Cleaner Energy Systems 4 (2023) 100052

Contents lists available at ScienceDirect

Cleaner Energy Systems

journal homepage: www.elsevier.com/locate/cles

Public attitudes of offshore wind energy in Japan: An empirical study using choice experiments

Kengo Iwata[a,*], Shinsuke Kyoi[b], Yoshiaki Ushifusa[c]

[a] Graduate School of Global Environmental Studies, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan
[b] Graduate School of Agriculture, Kyoto University, Kitashirakawa Oiwake-cho, Sakyo-ku, Kyoto 606-8502, Japan
[c] Faculty of Economics and Business Administration, The University of Kitakyushu, 4-2-1, Kitagata, Kokuraminami-ku, Kitakyushu, Fukuoka 802-8577, Japan

ARTICLE INFO

Keywords:
Offshore wind energy
Social acceptance
Choice experiments
Mixed logit model

ABSTRACT

This study investigates the conflicts between decarbonization by renewable energy use and local environmental preservation. It also proposes the policy implication for the introduction of offshore wind turbines in Japan. In 2020, the Japanese government declared its goal to achieve zero greenhouse gas emissions by 2050. Subsequently, the interest in renewable energy, such as offshore wind power, has been growing. However, coastal communities have concerns about the negative impact of offshore wind turbines on the landscapes, health, and the environment, and often oppose the construction of offshore wind turbines. In Europe—an advanced region of offshore wind power—there are many studies on its social acceptance; however, Japan records few cases of acceptance. This study conducted a nationwide online survey and a choice experiment for Japanese respondents. It found that offshore wind turbines are positively evaluated in terms of climate change mitigation, but negatively in terms of their impact on the landscape. Heterogeneity was also observed in people's preferences.

1. Introduction

As noted in the 2015 Paris Agreement, "energy decarbonization" has been a pressing issue on a global scale. Consequently, in recent years, the worldwide development of wind-power generation has been expanding. So far, European countries have been at the forefront of wind power development. However, in Europe, the construction of onshore wind power is saturated while the development of offshore wind power is booming (Fig. 1). Currently, the United Kingdom has the largest installed capacity for offshore wind power in Europe, accounting for 45% of the total, followed by Germany (34%) and Denmark (8%) (WindEurope, 2020). The installed capacity in Europe is expected to increase from 22 GW 030 (Soares-Ramos et al., 2020).

However, the breakthrough in offshore wind development in China surpasses that of Europe. China's central and local governments each set their own 13th-period targets for 2016–2020, and the sum of those provincial targets exceeds the national target of 5 GW (Li, 2022). In addition, 12,689 MW of new installed capacity was added in 2021, bringing the total installed capacity to 19.7 GW (WFO, 2021). This is almost equal to the total of the United Kingdom (12.3 MW) and Germany (7.7 MW), making China the world's largest offshore wind power market.

In Japan, the public is increasingly interested in promoting the introduction and use of renewable energies, including wind power, in response to the Fukushima nuclear power plant accident caused by the Great East Japan Earthquake and to counter climate change. Moreover, the national government has been working on a legal framework to promote the spread of renewable energy. An example of its efforts in this regard is the 2012 enactment of the "Act on Special Measures concerning the Procurement of Renewable Electric Energy by Operators of Electric Utilities" (Japanese Law, 2011).

In October 2020, Prime Minister Suga announced Japan's goal of either reducing greenhouse gas emissions to virtually zero or becoming carbon neutral by 2050. In December 2020, the government released its "Green Growth Strategy for Carbon Neutrality by 2050." Under this strategy, the government established action plans for 14 key areas where growth is expected in terms of both industrial and energy policies. One of these 14 areas is offshore wind power, with the goal of introducing 10 million kW of offshore wind power by 2030 and 30–45 million kW by 2040. To achieve this ambitious goal, accelerated diffusion of offshore wind power is required.

However, the introduction of extensive offshore wind power in Japan's waters may affect the landscape and marine ecosystems. Therefore, local stakeholders' concerns (residents and fishermen) and opposition to offshore wind power may increase in the future. For example, in the United Kingdom, although 80% of the general public supported wind power, 75% of all wind power projects were canceled owing to a lack of local acceptance (Bell et al., 2005). In Japan, after a large-scale offshore wind power generation project was announced off the coast of

* Corresponding author.
E-mail address: iwata.kengo.66r@st.kyoto-u.ac.jp (K. Iwata).

https://doi.org/10.1016/j.cles.2023.100052
Received 4 July 2022; Received in revised form 3 January 2023; Accepted 7 January 2023
Available online 10 January 2023
2772-7831/

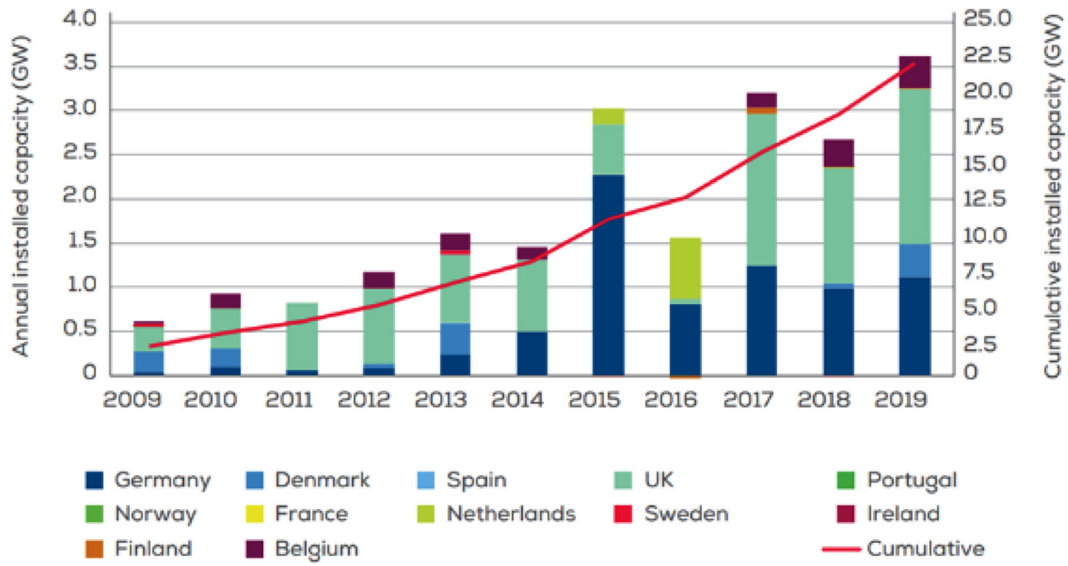

Fig. 1. Annual offshore wind installations by country and cumulative capacity.
Source: WindEurope (2020).

