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Surveys

Tipping the decision of offshore wind farm decommissioning – The causal effects of biodiversity illustrations and information on the social acceptance

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ABSTRACT

The first offshore wind farms are reaching the end of their lifetime and will need decommissioning. This introduces both environmental challenges and questions regarding the social acceptance of different decommissioning options. This study explores Danish public attitudes towards leaving structural elements in the sea when decommissioning for biodiversity benefits versus removing and recycling for climate gains. A national survey (n = 2,348) was conducted using a randomized control setup with variations in written and visual information. Respondents received one of three text versions regarding biodiversity and climate impacts, accompanied by illustrations of structures with or without marine life. Results suggest that written information significantly influenced acceptance: texts emphasizing biodiversity benefits increased the acceptance of leaving structural elements in the sea when decommissioning, whereas additional details on climate benefits from recycling prompted greater hesitation. Visual information without marine life amplified the effect of written content. Sociodemographic factors, such as gender and income, influenced attitudes. Additionally, the respondents' willingness to take risks and perceptions of marine health further correlated with attitudes. These findings are vital for policymakers and stakeholders as they navigate the complex decisions surrounding offshore wind decommissioning, aiming for solutions that balance ecological benefits with public acceptance.

1. Introduction

Wind power is critical to delivering a global source of renewable energy, and the capacity of offshore wind energy is increasing (Addamo et al., 2022; Williams and Zhao, 2023). While major development projects are put in motion to support the green transition, the first smaller offshore wind farms have been decommissioned (Topham et al., 2019b), while the first large-scale offshore wind farms are nearing the end of their lifetime, and an increasing number of wind turbines will need decommissioning (Lacal-Arántegui et al., 2019). In Europe alone, approximately 1,800 offshore wind turbines are projected to be decommissioned by 2030, and potentially 20,000 turbines are facing decommissioning between 2030 and 2040 (4C Offshore, 2023; Topham et al., 2019a). The term "decommissioning" refers to the process undertaken when a structure reaches the end of its operational life, encompassing a broad range of options varying from complete removal of the structures to leaving larger parts in the sea (Claisse et al., 2015; Lemasson et al., 2021; Smyth et al., 2015; Sommer et al., 2019). Due to the size and weight of the structural elements, removing an offshore wind farm is a complex engineering process and will require heavy lifting operations. The costs of completely removing an offshore wind farm with a capacity of 500 megawatts (MW) are estimated to range between €172 and €287 million[1] (Adedipe and Shafiee, 2021), which, according to Topham and McMillan (2017), corresponds to 2–3 % of the whole life costs of an offshore wind farm. It is estimated that about 35 % of the total decommissioning costs are associated with foundation

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[1] The cost estimates have been converted from GBP to EUR using the average conversion rate from 2021 (1£ = 1.1878€), source: European Central Bank. (2021). *Pound sterling (GBP)*. Retrieved 5 June from https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-gbp.en.html

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removal and can, therefore, be reduced if some foundational elements are to be left in the sea (Topham and McMillan, 2017). On the other hand, Hall et al. (2022) estimated that recycling the removed elements can reduce the decommissioning costs by 20 %, depending on the metal scrap prices.

Offshore wind power locations are often strictly preferred to onshore or nearshore locations (Ladenburg, 2008; Sonnberger and Ruddat, 2017; Wen et al., 2018), and the offshore acceptance positively correlates with biodiversity perceptions (Börger et al., 2015). Furthermore, Klain et al. (2020) find positive preferences for offshore wind turbine designs that provide high-quality artificial reef habitats. Studies have demonstrated that wind turbine structures can act as artificial reefs and become species-rich habitats during their operational lifetime (Dannheim et al., 2020; Hall et al., 2020; Knorrn et al., 2024; Smyth et al., 2015). Hofstede et al. (2022) showed that the species community on offshore wind farm structures differs from the community living in the surrounding seabed. Additionally, offshore wind farm structures have been found to host a high species diversity and species abundance (Coolen et al., 2022; Degraer et al., 2020; Hofstede et al., 2022; Knorrn et al., 2024; Werner et al., 2024). Prior to industrial marine activities, studies indicate that the North Sea was abundantly covered by hard substrates like rocks, coarse peat banks, and oyster beds, providing hard substrate habitats (Hofstede et al., 2022; Houziaux et al., 2011; Olsen, 1883; Thurstan et al., 2023). But large parts of these hard substrate habitats have been disturbed and largely destroyed due to anthropogenic activities like trawling, oyster dredging, and extraction of marine boulders for application on land (Bennema et al., 2020; Lengkeek and Bouma, 2010; Støttrup et al., 2017). On the grounds of this, it can be argued that compared to its natural state, the North Sea lacks hard substrates today (Coolen, 2017). In most parts of the North Sea, the current legislation requires the complete removal of the offshore structures when decommissioning (OSPAR Commission, 1998), but due to the artificial reef effect of the structures, removing the entire structure may entail a local loss of biodiversity. Consequently, it is questioned if complete removal provides an efficient solution for the marine ecosystem (Fortune and Paterson, 2020; Fowler et al., 2019; Hall et al., 2022). Alternative options could be to leave parts of the foundation, the cables, and the scour protection stones in the sea, which would likely maintain a considerable amount of biodiversity (Spielmann et al., 2023). However, future decommissioning projects will have to critically consider the trade-off between preserving the established artificial reef and the potential of recycling the materials that are removed from the sea (Fowler et al., 2019). A number of studies denote the material recycling potential when removing elements of offshore structures (Molen et al., 2018; Nicolette et al., 2023; Spielmann et al., 2021; Topham and McMillan, 2017). Additionally, Topham et al. (2019a), Fowler et al. (2019), and Hall et al. (2020) specifically state that about 95 % of the turbine structures can be recycled as they are primarily made of metals.

The different decommissioning options may also be associated with different levels of social acceptance. To the authors' knowledge, no scientific studies have been published on the acceptance of offshore wind decommissioning, considering the potential impacts on marine biodiversity. However, the following studies indicate that there may be a relationship between acceptance and biodiversity impacts. Firstly, Danish survey studies from 2004 and 2006, found that the acceptance of offshore wind farms is higher among respondents who believe that offshore wind farms have a positive impact on biodiversity in the sea (Ladenburg, 2008; Ladenburg and Möller, 2011). And secondly, using simple visualizations representing different levels of biodiversity, Klain et al. (2020) find strong and non-linear biodiversity loss aversion preferences for avoiding negative impacts on marine biodiversity and positive preferences for increasing marine biodiversity. The scientific energy research literature holds similar examples of information (visualizations or text) being used in energy technology acceptance studies (Langer et al., 2018; Rijnsoever et al., 2015; Scovell, 2022; Zuch and Ladenburg, 2023). Often, the information is added to ensure a common knowledge ground or to specifically test how variation in the information impacts acceptance or preference, see Needham et al. (2018) for a discussion. In this line of argument, perceptions of a wind farm decommissioning program will most likely be a function of the level and type of information provided to the public, making it necessary to understand and consider how the provided information and educational material type may influence responses and attitudes towards offshore wind farm decommissioning.

