Developing large-scale offshore wind power programs: A choice experiment analysis in France

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Abstract

Many offshore wind farms are expected to be installed along the European coasts in the next few years. However, developing offshore wind power may affect other maritime activities already established in the sea space (e.g. commercial fishing). We conducted a discrete choice experiment in France on a national sample, where a wide range of the effects that large-scale offshore wind power programs can have on maritime activities were considered. So far, the valuation of preferences for offshore wind power has mainly focused on the visibility of the wind farms and on their impacts on marine biodiversity. In addition to these impacts, our results show that other types of consequences matter to the public. Employment in the maritime economy, the effect on fresh seafood offer, and conditions for the practice of recreational activities are also found to be significant. Moreover, our study introduces a within-sample treatment in which an information script changes the current situation in the opt-out alternative. We find that social acceptance of offshore wind power varies depending on the information given to the public about other sources of electricity generation that could be prioritised. Policy implications of our results are discussed.

Keywords

Offshore wind power – Onshore wind power – Nuclear power – Maritime activities – Discrete choice experiment – Partial profile

1. Introduction

Following the signing of the Paris Agreement in 2015, the European Union (EU) and the United Kingdom (UK) have committed to achieving no net emissions of greenhouse gases by 2050 (European Commission, 2019; UK government, 2021). An increase in electricity generation from renewable sources, and in particular from offshore wind power, is needed to reach this target. Until now, European countries have been the driving force behind the growth of offshore wind farms (OWF). In 2018, more than 80% of global installed offshore wind power capacity was located in the EU and the UK (IEA, 2019). Installed capacity in Europe is expected to grow from 22 GW (gigawatt) in

2019 to 76 GW by 2030, corresponding to an increase of around 11,800 turbines (Soares-Ramos et al., 2020).

France presents a unique electricity mix with nuclear power representing 71% of the production in 2020, followed by renewables (wind, solar, hydro, bioenergy) at 21%, and fossil fuel at 8% (RTE,2020). The share of renewable energies in this mix is expected to reach 40% by 2030. The effort has so far been concentrated on onshore wind power, with about 2,000 wind farms installed in the country for a capacity of 18 GW (i.e. 8% of the national electricity production). France has the second largest offshore wind resource potential in Europe behind the UK, but still no wind farms have yet been installed in its waters. A first large-scale development program should be implemented by 2030. It includes the construction of 7 OWF, for a total of nearly 470 turbines and an installed capacity of 3 GW (French government, 2020).

Such a large-scale deployment of offshore wind power should be done in coordination with other maritime activities to ensure the sustainable use of the sea space and its resources (European Commission, 2020). As offshore wind power requires that large areas be available, conflicts with other users of the sea are likely to arise. Maritime activities competing for the same space as offshore wind power primarily include commercial fishing, recreational activities (e.g. boating, diving, kayaking, etc.), and maritime transport (European MSP Platform, 2018). Excluding some activities from OWF areas can have both direct effects on the concerned users as well as indirect effects on all other maritime sectors related to them (Hoagland et al., 2015). For example, an exclusion of commercial fisheries from OWF would first affect individual fishers (e.g. loss of profits), then secondly the fishing industry (e.g. increase in imports), to finally impact the wider society (e.g. consumers). As a result, the well-being of the population can possibly be affected. Exclusion from maritime areas and impacts on other sectors are two of the main factors of the lack of social acceptance of offshore wind power (Soma and Haggett, 2015).

These potential conflicts should be taken into account in the public decision-making process in order to decide the best locations and characteristics of OWF (White et al., 2012). To that end,

stated (contingent valuation, contingent ranking, choice experiment) or revealed (hedonic pricing method, travel cost method, etc) preference methods can be used (Ladenburg et al., 2005). In the context of our study, contingent valuation is not relevant for studying several impacts of a given policy (Hanley et al., 2001), while we cannot use a revealed preference method because no OWF have been installed in France yet[1]. Thus, the discrete choice experiment (Hanley et al., 1998; Louviere et al., 2000) approach (DCE) is applied. In our case, participants have to choose between several policy options of offshore wind power development. Each option has a cost and is described in terms of a set of attributes which specify the effects of the policy.

The literature regarding preferences for wind power largely concerns onshore wind farms, as shown by Mattmann et al. (2016). Applications of DCE to offshore wind power are relatively recent and scarce (i.e. twelve studies published between 2007 and 2021). To date, the valuation of preferences for offshore wind power has mainly focused on the visibility of OWF, which still remains one of the most sensitive issues for the social acceptance of wind turbines (Zerrahn, 2017). Latest studies seem to pay more attention to environmental impacts of OWF, a rising topic in view of the uncertainty surrounding the potential effects on marine biodiversity (Vaissière et al., 2014). However, it appears that preferences concerning conflicts between OWF and maritime activities have not yet been investigated. Moreover, the majority of DCEs focused on site-specific OWF projects, and we found only two studies (Ladenburg and Dubgaard, 2007; Ladenburg et al., 2020) based on large-scale development scenarios of offshore wind power.

The present study fills this gap in the literature by considering many effects that large-scale offshore wind power development programs can have on several maritime activities. A DCE was applied at the national level (i.e. in France) with original attributes related to conflicts between users of the sea. This research therefore aims at highlighting the conditions for a socially acceptable development of offshore wind power. The support for offshore wind power was assessed by eliciting

[1] For recent applications on offshore wind power, see Nepal et al. (2018) for the contingent valuation, Skenteris et al. (2019) for the hedonic price method, or Kipperberg et al. (2019) for the travel cost method.

preferences of a representative sample of the French population for one large-scale OWF development program over the other ("Option A" or "Option B"). Each program varies according to monetary cost, electricity production, visibility from the coast, knowledge of biodiversity impacts, effect on jobs in the maritime economy, the main country of origin for fresh seafood, and permission for recreational boating in OWF areas. These last three attributes allow us to value for the first time in a DCE the constraints that offshore wind power can impose on other maritime activities.

Large-scale development of new electricity infrastructures remains highly debated, especially in France with 7 out of 10 projects being challenged by local policy decision makers or inhabitants in administrative courts (Enevoldsen and Sovacool, 2016). That is why to preserve the realism of the choice situations, respondents also had the possibility to reject offshore wind power development by choosing an opt-out alternative at no cost ("Option C"). This opt-out alternative stood for France's current situation at the time of the survey administration in terms of electricity production (i.e. 71% nuclear, 8% fossil, and 21% renewables but 0% offshore wind power; RTE, 2020). It has been observed in the DCE literature that a large proportion of choices are usually made in favour of the opt-out alternative (Meyerhoff and Liebe, 2009). One of the main motivations behind this behaviour is the respondents' propensity for preferring their current situation over the other alternatives (Boxall et al., 2009). However, at a time of energy transition, preferring the current situation is an increasingly difficult argument to support in order to achieve no net emissions of greenhouse gases (Hainsch et al., 2022). All the electricity mix scenarios for 2050 currently studied imply significant changes in the distribution of electricity production sources (RTE, 2021). Wind power should account for a large share, but nuclear power still remains an option. The few studies that have looked at people's preferences for the electricity mix suggest a preference for renewable energy over conventional electricity technologies (including nuclear power, see the review made by Welsch, 2016).