Toyoura Town in Yamaguchi Prefecture, the failure to reach a consensus with local residents and fishermen led to an opposition movement (Chosyu-shimbun, 2020). There is a possibility that there would be frequent opposition and dissent in Japan in the future.

Thus, a detailed analysis of social acceptability and the development of a local consensus are urgent issues in the promotion of offshore wind power. To understand social acceptability in detail, it is necessary to understand people's preferences for offshore wind power. In Japan, however, there has been no objective evaluation of the public and local residents' preferences for offshore wind power generation. Here, this study employed an internet survey of the general public in Japan along with choice experiments. In the choice experiments, the study evaluated people's preferences for the introduction of offshore wind power in terms of monetary value (willingness to pay; WTP) for six different attributes. To include the heterogeneity of people's preferences in the model, a mixed logit model was used to estimate the preferences. Thus, the goal of this study is to close the academic and practical gaps by examining the Japanese public's preference and economic evaluation of offshore wind power from various perspectives.

The remainder of this paper is organized as follows: Section 2 reviews the literature on preference analysis for offshore wind. Section 3 details the methodology of this study. Section 4 reports the results of the data analysis and the estimation results of the choice experiments. Section 5 concludes with a discussion of the results and policy implications.

2. Literature review

2.1. International trends on social acceptance

Quantitative assessments of social acceptance and preferences for offshore wind power are often based on surveys of citizens, local residents, and tourists. Studies have identified the characteristics of local residents and tourists who are receptive to offshore wind power facilities; prioritizing these characteristics/factors may enhance social acceptance. Haggett (2011) discussed the adaptability of offshore wind based on a literature review on onshore wind, and identified five common factors that influence people's responses. Westerberg et al. (2013) investigated the impact of offshore wind farms on coastal tourism in Languedoc Rousillon, Southern France. The authors conducted choice experiments to elicit tourists' preferences for offshore wind turbines at various distances from the coast. The results showed that age, nationality, vacation activities, and loyalty to the destination influenced attitudes toward the compensation policy. In addition, a study using contingent valuation method (CVM) estimated Greek residents' WTP for electricity produced by offshore wind farms located on two Greek islands (Georgiou and Areal, 2015). Another study focused on Atlantic City, New Jersey, US, included a survey of coastal Delaware residents (Bates and Firestone, 2015).

Another feature of the latest literature is that many of them employ mixed logit models (random parameter logit models) in estimating preferences in choice experiments. Ladenburg and Krause (2011) analyzed preferences for the development of a 3600 MW offshore wind farm in Denmark by using a willingness-to-pay space mix-logit model. The results show that there are large differences in willingness to pay as a function of respondents' age, income level, vista point to offshore wind farms, and frequency of beach visits. Oluoch et al. (2021) applied a random parameter logit model to determine how attributes affect Kenyans' willingness to pay for renewable energy development. The results revealed that Kenyans place a high value on environmental impact, followed by the type of renewable energy and job creation in the community.

Empirical studies are also accumulating on whether onshore or offshore wind turbines are preferred. Linnerud et al. (2022) estimated preferences for onshore and offshore wind farms using a choice experiment (applying a mixed logit regression model) with Norwegian citizens. Results showed that respondents preferred offshore locations to onshore; however, they were interested in maintaining local or national control through ownership and intended use of the added power. Lamy et al. (2020) surveyed participants in two coastal municipalities in Massachusetts (US) on their willingness to accept compensation (WTA) for various characteristics of a hypothetical wind project using a model involving mixed-logit estimator regression to estimate utility functions for preferences. The results show that participants prefer onshore to offshore. This result may be driven by cultural identity that favors unobstructed ocean views. In contrast, Ladenburg et al. (2020) investigated spatial preferences for onshore and offshore wind turbines using spatial data processed with a geographic information system (GIS). A flexible mixed logit model was applied to estimate utility/preference parameters and found a significant preference for offshore wind turbines compared to onshore wind turbines.

One relatively unique study analyzes the artificial reefs generated at the base of offshore wind turbines as a positive externality. Klain et al. (2020) conducted choice experiments with residents of an area along the New England coast (US), where a utility-scale offshore wind farm was being planned. The authors found that local residents showed a strong preference for offshore wind turbines that provide high-quality artificial reefs. Dugstad et al. (2020) examined whether people's acceptance of new wind turbine development increases or decreases with exposure to and habituation to wind turbines, demonstrating that exposure can decrease acceptance. Dalton et al. (2020) also conducted an experiment and used a mixed logit model to evaluate the potential impact of offshore wind farms on recreational boaters. Results showed that the value of recreational boating experiences decreases in areas where offshore wind farms are located.

In addition, literature on wind power preference evaluation in Korea has accumulated in recent years. Kim et al. (2019) conducted choice experiments on the impact of offshore wind-energy development projects on Korean citizens. The results of the experiments were added to a cost-benefit analysis, which suggested that the projects' benefits were unlikely to outweigh their costs. Kim et al. (2020) applied an ordered probit model to analyze the determinants of project approval or disapproval for the installation of large-scale offshore wind power among Korean citizens. The results showed that those living in the Seoul metropolitan area, those who are wealthier than others, and those who have installed household photovoltaic systems support the project. Kim et al. (2021) evaluated the Korean public's preference for offshore wind farms by using a mixed logit model. Five attributes were selected: distance from land to offshore wind farms, number of generators at the offshore wind farms, the height of generators visible from the sea surface, reduction in marine life, and location of offshore wind farms. Lee et al. (2020) investigated the Korean public's attitude toward reducing the environmental impact of onshore wind farms, focusing on three areas: visual impact, ecosystem destruction, and noise pollution. Analyzed using a mixed logit model, the results revealed heterogeneity in respondents' preferences, with visual impacts and ecosystem destruction being more important than noise pollution.