In this study, we investigate the attitude of the Danish general public towards offshore wind farm decommissioning. This is done through a nationwide online survey, where the respondents are asked about their perception of leaving elements of the turbine foundation in the sea if (a) assessed to have a positive effect on the marine environment and (b) if assessed to have a positive effect on the marine environment while at the same time, it is assessed that there will be a climate gain (CO_2 savings) in removing and recycling the parts. By providing the respondents with different written and visual information, we assess if the attitude is casually impacted by the written and visual information provided.

The remainder of the study is structured as follows: Chapter 2 gives an overview of related literature relevant to the study. Chapter 3 outlines the employed materials and methods, including survey design, data collection, and econometric framework. The study's empirical results are presented in Chapter 4, followed by a discussion of the main findings and an assessment of critical survey-design elements. The final chapter summarizes and concludes the study's key findings.

2. Past decommissioning research

To the authors' knowledge, only one study (master's thesis) has investigated the social acceptance of offshore wind farm decommissioning (de Kruijf, 2021). Using NGOs as representatives for the general public, de Kruijf (2021) finds that the level of acceptance is highly dependent on how ecological research is included in the decommissioning considerations. As studies on social acceptance of offshore wind decommissioning are highly limited, we have investigated the literature published on three related topics: 1) how biodiversity impacts affect acceptance or preferences for offshore wind farms, 2) the acceptance of offshore oil and gas decommissioning, as this is highly comparable in terms of structural design, material use, and impacts on marine ecology (Fowler et al., 2018; Lemasson et al., 2022; Stranddorf et al., 2024), and 3) how the combination of visual and textual information experiments affect offshore wind farm acceptance and preferences.

Overall, existing evidence shows that positive biodiversity changes (e.g., increased species richness and abundance) tend to increase support for offshore wind (Börger et al., 2015; Joalland and Mahieu, 2023; Kermagoret et al., 2016; Klain et al., 2020; Meyerhoff, 2013; Westerberg et al., 2013). Studies of oil and gas platform decommissioning similarly find public leanings towards leaving structures in situ for reef-like benefits rather than complete removal (Elrick-Barr et al., 2022; Fowler et al., 2018; McKinley, 2022). Additionally, studies have shown that the way information is presented (both imagery and wording) can significantly sway preferences for wind farm siting and development (Joalland and Mahieu, 2023; Ladenburg et al., 2011; Lutzeyer et al., 2018; Nytte et al., 2024; Parsons and Yan, 2021). For example, the order in which nearshore versus farshore visualizations are displayed and the inclusion of nighttime images can alter respondents' acceptance distances (Lutzeyer et al., 2018; Parsons and Yan, 2021), while providing the respondents with necessary information (so-called Cheap Talk Scripts) prior to stating their preference for offshore wind locations, impacts the preferences for wind turbines at different distances (Ladenburg et al., 2011). However, no empirical studies have analyzed the acceptance and preferences for different offshore wind decommissioning scenarios, nor how experimentally induced visual and text information impacts decommissioning acceptance and preferences. A full account of our literature investigation and detailed findings is provided in the study's

Supplementary Information 1 (SI1).

3. Methodology

3.1. Survey design

Data on the acceptance of offshore wind farm decommissioning in Denmark was collected through a large web survey conducted in the Danish society as part of the Bifrost project (Prevost et al., 2022). The questionnaire was developed through a series of focus group interviews and two pilot tests conducted in the summer and early autumn of 2023. To obtain a nationally representative sample, permission was granted by the Danish Health Data Authority to randomly select 60,000 individuals based on their personal identification numbers. The research project description received approval, and on October 13, 2023, participants were invited to participate in the survey via *e-boks*, Denmark's digital mailbox system, where all adults (18+ years) receive communications from public authorities, insurance companies, banks, and other official institutions.

The main part of the survey focused on perceptions and preferences for carbon capture and storage (CCS). In the final part of the survey, the respondents were randomly divided into three sub-surveys covering different energy topics. One of the sub-surveys concerned the decommissioning of offshore wind turbines and is the focal point of this study. In total, 2348 respondents completed the sub-survey about offshore wind decommissioning, resulting in an effective response rate of 11.74 % (2348/(60,000/3)). Compared to other energy-related studies, the number of respondents is at the very high end (Brunnschweiler et al., 2025; Drews et al., 2024), comparable (Ladenburg et al., 2024a; Mundaca and Wamsler, 2025) or lower (Baltruszewicz et al., 2023). The sub-survey included questions about the marine environment and offshore wind farm decommissioning. Two questions (Q1 and Q2) about offshore wind farm decommissioning are used as the outcome/dependent variables in this study (Fig. 1).

While Q1 is linearly constructed, reflecting only one environmental aspect, Q2 introduces a trade-off, reflecting impacts on both the marine environment and climate change in relation to the reuse of materials. The trade-off question was included to investigate if and to what extent the respondents weigh climate change impacts and impacts on marine life differently. The survey was given in Danish but has been translated into English for the purpose of the study. The original Danish version and the English-translated version of the questionnaire can be found in SI2. The survey also included specific questions on the respondent's sociodemographic (age, gender, education, occupation, and income) and household-specific characteristics (housing type and ownership, area of living, solar panel ownership, and ownership of an electric and/or hybrid vehicle). Furthermore, the survey included questions about the perception of climate change, willingness to take risks, and the perception of a good marine environment (SI2).

Importantly, the sub-survey included an information experiment designed specifically to assess the causal effect of information provision and presentation mode on the acceptance of offshore wind farm decommissioning. In the experiment, we employed both written and visual information materials that were provided to the respondents prior to the two acceptance questions (Q1 and Q2). Using a Randomized Controlled Trial (RCT) setup (Harris and Skeels, 2011; Solomon et al., 2009; Sovacool et al., 2018), each respondent received an information text and an illustration of an offshore wind turbine. We used three texts containing different levels of detail regarding offshore wind farm decommissioning, impacts on marine life, and climate change benefits from material recycling (Table 1). Furthermore, we included two illustrations: one without marine life and one with marine life on and around the structure (Fig. 2). The texts and illustrations were randomized and evenly distributed among the respondents (3 × 2 RCT experiment). The number of respondents in each of the six experimental groups and the characteristics of the respondents in the groups are shown in SI3. SI3 also reports structural differences across treatment groups based on student *t*-tests. The test statistics indicate that the sub-groups are not perfectly balanced in terms of education, occupation, type of housing, and positions towards the status of marine ecosystems. Thus, the main analyses include the variables in Table 2 for transparency and to control for any confounding effects from a partially imbalanced dataset.

3.2. Data characteristics

The sample and national means of the respondents' sociodemographic and household-specific characteristics are listed in Table 2 along with additional observational information from the survey (control variables). The different control variables represent typical sociodemographic (Ellis and Ferraro, 2016; Ladenburg and Lutzeyer, 2012; Rand and Hoen, 2017) and spatial (Ladenburg et al., 2020; Ladenburg et al., 2024b) variables included in wind power acceptance/preference studies and found to correlate with acceptance/preferences.

The respondents' average age (AGE) is about 7 years (15 %) higher than the national mean, and the sample includes a 12 % smaller proportion of females (FEMALE). There is a lower probability of the respondent's highest level of education being primary school (PRIM), high school (HIGH), or vocational education (VOC), while the probability of the respondent holding a short-term (S-TERM), medium-term (M-TERM), bachelor's (BACH), or master's/PhD (MPHD) degrees is higher compared to the overall Danish population. The sample contains a 78 % lower share of people who are not employed (UNEMP) than the Danish average. This group covers people who are retired, staying at home, in activation, or for other reasons not employed. The share of privately employed people (PRIVATE) is lower, while the share of publicly employed (PUBLIC), self-employed (SELF), students (STUD), and people

Q1 If it is assessed to have a positive effect on the marine environment, what is your position on leaving parts (pile, stones, and cables) of the wind turbine foundation in the sea?

