Social acceptance and external effects of offshore wind in the green transition

Samfunnmessig aksept og eksterne effekter av havvind i det grønne skiftet

Philosophiae Doctor (PhD) Thesis

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Dedication

To my lovely parents, and siblings, my pillar of strength and infinite supporters. I am because you are.

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To my family and lovely friends, you inspire me to be the best version of myself. To the nature around Ås, thank you for grounding me, and for the wonderful five years.

Sharon Nytte

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Summary

Increasing electricity production from offshore wind is pertinent to realizing net zero carbon emissions by 2050. However, integrating offshore wind in the transition to green energy is not without social challenges. Therefore, a seamless transition necessitates assessing and addressing social acceptance issues that this energy source faces. To this end, this thesis investigates the social acceptance of new floating offshore wind power development in Norway and reviews studies employing Discrete Choice Experiment (DCE) to value external costs and benefits of offshore wind.

Paper I estimates Norwegian households' willingness to pay (WTP) for floating offshore wind power development. The paper uses a split-sample DCE survey of a random sample of Norwegians; with two policy framings differing with regards to the objective of deploying offshore wind power projects; either to meet increasing electricity demand or to achieve climate objectives. The DCE describes the development of offshore wind by five attributes: project size, share of Norwegian technology, reduction in technology costs by 2030, use of electricity, and an increase in the household's electricity bill. Two of these attributes are novel for DCEs of offshore wind: (i) the share of Norwegian technology, and (ii) a reduction in technology costs by 2030. Assuming heterogeneous preferences for offshore wind, the paper applies a mixed logit model to estimate the WTP for the different attributes. Norwegians have a positive WTP for developing floating offshore wind projects utilizing domestic technology and supplying electricity to the Norwegian mainland and the offshore oil and gas sector. In contrast, the respondents are less willing to pay for new projects to stimulate a reduction in technology costs. With regards to the two policy framings, projects developed to meet increasing electricity demand receive broader support than those developed to meet climate objectives.

Paper II uses other data from the same national survey to test whether people's attitudes towards existing offshore industries affect their acceptance of floating offshore wind power. Results show that people's attitudes towards expanding oil and gas extraction, ocean aquaculture, and tourism together with their sociodemographic characteristics are robust indicators of their acceptance of new floating offshore wind power projects. Notably, positive attitudes towards expanding ocean aquaculture and tourism increase social acceptance whereas people who are positive about expanding oil and gas extraction activities are less willing to pay for new floating offshore wind power projects.

Paper III explores the drivers of people's attitudes towards floating offshore wind and uses a subset of the data from the same national survey. People-ocean relations are measured by

people's responses to statements about different dimensions of two socially constructed concepts, place (ocean) meanings and place attachment that together make up the concept of 'sense of place'. Results show that respondents' socio-demographic characteristics, their stated ocean meanings, and their technology risk and benefit perceptions are important predictors for their attitudes towards floating offshore wind power. Place attachment was not a significant predictor. The paper also explores the role of policy framings in shaping attitudes and finds that more dimensions of "ocean meanings" have a significant negative effect on people's attitudes towards floating offshore wind in the climate framing than in the electricity framing.

Paper IV reviews and analyses the existing offshore wind power DCE studies by identifying and comparing the attributes used, their design and the associated WTP estimates. A systematic review identified thirteen peer-reviewed published papers based on DCEs conducted in three continents: North America, Europe, and Asia. The review provides WTP estimates for visibility attributes such as distance from the shore, project size, and turbine height; but it also covers attributes reflecting offshore wind's impact on the marine environment, offshore industries and activities as well as other factors such as carbon emissions abatement, and project ownership, not examined by preceding review studies. Results show that people across the studies are willing to pay more to minimize the visual intrusion of offshore wind and, safeguard marine ecosystems while existing offshore activities' impact on WTP for offshore wind differs across studies and countries.

Sammendrag

Økt strømproduksjon fra havvind er viktig for å oppnå netto nullutslipp av klimagasser innen 2050. Å integrere havvind i overgangen til grønn energi er imidlertid ikke uten samfunnsmessige utfordringer. For å sikre en sømløs overgang er det derfor nødvendig å vurdere og løse problemene med samfunnsmessig aksept for denne energikilden. Denne avhandlingen undersøker derfor den samfunnsmessige aksepten for utbygging av flytende havvind i Norge, og gjennomgår studier som benytter diskrete valgeksperimenter (DCE) for å verdsette eksterne kostnader og fordeler ved havvind.

Artikkel I estimerer norske husholdningers betalingsvillighet for utbygging av flytende havvind. I artikkelen benyttes en DCE-undersøkelse av et tilfeldig utvalg av nordmenn, med to underutvalg som gir ulike politiske innramminger av formålet med havvindprosjekter; enten å møte den økende etterspørselen etter elektrisitet eller å oppnå klimamål. DCE beskriver utbyggingen av havvind ved hjelp av fem attributter: prosjektstørrelse, andel norsk teknologi, reduksjon i teknologikostnader innen 2030, bruk av elektrisitet og økning i husholdningens strømregning. To av disse attributter er nye i DCE av havvind: (i) andelen norsk teknologi og (ii) en reduksjon i teknologikostnadene innen 2030. Med utgangspunkt i heterogene preferanser for havvind anvender artikkelen en blended logistisk-modell for å estimere betalingsvilligheten for de ulike attributtene. Nordmenn har en positiv betalingsvillighet for å utvikle flytende havvindprosjekter som bruker norsk teknologi og leverer strøm til det norske fastlandet og olje- og gassektoren offshore. Derimot er respondentene mindre villige til å betale for nye prosjekter for å stimulere til reduserte teknologikostnader. Når det gjelder de to politiske innrammingene, får prosjekter som er utviklet for å dekke økt etterspørsel etter elektrisitet bredere støtte enn prosjekter som er utviklet for å nå klimamålene.