Consequently, a within-sample treatment was introduced in the DCE (Lang et al., 2021). Respondents were presented with two sets of DCE choice tasks with an information script in-

between. After a first round of eight choice tasks, participants were informed about implications related to the rejection of offshore wind power programs. A short script indicated to respondents the electricity generation source that would be prioritised in France if the opt-out alternative was chosen. The electricity source was randomly assigned between a “significant increase in the lifespan of existing nuclear power plants” and a “significant increase in the number of onshore wind turbines”. Following this information script, the opt-out alternative no longer stood for the respondents’ current situation. Participants then completed a second set of four choice tasks, allowing us to identify the impact of information on the choice of the opt-out alternative. With this within-sample treatment, our study contributes to the DCE literature in the field of energy policy by taking into account in the opt-out alternative the necessary changes that energy transition implies for society.

Results of our study show that all the attributes have a significant impact on choices. This suggests that the public cares about the impacts that offshore wind power development can have on other maritime activities, which contributes to the growing literature on OWF preferences. Moreover, the within-sample treatment shows that social acceptance of offshore wind power is related to the type of information given to the public about other sources of electricity generation.

The remainder of this article is organised as follows. Section 2 details the DCE literature regarding offshore wind power. Section 3 presents the methodology including the survey design, the within-sample treatment, and the econometric modelling. Section 4 is dedicated to the results and section 5 discusses them. Section 6 concludes.

2. Literature review

A review of DCE studies published in scientific journals and dedicated to the valuation of offshore wind power preferences was conducted. Twelve studies published between 2007 and 2021 were identified[2]. The key elements of this literature are summarised in Table 1.

Valuation scenarios of these twelve studies can be classified as follows: seven articles aimed at eliciting preferences on the conditions for the installation of new OWF, four articles focused on the conditions for practicing a recreational activity (beach, sailing, vacation) in the sight of an OWF, and one paper studied the conditions for a compensation program for the installation of a new OWF.

Until now, DCEs were mainly based on single OWF projects. Only two studies valued preferences for a scenario of offshore wind power development at a national scale. Ladenburg and Dubgaard (2007) focused on the expansion of Denmark's OWF program, and Ladenburg et al. (2020) valued a program of wind farm expansion in Denmark, where "offshore" is one of the alternatives in the design (versus the "onshore" alternative). In these two national-scaled studies, the surveyed population already experienced living in a country with OWF, which is not the case in our study.

Two main categories of attributes have been found in this literature review. Firstly, the visibility of OWF is the most frequent attribute, with eleven studies including it. Visibility has been widely highlighted in the wind power literature as one of the main negative externalities associated with turbines, both onshore and offshore (Zerrahn, 2017). However, researchers assessed OWF visibility differently in the attribute definition: either using textual descriptions (e.g. "visible from the coast", "highly prominent", "barely visible"), or using descriptive characteristics as proxies (e.g. distance to the coast, distance to the respondent, number of turbines, and height of turbines).

The main results regarding the visibility of OWF are related to the distance decay. Respondents further away from the coast are less concerned about visual impact created by offshore

[2] Identification of the studies was made with Google Scholar using the following keywords: *"choice experiment"* or *"willingness to pay"* combined with *"offshore wind"*. When several studies were found reporting the same survey, only one was selected in our review.

turbines according to Börger et al. (2015). For Kim et al. (2019, 2021), as the distance from the offshore wind turbine to the land rises, the utility of the population increases. In these studies, people are willing to pay to place wind farms more than 10 miles from shore. Ladenburg and Dubgaard (2007) had already made this observation, with greater willingness to pay to place turbines at greater distances (more than 8 km to the coast). In a detailed spatial analysis, Ladenburg et al. (2020) found a significant effect of respondents' distance to potential OWF and the number of wind turbines seen from the residence. These authors also showed that people express strong preferences towards offshore wind turbines as opposed to onshore. Studies focusing on the effects on recreational activities also found results regarding the visibility of OWF. Landry et al. (2012) estimated an average compensating variation for wind farms located one mile from the shore at $55 per household. Lutzeyer et al. (2018) found rental value losses up to 10% if a wind farm is placed within 8 miles of shore. For Westerberg et al. (2013), wind farms should be located no closer than 12 km from the shore without a loss in tourism revenues, unless a coherent environmental policy and associated recreational activities are put in place.

Secondly, biodiversity impacts of OWF also have received a lot of interest and can be found in six studies. These impacts are uncertain by nature, as underlined in the scientific literature (Vaissière et al., 2014), and can potentially be both positive and negative[3]. It is therefore complex to include them as attributes in the choice set design. For example, Kim et al. (2019, 2021) used a negative impact for the biodiversity attribute ("decrease in the population of marine life") and found a negative effect concerning the reduction in the population of marine life because of construction and operation of OWF. Börger et al. (2015) used two attributes, a positive ("enhanced biodiversity") and a negative one ("electromagnetic fields from cabling"). Respondents expressed preferences for

[3] Potential negative impacts include risks of collision for birds, disturbance for marine mammals and fish due to the noise and vibrations, or habitat loss during the construction phase. Potential positive impacts embrace the artificial reef effect created by the turbine foundations, and the reserve effect for fish in offshore wind farm areas (Vaissière et al., 2014).

ecological improvement, i.e. increases in species diversity and prevention of the impact of cables. Klain et al. (2020) introduced uncertainty using an attribute with both positive and negative levels ("percent change in marine biodiversity" ranges from -60% to +60%). They found strong preferences for wind farms that provide high quality artificial reef habitat and that avoid 60% loss of species abundance and diversity. From these studies, people place significant value on reducing the environmental impacts of offshore wind power development. If environmental offset has to be put in place, Kermagoret et al. (2016) showed that ecological restoration is preferred primarily to benefit the professional fishers of the area.

Other categories of attributes found in this literature review include attributes describing the geographical location of an OWF, attributes focusing on the distributional aspects of the projects (e.g. ownership, subsidies, royalties), and attributes specifying the practice of a recreational activity near an OWF. Finally, almost all studies used a payment vehicle to allow measures of willingness-to-pay (WTP). The most common payment vehicle is the increase in the electricity bill of the respondent (found in four studies). This literature review shows that conflicts between offshore wind power and other maritime activities have not yet been investigated. We therefore integrate as new attributes the effect on jobs in the maritime economy, the main country of origin for fresh seafood, and the permission for recreational boating in OWF areas.