- ❑ Very negative (1)
- ❑ Somewhat negative (2)
- ❑ Neutral (3)
- ❑ Somewhat positive (4)
- ❑ Very positive (5)

- ❑ Don't know (separate model, 0/1)

Q2 If leaving parts (pile, stones, and cables) of the wind turbine foundation in the sea is assessed to have a positive effect on the marine environment, but there will also be a climate gain (CO_2 savings) in removing and recycling the parts, what is your attitude?

- ❑ The parts must be removed (0)
- ❑ The parts must be left in the sea (1)

- ❑ Don't know (separate model, 0/1)

Fig. 1. Questions (Q1 and Q2) included in the survey. Numbers in brackets indicate how the variables were coded. The "Don't know" responses were analyzed in a separate model, where the response was coded as a dummy variable (0 = didn't answer "don't know", 1 = answered "don't know").

Table 1
Information texts provided to the survey respondents. The Baseline information contains information on the structure and legal requirements for wind farm decommissioning. Information A contains the Baseline information + information concerning the artificial reef effect. Information B contains the Baseline information + information concerning the artificial reef effect + information on the recycling potential of the structural turbine elements.

Baseline information
Offshore wind turbines produce power for 20–25 years, after which they are decommissioned. The foundation of most offshore wind turbines consists of a steel pile in the seabed with large protective stones around it. Buried underwater cables connect the wind turbines and carry the produced electricity to land.
When an offshore wind turbine is no longer to produce electricity, the current legislation requires that cables and steel pipes and the stones around the foundation must be removed. This is even though the stones act as a habitat for several plants and animals.
Information A: Baseline + Artificial reef effect
Baseline information + The protective rocks most often act as artificial reefs, where plants and smaller animals grow, which are food for fish, porpoises, and other mammals. The rocks are also hiding places for various animals. The plant and animal life around the offshore wind turbines is, therefore, often increased through the lifetime of an offshore wind farm, and the occurrence of, e.g., cod and seals can be particularly high around offshore wind turbines.
Information B: Baseline + Artificial reef effect + Recycling/climate potential
Information A + The foundations and cables of offshore wind turbines include steel, copper, and aluminum. These materials require energy to produce, and there can, therefore, be a climate gain (CO_2 saving) in recycling the materials.

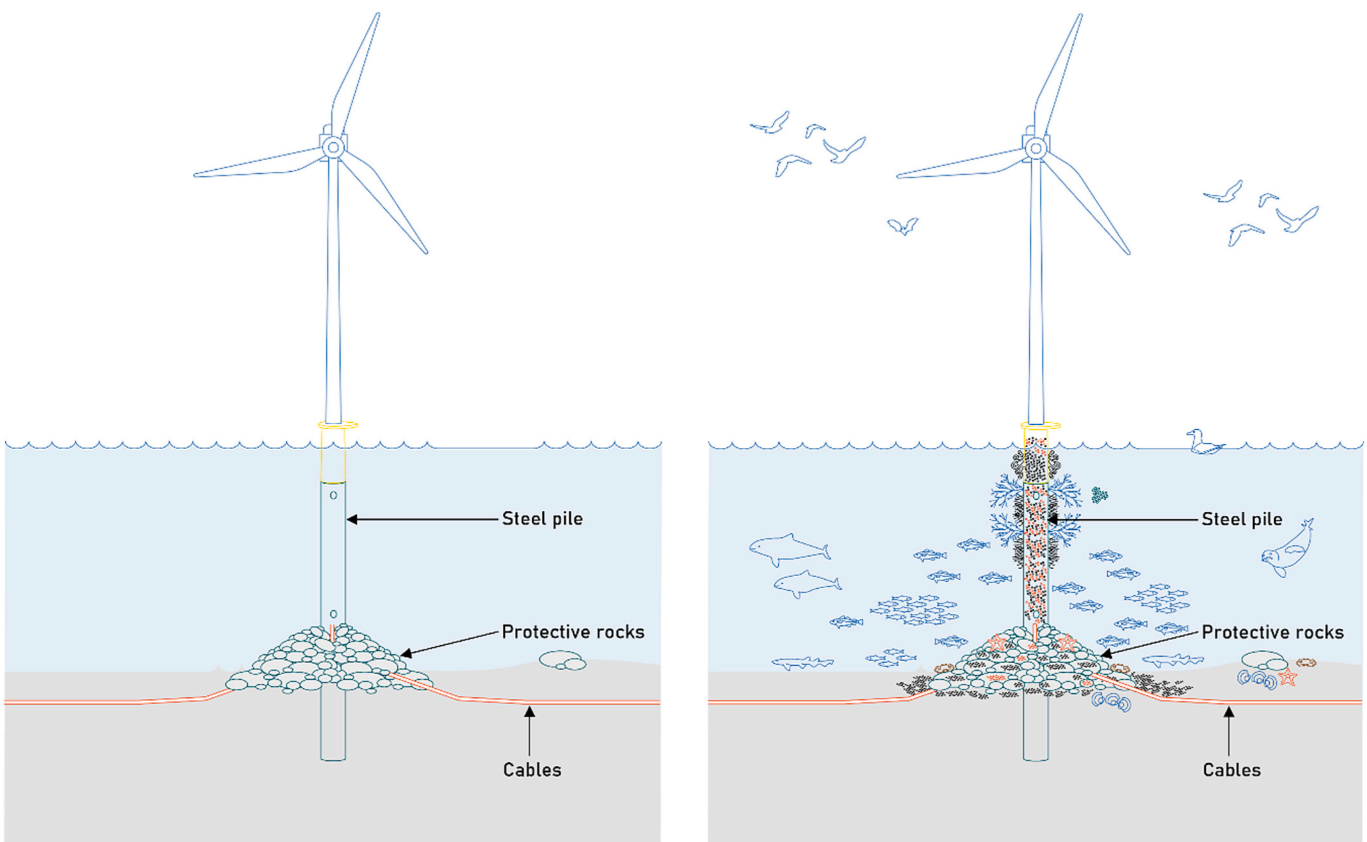

Fig. 2. Illustration options 1 (without marine life, left) and 2 (with marine life, right). English version, translated from Danish.

with other occupations (OTH-OCC) is higher than the Danish average. The mean household income in the sample (HHI) is 14 % higher than the national mean, and the sample holds a higher share of respondents living in the countryside (AREA). The proportion of respondents living in an apartment (APART) or in a room (ROOM) is considerably lower than the national average, while the proportion of respondents living in a house (HOUSE) or on a farm (FARM) is higher. It has not been possible to obtain national statistics for the share living in farmhouses. The share of people living in other residence types (OTH-RES) is very small, both in the sample and nationally, but slightly lower in the applied survey sample. The share of tenants (TENANT) is lower in the sample, while the share of owners (OWNER) and cooperative owners (COOP) is higher.

