Social acceptance of wind turbines: An empirical study using choice experiments

by

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Abstract

The purpose of this study is to investigate the conflicts between decarbonization by renewable energy use and local environments preservation, often referred to as the “green vs. green debate,” and propose the policy implication on the introduction of offshore wind turbines. In Japan, the interest in renewable energies, such as offshore wind power, is growing to achieve zero greenhouse gas emissions by 2050. However, coastal communities have concerns about the negative impact of offshore wind turbines on the landscapes, health, economic, and environmental aspects and often oppose the construction of offshore wind turbines. Therefore, understanding the people’s perceptions about offshore wind turbines is essential to build the consensus among local people and promote offshore wind farms in Japan. This study conducted a nationwide online survey and a choice experiment for 900 valid respondents. A mixed logit model reveals that the marginal willingness to pay (MWTP) for the distance to the wind turbines was JPY 98.2, which indicates that people prefer far away wind farms to neighboring turbines. Additionally, the model estimated JPY 36.6 for the number of wind turbines and JPY 74.2 JPY for CO_2 reduction, which means that people demand more wind turbines and reduce CO_2 emissions. People evaluate offshore wind turbines positively in terms of climate change mitigation, but negatively in terms of the impact on the landscape. The planner should understand local people’s preferences for offshore wind turbines to overcome the “green vs. green debate.”

1 Introduction

This study investigates the conflicts between decarbonization via renewable energy use and local environments preservation, often referred to as the “green vs. green debate,” (Warren et al. 2005; Groothuis et al. 2008), and propose corresponding policy implications regarding the introduction of offshore wind turbines.

As noted in the 2015 Paris Agreement, "energy decarbonization" has been a pressing issue on a global scale. Consequently, in recent years, the development of wind-power generation is expanding worldwide. However, in Europe, the construction of onshore wind power is saturated; instead, the development of offshore wind power is booming (Figure 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).

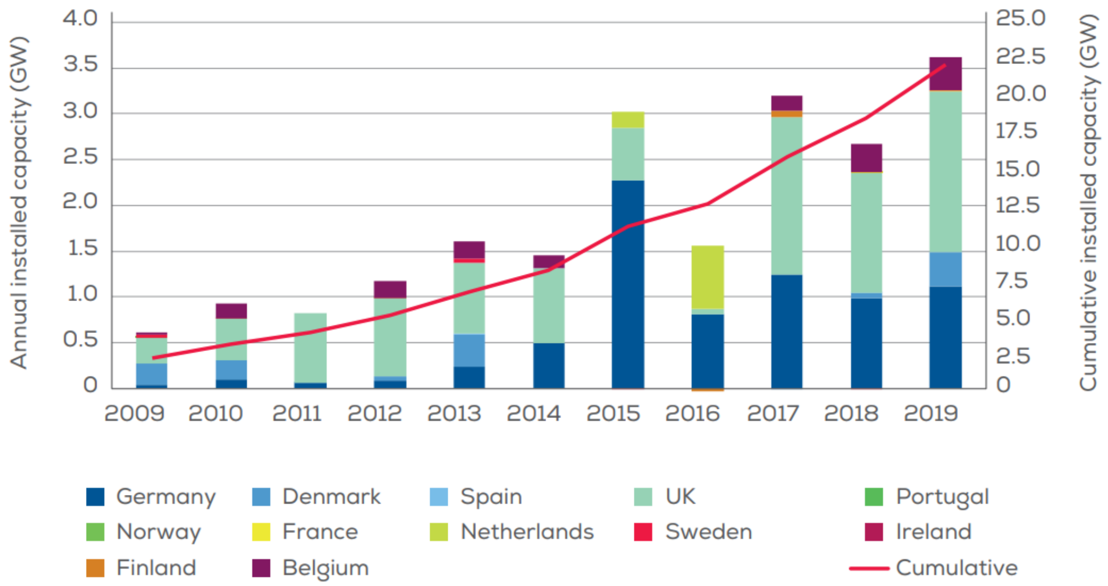

Figure 1. Annual offshore wind installations by country and cumulative capacity

Source: WindEurope (2020)

In October 2020, Prime Minister Suga announced Japan's goal of reducing greenhouse gas emissions to virtually zero, or carbon neutral, by 2050. Subsequently, 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.

However, the introduction of extensive offshore wind power in Japan's waters may affect the landscape and marine ecosystems. Therefore, concerns of local stakeholders (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 cancelled owing to a lack of local acceptance (Bell et al. 2005).

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, we need to understand people's preference for offshore wind power. Here, we conducted an internet survey of the general public in Japan along with choice experiments. In the choice experiments, we 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.

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 local residents and tourists (e.g., Voke et al. 2013; Westerberg et al. 2015; Kim et al. 2019; Ladenburg et al. 2020). 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. Klain et al. (2020) conducted choice experiments with residents of an area along the New England coast in the United States, 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. Similarly, Kim et al. (2019) conducted choice experiments on the impact of offshore wind-energy development projects on Korean citizens. The experiments' results were added to a cost-benefit analysis, which suggested that the projects' benefits were unlikely to outweigh their costs. Finally, 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.

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 are not objecting to 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 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, it is related to support for liberalization of the electricity retail market and 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.

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, we include Japan's nationals conditions to incorporate region-specific factors into our analysis of social acceptance.

2.3 Green versus green debate

Energy generated by wind is classified in the green energy category. Green energy has the external benefit of mitigating climate change and air pollution because it is fossil fuelindependent energy. Wind power development is also typically viewed as emblematic of such climate and pollution mitigation efforts (Ellis et al. 2007; Jones et al. 2011). However, wind power is highly visible in nature and significantly affects the landscape. Several studies have argued that the landscape is the most important determinant of attitudes toward wind power planning and development (Pasqualetti 2001; Groothuis et al. 2008; Jones and Eiser 2009; Wolsink 2010). Besides negative impacts on landscapes, concerns are often expressed about noise and ecological impacts.