Artikkel II bruker andre data fra den samme nasjonale undersøkelsen for å teste om folks holdninger til eksisterende offshoreindustrier påvirker deres aksept for flytende havvind. Resultatene viser at folks holdninger til økt olje- og gassutvinning, havbruk og turisme sammen med sosiodemografiske kjennetegn er robuste indikatorer for deres aksept av nye flytende havvindprosjekter. Positive holdninger til havbruk og turisme øker den sosiale aksepten, mens folk som er positive til økt olje- og gassutvinning, er mindre villige til å betale for nye flytende havvindprosjekter.

Artikkel III utforsker drivkreftene bak folks holdninger til flytende havvind og bruker en dele av dataene fra den samme nasjonale undersøkelsen. Forholdet mellom mennesker og hav måles ved hjelp av folks svar på utsagn om ulike dimensjoner av to sosialt konstruerte konsepter,

stedsbetydning (hav) og stedstilknytning, som til sammen utgjør begrepet "stedstilhørighet". Resultatene viser at respondentenes sosiodemografiske kjennetegn, deres uttalte havbetydning og deres oppfatning av risiko og fordeler ved teknologien er viktige prediktorer for deres holdninger til flytende havvind. Stedstilknytning var ikke en signifikant prediktor. Artikkelen undersøker også hvilken rolle ulike politiske innramminger spiller for holdningsdannelsen, og finner at flere dimensjoner av "havets betydning" har en signifikant negativ effekt på folks holdninger til flytende havvind i klimarammen enn i elektrisitetsrammen.

Artikkel IV gjennomgår og analyserer eksisterende DCE-studier av havvind ved å identifisere og sammenligne attributtene som brukes, deres design og tilhørende betalingsvillighetsestimater. En systematisk gjennomgang identifiserte tretten fagfellevurderte publiserte artikler basert på diskrete valgeksperimenter utført på tre kontinenter: Nord-Amerika, Europa og Asia. Gjennomgangen gir betalingsvillighetsestimater for synlighetsattributter som avstand fra land, prosjektstørrelse og turbinhøyde; men den dekker også attributter som reflekterer havvinds innvirkning på havmiljøet, offshoreindustrier og -aktiviteter, samt andre faktorer som reduksjon av karbonutslipp og prosjekteierskap, som ikke er undersøkt av tidligere slike sammenstillingsstudier. Resultatene viser at folk på tvers av studiene er villige til å betale mer for å minimere visuell effekt av havvind og sikre marine økosystemer, mens eksisterende aktiviteters innvirkning på betalingsvillighet for havvind varierer mellom studier og land.

Synopsis

1 Introduction

1.1 The green energy transition

Energy transitions are not extraordinary, as people have historically moved from one energy source to another (i.e., wood to coal in the 18th century). However, the green energy transition happening now is unlike its predecessors. It is informed by the need to curtail greenhouse gas emissions, which emanate mainly from the combustion of fossil fuels in energy production, transportation and industrial processes (United Nations, 2023). Consequently, an effective green energy transition calls for overhauling the entire energy system, not just the closure of fossil-fuel-powered plants (IRENA, 2023). It also involves electrifying industries and the transport sector, promoting energy efficiency, digitalization, and increasing the use of renewable energy sources.

Renewable energy sources are the cornerstone of the green energy transition, as they are not only low carbon but also inexhaustible. To advance the shift to renewable energy, the United Nations (2023) proposes five actions: (i) triple investments in renewable energy, (ii) transfer fossil fuel subsidies to renewable energy, (iii) streamline policies and processes to enable a level playing field, (iv) expedite easy access to raw materials and components, and lastly, (v) facilitate knowledge sharing and easy transfer of technology innovations across countries. This thesis aims at contributing knowledge necessary for implementing actions (i), (ii) and (v), through mapping social acceptance and willingness to pay (WTP) for floating offshore wind power innovation in Norway, as well as reviewing existing literature on externalities of offshore wind.

Until recently, wind power's position in the green energy transition was marginal compared to other mature energy sources, such as hydropower and geothermal. However, advances in technological innovation, including improved wind turbine efficiency, and the application of floating wind technology combined with falling technology costs have stamped wind power's position as an integral renewable source (IRENA, 2022). A case in point is that installing onshore and offshore wind projects cost 68% and 60%, respectively in 2022, compared to 2010 cost levels (IRENA, 2022). Succinctly, limiting global warming implies more than a nine-fold increment in the total installed capacity for onshore and offshore wind by 2050. Together with extensive electrification would result in at least a 25% reduction in carbon emissions by 2050 (IRENA, 2019). Preferably, wind power should become the dominant source of electricity production by 2050 (IRENA, 2019).

1.2 The potential for offshore wind

The ocean and open seas offer the most promising renewable energy sources, including floating solar photovoltaics, tidal, ocean thermal, wave energy, and wind energy. The renewable energy group at the World Bank appraises offshore wind potential at over 17000 gigawatts (GW) (ESMAP, 2023). Exploiting these offshore wind resources could cover the current global energy demand. Similarly, tapping just 1400 GW could contribute to 1.5º C by 2050 (OREAC, 2020). Following the global total installed offshore wind power capacity, which stood at 64 GW by the end of 2022 (GWEC, 2023), we must deploy more projects to significantly limit global warming.