The share of people owning photovoltaics (PV), electric vehicles (EV), and hybrid vehicles (HYB) is higher in the sample relative to the Danish population. Important to note is that the national average for PV reflects the proportion of (private) buildings with solar panels in Denmark and thus does not directly reflect the proportion of the population that owns a PV system. The last two control variables in Table 2 capture the respondent's distance to the coast (DIST_COAST) and the distance to the nearest offshore wind farm (DIST_OWF). On average, the respondents live about 6.5 km and 29 km from the nearest shoreline and viewpoint of an offshore wind farm, respectively. For both variables, the sample's mean distances do not deviate from those of the Danish population.

Table 2 also lists mean responses to the three position-based

Table 2
Sociodemographic, household-specific, and position-based variables: sample means, sample standard deviation (s.d.), national means, and model coding.

Variable	Sample mean	Sample s.d.	National mean	Coding
Control variables				
AGE	55.68	15.58	48.52[a]	Continuous *(in years)*
FEMALE	0.45	0.50	0.51[a]	= 1 if female, else = 0
PRIM	0.079	0.27	0.17[b]	Educational reference group
HIGH	0.086	0.28	0.11[b]	Educational reference group
VOC	0.23	0.42	0.30[b]	= 1 if vocational education, else = 0
S-TERM	0.093	0.29	0.059[b]	= 1 if short-term education, else = 0
M-TERM	0.21	0.41	0.17[b]	= 1 if medium-term education, else = 0
BACH	0.093	0.29	0.035[b]	= 1 if bachelor's degree, else = 0
MPHD	0.21	0.41	0.14[b]	= 1 if master's/PhD degree, else = 0
UNEMP	0.075	0.26	0.34[c1]	Occupational reference
OTH-OCC	0.019	0.14	0.013[c1]	Occupational reference
PUBLIC	0.20	0.40	0.18[c1, c2]	= 1 if publicly employed, else = 0
PRIV	0.32	0.47	0.40[c1, c2]	= 1 if privately employed, else = 0
SELF	0.067	0.25	0.041[c1]	= 1 if self-employed, else = 0
STUD	0.041	0.20	0.027[c1]	= 1 if student, else = 0
HHI-M	0.10	0.30	NA	=1 if income was not stated, else = 0
HHI[d] (1,000 €)	90.32	NA	79.39[e]	Continuous *(in €)*
AREA	0.23	0.42	0.12[f]	= 1 if living in the countryside, = 0 if living in a city
APART	0.24	0.43	0.40[g]	Residence type reference group
ROOM	0.0043	0.065	0.014[g]	Residence type reference group
OTH-RES	0.017	0.090	0.014[g]	Residence type reference group
HOUSE	0.66	0.47	0.57[g]	= 1 if living in a house, else = 0
FARM	0.072	0.26	NA	= 1 if living on a farm, else = 0
TENANT	0.24	0.43	0.38[h]	Residence owner reference group
OWNER	0.69	0.46	0.57[h]	= 1 if owner of residence, else = 0
COOP	0.077	0.26	0.058[h]	= 1 if owner of coop residence, else = 0
PV	0.12	0.32	0.036[i]	= 1 if owner of PV, else = 0
EV	0.13	0.33	0.064[j]	= 1 if owner of electric vehicle, else = 0
HYB	0.075	0.27	0.038[j]	= 1 if owner of hybrid vehicle, else = 0
DIST_COAST[k]	6.66	8.65	6.47[l]	Continuous *(in kilometers)*
DIST_OWF[k,m]	28.87	26.86	28.40[l,m]	Continuous *(in kilometers)*
Position-based variables				
CLIM	4.30	0.96	NA	Scale from 1 (strongly disagree) to 5 (strongly agree), excluding "Don't know" (6)
RISK	5.44	1.92	NA	Scale from 1 (not willing to take risks at all) to 10 (very willing to take risks)
MAR1	0.17	0.37	NA	Marine position reference group. Respondent thinks that a healthy marine environment means no human disturbance
MAR2	0.19	0.39	NA	= 1 if respondent thinks a healthy marine environment means high protection of marine life and limited human activity, else = 0
MAR3	0.60	0.49	NA	= 1 if respondent thinks a healthy marine environment means a balance between protection and human activity, else = 0
MAR4	0.044	0.21	NA	= 1 if respondent thinks a healthy marine environment means high value for humans and high level of human activities, else = 0

[a] FOLK1A: Population at the first day of the quarter by region, sex, age and marital status (quarter: 2023 Q4). Conditional on the age group 20–80 years, https://www.statistikbanken.dk/statbank5a/SelectVarVal/Define.asp?Maintable=FOLK1A&PLanguage=1 (accessed: 21-05-2025).
[b] Educational attainment (15–69 years) by age, region, ancestry, sex, highest education completed and time (year: 2023). https://www.statbank.dk/statbank5a/selectvarval/define.asp?PLanguage=1&subword=tabsel&MainTable=HFUDD11&PXSId=222202&tablestyle=&ST=SD&buttons=0 (accessed: 21-05-2025).
[c1] RAS202: Population by socioeconomic status, age and sex (year: 2023). https://www.statistikbanken.dk/statbank5a/SelectVarVal/Define.asp?MainTable=RAS202&PLanguage=0&PXSId=0&wsid=cftree (accessed: 21-05-2025).
[c2] LBESK21: Employees by unit and sector (quarter: 2023 Q4). https://www.statistikbanken.dk/statbank5a/SelectVarVal/Define.asp?MainTable=LBESK21&PLanguage=0&PXSId=0&wsid=cftree (accessed: 21-05-2025).
[d] Income Average is the annual income before tax and without pension. Calculated by using data from note [e]. The survey respondents indicated their income on a range corresponding to the income groups in [e]. To calculate the average income, we applied the mean of each range.
[e] INDKF122: Income by income interval, family type, unit, region and time (year, 2023). https://www.statbank.dk/INDKF122 (accessed: 21-05-2025).
[f] Færre bor på landet. (accessed: 21-05-2025).
[g] BOL103: Dwellings by county, type of resident, type of dwelling, number of rooms, size of dwelling in square meter and household size (year 2023). https://www.statbank.dk/BOL103 (accessed: 21-05-2025).
[h] Danish Authority of Social Services and Housing (year 2024). https://boligstat.dk/boligstat/dokumenter/Hvor_bor_hvilke/hvor_bor_hvilke.HTML (accessed: 21-05-2025).
[i] The value refers to the share of (private) buildings with solar PV panels in Denmark. It must be noted that it does not directly reflect population share owning a PV system. https://www.dst.dk/da/Statistik/nyheder-analyser-publ/bagtal/2023/2023-03-27-flest-solceller-i-jylland (accessed: 21-05-2025).
[j] BIL54: Stock of motor vehicles by region, type of vehicle, terms of use and propellant (month: 2023 M12). https://statistikbanken.dk/statbank5a/SelectVarVal/Define.asp?Maintable=BIL54&PLanguage=1 (accessed: 21-05-2025).
[k] The respondent's distance to the nearest coastline and to an offshore wind farm are only included as additional control variables in the robustness tests (see Tables S10 and S11 in SI5). Both variables were computed ex-post in GIS based on the exact location of the respondents' residence (see SI5 for a detailed overview).
[l] The national mean is based on the full survey sample of invited respondents (n = 60,000), randomly drawn from the Danish population. The distance measure is based on the precise location of the individuals' residence.
[m] Spatial data on existing offshore wind farms in Denmark (n = 9) were obtained from the Danish Energy Agency. https://ens.dk/analyser-og-statistik/data-oversigt-over-energisektoren (accessed: 21-05-2025) (see SI5 for a detailed overview).

questions included in the study as position-based parameters. No national means exist for the respective variables. Regarding climate change perception (CLIM), being adopted from Whitmarsh (2011), the respondents were asked to indicate on a 5-point Likert scale to what extent they agree with the statement *"I am convinced that climate change is really happening"*. The mean agrees with this statement. Additionally, the respondents were asked to indicate on a 10-point scale how willing they are to take risks (RISK) (Dohmen et al., 2011). The mean is 5.44, meaning slightly above the median of the scale. To ensure that the question on climate change and willingness to take risk do not capture the same perception dimension, the Pearson's correlation test of the CLIM and RISK parameters is estimated and found to be −0.016.

