment timeframe effects in choice experiments, Energy Policy 41 (2012) 798–806, https://doi.org/10.1016/j.enpol.2011.11.048.

[27] H. Andersson, J.K. Hammitt, G. Lindberg, K. Sundström, Willingness to pay and sensitivity to time framing: a theoretical analysis and an application to car safety, Environ. Resour. Econ. 56 (2013) 437–456, https://doi.org/10.1007/s10640-013-9644-0.

[28] C.A. Vossler, G.L. Poe, M.P. Welsh, R.G. Ethier, Bid design effects in multiple bounded discrete choice contingent valuation, Environ. Resour. Econ. 29 (2004) 401–418, https://doi.org/10.1007/s10640-004-9457-2.

[29] A. Alberini, K. Boyle, M. Welsh, Analysis of contingent valuation data with multiple bids and response options allowing respondents to express uncertainty, J. Environ. Econ. Manag. 45 (1) (2003) 40–62, https://doi.org/10.1016/S0095-0696(02)00010-4.

[30] M. Boman, To pay or not to pay for biodiversity in forests - what scale determines responses to willingness to pay questions with uncertain response options? J. For. Econ. 15 (1–2) (2009) 79–91, https://doi.org/10.1016/j.jfe.2008.03.004.

[31] P.-A. Mahieu, P. Riera, B. Kriström, R. Brännlund, M. Giergiczny, Exploring the determinants of uncertainty in contingent valuation surveys, J. Environ. Econ. Policy 3 (2) (2014) 186–200, https://doi.org/10.1080/21606544.2013.876941.

[32] M. Domínguez-Torreiro, M. Soliño, Pricing a rural development program: uncertainty, indifference and protest behaviors, Agric. Econ. 47 (5) (2016) 559–569, https://doi.org/10.1111/agec.12255.

[33] K.J. Egan, J.R. Corrigan, D.F. Dwyer, Three reasons to use annual payments in contingent valuation surveys: convergent validity, discount rates, and mental accounting, J. Environ. Econ. Manag. 72 (2015) 123–136, https://doi.org/10.1016/j.jeem.2015.05.002.

[34] T. Broberg, R. Brännlund, An alternative interpretation of multiple bounded WTP data - certainty dependent payment card intervals, Resour. Energy Econ. 30 (4) (2008) 555–567, https://doi.org/10.1016/j.reseneeco.2008.09.001.

[35] M. Domínguez-Torreiro, M. Soliño, Dealing with uncertainty in public preferences for rural development policies: a contingent valuation survey, Reg. Stud. 49 (4) (2015) 555–567, https://doi.org/10.1080/00343404.2013.783694.

[36] J. Loomis, E. Ekstrand, Economic benefits of critical habitat for the Mexican spotted owl: a scope test using a multiple-bounded contingent valuation survey, J. Agric. Resour. Econ. 22 (2) (1997) 356–366. https://www.jstor.org/stable/40986954.

[37] I. Krinsky, A.L. Robb, On approximating the statistical properties of elasticities, Rev. Econ. Stat. 68 (4) (1986) 715–719, https://doi.org/10.2307/1924536.

[38] D. Rowen, K. Stevens, A. Labeit, J. Elliott, B. Mulhern, J. Carlton, H. Basarir, J. Ratcliffe, J. Brazier, Using a discrete-choice experiment involving cost to value a classification system measuring the quality-of-life impact of self-management for diabetes, Value Health 21 (1) (2018) 69–77, https://doi.org/10.1016/j.jval.2017.06.016.

[39] M.A. Cunha-e-Sá, T. Dietrich, A. Faria, L.C. Nunes, M. Ortigão, R. Rosa, C. Viera-da-Silva, Willingness to pay for nature protection: crowdfunding as a payment mechanism, Environ. Resour. Econ. 88 (2025) 367–396, https://doi.org/10.1007/s10640-024-00933-3.

[40] F. McGowan, E. Denny, P.D. Lunn, Looking beyond time preference: testing potential causes of low willingness to pay for fuel economy improvements, Resour. Energy Econ. 75 (2023) 101404, https://doi.org/10.1016/j.reseneeco.2023.101404.

[41] G. Stelmach, S. Hazboun, D. Brandt, H. Boudet, Public perceptions of wave energy development on the West coast of North America: risks, benefits, and coastal attachment, Ocean Coast Manag. 241 (2023) 106666, https://doi.org/10.1016/j.ocecoaman.2023.106666.

[42] M. Carrasco-Garcés, F. Vásquez-Lavín, R.D. Ponce-Oliva, F. Diaz-Pincheira, M. Barrientos, Estimating the implicit discount rate for new technology adoption of wood-burning stoves, Energy Policy 156 (2021) 112407, https://doi.org/10.1016/j.enpol.2021.112407.

[43] A. Nesticò, G. Maselli, P. Ghisellini, S. Ulgiati, A dual probabilistic discounting approach to assess economic and environmental impacts, Environ. Resour. Econ. 85 (2023) 239–265, https://doi.org/10.1007/s10640-023-00766-6.

[44] H. Wang, J. Je, Implicit individual discount rate in China: a contingent valuation study, J. Environ. Manag. 15 (2018) 51–70, https://doi.org/10.1016/j.jenvman.2017.12.058.