The overall impact of offshore wind power on the maritime economy has only been studied from the angle of coastal tourism (see Landry et al., 2012; Lutzeyer et al., 2018; Westerberg et al., 2013). No study has looked at the employment impact despite its importance in the social acceptance of renewable energy policies. For example, Bergmann et al. (2006) as well as Longo et al. (2008) introduced employment as an attribute to value renewable energies development. They both found that this attribute has an impact on respondents' choices. Recent DCE dealing with renewable energy and coastal activities (Vazquez and Iglesias, 2015; Aanesen et al., 2018) also used an employment attribute in their choice experiment and found that people care about the creation of jobs.

The major topic of interactions with commercial fishing is also missing, although it is a maritime activity that is primarily concerned with exclusion from OWF areas (Stelzenmüller et al., 2022). A report for the European Commission (Van Hoey et al., 2021) showed that the main economic effect of OWF on fisheries can be the loss of fishing grounds with an influence on the catch volume. Hoagland et al. (2015) demonstrated that a reduction in outputs from the seafood sector due to OWF exclusion can then result in increased imports. As it has been shown that consumers largely prefer domestic rather than imported products (Cantillo et al., 2020), the country of origin for fresh seafood appears to be a component of a large-scale offshore wind power development.

Looking at the possibility of practicing a recreational activity in an OWF area, Dalton et al. (2020) indicated that the value of a recreational boating experience is considerably reduced in areas with OWF. Hooper et al. (2017) highlighted the fact that recreational users feel poorly informed and inadequately consulted regarding OWF developments.

Finally, the review of DCE studies showed that almost all designs included an opt-out alternative. Two studies (Klain et al., 2020; Krueger et al., 2011) used it to allow respondents to reject OWF implementation at no cost. In these studies, rejection of offshore wind power implied the building of a new fossil fuel plant (coal or gas). The only studies that did not include an opt-out alternative are the two national-scaled ones. Their authors argued that the development of the policy had already been decided by the relevant authorities at the time of the surveys. This argument cannot be applied in the context of our study, as it is common in France to see public projects amended or even cancelled after many years of debate (Enevoldsen and Sovacool, 2016).

3. Methodology

A DCE was used to value the preferences of the population regarding the consequences of a large-scale offshore wind power development program. This section details the survey, the choice experiment (attributes, design, and within-sample treatment), and finally the econometric modelling used to analyse the data.

3.1. The survey

An online national survey was administered in May 2021 by a market research company[4]. A representative sample of the French population was targeted based on gender and age. For this sampling reason, the questionnaire started with a question about the residential area of the respondent, followed by the collection of usual socio-economic characteristics (gender, age, education, income, household composition, profession, etc.).

The second part of the questionnaire introduced the choice tasks to the respondents. With the help of a pie chart, respondents were informed about how electricity was currently produced in France. They were told that the share of renewable energy in the electricity mix is about to increase according to France's climate policy objective. Respondents were then briefly informed that some OWF projects are underway in France, at various stages of development. The fact that no OWF is yet installed in France was highlighted, and that this survey could help for further policy decisions made on this issue. Then the choice exercise began.

Debriefing questions were asked, including questions concerning the reasons for rejecting the programs. Other follow-up questions explored respondents' experience with the sea, and their opinion on the consequences of offshore wind power on maritime activities.

3.2. The choice experiment

3.2.1. Attributes

Attributes to include in the DCE were identified on the basis of the literature review, and with the help of experts in the field of offshore wind power, marine spatial planning, and commercial fishing. The following attributes and levels have been designed to be as realistic as possible. The hypothetical scenario told respondents that developing a large-scale offshore wind power program in France would have several consequences. Seven consequences have been selected and constitute the attributes of the DCE.

[4] A series of individual interviews were conducted in February 2021 to ensure that each attribute, the choice tasks, and the entire questionnaire were well understood.

i) Number of households supplied: this attribute represents the offshore wind power installed capacity. In the DCE literature, OWF capacity always appeared in the hypothetical scenario. Introducing it as an attribute allows us to value preferences for the size of the program. Offshore wind power capacity (in GW) was converted into the number of households to be supplied with electricity. Levels are “3 million households”, “6 million households”, and “10 million households” (corresponding approximately to a 3 GW, 6 GW, and 10 GW program respectively). These levels are the possible targets for offshore wind power development envisaged in France by 2030 by the public authorities and the offshore wind industry (French government, 2020; France Energie Eolienne, 2021).

ii) Visibility from the coast: visibility is introduced in the simplest possible manner, using a 2-levels attribute with only text descriptions (“highly prominent” or “barely visible”, following Klain et al., 2020). While the majority of previous studies incorporated visualisations of offshore wind turbines, we only used the aforementioned text-descriptions. This decision was guided by the fact that the characteristics of offshore wind turbines to be installed in France had not been decided at the time of the survey. It can also be argued that the French population is already familiar with wind turbines, although they are only onshore. Moreover, a debate exists on the usefulness of such visualisations to help respondents in their choice-making process (Hevia-Koch and Ladenburg, 2019). By not using any visualisations, we therefore “rely on the cognitive skills of the respondents to imagine wind turbines of different sizes and at different locations” (Hevia-Koch and Ladenburg, 2019, p1).

iii) Impacts on marine biodiversity: this attribute was designed to reflect the efforts made to remove the uncertainty surrounding the environmental impacts of OWF. A key element of the social acceptance of OWF projects is indeed whether enough research efforts are taken to improve the knowledge of the impacts on marine ecosystems (Vaissière et al., 2014). The attribute here describes the possible state of knowledge of these impacts. Consequently, the level for the impacts on marine biodiversity is either “known” or “unknown”.

iv) Effect on jobs in the maritime economy: this attribute reflects the economic impact of the program. It has been argued that people may not only have preferences for their own job or job opportunities but they may also derive satisfaction from knowing about the existence or creation of other jobs, a concept referred in stated preference literature as the "non-use value of employment" (Bennett and Blamey, 2001). Developing offshore wind power is expected to create new jobs in the marine renewable energy sector as well as in other related sectors, such as port activities, submarine cables, aquaculture, or environmental research (Kahouli and Martin, 2017). However, for other maritime sectors the effect on employment could potentially be negative with job losses (e.g. in commercial fishing, seafood trade, coastal tourism). This negative effect on "traditional" maritime activities has been highlighted by Börger et al. (2020). In total, following offshore wind power development, either more jobs will be created than destroyed in the maritime economy, or the opposite. The following levels were chosen: "-2,000 jobs lost", "+1,000 jobs created", "+5,000 jobs created".

v) Main country of origin for fresh seafood: it stands for the potential conflicts between offshore wind power and commercial fishing. The French commercial fishing industry would be affected if there were strict restrictions concerning the fishing areas available in OWF. It could eventually lead to a decrease in the domestic supply of fresh seafood, in favour of France' main neighbouring competitors. France imports about 46% of its annual fresh seafood consumption, mainly from the UK and Spain (FranceAgriMer, 2020). The levels for the main country of origin for fresh seafood are: "France", "United Kingdom", and "Spain"[5].

vi) Permission for recreational boating: it stands for the potential conflicts between offshore wind power and recreational boaters. In the context of offshore wind power development, recreational boating could be "allowed" or "forbidden" in OWF areas.