In the last position-based question, for the purpose of the study, we developed questions related to their perceptions of a healthy marine environment. Specifically, the respondents were asked to choose the one out of four statements (MAR1–4) they think best describes what a healthy marine environment means. The majority (60 %) chose MAR3, meaning that a healthy marine environment means a balance between protecting and using the sea.

3.3. Data processing and analysis

Respondent i's acceptance of leaving structural wind turbine elements in the sea can be expressed by Eq. 1, where k is the question number, i.e., 1 or 2. $Accept_i\_Q(1)$ indicates the acceptance if assessed to positively influence the marine life (Q1) and can take values ranging from 1 (very low acceptance) to 5 (very high acceptance). $Accept_i\_Q(2)$ indicates the acceptance of such an ecologically beneficial decommissioning plan, while foregoing CO_2 savings from removing and recycling structural turbine elements (Q2). Given the design of Q2, the binary dependent variable ($Accept_i\_Q(2)$) can take the values 0 (the parts must be removed) or 1 (the parts must be left in the sea).

$$Accept_i\_Q(k) = Constant + \beta_{ILLU} \bullet ILLU_i + \beta_{INFO\_A} \bullet INFO\_A_i + \beta_{INFO\_B} \bullet INFO\_B_i + \beta_{CONTROLS} \bullet CONTROLS_i + \beta_{POSITIONS} \bullet POSITIONS_i + \varepsilon_i \tag{1}$$

In Eq. 1, *Constant* is the constant estimate, β_{ILLU} is the impact of the illustration with marine life on acceptance, β_{INFO_A} is the impact of Information A (baseline + artificial reef) on the acceptance and β_{INFO_B} is the impact of Information B (baseline + artificial reef + recycling/climate potential) on the acceptance. The constant estimate thus represents respondents receiving the illustration with no biodiversity and the baseline information sheet. The term $\beta_{CONTROLS}$ is a vector of parameter estimates related to the control variables and $\beta_{POSITIONS}$ is a vector of parameter estimates related to position variables. ε_i is the error term assumed to have a normal distribution. Thus, despite the response options for Q1 being categorical ordinal, our main model for Q1 is a linear regression model with robust standard errors, as the model enables us to directly interpret the causal effects of information and illustrations as unit changes on a five-point scale. Likewise, our main model for Q2 is a linear probability model with robust standard errors, despite the response options for Q2 being binary. This enables us to interpret the impact of the experimentally induced differences in visualization and text as approximate marginal effects, unit changes, or percentage changes (Angrist and Pischke, 2008; Wooldridge, 2010). All control variables were coded as dummy variables (0/1). Exceptions are age, household income level and the distance variables, which are continuous variable (see Table 2). The text, illustration, and position-based variables about a good marine are also coded as binary variables. Position-based variables related to climate change and risk perception are coded as categorical ordinal variables.

The two acceptance questions include a "don't know" response option. This uncertainty statement was separated from the study's core analyses but is analyzed in a separate linear probability model with robust standard errors. In total, 59 and 576 respondents answered "don't know" in Q1 and Q2, respectively. The larger share of "don't know" responses to Q2 is assumed to occur due to the increased complexity of the question compared to Q1. Furthermore, Q1 allows the respondents to answer on a graded scale, while in Q2, the respondent is required to either fully accept or reject the option of leaving elements in the sea. Data processing and analysis were carried out using the software R version 4.3.2.

As a robustness test, we estimate the full models using ordered probit models of Q1 and probit regression models of Q2. Both the ordered probit of Q1 and the probit model of Q2 include postal zone fixed effects and cluster robust standard errors clustered at the postal code level. The results of the robustness models are shown in the study's supplementary information (Table S10 and S11, SI5). Including fixed effects ordered probit/binary probit models with and without distance variables to the coast and offshore wind farm does not change the study's findings.

In the main text of the study, we report the results of the linear regression models on Q1 and Q2, focusing on the estimated information effects. The results of the full models, including the coefficient estimates of all applied control variables and position-based variables can be found in SI4. Three types of models are presented for each of the questions in the main paper (Table 3); the first model (Q(k)-I) includes the provided texts and illustrations as independent variables and all sociodemographic and position-based variables; the second model (Q(k)-II) includes the provided texts and illustrations and interactions between texts and illustrations; the third model (Q(k)-III) includes text and illustration, interactions between those, and all sociodemographic and position-based variables (later referred to as the "full models"). In addition, we apply a fully-specified linear probability regression model to investigate determinants of stating a "don't know" response, conditional on the respective acceptance questions (Table 4).

4. Results

Regarding the answer distribution of Q1, about two-thirds (65 %) of the respondents chose the answer option 4 (positive) or 5 (very positive) in Q1. This indicates that the attitude towards leaving elements of the wind turbine foundation is generally positive if it is assessed to have a positive effect on the marine environment (Q1). About 17 % of the respondents are negatively positioned in Q1 (response option 1 or 2), while 18 % are neutral or don't know (response option 3 or 6). When asking about the position of leaving the foundation elements in the sea if it is assessed to have a positive effect on the marine environment, but there will also be a climate gain (CO_2 savings) in removing and recycling the parts (Q2), the general attitude is less positive towards leaving the elements. In Q2, 45 % answered that the elements should be removed (response option 1), 30 % that the elements should be left (response option 2), and 25 % don't know (response option 3).

The following sections report on the effect of the text and illustrations on the two acceptance measures (Section 4.1) and how the sociodemographic variables (Section 4.2), and position-based variables (section 4.3) correlate with the acceptance. In Table 3, all models named with Q1 reflect the responses to Q1, and models named with Q2 reflect the responses to Q2. For all models, we indicate the significance of the difference between Information A and Information B on the acceptance (based on an F-test). The bottom of Table 3 shows model fit statistics, i.e., R^2, adjusted R^2, AIC, BIC, and log-likelihood (LL(β)). In addition, Table 3 shows the log-likelihood ratio (LR) test values and statistics comparing models I-III (Q1 and Q2) to corresponding linear regression models including postal code fixed effects. The models including postal code fixed effects can be found in Tables S13 and S14 in SI5.

4.1. Influence of text and visualization experiments

The magnitude and significance of the estimated effects of the text information experiments vary between the two questions (Q1 and Q2).