One of the characteristics of preference analysis in Korea is that it does not analyze the preferences of residents of a specific region, rather, it investigates the preferences (public attitudes) of the Korean people. This is due to the fact that, for offshore wind power, which is expected to develop in the future, it is necessary first to understand macro preferences/values, rather than preferences in a specific area. As offshore wind power is expected to develop in Japan and Korea in the future, it is highly significant to quantitatively evaluate the preferences of the Japanese public.

2.2. Japanese trends on social acceptance

In Japan, research has examined the social acceptance of renewable energy, in general, and wind power, in particular. Maruyama et al. (2007) analyzed the socioeconomic dynamics of renewable energy technologies. The authors examined community wind power generation, where the initial costs are financed by citizens, and examined how citizen initiatives can influence the social acceptance of renewable energy and social change. Meanwhile, Motosu and Maruyama (2016) focused on the acceptance of people who do not object to having a wind farm in their backyard and clarifies the implications of the silent situation. The authors' survey revealed that most respondents were receptive to existing local wind turbines but had a negative attitude towards new wind turbines.

Meanwhile, the most recent studies have been by Nakano et al. (2018) and Keeley et al. (2021). Nakano et al. (2018) focused on understanding the differences between eastern and western Japan in terms of citizens' preferences for renewable energy. The authors found that the social acceptance of renewable energy and WTP in eastern Japan are influenced by citizens' strong concern for the global environment and willingness to participate in policymaking. Meanwhile, in western Japan, social acceptance of renewable energy is related to support for the liberalization of the electricity retail market and the development of distributed power systems. Keeley et al. (2021) identified the key factors influencing the social acceptance of renewable energy in Japan, using WTP as a measure, by incorporating spatial data on renewable and non-renewable power plants, natural and productive capital, and renewable energy potential.

Table 1
Respondents' attributes (N = 900).

Variable	Definition	Mean	S.D.	Min	Max
sex	1: male; 2: female	1.49	0.50	1	2
age	Age in year	45.81	13.48	20	69
famsize	Number of family members. 1: 1 person; …; 7: 7 or more	2.74	1.30	1	7
income	Household income per year. 1: ⟨ 2 million yen; …; 8: ⟩ 20 million yen	3.46	1.61	1	8
attitude	Pros and cons of offshore wind power in Japan. 1: Pro; …; 5: Con	2.41	0.87	1	5

Note: S.D. indicates the standard deviation.

Studies also suggest that region-specific factors which influence the social acceptance of offshore wind should not be underestimated. The unique conditions of each region, such as social networks and spatial factors, strongly influence residents' social acceptance. Hence, research should incorporate these factors in the analytical framework and evaluate social acceptance in the context of each region. Here, Japan's national conditions to incorporate region-specific factors are included in the analysis of social acceptance.

Based on the literature, this study aims to quantitatively evaluate the Japanese public's preference for offshore wind power. Specifically, this study estimates the WTP for the attributes (distance from the coast, number of wind turbines, affected species, CO_2 reduction, and job creation) using a choice experiment. Furthermore, given that a mixed logit model is used, the study will examine whether there is heterogeneity in respondents' preferences. Although public values and preferences for wind power (onshore and offshore) have already been evaluated in many countries, the characteristics of the energy market and the acceptance and attitude of the general public differ from country to country, and it is important to conduct empirical studies in each region. Therefore, from both academic and policy perspectives, it is important to conduct a preference analysis of public acceptance of offshore wind energy in Japan.

3. Methodology

3.1. Overview of survey

The survey was conducted online by Rakuten Insight Inc. from December 22 to 23, 2020. 900 questionnaires were returned by 900 monitors registered with Rakuten Insight Inc., in the national range, aged between 20 and 69 years. The number of samples is acceptable because it is generally considered desirable to have approximately 1000 samples to conduct choice experiments. Table 1 shows the means and standard deviations of the respondents' attributes, such as gender and age. The gender ratio of the respondents was approximately 50% for both men and women, indicating almost no bias in sample collection. The age of respondents varied, but not substantially, and the sample was drawn from all age groups.

3.2. Choice experiments

The conjoint analysis used in this study is a method to understand the goods by evaluating their multiple attributes, representing them by mul-

Table 2
Attributes and levels.

Attributes	Level 1	Level 2	Level 3
Distance from the shore (km)	10	15	30
Number of the turbines	20	30	40
Levy on renewable energy (yen/kW)	1	3	5
Number of species that may be affected	30	60	90
CO_2 reduction (t/kW)	5	7	10
New job creation (worker/turbine)	20	30	50

Table 3
Sample question for the choice experiment.

Attribute	Option 1	Option 2	Option 3
Distance from the shore	10 km	10 km	No wind-
Number of the turbines	40	30	mills
Levy on renewable energy	5 yen/kWh	3 yen/kWh	(Status
Number of species that may be affected	30	60	quo)
CO_2 reduction	7 t/kw	10 t/kw	
New job creation per turbine	30	20	
Choose the most preferred option			

tiple types and attribute levels, and clarifying the evaluation of marginal changes in each attribute. Various question formats have been proposed for conjoint analysis. However, in the field of environmental economics, "choice experiments" are commonly used. In these experiments, participants are asked to choose the most preferable option among multiple alternatives. This study also employs choice experiments.

The attributes and levels pertaining to the choice experiments were set as shown in Table 2. The following is a description of each attribute and an overview of how the levels were set. "Distance to shore" and "number of wind turbines" are attributes that are mainly considered as "not in my backyard" (NIMBY) issues arising from the landscape impact of wind power generation facilities. The levels were set after referring to current performance data and the literature.

For "levy on renewable energy," three levels were set as 1 yen/kWh, 3 yen/kWh, and 5 yen/kWh based on the Ministry of Economy, Trade and Industry's "levy to promote renewable energy generation," which was in place from May 2019 to April 2020 and set at 2 yen 98 sen per kWh. This attribute is necessary for economic evaluation (WTP estimation).

"Species" represents the number of species that may be affected by the construction and operation of offshore wind power facilities. Data from the New Energy and Industrial Technology Development Organization was used to set baseline values for the levels. The number of species of marine organisms and birds was 44 each, for a total of 88 species. As all species may not be affected at the same time, the levels were set at 30, 60, and 90 species, with 60 species serving as the reference value.