[5] "Norway" was not used as an attribute level, because importations from Norway concerned salmon which is a seafood product not impacted by offshore wind power development in France.

vii) Increase in the monthly electricity bill (for ten years): it is the payment vehicle used to estimate WTP. Using a compulsory vehicle payment avoids free riding behaviour (Carson and Groves, 2007). We varied the commonly used cost vectors (i.e. “€2”, “€5”, “€10”, “€20”) by plus or minus 10% in order to offer a more realistic range of cost vectors to respondents. Levels for the cost vector are “€1.8”, “€2”, “€2.2”, “€4.5”, “€5”, “€5.5”, “€9”, “€10”, “€11”, “€18”, “€20” and “€22” per month for ten years.

3.2.2. Design

The main constraint for generating the design is the high number of attributes (i.e. seven). Consequently, a partial profile design was created (Chrzan, 2010). With this method, respondents choose among alternatives that differ on only a small number of attributes, regardless of the total number of attributes in the experiment. By limiting the cognitive burden for respondents, this method allows the respondents to increase the validity and reliability of their answers.

Practically, in our design, respondents were presented with eight choice tasks, describing two alternatives of large-scale offshore wind power development programs for France (“Option A” and “Option B”) and one opt-out alternative with no offshore wind power development (“Option C”). We opted for a partial profile design that involves three “fixed attributes” (i.e. attribute level is the same for programs A and B) and four “varying attributes” (i.e. attribute level is different for programs A and B) in each of the choice tasks. The three “fixed attributes” were different in each of the eight choice tasks, ensuring that respondents encountered all attributes and all attribute levels during the experiment. To preserve the realism of the choice situations, the cost of a program was always set as a “varying attribute”. Finally, the order of the eight choice tasks was random across respondents.

To generate the design, a candidate set of all possible partial profile choice tasks was first created using the R software (R Core Team, 2020). Next, the Ngene software (ChoiceMetrics, 2018) searched for the most efficient partial profile design in this candidate set, based on the D-error criterion and the modified Federov algorithm, with prior information on coefficient estimates obtained from the sample of a pre-test survey (n=57). Table 2 provides an example of a choice task.

3.2.3. Within-sample treatment

The within-sample treatment consisted in an information script indicating to respondents the electricity generation source that would be prioritised in France if the opt-out alternative was chosen. The information script appeared after the first round of eight choices. The electricity source was randomly assigned between a “significant increase in the lifespan of existing nuclear power plants in the coming years” and a “significant increase in the number of onshore wind turbines in the coming years”. These information scripts were chosen based on the various electricity mix scenarios being studied to achieve no net emissions of greenhouse gases in France (RTE, 2021). After reading the script, respondents then completed a second round of choice tasks, consisting in a repetition of the first four choice tasks they had previously answered in the first round. This will allow us to compare the proportion of opt-out choices between the treatment groups in the first and second rounds. Figure 1 details the within-sample treatment. In total, respondents answered twelve choice tasks.

We opted for a within-sample treatment (instead of a between-sample treatment) after considering our research question and in terms of practical implementation (Charness et al., 2012). First, we are interested in how people would react to a change in the current situation (i.e. the status quo), and if this reaction depends on the nature of the change (giving priority to a specific electricity generation source). The first round of choices might play here as an “anchor”, according to coherent arbitrariness (Ariely et al., 2003), meaning that the choices made in the second round should be consistent with the choices made in the first one. Second, the within-sample treatment makes the change of the current situation more salient in a long and complex questionnaire. Third, comparison between treatment groups is easier and requires no assumptions or estimations. Moreover, fatigue or learning should not alter the results of the comparison as all respondents participated in the same first round.

3.3. Econometric modelling

Following a standard econometric approach, analysis of DCE data is based on the random utility model (McFadden, 1980). The utility of respondent *n* from choosing alternative *i* in choice situation *t* can be expressed as a function of a vector of attributes X:

$$\mathrm{U_{nit}} = \beta_{\mathrm{n}}\mathrm{X_{nit}} + \varepsilon_{\mathrm{nit}} \quad (1)$$

where ε_{nit} is the specific error term which follows an extreme value distribution with variance $\pi^2/6s^2$ with *s* the scale parameter typically set to 1. The multinomial logit model assumes that there is no heterogeneity in preferences across respondents, meaning $\beta_n = \beta$.

To estimate respondent-specific coefficients, the mixed logit model is used. It assumes $\beta_n = \beta + \eta_n$ with the coefficients following a random distribution of mean β and variance η_n. The WTP for a given attribute in the mixed logit model is obtained through the ratio of two random parameter distributions (for the non-cost attribute and for the cost attribute). This procedure is known as the preference space approach (Train and Weeks, 2005). However, depending on the distributional assumptions made by the researcher, this approach can lead to undefined moments of the WTP distribution (Daly et al., 2012). A first solution is to specify the negative of the cost coefficient to be log-normally distributed. This allows the possibility of obtaining distributions of WTP with finite moments, but it may produce extremely high WTP estimates. Train and Weeks (2005) therefore suggest estimating the mixed logit model in WTP-space rather than in preference space. Equation (1) therefore becomes:

$$\mathrm{U_{nit}} = \beta^{-\mathrm{c}}{}_{\mathrm{n}}\mathrm{X}^{-\mathrm{c}}{}_{\mathrm{nit}} + \gamma_{\mathrm{nit}}\mathrm{c_{nit}} + \varepsilon_{\mathrm{nit}} \quad (2)$$

where $X^{-c}{}_{nit}$ is a vector of non-monetary attributes, c_{nit} is the cost attribute, and γ_{nit} the marginal utility of income.