Table 3
Linear robust regression models for question 1 (Q1) and question 2 (Q2). Model estimates and [std. errors]. x indicates when the sociodemographic or position-based variables are included. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

	Question 1			Question 2		
	Q1-I	Q1-II	Q1-III	Q2-I	Q2-II	Q2-III
Constant	3.4	3.9	3.5	0.31	0.46	0.33
	[0.22]***	[0.057]***	[0.23]***	[0.10]***	[0.028]***	[0.10]**
Illustration w. marine life	−0.060	−0.091	−0.11	−0.034	−0.066	−0.074
	[0.047]	[0.081]	[0.080]	[0.023]	[0.040]	[0.040]
Information A	0.078	0.055	0.041	0.018	0.0051	0.0014
	[0.057]	[0.080]	[0.080]	[0.029]	[0.041]	[0.040]
Information B[a]	−0.11	−0.15	−0.16	−0.10	−0.14	−0.14
	[0.058]/***	[0.081]/*	[0.080]*/*	[0.028]***/***	[0.039]***/***	[0.039]***/***
Information A x Illustration w. marine life	–	0.073	0.074	–	0.028	0.039
		[0.11]	[0.11]		[0.058]	[0.058]
Information B x Illustration w. marine life	–	0.074	0.089	–	0.073	0.076
		[0.12]	[0.12]		[0.056]	[0.056]
Demographic and socio-economic variables	x	–	x	x	–	x
Position-based variables	x	–	x	x	–	x
N	2289	2289	2289	1772	1772	1772
R^2	0.058	0.0068	0.049	0.037	0.013	0.038
Adj. R^2	0.046	0.0047	0.038	0.021	0.011	0.021
AIC	7238	7098	7060	2493	2489	2496
BIC	7410	7133	7244	2663	2527	2676
LL(β)	−3589	−3649	−3587	−1216	−1223	−1215
LR test vs. robustness w. postal code fixed effects	2.64×10^{-25}	1.40×10^{-37}	4.91×10^{-25}	0.11	0.028	0.11

[a] Two significance indicators are included for this parameter. The first one is the significance of the parameter estimate on the acceptance. The second one indicates the significance of the difference between Information A and Information B on the acceptance (based on an F-test).

Table 4
Models for those answering “don’t know”. Linear robust regression models for question 1 (Q1-IV) and question 2 (Q2-IV). Model estimates and [std. errors]. x indicates when the sociodemographic or position-based variables are included. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

	Question 1 Q1-IV	Question 2 Q2-IV
Constant	0.081	0.23
	[0.034]*	[0.079]**
Illustration w. marine life	−0.0031	0.041
	[0.013]	[0.031]
Information A	−0.022	0.058
	[0.011]*	[0.032]
Information B[a]	−0.011	−0.010
	[0.012]/	[0.029]/*
Information A x Illustration w. marine life	0.016	−0.087
	[0.016]	[0.045]
Information B x Illustration w. marine life	0.0044	−0.025
	[0.017]	[0.042]
Demographic and socio-economic variables	x	x
Position-based variables	x	x
N	59	576
R^2	0.028	0.024
Adj. R^2	0.015	0.011
AIC	−2048	2711
BIC	−1858	2901
LL(β)	1057	−1323
LR test vs. robustness w. postal code fixed effects	0.0015	0.16

[a] Two significance indicators are included for this parameter. The first one is the significance of the parameter estimate on the acceptance. The second one indicates the significance of the difference between Information A and Information B on the acceptance (based on an F-test).

Compared to receiving the Baseline information, receiving the text where information on marine life is added (Information A) does not have a significant effect on the acceptance in any of the questions. In contrast, receiving the text that includes additional information on recycling and the associated climate benefits (Information B), decreases the acceptance of leaving structural elements in both questions, compared to receiving the Baseline information (Table 3). For Q1, this effect is statistically significant at a 5 % level in the full model, where the acceptance decreases by 0.16 acceptance units (Model Q1-III). For Q2, the effect of Information B is significant at a 0.1 % level in all three models (Q2-I, Q2-II, Q2-III) and decreases the acceptance with 0.10–0.14 units, corresponding to a 10–14 % lower probability of answering “The parts must be left in the sea”, relative to “The parts must be removed”.

The estimated effects of the illustrations themselves on the responses to either Q1 or Q2 are not statistically significant, and neither are the interactions between text information and illustration. However, the estimates for receiving the illustration with marine life are systematically negative, indicating that the general acceptance will decrease if receiving the illustration with marine life. A further investigation of the combined effects of texts and visualizations on the acceptance can be found in SI6. Overall, the highest acceptance level is estimated when the respondents receive the Baseline information and information on marine life (Information A) in combination with the illustration without marine life. The lowest level of acceptance is estimated when the respondents receive the text including Baseline information, information on marine life, and information on the recycling/climate potential (Information B) and the illustration with marine life. These findings are robust to accounting for postal code fixed effects and when applying ordered probit (Q1) and binary probit (Q2) regression analyses (see SI5).

4.2. *Influence of sociodemographic variables*

The responses to Q1 are significantly influenced by gender, income level, and the ownership of housing (see Table S7 in SI4). Female respondents are generally less positively positioned towards leaving elements in the sea than their male counterparts. Being female decreases the acceptance in Q1 significantly with 0.19 acceptance units (in all models). Additionally, higher income is associated with higher acceptance of leaving the elements in the sea. Increasing the income by one income level increases the acceptance significantly by approximately 0.023 acceptance units. If owning the place of residence, in comparison to shared ownership or rental, the acceptance increases acceptance under Q1 significantly by 0.21 acceptance units.

The responses to Q2 are generally less influenced by sociodemographic variables (see Table S8 in SI4), and none of the considered sociodemographic variables are statistically significant in influencing the acceptance. An exception is found for the level of education, which has a marginally significant influence on the acceptance at a 10 % level. People with higher education than the reference group (primary school and high school) are generally more positively positioned towards leaving elements in the sea. Having a vocational education, short-term education, or education at a master's or PhD level increases the acceptance by 0.073 ($p = 0.055$), 0.091 ($p = 0.062$), and 0.073 ($p = 0.077$) acceptance units, respectively (see Model SQ2-III, Table S8 in SI4).

4.3. Influence of position-based variables

The responses to Q1 and Q2 are both significantly influenced by the perception of a healthy marine environment. The ones who think that a healthy marine environment means a balance between protecting and using the oceans, where human activity is necessary but with the least possible negative impact on the marine environment (MAR3), are more positively positioned towards leaving structural elements (see Tables S7 and Table S8 in SI4). The acceptance increases by 0.20 acceptance units in Q1 and 10 % (0.10 units) in Q2 for those responding MAR3, compared to those responding MAR1. i.e., that a healthy marine environment means "that the sea's plant and animal species thrive unaffected by human activity". Additionally, Q2 is significantly influenced by the willingness to take risks (RISK). A one-unit increase on the ten-point scale of willingness to take risks is associated with a 1.6 % increase in acceptance of leaving the structural elements in the sea.

4.4. Who answers "don't know"?

We conducted a linear probability regression analysis on the likelihood of giving a "don't know" answer. The results of the regression models conditional on Q1 (Q1-IV) and Q2 (Q2-IV) are presented in Table 4. Receiving Information A, relative to receiving the Baseline information decreases the probability of answering "don't know" to Q1 significantly by 0.022 units (Table 4, Q1-IV). Compared to receiving the Baseline information, neither Information A nor Information B has a significant influence on answering "don't know" to Q2. But compared to Information B, Information A significantly decreases the probability of answering "don't know". The illustrations do not significantly influence the probability of observing a "don't know" response, regardless of the considered acceptance question.