Offshore wind can stimulate the local economy by creating new jobs, providing revenue, and sustainable operations (GWEC, 2023). New offshore wind projects require skilled labour, including engineers, project managers, technicians, and financial experts, that can be sourced from existing oil and gas industries (IRENA, 2019; DNB, 2021) and the general workforce. Furthermore, offshore wind power can induce employment opportunities in other blue economy sectors. In addition, electrifying conventional offshore industries promotes sustainability as dirty energy sources, including fossil fuels, are replaced by cleaner sources.

1.3 The technological and economical challenges facing offshore wind

Integrating offshore wind in the green energy transition faces numerous technological and economic barriers. (IRENA, 2019; GWEC, 2023). First, the conventional commercially feasible fixed-bottom technology is limited to depths below 60m (James and Ros, 2015). However, vast offshore wind resources are located in deep waters, including 80% in Europe and Japan, 58% in the USA and 60% in China. Accordingly, most offshore wind projects must apply floating wind technology (IRENA, 2019). Floating wind technology relies on mooring and anchoring systems to remain stationary in deeper waters, still, this technology, though applied in the oil and gas sector for a few decades, is considered 'immature' in the wind power sector.

Offshore wind projects currently face inflation, an upsurge in capital costs and supply chain crises that have heightened uncertainty and derailed project deployment. Moreover, compared to fixed-bottom technology's generation costs of USD 80/MWh, floating technology costs are significantly higher, and above USD100/MWh (GWEC, 2023). Consequently, deploying offshore floating wind projects necessitates both public and private financing. It is common knowledge that mobilizing renewable energy financing remains a serious challenge, especially in the context of climate change (Stern, 2015). This assertion remains pertinent today, exemplified by the dwindling investments in renewable energy observed in 2022 (GWEC, 2023; IRENA, 2023). This trend is unsettling because lower investments hinder mass deployment and deter supply chain growth, and innovation necessary for catalysing reduction in technology costs.

1.4 The social acceptance of offshore wind

Social acceptance problems may arise when inaugurating offshore wind, and they emanate from the general public, local communities, and markets (Wüstenhagen et al., 2007) and if left unresolved, can impede project deployment.

Studies conducted in Europe, the United States and Asia reveal people's aversion towards offshore wind power's negative externalities, including visual and sound effects (Ladenburg and Dubgaard, 2007; Westerberg et al., 2013; Kim et al., 2019; Kim et al., 2021), the negative impacts on marine species (Davis et al., 2016; Klain et al., 2020; Maxwell et al., 2022), and the expected conflicts with existing offshore industries (Christie et al., 2014; Börger et al., 2020; Joalland and Mahieu, 2023; Chaji and Werner, 2023). A comparable hurdle is people's beliefs and attachment to the ocean landscapes, which can also hinder faster growth in offshore wind projects (Devine-Wright and Howes, 2010; Westerberg et al., 2013; Bidwell, 2017; Firestone et al., 2018; Devine-Wright and Wiersma, 2020; Lamy et al., 2020; Russell et al., 2020; Bidwell et al., 2023; Bingaman et al., 2022).

In contrast, a few studies reveal that positive externalities including energy security, mitigation of climate change, increased electricity production, and the stimulation of the local economy can boost social acceptance of offshore wind (e.g., Westerberg et al., 2013; Joalland and Mahieu, 2023).

1.5 Offshore Wind Power Development in Norway

Contextualizing this thesis, this subsection accentuates Norway's existing technological, social, and market conditions. Norway has abundant offshore wind resources, with a potential of 1416 GW for floating offshore wind and 60 GW for fixed-bottom offshore wind (GWEC, 2021). The higher potential for floating wind power stems from Norway's physical characteristics: deep oceans, and sea waters even along the coastlines. Specifically, the average water depths are 60m for the North Sea, 1600m for the Norwegian Sea, and 230m for the Barents Sea. Thus, Norway will utilize floating wind technology to achieve its 30GW offshore wind power ambitions by 2040. These projects will be located in the Utsira Nord and Sørlige Nordsjø II ocean areas (see Figure 1), opened in 2020 (Norwegian government, 2020) and the other ocean areas (see Figure 2), opened in 2023.