The WTP-space model is:

$$\mathrm{U_{nit}} = \gamma_{\mathrm{n}}(\mathrm{X}^{-\mathrm{c}}{}_{\mathrm{nit}}\delta_{\mathrm{n}} + \mathrm{c_{nit}}) + \varepsilon_{\mathrm{nit}} \quad (3)$$

where $\delta_n = \beta^{-c}{}_n/\gamma_n$ is a vector of the coefficients to be estimated, which directly captures marginal WTP for the non-monetary attributes. These are assumed to be normally distributed, and the cost coefficient to be log-normally distributed (Train and Weeks, 2005).

All models presented in this article were estimated with the R software (R Core Team, 2020) using the apollo package (version 0.2.1) developed by Hess and Palma (2019).

4. Results

4.1. Sample characteristics

Respondents aged between 18 and 75 years old were recruited from a panel chosen by the market research company that administered the survey. In total 2,525 questionnaires were completed from which 89 respondents were removed, as they can be considered as "protesters"[6], leaving us with 2,436 usable answers. This was the largest sample ever used for a DCE on offshore wind power. The sample is representative of the French population at large based on the sampling criteria of gender and age (Table 3). Concerning offshore wind power development (Table 4), 75% of the respondents are interested in this topic and 65% declare to have already heard of OWF projects in France. Also, 37% of the respondents think OWF will not really be installed in the next few years, which supports the decision to have introduced the opt-out alternative in the design.

4.2. Preferences for offshore wind power programs

This section presents the results of attributes-only models: a multinomial logit model (MNL) and a mixed logit model (MMNL) both estimated in WTP-space (Table 5). These models are based on the first round of eight choices made by the respondents. Estimation in WTP-space allows to directly interpret attribute coefficients as estimates of mean marginal WTP. The cost coefficient in these models is significant at the 1% level with a positive sign because of the sign reversal for this attribute ("-Cost"). Estimates in WTP-space are close between the two models, with slight variations of marginal WTP. The largest variation is observed for the job destruction coefficient ("Jobs (-2000)"). In

[6] These respondents chose *"Option C"* twelve times because they consider that they already pay *"too many taxes"*, as revealed by a follow-up question.

the MMNL model, all the non-monetary coefficients highlight the existence of significant heterogeneity in marginal WTP, with the exception of the job creation coefficient ("Jobs (+5000)"). The MMNL model fits the data better than the MNL model, as suggested by the lower BIC. Moreover, mixed logit models do not exhibit independence from irrelevant alternatives. Main estimates of marginal WTP from this study should therefore be taken from the MMNL model, as we do in the rest of the article.

On average, respondents show a slightly positive WTP of €0.20 per month for having an additional million households supplied by offshore wind power. A "highly prominent" visibility of wind turbines from the coast leads to welfare losses in the population of €-2.63 per month on average (in comparison to "barely visible" wind turbines). The model also found a negative WTP of €-5.58 per month on average when impacts on the marine biodiversity are "unknown" (compared to biodiversity impacts being "known"). The coefficient for "recreational boating" is significant in the MMNL model at the 1% level. The positive sign indicates that banning recreational boating from OWF areas is valued by respondents (WTP is €3.00 per month on average). Regarding the effect on jobs in the maritime economy, this attribute was introduced as a categorical variable in the model with the baseline being "+1000 jobs created". High welfare losses are associated with the destruction of jobs (€-8.24 per month on average for "-2000 jobs"). Conversely, respondents value a strong increase in job creation (€6.69 per month on average for "+5000 jobs"). Finally the highest WTPs are found for the main country of origin of fresh seafood. Respondents express negative WTP of €-12.89 and €-10.96 per month on average to see the UK and Spain respectively becoming the main countries of origin of fresh seafood (compared to France).

4.3. Rejection of offshore wind power programs

All the following results are derived from the four choices made in the second round. During this second round, there was on average the same proportion of opt-out choices for the choice tasks 1 to 4 compared to the first round (33.3%, see Table 6). As a reminder, an information script highlighted the electricity generation source that would be prioritised if the opt-out alternative was

chosen in the choice tasks of the second round. In the group that received the information script on onshore wind turbines (n=1,254), the opt-out alternative was less frequently chosen than in the first round. Conversely, the opt-out was more frequently chosen than in the first round in the group that received the information script on nuclear power plants (n=1,182). This difference in proportions between the two groups is significant at the 1% level based on the z-test (stat=15.99, p-value=0.00).

To confirm this result, an additional MMNL model was estimated from the choices made in the second round (Table 7). An interaction term was introduced between the alternative-specific constant and the information script received by respondents. The interaction estimate confirms that the information script on onshore wind turbines has a negative and significant effect (at the 1% level) on the choice of the opt-out alternative.

This difference in opt-out choices according to the information received is also found when looking at respondents who systematically chose the opt-out option in the first round (i.e. 297 participants who chose 8 times “Option C”). Among these respondents, those who received the script on onshore wind turbines (n=150) chose the opt-out less in the second round than those who received the script on nuclear power plants (n=147), as shown by Figure 2. This difference in proportions is significant at the 1% level based on the z-test (stat= 87.34, p-value=0.00). Finally we estimated a probit regression to see what could explain these changes in opt-out choices in this subsample (Table 8). In this model, the explained variable was coded 1 if a respondent switched at least one time in the second round from the opt-out alternative to “Option A” or “Option B”, and 0 otherwise. Results confirmed that respondents who received information about onshore wind turbines were more likely to change their choices from the opt-out alternative.

5. Discussion

Estimates of WTP suggest that the French population has a preference for offshore wind power programs that create jobs in the maritime economy. Previous DCEs also found that respondents are more likely to favour a renewable energy policy that supports the creation of jobs. In line with these studies, our results suggest that employment is an important aspect of the social

acceptance of offshore wind power development. Looking at the French case, Kahouli and Martin (2017) assessed the potential local economic impacts of one of the planned OWF in France (i.e. in the bay of Saint-Brieuc in Brittany). These authors showed that the project was expected to induce positive, though small, employment impacts at the regional scale. Consequently, public decision-makers should be careful that the jobs created by the offshore wind power industry benefit the economy of the regions hosting OWF projects. From a macroeconomic standpoint, a significant employment effect of renewable energies deployment is however not clear in the literature. A review by Meyer and Sommer (2016) highlighted that even if most studies analysing the increased share of renewable energy in the electricity mix show positive net effects in job creation, robust scientific evidence is difficult to derive considering the variety of assumptions, methodologies and models used. This observation is also shared by Aldieri et al. (2020) and Dorrell and Lee (2020).