Considering sociodemographic parameters (see Table S9 in SI4), being female increases the probability of answering "don't know" significantly by 0.017 units in Q1 and by 0.05 units in Q2. Compared to living in a city, living in the countryside (AREA) decreases the probability of answering "don't know" significantly by 0.019 units in Q1 and by 0.054 units in Q2. The results denote a significant relationship between "don't know" answer probability and the respondent's type of housing. Specifically, living in a house decreases the probability of answering "don't know" in Q1 by 0.019 units, relative to the reference group. Respondents who wished not to disclose their annual household income (HHI-M = 1) are about 10 % more likely to state 'don't know' to Q2 than those who provided income-related information.

Regarding the position-based parameters, a lower willingness to take risks is associated with a higher probability of answering "don't know" to both Q1 and Q2. Lowering the willingness to take risks by one level (on a scale from 1 to 10) increases the probability of a "don't know" response by 0.005 units to Q1 and by 0.011 units to Q2.

5. Discussion

5.1. Effects of information

Interestingly, the results denote that neither the illustrations of higher levels of biodiversity nor Information A (baseline + reef effect), solely focusing on the effects on biodiversity when leaving turbine structures in the sea, significantly increases the likelihood of being positive towards leaving structural elements when decommissioning. This contrasts the findings from the offshore wind power literature, which generally indicate a positive relationship between increased biodiversity and wind farm acceptance (Börger et al., 2015; Kermagoret et al., 2016; Klain et al., 2020). One obvious reason is that the respondents included in the studies mentioned are presented with all possible levels of biodiversity changes (within-subject information treatment), whereas we only present the respondents with one level of information each (between-subject treatment). If we had first presented the respondents with the "no biodiversity" picture, then asked the decommissioning acceptance questions, then presented them with the "high biodiversity" picture and then asked the decommissioning acceptance questions again, then we might have triggered a different decommissioning preferences response in our survey, as discussed in the scope/embedding literature (Bishop et al., 2017; Carson and Mitchell, 1995; Jacobsen et al., 2011). That said, we do observe an effect of information B (baseline + reef effect + recycling potential) relative to the Baseline information and Information A, denoting that the information experiment does induce changes in the acceptance of decommissioning strategies.

In light of the level of information contained in the three texts, the analysis shows that if the provided text includes details on both the potential benefits for the marine ecosystem from leaving elements in the sea and the potential CO_2-equivalent savings from recycling materials, the respondents are significantly less likely to be positively positioned towards leaving foundational elements in the sea. This indicates that the respondents weigh the reduction of climate impacts higher than protecting and maintaining the established ecosystem and biodiversity on the turbine structures.

A considerably larger share of respondents answered "don't know" in Q2 (25 %) than in Q1 (3 %), and the results also show that receiving Information A (baseline + marine life) compared to Information B (baseline + marine life + recycling) significantly increases the probability of answering "don't know" in Q2. This may be explained by the fact that Information A only provides information on one (marine life) of the two aspects introduced in Q2 (marine life on climate/circularity). Thereby, respondents are only partially equipped to answer the question and might get confused by the lack of information on the climate/circularity aspect. Additionally, a considerably larger share of those receiving Information A is negatively positioned towards leaving the elements. Among those receiving Information B, 52 % say that the elements should be removed, while 41 % of those receiving Information A and 43 % of those receiving the Baseline text say that the elements should be removed. This indicates that providing information on the climate/circularity aspect in addition to the information on marine life makes people more negative towards leaving the elements and supports the theory that the respondents weigh the reduction of climate impacts higher than impacts on marine life. None of the texts have a significant influence on answering "don't know" to Q1.

5.2. Effects of sociodemographic and position variables

Only a few sociodemographic variables influence the responses significantly, including gender and income level. Considering the acceptance of offshore wind, these are typical influential sociodemographic variables (Ladenburg and Möller, 2011). In our study, we find that female respondents are generally more likely to be negatively positioned towards leaving elements in the sea. This corresponds with previous studies, which found that females tend to perceive more risk (Kahan et al., 2007; Scovell, 2022). Additionally, we find that higher income is associated with higher acceptance of leaving the elements in the sea, primarily in Q1, where only the impacts on marine biodiversity are included. This corresponds with the findings of Liu et al. (2023), who indicate that higher income is associated with higher recognition of environmental problems caused by anthropogenic activities.

Considering the position-based variables, the responses are significantly correlated with the perception of a healthy marine environment. The perception of a healthy marine environment is based on a question where the respondents were asked to choose the expression that best matches what they think a healthy marine environment is (see SI2). The ones who think that a healthy marine environment means '*a balance between protecting and using the oceans where human activity is necessary but with the least possible negative impact on the marine environment*' (MAR3) are more positively positioned towards leaving structural elements. While the other expressions either reflect that no human activities should be allowed (MAR1), only a limited level of human activities should be allowed (MAR2), or that the sea should provide the greatest possible value for people (MAR4), MAR3 is more balanced, considering both human activities and mitigating the impact on the marine environment. This highly correlates with those responding that the structural elements should be left in the sea if that is assessed to be the best option for marine biodiversity.

Additionally, the willingness to take risks significantly influences the acceptance of leaving the elements in the sea. A higher willingness to take risks is associated with a higher acceptance of leaving the structural elements in the sea. Considering that the current decommissioning policies are based on the assumption that "leaving the seabed as you found it" will minimize the impacts on the marine environment (Fowler et al., 2018; OSPAR Commission, 1998), leaving elements in the sea may be perceived as a risk.

5.3. Limitations

Our results should be interpreted in light of the following limitations. First, a natural limitation of most survey studies is the representativity of the survey sample at a national level, e.g., our sample contains a less balanced gender distribution compared to the national average, a higher level of education, and a higher income (14 %) than the Danish average. Additionally, there is a considerably smaller share of people being unemployed in the survey compared to the national average. These biases in sample characteristics should be considered if the findings are to be generalized to the entire Danish population. Secondly, the project conducting the survey (Prevost et al., 2022) was not able to send a reminder to answer the survey, which may have limited the number of respondents. Finally, the survey design is expected to influence the responses and, thereby, the results of this study. Here, we highlight three aspects of the survey design that may have influenced the results to a greater or lesser extent.

Firstly, the survey used in this study followed a linear design and question sequence and did not include randomization of the question order, meaning that all respondents received all questions in the same order. However, studies have shown significant effects of question orders (Schwarz and Sudman, 1992; Tourangeau et al., 2003). Tourangeau et al. (2003) find that respondents are generally likely to use previous questions as an interpretive framework, providing a context for understanding the current question and guiding the response. In light of these studies, it can be expected that the responses to our survey may have been affected by not including a question order randomization, especially for the applied acceptance questions. Considering the response tendencies found in Tourangeau et al. (2003), the responses to Q1 may have been more positively oriented solely on the basis that the respondents were presented with this question first, and the responses to Q2 are expected to be somewhat reflecting the context of and response to Q1.

Another aspect expected to influence the results of this study is that the response options in the two questions investigated were not phrased identically. Besides the option of answering "don't know", Q1 allows the respondents to answer on a gradient scale with five levels, while Q2 holds a binary response option. As the response options in Q2 are more strict, this might lead to more people doubting their position, thereby choosing the "don't know" option. This might explain the relatively high share (25 %) of "don't know" responses in Q2. Additionally, the inherent conflict of Q2, reflecting both the marine environment and climate, is expected to also influence the share of respondents answering "don't know".