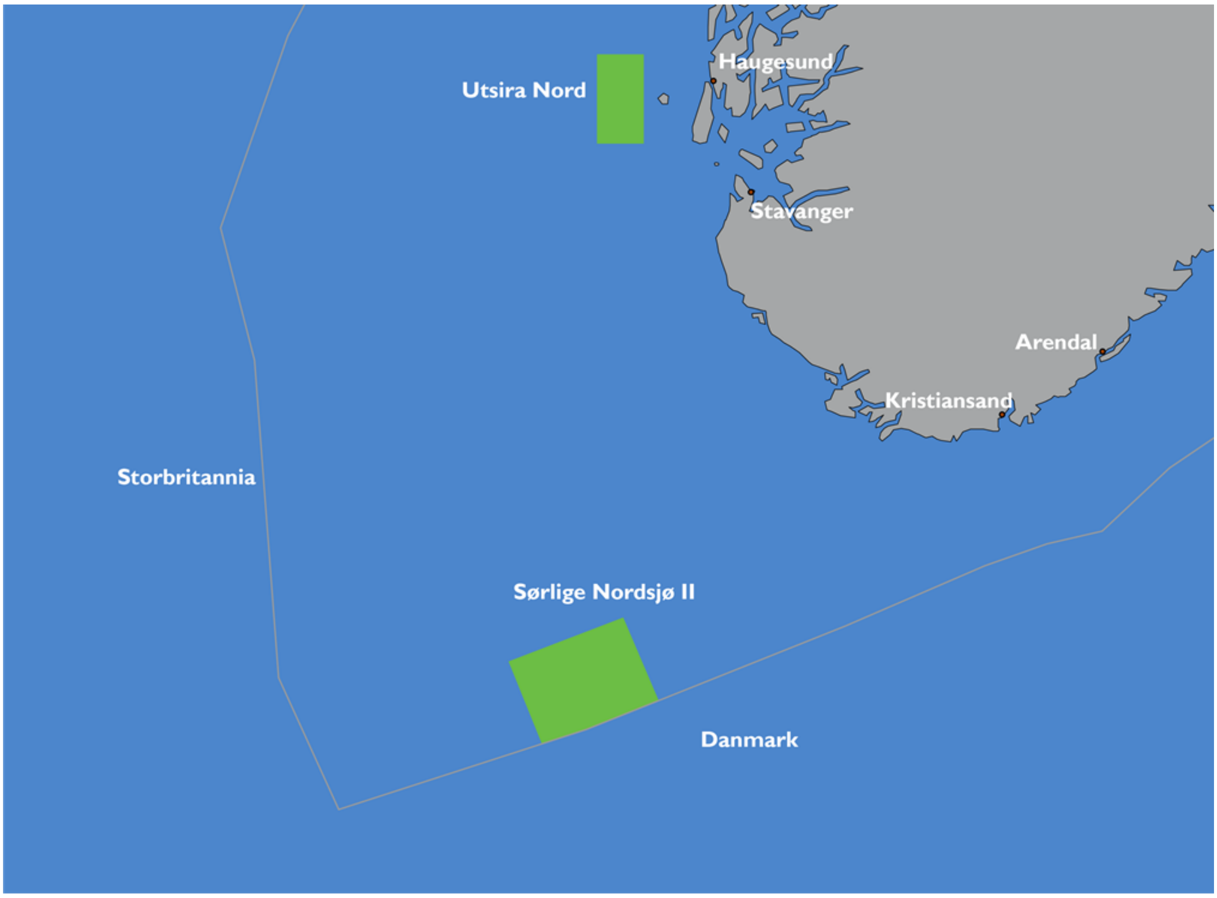

Figure 1 Utsira Nord and Sørlige Nordsjø II are ocean areas that were opened in June 2020. The areas are under consideration for developing offshore wind. (Source: Norwegian Government, 2020)

While Utsira Nord will employ floating wind technology for the 1500MW total installed capacity, Sørlige Nordsjø II will probably apply both fixed-bottom and floating wind technology to realize the 3000MW targets. More information about the two projects is detailed in Paper I of this research thesis. The choice of technology for the remaining project areas, illustrated in Figure 2, is conditional on water depths and commercial feasibility.

Figure 2 Ocean areas that were opened in March 2023. The areas are under consideration for developing offshore wind (source: NVE, 2023)

To bypass the imminent technology and cost hurdles, Norway can leverage the existing technical know-how in the offshore oil and gas sector. A case in point is Spar Bouy, one of the common floating platforms used in offshore wind, which was developed by a Norwegian company, Equinor. Floating technology is proven technically feasible, and cost reductions can occur with increased production, as theorised by the learning by-doing (Wright, 1936), also depicted by the learning curve in section 2.

To sum up, offshore wind is an integral instrument for expanding energy production, mitigating climate change and being a revenue source in Norway (DNB, 2021). Norway relies heavily on hydropower. However, the growing energy demands, primarily due to economic growth and increased electrification, calls for expanding energy production. Lately, electrifying oil and gas fields using offshore wind and electricity from the Norwegian mainland is gaining momentum. The political commitment is apparent, exemplified by the substantial subsidies given to the 88MW Hywind Tampen project, which covers 35% of the Snørre and Gullfaks oil platforms' annual electricity requirements. Another proof of the government's stand on electrifying the oil and gas sector is demonstrated by its recent approval of connecting the Melkøya gas processing plant with transmission cables from the Norwegian mainland. So far, public support for electrifying the oil and gas industry is varied, with some people labelling the initiatives as greenwashing. Thus, Norwegians' perspectives on the use of electricity produced by the proposed floating offshore wind power projects can influence their attitude towards these projects and will be explored in this thesis.

1.6 Thesis objective, research questions, and contribution

The thesis aims to assess the social acceptance of floating offshore wind power development in Norway. The first three papers map people's preferences, WTP and drivers of social acceptance of floating offshore wind development in Norway. The fourth paper is a systematic review of the offshore wind DCE's studies conducted worldwide to date, and an evaluation and comparison of the attributes used, including external costs and benefits of offshore wind. To meet the overall aim of the thesis, the four papers address the following research questions:

Paper I. Public support and opposition towards floating offshore wind power development

a) What is the Norwegian households' WTP for floating offshore wind power development?
b) To what extent does WTP vary due to policy framings?
c) What are the characteristics of the status-quo choosers?

Paper II. Social acceptance of new floating offshore wind technology: Do attitudes towards existing offshore industries matter?

a) Do people's attitudes towards expanding existing offshore industries predict attitudes towards developing new floating offshore wind power?
b) Are socio-demographics significant determinants of attitudes towards developing new floating offshore wind power?
c) Do positive attitudes towards expanding different offshore industries influence WTP for new floating offshore wind power?
d) Do socio-demographics influence WTP for new floating offshore wind power?

Paper III. People, power and the ocean: Analysing public attitudes towards floating offshore wind power in Norway

a) Do ocean meanings influence attitudes towards floating offshore wind power?
b) Does place attachment influence attitudes towards floating offshore wind power?
c) Do risks and benefits perceptions about floating technology matter?
d) To what extent do attitudes differ due to energy policy framing?

Paper IV. Valuing externalities of offshore wind power: A review of discrete choice experiment (DCE) studies

a) What attributes are valued in offshore wind DCE studies?
b) How are the attributes designed regarding presentation and attribute levels?
c) What are the WTP estimates for these attributes across various studies?