The standard values for "CO_2 reduction" and "new job creation" were calculated based on the estimated data in the proposal for the promotion of offshore wind power generation by the Japan Wind Power Association. Three levels were set with reference to the calculation results (CO_2 reduction of 7.1 t/kW, and job creation of 27 people per wind turbine).

After establishing the attributes and levels, three profiles of the choice experiments were developed. These three profiles consist of two offshore wind power generation plans created by orthogonal planning, and one "status quo" profile with no offshore wind power generation plan and conventional power generation continues. The questions were designed as shown in Table 3 and each respondent was asked six times. Table 4 lists variable names and their definitions.

Table 4
Definition of variables.

Variable	Variable Definition
distance	Distance from the shore
n_turbin	Number of offshore wind turbines
species	Number of species that might be affected
co2_red	Amount of CO_2 reduction
labor	Number of new jobs created
cost	Levy on renewable energy

3.3. Mixed logit model

This study uses a mixed logit model as its analytical model. This model was proposed by Revelt and Train (1998) as one that relaxes the restrictive assumptions in the conditional logit model. The mixed logit model simultaneously resolves the relaxation of the independence of irrelevant alternatives (IIA), assumption, and homogeneity of preferences. Further, this model is a flexible model that can approximate any random utility model (McFadden and Train, 2000). First, let U_{ni} be the utility of respondent n when they choose option i from the choice set C, and consider the random utility function as in Eq. (1) below.

$$\begin{aligned} U_{ni} &= V_{ni}(\beta_n) + \varepsilon_{ni} \\ &= \beta'_n x_{ni} + \varepsilon_{ni} \end{aligned} \quad (1)$$

where the error terms ε_{ni} are assumed to follow type I extreme value distribution independently and identically. In the conditional logit model, the utility parameter is uniform across individuals. However, as indicated by the subscript n in the utility parameter, the mixed logit model incorporates the assumption that different individuals have different preferences.

Furthermore, the distribution of β_n is assumed to be the normal distribution $(\beta|b,)$ with mean b and variance-covariance W. Then, the selection probabilities for the mixed logit model are as follows (McFadden, 1973; Train 2009).

$$P_{ni}(b, W) = \int \prod_{t=1}^{T} \left[\frac{\exp(V_{nit}(\beta_n))}{\sum_{j\in C} \exp(V_{njt}(\beta_n))} \right] \cdot \phi(\beta|b, W) d\beta \quad (2)$$

In general, the integral calculations are not algebraically solvable and the estimation requires the use of approximate calculations by simulation. Thus, the selection probability is computed using the following procedure:

1 Extract β from $\phi(\beta|b, W)$ R times,
2 Substitute the extracted β into the conditional selection probability formula (Eq. (3)) and calculate R selection probabilities,

$$L_{ni}(\beta_n) = \prod_{t=1}^{T} \left[\frac{\exp(V_{nit}(\beta_n))}{\sum_{j\in C} \exp(V_{njt}(\beta_n))} \right] \quad (3)$$

and

1 Find the mean value of the result using Eq. (4). where β^r is the r^{th} extracted β.

$$SP_{ni} = \frac{1}{R} \sum_r L_{ni}(\beta^r) \quad (4)$$

Note that SP_{ni} (simulated probability) is an unbiased estimator of P_{ni}, that is, $E(SP_{ni}) = P_{ni}$ (Train 2009). If δ_n^i is a dummy variable that equals one when individual n chooses option i, the simulated log-likelihood (SLL) function can be expressed as in Eq. (5).

$$SLL(b, W) = \sum_n \sum_i \delta_n^i \ln SP_{ni}(b, W) \quad (5)$$

The parameters to be estimated (b, W) are the maximum simulated likelihood estimator that maximizes SLL (McFadden and Train, 2000).

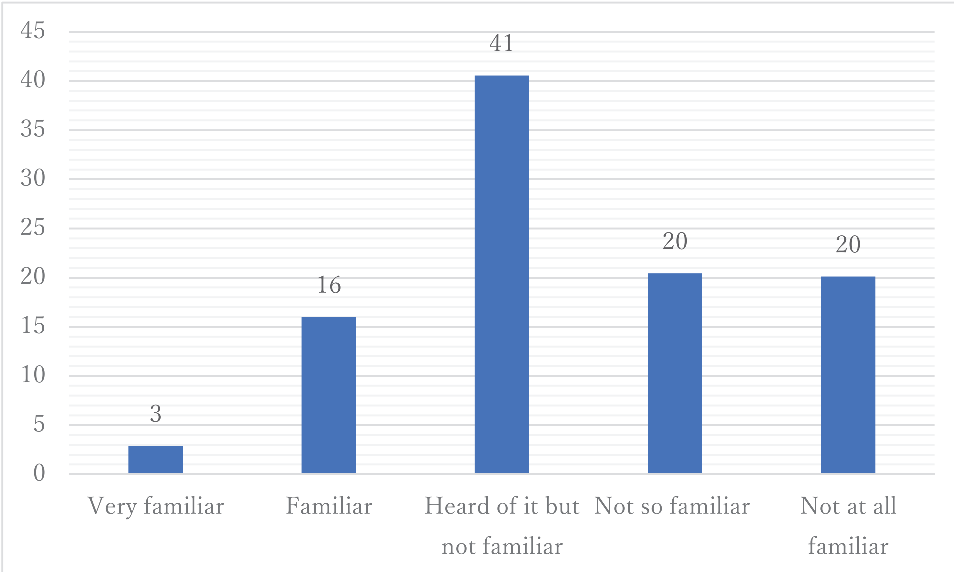

Fig. 2. Familiarity of offshore wind power (%).

Thus, the mixed logit model allows us to obtain not only the mean parameter *b* but also information *W* on the variance of the utility parameter. Note that Eq. (2) shows, the ratio of choice probabilities P_{ni}/P_{nj} in the mixed logit model includes the denominator $L_{ni}(\beta)$ in the integral; this denominator depends on all alternatives. This shows that the ratio of choice probabilities also depends on all alternatives except i and j, completely relaxing the IIA assumption.

The marginal WTP (MWTP) can be obtained from the estimation of the parameter vector β by Eq. (6).

$$MWTP = -\frac{\partial V}{\partial x^*} / \frac{\partial V}{\partial PRICE} = -\frac{\beta_*}{\beta_p} \tag{6}$$

where β_* denotes the estimated parameters other than the amount of the levy.