Thus, on the one hand, the pro-energy group argues that renewable energy facilities should be promoted as an energy source that does not increase the environmental burden on the earth. On the other hand, the opposition group argues that renewable energy facilities should not be promoted because they may destroy the natural landscape and have an inevitable impact on the landscape, although they share the same concern for the environment. One of the objectives of this study is to investigate this "green vs. green debate," the conflict between decarbonization and local environmental protection regarding the use of renewable energy. We assess the public's preferences for the various environmental impacts of offshore wind and identify the various relationships between these impacts. Furthermore, by assessing the diversity of preferences, we identify potential conflicts in the implementation of offshore wind power. Specifically, we use a mixed logit model to analyze the public's preferences for five attributes of offshore wind power: distance from the shore, number of wind turbines, number of species, carbon dioxide (CO_2) reduction, and new job creation.

3 Methodology

3.1 Choice experiments

The conjoint analysis used in this study is a method to understand the goods to be evaluated as consisting of multiple attributes, represent multiple types of goods by the differences in attribute levels, and clarify 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.

3.2 Analytical Model

We use a mixed logit model as our 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 equation (1) below.

$$U_{ni} = V_{ni}(\beta_n) + \varepsilon_{ni}$$
$$= \beta'_n x_{ni} + \varepsilon_{ni}$$

(1)

where the error terms ε_{ni} are assumed to follow the first kind 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, our mixed logit model incorporates the assumption that different individuals have different preferences.

Furthermore, we assume that the distribution of β_n is the normal distribution $\phi(\beta|b,W)$ with mean *b* and variance-covariance *W*. Then, the selection probabilities for the mixed logit model are as follows (McFadden 1974; Train 2009).

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

(2)

In general, the integral calculations here are not algebraically solvable and the estimation requires the use of approximate calculations by simulation. Here, we compute the selection probability 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 (equation (3)) and calculate *R* selection probabilities,

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

(3)

and

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

$$SP_{ni} = \frac{1}{R}\sum_{r} L_{ni}\,(\beta^r)$$

(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 equation (5).

$$SLL(b, W) = \sum_{n}\sum_{i} \delta_n^i \, lnSP_{ni}(b, W)$$

(5)

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

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 equation (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 Equation (6).

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

(6)

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

3.3 Overview of the 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 1,000 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.

Table 1. Respondents' Attributes

Variable	Mean	Std. Dev.	Min	Max
sex 1: male 2: female	1.497	0.500	1	2
age Age (20-69)	45.817	13.481	20	69
nf Number of family members 1: 1 person, ..., 7: 7 or more	2.749	1.307	1	7
wj Offshore wind power in Japan (Pros or Cons) 1: Pro, ... 5: Con	2.419	0.875	1	5
hi Household income 1: less than 2 million yen, ..., 8: 20 million yen or more	3.468	1.614	1	8

3.4 Attributes and Levels

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 (NEDO) 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 of the proposal for the promotion of offshore wind power generation by the Japan Wind Power Association (JWPA). 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).

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

3.5 Profile Design

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 3. Sample questions for the choice experiment

Given the following offshore wind farm project plans, which plan do you think is preferable? Please choose one from plan numbers (1), (2), and (3).

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

4 Results

The statistical software Stata16 was used to estimate the parameters. Table 4 defines the variables used in the estimation and 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 MTWP 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 number 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).

Next, we examined the estimation results for the heterogeneity of preferences. 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. We discuss the estimation results in detail in the next section.

Table 4. Definition of Variables

Variable Name	Variable Definition
distance	Distance from the shore
nturbin	Number of offshore wind turbines
species	Number of species that might be affected
co2	Amount of CO_2 reduction
labor	Number of new jobs created
cost	Levy on renewable energy

Table 5. Estimated results

	Mixed logit model		
	Coef: Mean	Coef: S.D.	MWTP (yen)
distance	0.1216359	0.2242497	98.2096
	(10.67)	(17.47)	[50.89, 145.53]
nturbin	0.0453652	0.0437624	36.6282
	(10.74)	(8.22)	[18.31, 54.95]
species	-0.0100418	0.0336692	-8.1078
	(-4.33)	(14.32)	[-14.82, -1.39]
co2	0.0918798	0.163447	74.1843
	(5.78)	(7.95)	[17.56, 130.81]
labor	-0.0134502	-0.0306567	-10.8597
	(-4.48)	(-5.21)	[-19.19, -2.53]
cost	-0.1238534		
	(-3.66)		
Number of observations	16200		
Log likelihood	-4198.5558		

Note: Z-values are in parentheses. 95% confidence intervals are in square brackets.

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

First, we evaluated the public's preferences for offshore wind power through the choice experiments. We found that the MWTP was 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). Our 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. Notably, the public highly evaluated "CO_2 reduction" as an external benefit.

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 participant's 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 may not be 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, we provide 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, 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 of these two attributes (“distance” and “CO_2 reduction”) suggest that there may be a “green vs green debate” 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.

Finally, our study has the following policy implications. 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 we show, 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 in recent years, the number of Japanese citizens interested in global environmental issues has been increasing rapidly, as in developed countries in Europe and the United States. Appealing to such people may significant affect the social acceptability of offshore wind among the Japanese public.

In summary, planners will need to understand people's preferences for offshore wind power to overcome the "green vs. green debate."

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