By addressing these questions, the thesis seeks to deepen the understanding of factors that can either spur or derail floating wind power technology development in Norway. The data and methods employed allow the research to capture heterogeneity across respondents, that are crucial for formulating relevant policy. By using a national sample, the thesis provides results that advance our knowledge of public-level support, which may not be the case if we utilized either county or municipal samples. In addition, developing floating offshore wind power projects demands the use of public funds in terms of subsidies, thus, a national sample is inherently preferred.

The papers have novel contributions to the social acceptance literature. First, the approach for Papers I, II, and III deviates from existing research by eliciting willingness to support and the WTP for developing *floating wind power technology*. Second, the two novel technology attributes: (i) share of Norwegian technology, and (ii) reduction in technology costs by 2030, provide insights into people's preferences for establishing new energy industries, local supply chains and supporting technology innovation and development. Third, Paper III adds to the people-place literature by dissecting the relations between attitudes towards floating offshore wind and respondents' ocean meanings and place attachment. Lastly, the review of existing offshore wind DCEs in Paper IV confirms that the visibility attributes are commonly featured by offshore wind studies, but also reveals the use of non-visibility attributes, including offshore wind's probable impact on the marine environment and offshore activities. The latter attributes are likely to become increasingly important for future offshore wind power projects which will be located further away from the shore. Table 1 highlights the key research questions, data sources, methods, and main findings.

Table 1 A snapshot of the thesis

Paper	Research questions	Data sources	Methods	Main findings
I	(i) What is the Norwegian households' WTP for floating offshore wind power development? (ii) To what extent does WTP vary due to policy framing? (iii)What are the characteristics of the status−quo choosers?	An online DCE survey was administered to Norwegian households.	Mixed logit model, Binary logit model	(i) People have a higher WTP for using Norwegian technology and the use of electricity in Norway (ii) Electricity framing results in higher WTP than climate framing (ii) Status-quo choosers are mostly climate skeptics
II	(i) Do people's attitudes towards expanding existing offshore industries predict attitudes towards developing new floating offshore wind power projects (ii) Are socio-demographics significant determinants of attitudes towards the development of new floating offshore wind power projects? (iii) Do positive attitudes towards expanding different offshore industries influence people's WTP for new floating offshore wind power development? (iv) Do people's socio-demographic characteristics influence their WTP for new floating offshore wind power development?	An online DCE as in Paper I.	Mixed logit model Ordinal logistic regression,	(i) Attitudes towards existing offshore industries are important predictors (ii) Gender and level of education predict attitudes toward floating offshore wind (iii) Positive attitudes towards expanding tourism, and aquaculture increase WTP (iv) Positive attitudes towards expanding oil and gas extraction decreases WTP (v) Highly educated people have higher WTP for new floating offshore wind
II1	i) Do ocean meanings influence attitudes towards floating offshore wind power? (ii) Does place attachment influence attitudes towards floating offshore wind power? (iii) Do risk and benefit perceptions of floating wind power technology matter? (iv) To what extent do attitudes differ due to policy framing?	An online survey, as for paper I and II, but capturing attitudes	Ordinal logistic regression, Probit model, Linear regression	(i)Positivity towards floating offshore wind power increases when the ocean landscape is viewed as beautiful. (ii)Technology risks and benefits are the most important predictors of attitudes. (iii)Ocean meanings are stronger predictors of attitudes in climate framing
IV	(i) What attributes are valued in offshore wind DCE studies? (ii) How are the attributes designed regarding presentation and attribute levels? (iii) What are the WTP estimates for these attributes across various studies	Peer-reviewed published offshore wind DCE studies.	Systematic review	(i) Visibility attributes dominate (ii) Impacts on the environment and competing offshore activities are increasingly valued (iii) Attributes description and design are similar for some attributes, including turbine height, but differ significantly for others i.e effect on the marine environment (iii) Visibility attributes result in significantly higher WTP. (iv) Offshore activities' impact on WTP varies significantly across studies

2. Theory

2.1 Offshore wind power externalities

The concept of externalities was introduced by Pigou (1920). Externalities ensue when the actions of one or innumerable economic agents alter other agents' wellbeing or production possibilities (Perman et al., 2003). Large offshore wind farms create negative externalities. Wind turbines can kill birds, impact the marine environment and deteriorate the ocean landscape. Economists use stated and revealed preference techniques to quantify external costs and benefits. However, there are uncertainties in assessing external costs due to both unpredictable physical impacts and uncertainties in the economic valuation of theses impacts using revealed or stated preference methods. Moreover, installation costs can vary over time due to technological innovation and development. Therefore, it is challenging to formulate the correct shape and slope of the marginal cost curves.