4. Results

4.1. Survey results

First, let us start with the results of the simple tabulation of the data. Question 3 of the survey asked respondents about their awareness of offshore wind (Fig. 2). 2.9% of respondents were “very familiar” with offshore wind power, and another 16% were “familiar” with it, for a total of 18.9%. In contrast, 20.4% of the respondents answered that they did not know much about it, and 20.1% answered that they did not know it at all, for a total of 40.6%. The total of 40.6% of the respondents answered that they had heard of it but did not know much about it. These results indicate that awareness of offshore wind power is still low in Japan.

Question 6 asked respondents whether Japan should promote the introduction of offshore wind power or not (Fig. 3). 13.9% said they should promote it, and 40.3% said they should rather promote it, for a total of 54.2%. This is a significantly higher percentage than the combined result of those who are “opposed” or “relatively opposed” to the promotion of offshore wind power (7.8%). This result suggests that Japanese people have a positive attitude towards offshore wind power, and that public acceptance at the macro level is high, as is the case with other countries.

Question 4 of the questionnaire asked respondents how much they expected each of the potential benefits (positive aspects) of offshore wind (Fig. 4). The highest expectation was “global warming countermeasures and CO_2 emission reduction,” with a total of 70.9% of the respondents selecting “high expectations” or “expectations,” followed by “energy supply that does not depend on imports.” This was followed by “expectations for an energy supply source that does not rely on imports” (66.9%), “priority distribution of wind-generated electricity in emergencies such as power outages” (61.2%), and “the possibility of creating an industry based on offshore wind power” (57.5%). In contrast, the lowest expectation was “creation of new tourism and regional image” (by the construction of offshore wind turbines), with a total of 39.9% of respondents selecting “high expectations” or “expectations.”

Question 5 asked respondents how concerned they were about each of the possible disadvantages (negative aspects) of offshore wind power (Fig. 5). As a result, the most common concern was “durability against typhoons and earthquakes, and accidents due to collapse,” at 72.6%, including “very concerned” and “somewhat concerned.” This was followed by “impact on local industries such as fishing” (61.4%) and “impact on the ecosystem” (57.9%). Relatively few respondents (53.2%) expressed concern about the possibility of “damage to the landscape.” Japan is unique in that it is prone to disasters such as typhoons and earthquakes, and the effects of these disasters are increasing due to the effects of climate change. This result seems to reflect such a context in Japan.

4.2. Mixed logit estimation results

A nationwide CE survey was conducted in December 2020 by a specialized research firm on 900 randomly selected households, yielding six observations per household. The statistical software Stata16 was used to estimate the parameters. Table 5 shows the estimation results obtained using the mixed logit model. As the z-values of the coefficients shows, the coefficients for each attribute (explanatory variable) are statistically significant at the 1% level. The coefficient estimates for distance, number of wind turbines, and CO_2 reduction were positive-signed, while those for species and new employment were negative-signed. For example, the longer the distance from the coast to the offshore wind turbine, the higher the utility of Japanese citizens. The coefficient on cost also has a negative sign. This means that utility decreases as prices increase, which is reasonable given the negative contribution of prices to utility.

Next, since the coefficients are significant for all attributes, the MWTP estimates can be derived when the level of each attribute increases and decreases. The estimation results are shown in Table 5, which also shows the 95% confidence intervals for the estimated values. The MWTP is 98.2 yen for distance (98.2 yen WTP for every 1 km distance of offshore wind turbines from the coast), 36.6 yen for num-

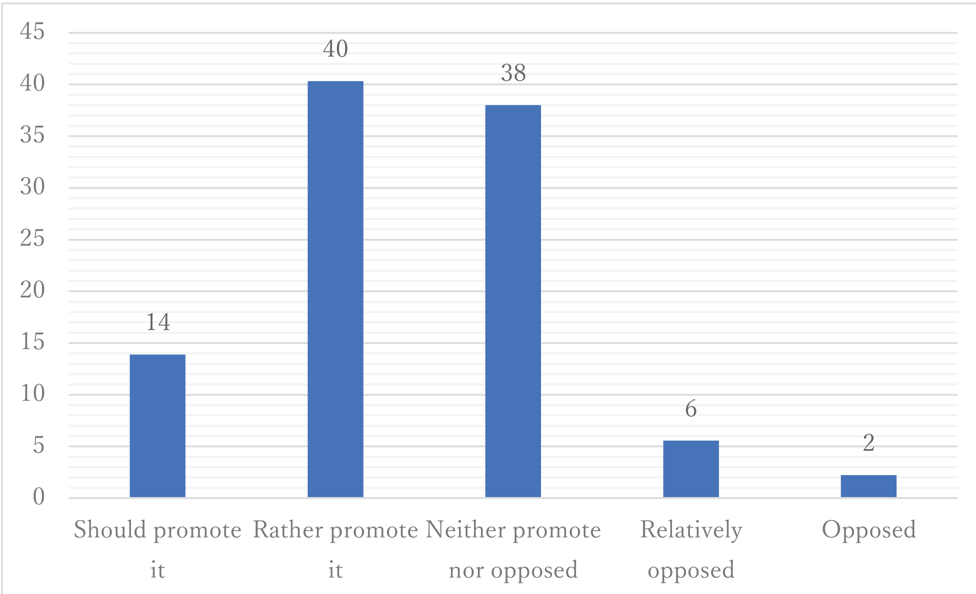

Fig. 3. Attitude towards offshore wind power (%).