In our study, respondents express a clear preference for domestic products, as demonstrated by the estimates for the "main country of origin for fresh seafood". This result is in line with Nguyen et al. (2015) who found that French consumers highly valued domestic seafood. The preference for domestic products has been widely highlighted in the literature on seafood consumption behaviour. Local products are generally preferred for different reasons such as trust, health and food safety issues, or the ethnocentrism of consumers (Cantillo et al., 2020). Ethnocentrism refers to the judgment of consumers concerning the morality of purchasing foreign made products (Verlegh and Steenkamp, 1999). In the context of offshore wind power development, this latter argument seems to prevail. In our survey, the majority of respondents considers that the quality of French seafood products is similar or superior to that of seafood products from the UK and Spain[7]. The assumption can therefore be made that the French population's preference for domestic seafood is a sign of support sent to local commercial fisheries. It has been shown that the limitation of commercial

[7] The question was: "In your opinion, is the quality of fresh seafood from French fisheries inferior, similar or superior to those caught in the UK?". Respondents answered "similar" or "superior" at 95.9% (respectively 95.0% for the same question relative to Spain).

fishing areas due to OWF is an argument that could significantly decrease offshore wind power acceptance in the population (Schmidt, 2017).

Banning recreational boating from OWF areas is valued by respondents. The reasons behind this result are not fully clear. A possible explanation is that such an activity could be perceived as non-essential by the general public. Additionally, the fact that an exclusion from OWF areas does not prevent boaters from practicing their activity elsewhere could also explain the result. In the boater community however, the value of a recreational boating experience is reduced in areas with OWF (Dalton et al., 2020), with navigational safety concerns being one of the possible explanations for avoiding OWF areas. In our sample, only a low proportion of respondents (around 10%) declared practicing this activity when going to the sea[8]. We could not find any other references on the preferences of the public regarding recreational boating and offshore wind power. This is a topic that can be further investigated in the future.

Other results found in this study are in line with the literature, i.e. people are willing to pay for green electricity (Sundt and Rehdanz, 2015), the importance of placing OWF further from the coastline (Knapp and Ladenburg, 2015), and the avoidance of the uncertainty surrounding OWF biodiversity impacts (Klain et al., 2020).

A within-sample treatment was implemented to see if changing respondents' current situation would influence their choices regarding the opt-out alternative. Significant differences in opt-out choices were found in the second round, depending on the information script provided to respondents. If offshore wind power development is rejected, lengthening the lifespan of nuclear power plants seems to be preferred rather than increasing the deployment of onshore wind turbines. This result can appear counterintuitive in comparison to the few studies assessing preferences for the electricity mix (Welsch, 2016). They suggest that renewable energies (solar and wind power) are preferred to conventional ones (fossil fuel and nuclear power). Our result might reflect a "saturation"

[8] The question was: "What activities do you do when you go to the sea?". "Recreational boating" was chosen by 10.5% of respondents.

effect of a segment of the French population against onshore wind farms. This feeling towards onshore wind power has already been observed in other European countries such as Denmark and Germany (Clausen et al., 2021).

A first limitation of our study is to be found in its design. It could be argued that eight choice tasks are not enough considering the number of levels and attributes, and the fact that no blocking strategy was used. However, the statistical design was checked following the simulation exercise proposed by Mariel et al. (2021). This post-analysis confirms the appropriateness of the experimental design in providing unbiased and consistent estimates of the population parameter values.

Another limitation lies in the complexity due to the number of attributes and the number of choice tasks. We used the partial profile method to reduce the cognitive burden on respondents by limiting the number of varying attributes to four in each choice task. This allows to lower response error, producing results with greater predictive validity (Chrzan, 2010), even if in theory, partial profile designs provide less information on the parameter values compared to full profile designs (Kessels et al. 2011). Also, a partial profile design performs best in applications where analysts only estimate main effects (Chrzan, 2010), which is the case of our study. Our results are significant and robust regarding changes in the model specification. Furthermore, partial profile designs limit the risk of lexicographic decision rules, and in the presence of a dominant attribute, information is obtained about trade-offs made between the remaining attributes. Few environmental studies compared the results of a partial profile design with a standard design. Sever and Verbic (2018) found no difference in terms of perceived difficulty of the choice tasks, self-reported choice certainty and choice consistency. For Kim et al. (2020), a partial profile can avoid overlooking important attributes, which could happen in a standard approach. Pandit et al. (2022) found in the focus group stage that most participants preferred the partial profile design over the standard design.

Moreover, caution should be made when comparing results between the two rounds of choices as learning or fatigue effects could occur in a within-sample treatment. However, our analysis primarily focused on the comparison of the choices between the two treatment groups in the second

round (onshore wind turbines group or nuclear power plants group). There is little reason why learning or fatigue effect should diverge given that the number and the structure of choice tasks were identical in the two treatment groups.

One last possible limitation of our survey is a possible presence of a "Covid-19 effect", meaning that preferences for environmental issues could have changed because of the Covid-19 pandemic. While we cannot totally exclude this possibility, we refer to Hynes et al. (2021) who showed that preferences remain relatively stable in the face of this major public health crisis.

6. Conclusion and policy implications

The present study used a DCE to highlight the conditions under which a large-scale development of offshore wind power is possible in France. Results show that in line with the literature, the public expressed a WTP for a reduced visibility of the turbines and a better knowledge of the biodiversity impacts. Our study is the first to value preferences for the effects of offshore wind power on maritime activities. Notably, respondents value job creation from offshore wind power development, and have a strong preference for domestic seafood products. Excluding other maritime activities from OWF areas, especially commercial fisheries, should therefore be made with caution as it appears to be an important factor in the social acceptance of offshore wind power. Exclusion of recreational activities such as boating does not however appear to be a problem.

From these results, some recommendations can be formulated to help the planning of large-scale offshore wind power programs. Policy makers should ensure transparency by ensuring that OWF developers commit to favour local job creation and to specify the conditions for other maritime activities (i.e. commercial fishing, and recreational boating) to access OWF areas. These criteria could, for example, be included in the specifications with which developers must comply to install OWF. As conflicts between offshore wind power and commercial fishing are expected to see a substantial increase (Stelzenmüller et al., 2022), multi-use solutions combining fisheries and OWF should be encouraged. More investments in marine research should also be required to reduce uncertainty over the impacts of OWF. In the case where there would be too much uncertainty

concerning marine biodiversity in an OWF project, the precautionary principle could prevail and lead developers to search for another area.

If oppositions remain strong despite a well-thought planning program, policy makers should also anticipate the alternatives that would be implemented if offshore wind power development was abandoned. Because preferring the current situation no longer stands to achieve no net emissions of greenhouse gases by 2050, our within-sample treatment provides valuable information on that matter. It confirms that acceptance of offshore wind power varies according to the type of information given to the public about other sources of electricity generation. When offshore wind power development is rejected, lengthening the lifespan of nuclear power plants seems to be preferred rather than increasing the deployment of onshore wind turbines.