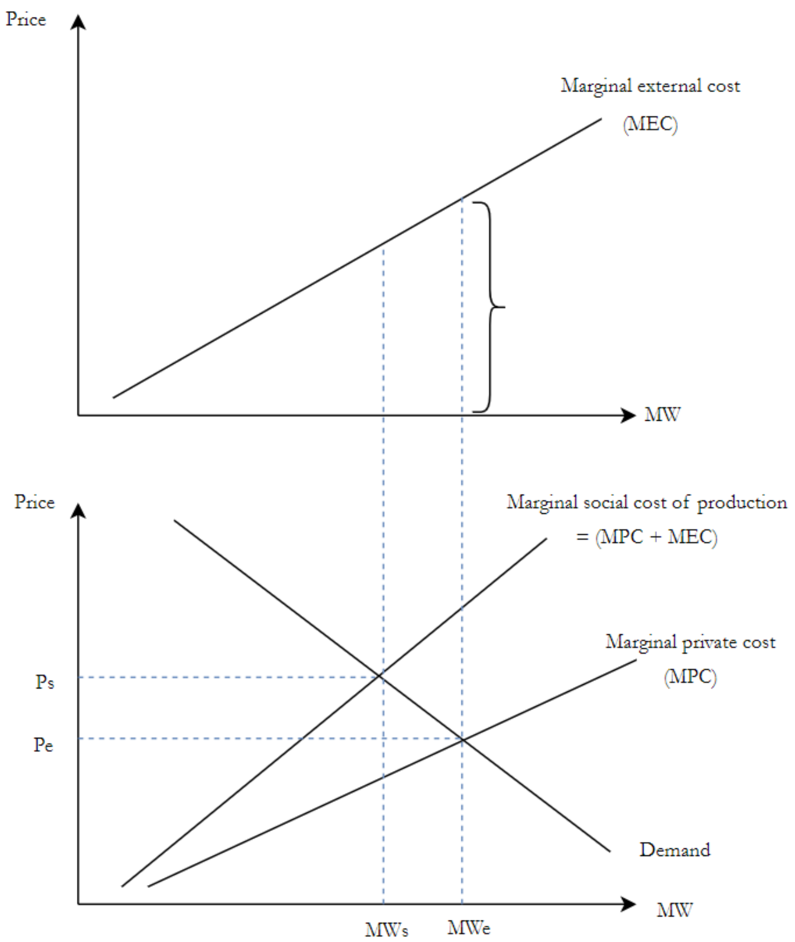

Figure 3 An illustration of a market with external costs.
(Source: Modified after Field and Field 2017, figure 4.3)
Note: Ps is the social optimum price, while Pe is the market equilibrium price. MWs is the social optimum electricity production from offshore wind/MW installed capacity, while MWe is the market equilibrium electricity production/MW installed capacity.

Technological innovation is a public good. Therefore, adding these marginal external benefits depicted in figure 3, could be subtracted from the marginal external costs. Depending on the size of the external benefits (and assuming all marginal external costs are accounted for), the net external costs could be lower, fully cancelling out the external costs (i.e., zero external costs) or be net positive; resulting in a higher social optimal installed capacity (MWs) than the private optimum (MWe) depicted on Figure 3.

Accordingly, to achieve socially optimal offshore wind installed capacity, subsidies or taxes can be applied to internalize the net external benefits and costs, respectively (Perman et al., 2003). Although economists prefer taxes to subsidies, the latter instrument is extensively used for new renewable energy projects (Johansson and Kriström, 2019). Households' WTP in increased electricity bills for developing new floating offshore wind (see Paper I and II), can be used as a measure of the external benefits of technological innovation in floating offshore wind. Thus, offering a basis for designing a subsidy reflecting these marginal external benefits.

2.2 Energy Technology Innovation

Energy technology innovation is a set of processes resulting in improved technologies that can boost the quality of energy services and minimize the economic, environmental, and political costs of using energy technologies (Gallagher et al., 2006). Technology innovation is characterized by three stages: (i) research and development, early idea screening and prototype testing, (ii) early adoption and learning, feasible technologies sold to early adopters, and (iii) widespread market diffusion, where the technology becomes the new standard (Greaker and Popp, 2022).

Floating wind technology is an emerging technology in the energy sector. The technology has been used in a few wind power projects but has not achieved widespread market diffusion. Hence, research and development activities are needed to increase market adoption. Slow adoption of this technology, like other new technologies, may stem from high costs, imperfect information, market structure, and regulations (For a review see, Juszczyk et al., 2022).

Faster deployment of floating wind technology can result in positive learning curve effects. The learning process is given by a simple equation $C = C_0(Q_t)^{-\alpha}$ conditional on $Q_t = \sum_0^t q_t$, where C_0 is the initial cost of technology, q_t is the duration per t sales of the technology, and α is the learning rate. The so-called learning curve is an integral concept related to technological innovation and was popularised in the academic literature by Wright (1936). The learning curve assumes diminishing costs with a doubling of cumulative installed capacity. However, experts argue that cost declines can result from other factors such as firms becoming more efficient, economies of scale, variations in input costs, policy shifts, or technology innovations from complementary industries. This would in our case be innovations in aquaculture and oil and gas industries that apply floating platforms (Nemet, 2006).

The learning curve is depicted in Figure 4, where Q* is the accumulated total installed floating offshore wind power capacity in 2030, while C is the technology cost. We observe cost decreases with increased quantity, and at point D, floating wind power technology becomes cost-competitive. Area A symbolizes the learning investment, the loss incurred if the technology is sold at prices lower than the P. Area B signifies the gains earned by an innovator when patented technology sales reach D. However, the technology becomes mainstream, and the prices will equal the unit cost of the technology at price P.