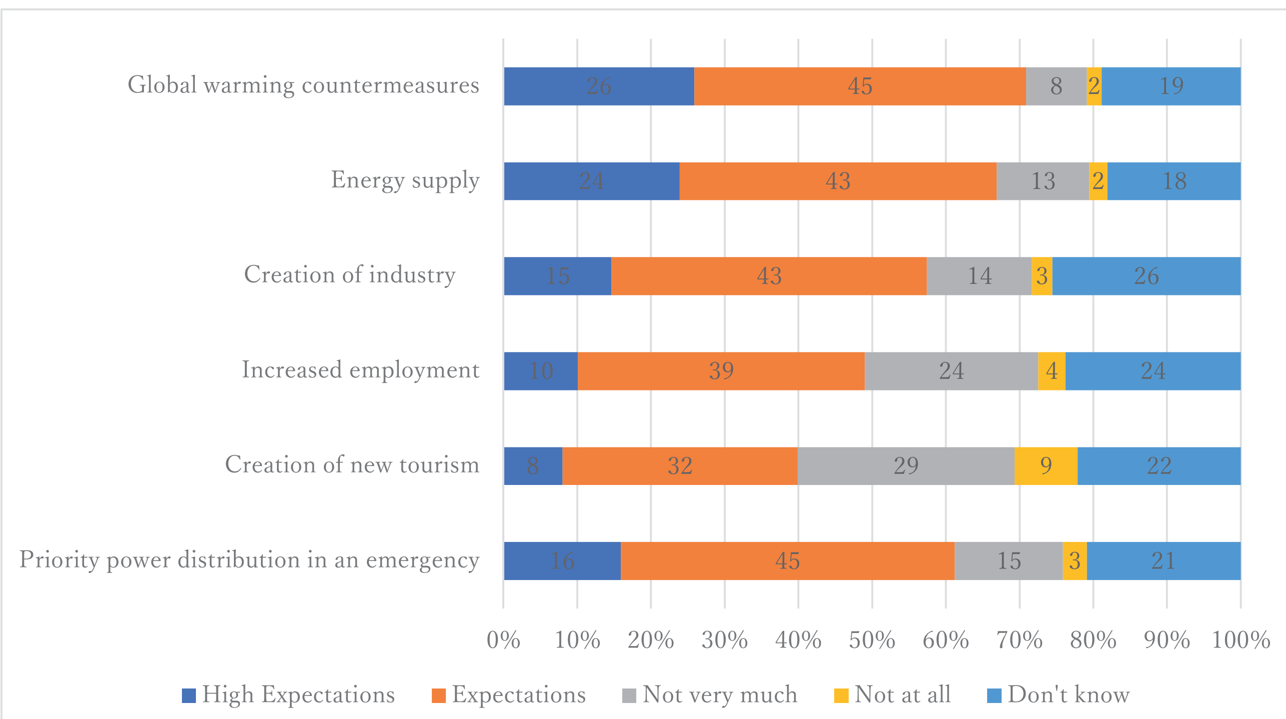

Fig. 4. Expectations for offshore wind power.

ber of wind turbines (36.6 yen WTP for every additional offshore wind turbine), −8.1 yen for species (−8.1 yen WTP for each species affected by offshore wind power construction), 74.2 yen for CO_2 reduction (74.2 yen WTP for each ton of CO_2 reduced by the offshore wind project), and −10.9 yen for job creation (−10.9 yen WTP for each new job created by the offshore wind project).

Furthermore, the estimation results for the heterogeneity of preferences is examined. In the estimation of the mixed logit model, all parameters except the levy (cost) are assumed to be random parameters following a normal distribution. The parameter "cost" is assumed to be a fixed parameter to account for the estimation of MWTP. The results show that the standard deviations of the random variables for all attributes, β, are significant at the 1% level. Thus, heterogeneity in preferences was observed for all attributes. The variation in preferences was particularly large for "distance" and "CO_2 reduction," suggesting a variety of preferences among respondents. For example, the 95% confidence interval of the MWTP for "CO_2 reduction" shows that the lower limit MWTP is 17.6 yen, while the upper limit MWTP is 130.8 yen. The estimation results are discussed in detail in the next section.

5. Discussion and conclusion

The purpose of this study was to determine the peoples' preferences for and the economic value of offshore wind power generation through an experimental questionnaire survey including choice experiments. A

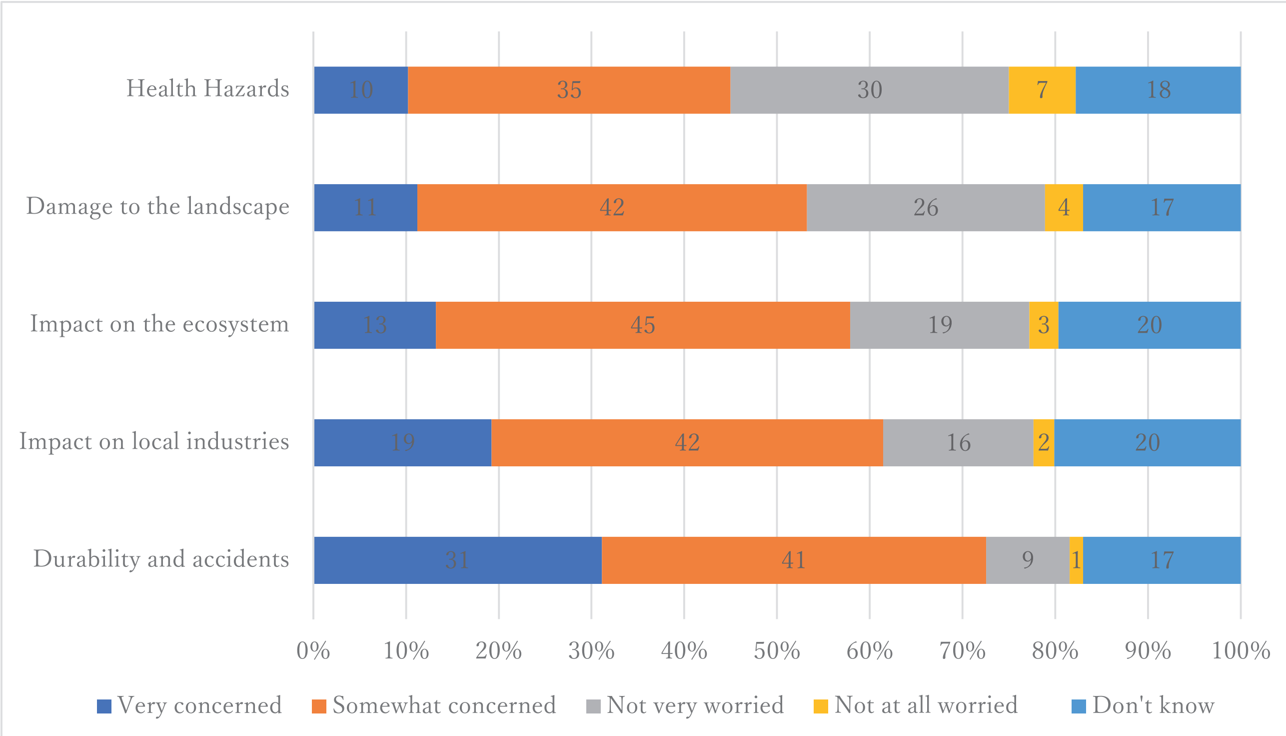

Fig. 5. Concerns about offshore wind power.