Thus, onshore wind farms are not appreciated by a segment of the population and policy makers can expect even stronger opposition if onshore wind power would be prioritised in the future. This trend highlights a “saturation” effect in countries that already have a large number of onshore wind farms. At the same time, preferring the lengthening of the lifespan of nuclear power plants would raise numerous questions regarding safety issues. As existing nuclear power plants in France are on average 40 years old, the perception of risks associated to nuclear power could become a sensitive issue. For example, Motz (2021) showed that people with a confident attitude towards the risk of accidents are more likely to accept nuclear electricity supply. This is a topic that should be discussed with the public. More generally, the future of the electricity mix should be debated at the national level to search for a consensus on this question.

Finally, future research applying stated preference valuation methods on offshore wind power is encouraged to deeply explore the subject of the share of the maritime space between its users. Furthermore, what lies behind the opt-out alternative should be taken into account in future DCEs focusing on this question.

Reference	National program	Valuation scenario	Alternatives	Opt-out (details)	Sample size	Visibility attributes	Biodiversity attributes	Other attributes	Payment vehicle
Borger et al. (2015)	No	Installation of an offshore wind farm	3	Yes (baseline project)	519	1	2	-	Tax
Dalton et al. (2020)	No	Boating trip near an offshore wind farm	3	Yes (no trip)	684	1	-	3	Trip cost
Kermagoret et al. (2016)	No	Compensation for installing an offshore wind farm	3	Yes (no compensation)	351	-	4	4	-
Kim et al. (2019)	No	Installation of an offshore wind farm	3	Yes (baseline project)	1000	3	1	-	Tax
Kim et al. (2021)	No	Installation of an offshore wind farm	3	Yes (baseline project)	1000	3	1	1	Tax
Klain et al. (2020)	No	Installation of an offshore wind farm	3	Yes (fossil fuel plant)	400	1	1	1	Electricity bill
Krueger et al. (2011)	No	Installation of an offshore wind farm	3	Yes (fossil fuel plant)	949	1	-	3	Electricity bill
Ladenburg and Dubgaard (2007)	Yes	Installation of multiple offshore wind farms	2	No	375	2	-	1	Electricity bill
Ladenburg et al. (2020)	Yes	Installation of multiple offshore wind farms	2	No	1754	1	-	1	Electricity bill
Landry et al. (2012)	No	Beach trip near an offshore wind farm	3	Yes (no trip)	118	2	-	2	Parking fee
Lutzeyer et al. (2018)	No	Rental vacation near an offshore wind farm	3	Yes (baseline rental)	484	3	-	-	Rental price
Westerberg et al. (2013)	No	Rental vacation near an offshore wind farm	3	Yes (no rental)	389	1	1	1	Rental price

Table 1. Literature review

	Option A	Option B	Option C
Number of households supplied	10 million	10 million	No offshore wind power
Visibility from the coast	Highly prominent	Barely visible	
Effect on jobs in the maritime economy	+5000 jobs	+5000 jobs	
Main country of origin for fresh seafood	United Kingdom	France	
Permission for recreational boating	Allowed	Allowed	
Impacts on marine biodiversity	Known	Unknown	
Increase in monthly electricity bill (during 10 years)	+2.2€	+10€	

Note: “fixed attributes” between Option A and Option B appears in grey.

Table 2. Example of a choice task (translated from French)

Variable	Sample	France[a]
Gender:		
Male	48.4%	47.6%
Female	51.6%	52.4%
Age:		
18 to 29	20.0%	19.5%
30 to 44	26.2%	26.4%
45 to 59	28.3%	28.1%
60 to 75	25.4%	26.0%

[a] Statistical data for France comes from Insee

Table 3. Sample characteristics and representativeness (n=2,436)

Questions	Answers
Are you interested in the subject of offshore wind power in France?	
Yes	75.2%
No	24.8%
Had you ever heard of offshore wind power in France?	
Yes	64.9%
No	35.1%
Do you think that offshore wind farms will really be installed in France in the next few years?	
Yes	63.2%
No	36.8%

Table 4. Opinions on offshore wind power in France (n=2,436)

	MNL WTP-space model			**MMNL WTP-space model**					
	Means			Means			Stand.dev.		
	coef.		s.e.	coef.		s.e.	coef.		s.e.
ASC opt-out	-0.8995	***	0.0421	-2.5513	***	0.0938	-2.7840	***	0.1076
Households supplied	0.1657	***	0.0646	0.2014	***	0.0469	0.5715	***	0.0857
Visibility (prominent)	-2.1615	***	0.4017	-2.6274	***	0.3272	-2.6403	***	0.5489
Jobs (-2000)	-6.3989	***	0.5357	-8.2439	***	0.4899	-8.7984	***	0.6062
Jobs (+5000)	6.7124	***	0.5033	6.6928	***	0.3044	0.4055		0.6425
Seafood (UK)	-13.4050	***	0.5418	-12.8851	***	0.3921	4.6607	***	0.4595
Seafood (Spain)	-12.3363	***	0.5528	-10.9638	***	0.4067	2.7573	***	0.5145
Boating (forbidden)	0.4835		0.4075	3.0021	***	0.2997	1.9192	***	0.4430
Biodiversity (unknown)	-4.8436	***	0.3753	-5.5836	***	0.2361	1.4334	***	0.3832
-Cost	0.0633	***	0.0019	2.2420	***	0.0404	-1.1806	***	0.0551
Number of individuals	2,436			2,436					
Number of observations	19,488			19,488					
BIC	40,463			33,012					
LL at convergence	-20,182			-16,407					
Adjusted R^2	0.06			0.23					
Number of draws	-			1000					

Note: significance levels are *p < 0.1, **p < 0.05, ***p < 0.01; “ASC opt-out” is coded 1 if the respondent chose “Option C”, and 0 otherwise.