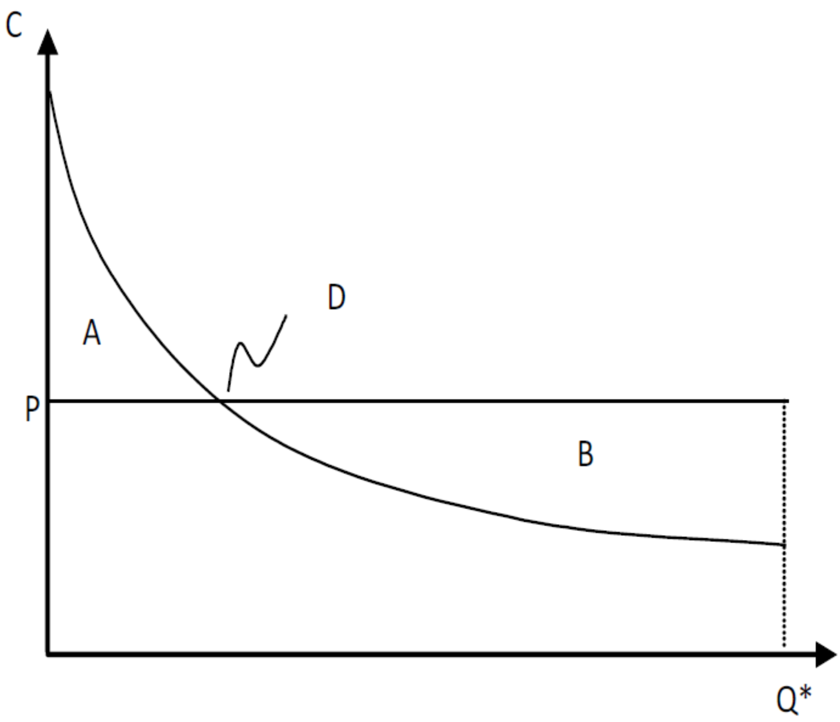

Figure 4 The learning curve

Note: C is technology cost, and q is the quantity produced. Area A represents the learning investment, while Area B represents the gains earned by the innovator. The technology is cost-competitive at point D.

Technology is knowledge (Kranzberg, 1986), and a public good. The likelihood of faster knowledge spillovers derails private investments (Spence, 1981). Boosting private investment in research and development activities entails slowing the learning investment phase to prevent Area A from being bigger than Area B, otherwise, the knowledge spillover occurs faster. Additionally, governments employ various techniques to stimulate research and development investments through intellectual property, public-private partnerships, and introducing subsidies.

3. Data and Methods

3.1 Data

Paper I, II, and III use data from an online survey conducted in Norway by an international company, Kantar. The data sets from the survey are collected at a household level covering households' preferences and attitudes for developing new floating offshore wind power projects. Papers I and II utilize data from a Discrete Choice Experiment (DCE), and the data takes a panel structure. The DCE features five attributes: (i) project size, (ii) share of Norwegian technology, (iii) reduction in technology costs by 2030, (iv) use of electricity, and (v) increase in household's electricity bill for three years. Both Paper I and Paper II use cross-sectional data from the same survey covering several aspects such as attitudes towards floating offshore wind, climate beliefs, attribute importance and attitudes towards offshore industries

Paper III employs cross-sectional data eliciting attitudes towards floating offshore wind power, ocean meanings, place attachment, and underlying technology risks and benefits. Lastly, Paper IV uses data from peer-reviewed articles found on academic databases including Web of Science and Scopus. The data collected from the thirteen articles include various offshore wind attributes including distance to the shore, project size, turbine height, effect on the environment, effect on offshore activities and industries, and their corresponding WTP estimates. The summary of attitudinal questions used in Paper I, Paper II, and Paper III are presented in Table 2.

Table 2 Attitude questions and their measures used in Papers I, II, and III.

Paper	Variables	Question	5-Point Likert scale
I	Attribute importance	How important or non-important were the following attributes when you made your choices? (i)Project size, (ii) share of Norwegian technology, (iii) reduction in technology costs by 2030, (iv) use of electricity (v) Increase in household's annual electricity bill in three years	1=not important to 5=very important
	Climate beliefs	How much do you disagree or agree with the following statements? (i)Climate change is one of the biggest problems facing humanity (ii)Climate change is mainly caused by human activity (ii)Climate change leads to significant negative consequences	1 = strongly disagree to 5 = strongly agree
II	Attitudes towards floating wind power	How positive or negative are you towards the development of floating offshore wind power projects?	1=very negative to 5=very positive.
	Attitudes towards wave energy	How positive or negative are you toward the Norwegian authorities facilitating the development of new wave power plants?	1=very negative to 5=very positive.
	Attitudes towards offshore industries	How positive or negative are you towards the Norwegian government facilitating the expansion of the following offshore industries in the Norwegian ocean space? (i)oil and gas, (ii)shipping, (iii)tourism, (iv)aquaculture, (v)carbon and capture storage	1=very negative to 5=very positive.
III	Attitudes towards floating wind power	How positive or negative are you towards the development of floating offshore wind power projects?	1=very negative to 5=very positive.
	Ocean meanings	How much do you disagree or agree with the following statements? I think of the ocean as... (i)A beautiful place to look at, (ii) a place for recreation, (iii) a place for relaxation, (iv) a place of inspiration, (v) a home for wild animals, (vi) a place for pristine nature, (vii) a place with intrinsic value.	1=strongly disagree to 5= strongly agree.
	Place attachment	How much do you disagree or agree with the following statements? (i) I miss the ocean when I am away, (ii) the ocean is my favourite place, (iii) I feel happiest when I am at the coast	1=strongly disagree to 5 = strongly agree.
	Technology benefits	To what extent is floating wind power technology… (i)Necessary, (ii)Beneficial (iii)Good	1=to a very small extent 5= to a very large extent.
	Technology risks	To what extent is floating wind power technology… (i)Risky, (ii)Controversial, (iii)Can affect the environment	1=to a very small extent 5=to a very large extent.

3.2 Methods

3.2.1 Discrete choice experiment

Discrete choice experiment (DCE) is one of the economic valuation methods used to quantify the welfare effects of changes in environmental goods and services and other non-market goods. Economists and social planners design a hypothetical market and ask individuals to choose between two or several alternatives. Consumers' decisions are constructed in a way that the discrete choice is isolated, and the consumer can only choose one alternative from the choice set. Their choices can reveal an underlying latent utility of the attributes that describe the alternatives. By including a cost attribute, economists can value the individual's welfare change in monetary terms.