Lastly, another survey design element worth discussing, is the choice of illustrations and textual information provided to the respondents. We applied two different illustrations to test the influence of visual elements on the responses: one illustration with no marine life and one illustration with much marine life. The study showed that the illustrations alone did not influence the results significantly but that the acceptance is generally lower when receiving the illustration with marine life. An expansion of this study could involve including more illustrations with gradients of marine life to investigate if a more moderate level of marine life would influence the acceptance. Another option could be to let some respondents receive the illustrations and others receive photos of actual structures, as these may provide people with a better impression of the life around the structures. Studies have shown that public awareness of the marine environmental status is generally low (Baechler et al., 2024; Liu et al., 2023) but that environmental knowledge and public awareness are important factors that influence environmental policy and management (Weidner and Janicke, 1997). Providing the respondents with actual pictures of how the structures in the sea look like may increase their awareness of the marine environment and thereby give a better basis for the respondents to assess their acceptance of leaving the structures in the sea. The awareness may also be enhanced by providing the respondents with information on quantified impacts on marine biodiversity and climate change/circularity. Such information could be broadened to include information on impacts on different species groups, including keystone species (species that play an essential role in the structure, functioning, and productivity of a habitat or ecosystem (WWF, 2024)) and invasive species (species that are non-native and harmful to the ecosystem under consideration (Pysek et al., 2020)), to give a better indication of the importance of impacts.

5.4. Policy implications

Based on the findings presented and discussed, several implications emerge for offshore wind farm decommissioning policy and public engagement. The overall policy message from the results denotes that the respondents are generally more likely to oppose leaving structures in the sea, particularly if they are presented with information about both the potential marine biodiversity benefits of leaving structures and climate impact savings from removing and recycling the structures. However, this opposition is not uniform as high risk tolerance, high income, and male respondents are likely to be more positive towards leaving elements in the sea. There is also a large share (25 %) of the respondents who remain uncertain about whether the structures should be left or removed. This heterogeneity suggests that there may not be a one-size-fits-all solution to offshore wind farm decommissioning. It is, though, important to recognize that the public's perception of offshore wind farm decommissioning scenarios is only one piece of the decision-making puzzle. Economic aspects (Adedipe and Shafiee, 2021; Hall et al., 2022; Topham and McMillan, 2017), national and international legislation and regulation (OSPAR Commission, 1998), and technical feasibility (Kerkvliet and Polatidis, 2016) are also key pieces. The potentially large cost savings (€100+ million) associated with a partial removal scenario (Adedipe and Shafiee, 2021) may favor a decision of partial removal. In contrast, the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Commission, 1998) generally requires full removal of all offshore installations, although the convention allows national authorities to grant exemptions if environmental protection and maritime safety can be ensured. However, historical decommissioning experience shows that economic and regulatory arguments alone may not be decisive. The 1990s controversy over the planned partial removal of the oil platform *Brent Spar* demonstrated how strong public opposition can overturn decommissioning plans despite regulatory approval, scientific justification, and economic arguments to leave structural elements in place (Bate, 1995). As a result, policy makers are now faced with complex decisions that should balance legal obligations, technical feasibility, environmental impacts, and broader societal considerations, including public attitudes towards different decommissioning approaches.

A second key policy implication arising from our findings is that even simple information cues can strongly influence public preferences regarding offshore wind farm decommissioning and highlight their environmental priorities. This suggests that many people may not be well-informed about the environmental consequences of decommissioning, and their views can shift depending on how the issue is presented. This highlights the importance of carefully designing surveys used to support policy decisions - especially when respondents may lack knowledge or hold misconceptions about the topic (Kataria et al., 2012; LaRiviere et al., 2014). Although the scenarios we presented were based on scientific literature, they were hypothetical. The fact that these scenarios still shaped public responses shows how crucial it is to base future communication on real-world data and context-specific assessments whenever possible.

Therefore, policy frameworks that aim to support evidence-based decision-making should ensure that public information is clearly presented, reflects key environmental trade-offs, and is grounded in reliable and transparent scientific evidence. Finally, when public opinion surveys are used in policy consultations, their design must be transparent and consistent, following best practices from the relevant scientific literature to ensure credible and unbiased insights.

6. Conclusion

Based on acceptance data from a Danish national household survey, this study investigated the attitudes of the Danish general public towards offshore wind farm decommissioning and how that may be influenced by the written and visual information provided to the respondents. Using a Randomized Controlled Trial (RCT) setup, each respondent received an information text and an illustration of an offshore wind turbine. We used three texts containing different levels of detail regarding offshore wind farm decommissioning, biodiversity impacts from removing the structures, and climate change benefits from material recycling after decommissioning. Furthermore, we included two illustrations: one without marine life and one with marine life on and around the structure.

Overall, the study finds support for leaving elements as part of the decommissioning when the question solely focuses on the potential positive biodiversity effects (Q1). But if the question also includes potential climate gains by removing the offshore wind farm elements, the acceptance tips towards complete decommissioning. The study demonstrates a significant effect of the written information on the responses. The respondents who were provided with detailed written information on both the potential biodiversity impacts and the potential CO_2 savings from removing and recycling the structural elements tend to be more critical of leaving parts of the structures in the sea. Additionally, receiving information on both the biodiversity impacts and the potential CO_2 savings increases the probability of answering “don’t know”. The absence of marine life in the provided visual information is found to amplify the impact of written information on respondents’ attitudes, however, this effect is not significant at a 5 % level. Sociodemographic factors, such as gender, income level, and education, also correlate with attitudes, with varying effects depending on the context of the questions posed. The willingness to take risks also is also related to the perception of decommissioning, as the positivity towards leaving foundation elements in the sea increases with the willingness to take risks.

The obtained insights are vital for policymakers and stakeholders as they navigate the complex decisions surrounding offshore wind farm decommissioning, aiming for solutions that balance ecological benefits with public acceptance. Firstly, the results indicate that detailed information can promote acceptance but might also induce hesitation and uncertainties. Thus, information campaigns should be carefully designed, ensuring a transparent and scientifically sound view of ecological and climate-related impacts associated with different offshore wind decommissioning options. As illustrative and textual materials might interact in shaping public attitudes, it is advised to critically reflect on the type, content, and presentation mode of information. Including visual aids that realistically present marine biodiversity can help align public perceptions with ecological realities and facilitate well-informed preference formation and responses. Secondly, the observed high share of”don’t know” answers signals widespread uncertainties in individual perceptions towards decommissioning strategies. Decommissioning program planners should address this issue proactively by designing case-specific communication campaigns, including expert engagement, stakeholder discussions, and clear information about potential trade-offs. Establishing such outreach programs can foster well-informed public attitudes and hence facilitate the design of efficient wind farm decommissioning programs that a) effectively balance biodiversity benefits, climate impacts, and public acceptance and b) are supported by economic, regulatory, technological, and societal considerations.

CRediT authorship contribution statement

Liv Stranddorf: Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jacob Ladenburg:** Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Matteo Zuch:** Writing – original draft, Investigation, Formal analysis.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2025.108796.

Data availability

The data that has been used is confidential.

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