Table 5. MNL and MMNL models in WTP-space (first round of eight choices)

Choice task	Aggregate	Task 1	Task 2	Task 3	Task 4
1st round	33.3%	28.5%	33.4%	34.5%	36.8%
2nd round	33.3%	32.1%	33.4%	33.7%	34.0%
- Onshore wind turbines group	31.5%	30.4%	31.2%	31.2%	33.1%
- Nuclear power plants group	35.3%	34.0%	35.8%	36.5%	34.9%

Table 6. Proportion of opt-out choices for tasks 1 to 4

	Means			**Stand.dev.**		
	coef.		s.e.	coef.		s.e.
ASC opt-out	-2.9198	***	0.1837	3.3349	***	0.1687
ASC*onshore wind turbines	-0.5069	***	0.1871			
Households supplied	0.2554	**	0.0887	0.5849	***	0.1708
Visibility (prominent)	-3.3567	***	0.5104	-1.9607		1.5872
Jobs (-2000)	-8.7160	***	0.7477	-10.9242	***	1.2714
Jobs (+5000)	6.4393	***	0.5108	-3.4467	***	1.1471
Seafood (UK)	-10.6835	***	0.5072	-2.7583	**	1.0715
Seafood (Spain)	-10.9499	***	0.5564	-0.2742		1.3349
Boating (forbidden)	1.3318	**	0.4635	-1.2538		1.3109
Biodiversity (unknown)	-5.4052	***	0.3727	-1.9961		1.2405
-Cost	2.1273	***	0.0523	0.9203	***	0.0933
Number of individuals	2,436					
Number of observations	9,744					
BIC	17,335					
LL at convergence	-8,571					
Adjusted R^2	0.19					
Number of draws	1000					

Note: significance levels are *p < 0.1, **p < 0.05, ***p < 0.01; “ASC opt-out” is coded 1 if the respondent chose “Option C”, and 0 otherwise; “ASC*onshore wind turbines” is coded 1 if the information script concerned onshore wind turbines, and 0 otherwise

Table 7. MMNL model in WTP-space with ASC interaction (second round of four choices)

	Linear model		
	coef.		s.e.
Constant	-0.5216	***	0.3597
Male	-0.2023		0.1675
Age	-0.0124	*	0.0057
Income	0.0000		0.0000
Treatment: onshore wind turbines	0.8799	***	0.1660
Number of individuals	297		
AIC	331.27		

Note: significance levels are *p < 0.1, **p < 0.05, ***p < 0.01

Table 8. Probit model explaining the switch from the opt-out alternative in the second round (n=297)

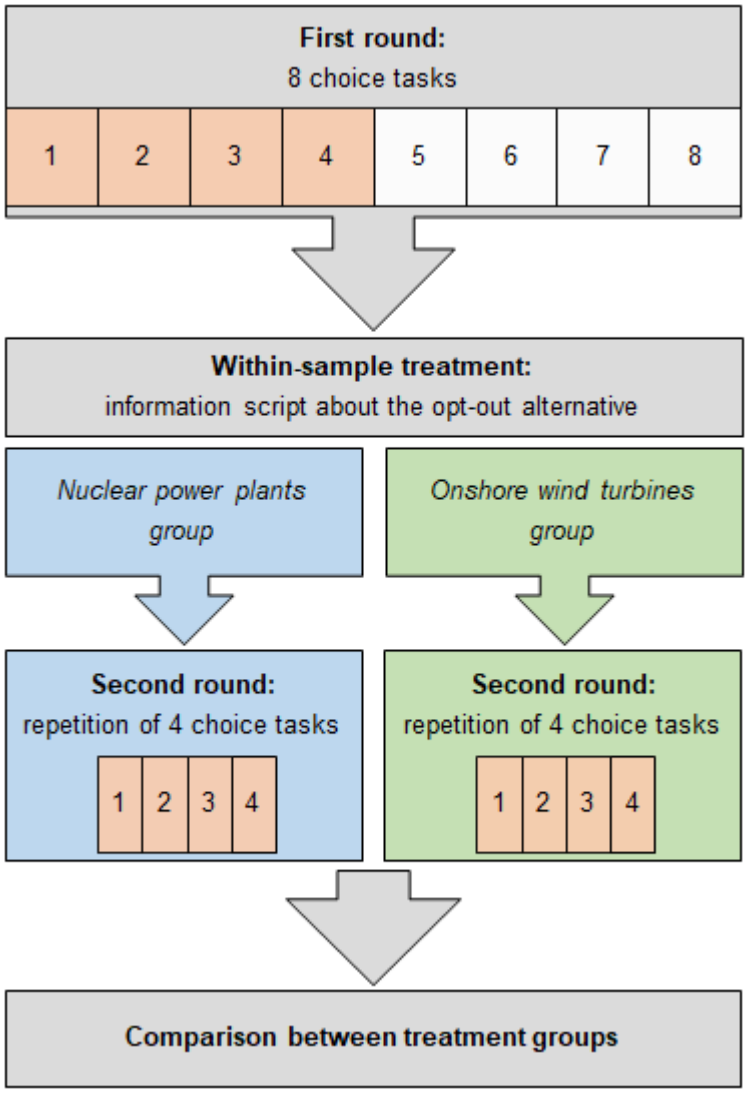
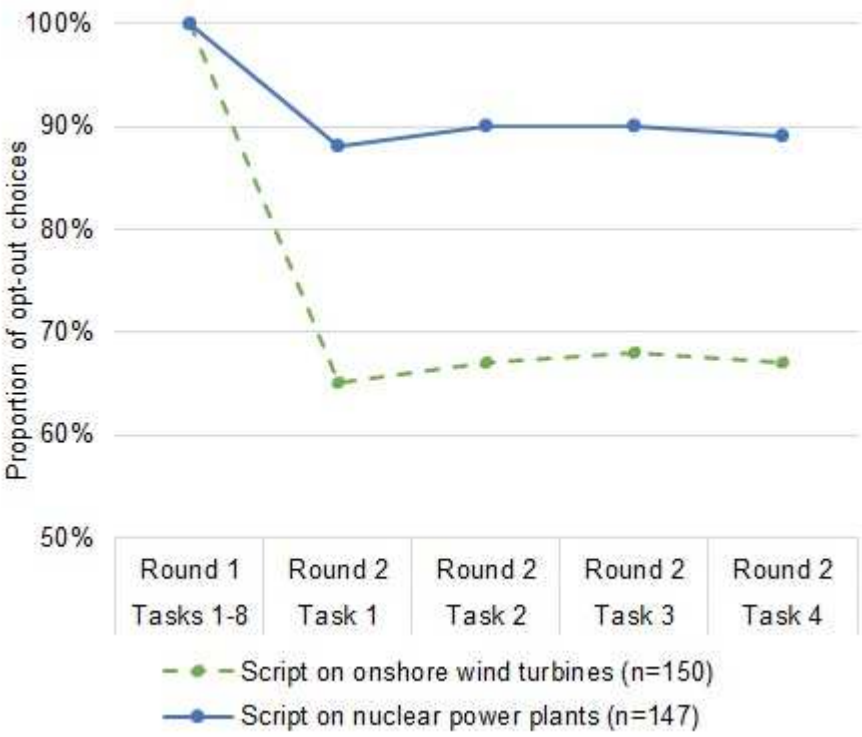


Figure 1. The within-sample treatment (single column fitting image, in color, online only)



Note: There are 297 respondents who chose 8 times "Option C" in Round 1. Consequently, the proportion of opt-out choices in Round 1 for these respondents is 100%.

Figure 2. Changes in proportion of opt-out choices according to the information script (n=297) (single column fitting image, in color, online only)

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