Table 5
Estimated results.

	Mixed logit model Mean	S.D.	MWTP (yen)
distance	0.12	0.22	98.20
	(10.67)	(17.47)	[50.89, 145.53]
n_turbin	0.04	0.04	36.62
	(10.74)	(8.22)	[18.31, 54.95]
species	−0.01	0.03	−8.10
	(−4.33)	(14.32)	[−14.82, −1.39]
co2_red	0.09	0.16	74.18
	(5.78)	(7.95)	[17.56, 130.81]
labor	−0.01	−0.03	−10.85
	(−4.48)	(−5.21)	[−19.19, −2.53]
cost	−0.12		
	(−3.66)		
Observations	16,200		
Log-likelihood	−4198.55		

Note: S.D. indicates the standard deviation. Z-values are provided in parenthesis. 95% confidence intervals are displayed in the bracket.

mixed logit model was used to quantitatively determine the diversity of preferences. The following discussion is based on the estimation results.

First, the public's preferences for offshore wind power were evaluated using the choice experiments. The MWTP was found to be 98.2 yen for "distance," 36.6 yen for "number of wind turbines," −8.1 yen for "species," 74.2 yen for "CO_2 reduction," and −10.9 yen for "job creation." The general public highly values offshore wind power for its "distance" effect on the landscape and its "CO_2 reduction" effect on climate change mitigation. This is line with previous evidence (e.g., Westerberg et al., 2013; Klain et al., 2020). This study's results provide supporting evidence that distance is directly related to landscape and that "how" highly visible wind turbines are located/constructed significantly affects their social acceptability. However, because Japan has few shallow seas, it is virtually impossible to install wind turbines out of sight of coastal areas now that fixed-foundation turbines are the mainstream. We will have to wait until the future when floating wind turbines become economically rational. Therefore, it is very important to plan complex measures and compensation systems for the local environment with the consent of residents. It is also noteworthy that the general public greatly appreciated the "CO_2 reduction" related to external benefits. This can be taken as an indication that, as a whole, the Japanese public also has a high level of interest in recent extreme weather events and climate change issues.

In contrast, the response (WTP) to effect on species due to offshore wind construction was relatively low. Although the scenario design of the choice experiments may affect participants' responses, the general public may not be very interested in the modification of the ecosystems (onshore and offshore) in areas where offshore wind turbines will be constructed. However, this assertion is not readily generalizable. Biases may have arisen in the responses because the scenarios and levels were vague. Further research is required on the importance of ecosystems affected by offshore wind turbines.

Second, the estimation results of the mixed logit model revealed that the general public has diverse preferences for all attributes. In particular, "distance" and "CO_2 reduction" showed a large variation in preferences and high MWTP. Importantly, this study provides empirical evidence in a Japanese context that "distance," which is related to the landscape, is an important determinant in the social acceptability of offshore wind power. This is in line with previous evidence (e.g., Westerberg et al., 2013; Kim et al., 2019). Meanwhile, the standard deviation for distance is the largest, with a 95% confidence interval of 50.9 to 145.5 yen. This suggests that the evaluation of this attribute varies greatly from person to person. One potential variable which may affect this is the respondents' place of residence. For example, the WTP may be very high in the planned construction site or area where offshore wind turbines will be constructed.

Furthermore, the preferences for "CO_2 reduction" varied substantially and had the second highest standard deviation with a 95% confidence interval of 17.6 to 130.8 yen. This may be due to the high level of environmental awareness of the respondents and the difference in their values for the public interest. Respondents who are usually environmentally conscious may naturally respond sensitively to climate change issues. Contrarily, some may be more interested in their daily lives than in preserving the global environment and ecosystems. In line with NIMBYism, the corresponding WTP may be relatively low in areas where offshore wind power could be constructed.

The results for these two attributes (“distance” and “CO_2 reduction”) suggest the possibility of the existence of a “green vs. green” debate (Warren et al., 2005; Groothuis et al., 2008), a conflict structure between pro and con groups based on environmental issues among people. However, the mixed logit model cannot perform detailed analyses, such as a factor analysis of preference heterogeneity. Future studies should further investigate whether the WTP of the “distance” (CO_2 reduction) coefficient is relatively high (low) in a particular area.

This study finds academic and practical contributions in the following aspects. First, the attribute-specific MWTP provided in this study present a detailed basis for assessing the economic value of offshore wind. Quantitative analysis of public preferences based on individual attributes using choice experiments is of great academic significance, and the results obtained can be used as basic data. In addition, since there are no existing studies in Japan that analyze the public’s preferences for offshore wind power, the study can be expected to provide new insights into the case study of the choice experiment and develop future research in Japan. For example, if the government and developers know the level of WTP before undertaking offshore wind development projects, this information could contribute to establishing guidelines for factors that could affect the projects.

Second, it provides a basis for setting priorities for improving environmental impacts during the installation of offshore wind farms. Specifically, the following two policy implications can be presented: First, when planning and zoning the construction of offshore wind projects, the distance of offshore wind turbines from the landscape, particularly from the coast, should be considered. This is especially important for fixed-foundation turbines (not floating wind turbines), where there is a trade-off between distance and construction cost. As demonstrated in this study, the general public may have a strong reaction to changes in their landscape. Second, policymakers and practitioners should emphasize that promoting offshore wind power will contribute to climate change mitigation. This is important as the number of Japanese citizens interested in global environmental issues has been increasing rapidly in recent years, as in developed countries in Europe and the United States. Appealing to such people may significantly affect the social acceptability of offshore wind among the Japanese public.

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.

Data Availability

Data will be made available on request.

Acknowledgments

The authors gratefully acknowledge the assistance of Ms. Cao Yue in preparing the questionnaire.

References

Bates, A., Firestone, J., 2015. A comparative assessment of proposed offshore wind power demonstration projects in the United States. Energy Res. Soc. Sci. 10, 192–205.

Bell, D., Gray, T., Haggett, C., 2005. The “Social gap” in wind farm siting decisions: explanations and policy responses. Environ. Polit. 14, 460–477. doi:10.1080/09644010500175833.

Chosyu-shimbun, August 22, 2020. Don’t make Shimonoseki full of wind power! Giant offshore wind farm planned off Toyoura. (URL: https://www.chosyu-journal.jp/yamaguchi/18327, accessed at 01/12/2021).

Dalton, T., Weir, M., Calianos, A., D’Aversa, N., Livermore, J., 2020. Recreational boaters’ preferences for boating trips associated with offshore wind farms in US waters. Mar. Policy 122, 104216.

Dugstad, A., Grimsrud, K.M., Kipperberg, G., Lindhjem, H., Navrud, S. 2020. Acceptance of national wind power development and exposure: a case-control choice experiment approach.

Georgiou, I., Areal, F.J., 2015. 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. 52, 717–724.

Groothuis, P.A., Groothuis, J.D., John, C.W., 2008. Green vs. green: measuring the compensation required to site electrical generation windmills in a viewshed. Energy Policy 36 (4), 1545–1550.

Haggett, C., 2011. Understanding public responses to offshore wind power. Energy Policy 39 (2), 503–510.

Japanese Law, 2011. Act on special measures concerning the procurement of renewable electric energy by operators of electric utilities. (URL: https://elaws.e-gov.go.jp/document?lawid=423AC0000000108, accessed at 05/12/2021).

Keeley, A.R., Komatsubara, K., Managi, S., 2021. The value of invisibility: factors affecting social acceptance of renewable energy. Energy Sources Part B Econ. Plan. Policy 1–20. doi:10.1080/15567249.2021.1983891.

Kim, H.J., Kim, J.H., Yoo, S.H., 2019. Social acceptance of offshore wind energy development in South Korea: results from a choice experiment survey. Renew. Sustain. Energy Rev. 113. doi:10.1016/J.RSER.2019.109253.

Kim, J.H., Nam, J., Yoo, S.H., 2020. Public acceptance of a large-scale offshore wind power project in South Korea. Mar. Policy 120, 104141.

Kim, J.H., Choi, K.R., Yoo, S.H., 2021. Evaluating the South Korean public perceptions and acceptance of offshore wind farming: evidence from a choice experiment study. Appl. Econ. 53, 3889–3899. doi:10.1080/00036846.2021.1888862.

Klain, S., Satterfield, T., Chan, K.M.A., Lindberg, K., 2020. Octopus’s garden under the blade: boosting biodiversity increases willingness to pay for offshore wind in the United States. Energy Res. Soc. Sci. 69, 101744. doi:10.1016/J.ERSS.2020.101744.

Ladenburg, J., Hevia-Koch, P., Petrović, S., Knapp, L., 2020. The offshore-onshore conundrum: preferences for wind energy considering spatial data in Denmark. Renew. Sustain. Energy Rev. 121, 109711.

Ladenburg, J., & Krause, G., 2011. Local attitudes towards wind power: the effect of prior experience. From turbine to wind farms: technical requirements and spin-off products, 3–14.

Lamy, J., de Bruin, W.B., Azevedo, I.M., Morgan, M.G., 2020. Keep wind projects close? A case study of distance, culture, and cost in offshore and onshore wind energy siting. Energy Res. Soc. Sci. 63, 101377.

Lee, H.J., Yoo, S.H., Huh, S.Y., 2020. Public perspectives on reducing the environmental impact of onshore wind farms: a discrete choice experiment in South Korea. Environ. Sci. Pollut. Res. 27, 25582–25599. doi:10.1007/S11356-020-08949-0.

Li, A., 2022. Centralization or decentralization: divergent paths of governing offshore wind between China and Japan. Energy Res. Soc. Sci. 84, 102426.

Linnerud, K., Dugstad, A., Rygg, B.J., 2022. Do people prefer offshore to onshore wind energy? The role of ownership and intended use. Renew. Sustain. Energy Rev. 168, 112732.

Maruyama, Y., Nishikido, M., Iida, T., 2007. The rise of community wind power in Japan: enhanced acceptance through social innovation. Energy Policy 35, 2761–2769. doi:10.1016/J.ENPOL.2006.12.010.

McFadden, D., 1973. Conditional logit analysis of qualitative choice behavior.

McFadden, D., Train, K., 2000. Mixed MNL models for discrete response. J. Appl. Econ. 15 (5), 447–470.

Motosu, M., Maruyama, Y., 2016. Local acceptance by people with unvoiced opinions living close to a wind farm: a case study from Japan. Energy Policy 91, 362–370. doi:10.1016/J.ENPOL.2016.01.018.

Nakano, R., Miwa, T., Morikawa, T., 2018. Comparative analysis on citizen’s subjective responses related to their willingness to pay for renewable energy in Japan using latent variables. Sustain 10, 2423. doi:10.3390/SU10072423.

Oluoch, S., Lal, P., Susaeta, A., Wolde, B., 2021. Public preferences for renewable energy options: a choice experiment in Kenya. Energy Econ. 98, 105256.

Revelt, D., Train, K., 1998. Mixed logit with repeated choices: households’ choices of appliance efficiency level. Rev. Econ. Stat. 80, 647–657.

Soares-Ramos, E.P., de Oliveira-Assis, L., Sarrias-Mena, R., Fernández-Ramírez, L.M., 2020. Current status and future trends of offshore wind power in Europe. Energy 202, 117787.

Train, K., 2009. Discrete Choice Methods With Simulation, 2nd ed. Cambridge University Press.

Warren, C.R., Lumsden, C., O’Dowd, S., Birnie, R.V., 2005. Green on green”: public perceptions of wind power in Scotland and Ireland. J. Environ. Plan. Manag. 48, 853–875. doi:10.1080/09640560500294376.

Westerberg, V., Jacobsen, J.B., Lifran, R., 2013. The case for offshore wind farms, artificial reefs and sustainable tourism in the French mediterranean. Tour. Manag. 34, 172–183. doi:10.1016/J.TOURMAN.2012.04.008.

WindEurope. 2020. Offshore wind in Europe - key trends and statistics 2019. (URL: https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2019.pdf, accessed at 05/12/2021).

World Forum Offshore Wind, 2021, Global Offshore Wind Report 2021. (URL: https://wfo-global.org/wp-content/uploads/2022/02/WFO_Global-Offshore-Wind-Report-2021.pdf, accessed at 01/10/2022).