DCE model builds on random utility theory (Thurstone, 1927), conditional logit model (McFadden, 1974) and theory of demand (Lancaster, 1966) together with experimental design theory and economic analysis. Random utility theory assumes stochastic preferences whereby, an individual's utility function is drawn based on random choices. The individual's utility is assumed to comprise deterministic and random components. Thus, under utility-maximizing behaviour, the probability of choosing an alternative equals the probability that its utility exceeds that of all other alternatives in the choice set.

In his seminal paper, Daniel McFadden incorporated random utility theory into the conditional logit model to provide an econometric model to study choice (McFadden, 1974). The conditional logit model uses econometrics to infer behaviour and implicitly adapts demand theory, where the choice of a good is linked to its characteristics (Lancaster, 1966). Thus, individuals differ in their tastes and preferences of a good's characteristics, and surveys can be used to compute individuals' WTP for the marginal changes in the good's characteristics (Adamowicz et al., 1998).

Applying DCEs in investigating preferences is linked to several challenges, including hypothetical bias (Diamond and Hausman, 1994; List, 2001), incentive incompatibility of the choice format, and task complexity (Swait and Adamowicz, 2001).

3.2.2 Logistic regression

To predict attitudes towards developing new floating offshore wind power projects, Papers I, II, and III use logistic regression, initially formulated by David Cox in 1958 (Cox, 1958). Paper I uses a binary logit model to predict belonging to the status quo segment. The explanatory variables include attribute importance, climate change beliefs, policy framing, and socio-demographics. The model uses logs odd ratio, which is the probability of an event occurring divided by the probability of an event not occurring, which is given by the function (1):

$$P_r(Y=1|x_1) = \frac{1}{1+e^{-\beta_0} + \sum \beta_1 x_1} \quad (1)$$

The maximum likelihood estimator is used to iteratively test different parameters to find the best fit for the log odds. In the basic version of logistic regression, the output variable is dichotomous, however, it can be extended to multiple classes including multinomial and ordinal logistic regression. Paper II and Paper III use ordinal logistic regression because their outcome variable is categorical, whereby the level has a natural ordering e.g., response is classified as very negative, negative, neutral, positive, or very positive. Let Y_1 be an ordinal outcome variable with C categories for the i-subject, alongside a vector of covariates x_i. A regression model links the relationship between the covariates and the set of the cumulative probabilities $g_{ci} = P_r(Y_i = Y_C|x_1) = c = ..1 \dots C$), and it is related to a linear predictor $\beta'_{xi} = \beta_0 + \beta_1 x_{1i} \dots$ through the logit function (2)

$$logit(g_{ci}) = \log(g_{ci}/1 - g_{ci})) = \propto_c + \beta'_1 x_i, C = 1,2..C-1 \quad (2)$$

Where $\propto_c$ are thresholds and are increasing in order $\propto_1 < \propto_2 \dots \propto_{c-1}$.The effect of the covariates is constant across response categories; also known as the parallel regression assumption. Logistic models are heteroskedastic in nature; thus, the maximum likelihood does not minimize the variance, and there are no equivalent r-squared statistics like in linear regression. However, several pseudo-R squared statistics such as McFadden's R squared, can be used to determine the model fit.

4. Main findings, study limitations and ideas for future research

This section summarizes the main findings from the four papers, the observed study limitations (study design and methods used) and proposes ideas for future research.

4.1 Public support and opposition towards floating offshore wind power development (Paper I)

Floating wind power technology is technically feasible but expensive to apply compared to other renewable energy technologies. Paper I analyses support and computes WTP for developing floating offshore wind power. The paper uses a national sample, policy framing; either meeting growing energy demand needs or climate objectives, and a DCE featuring five attributes, two project alternatives, and a status-quo alternative. The paper has several interesting findings.

First, Norwegians have a higher WTP for medium-sized projects that supply electricity to Norwegian households and inland industries, together with offshore oil and gas platforms. Second, WTP increases with an increase in the share of Norwegian technology used in the proposed projects. Third, Norwegians are unwilling to pay for projects to induce a substantial reduction in technology costs. Fourth, respondents in the electricity framing have a higher WTP for the development of floating offshore wind power than those in the climate framing. Lastly, the probable impact of offshore wind power on the environment and the usage of public funds which can be transferred to Norwegian households dwindles social acceptance. Furthermore, opposers of floating offshore wind power projects hold dissident views about the anthropogenic nature of climate change.

The main limitation of the paper lies in the design of the DCE. While the paper aims to investigate general acceptance, the DCE includes specific offshore wind power projects, thus introducing aspects of specific acceptance.

Future studies can incorporate other attributes. For instance, it would be enlightening to feature offshore wind's impact on marine biodiversity, offshore industries, and the effect on the national economy.

4.2 Social acceptance of new floating offshore wind power: Do attitudes towards existing offshore industries matter? (Paper II)

The ocean is a resource and a hub for several offshore industries. Accordingly, inaugurating new offshore wind can induce conflicts between offshore industries. Paper II evaluates whether households' attitudes towards expanding existing offshore industries can predict their attitudes towards developing new floating offshore wind power projects. Similar to Paper I, this paper calculates the WTP estimates. However, the paper expands the mixed logit model to capture interaction effects, whereby indicator variables for each of the four main offshore industries interact with the alternative status constant.

The paper finds that underlying attitudes towards expanding oil and gas extraction, tourism, ocean aquaculture and socio-demographics are significant predictors of attitudes. Attitudes towards new floating offshore wind are homogenous across regions in Norway, including coastal and non-coastal populations. The paper finds that positive attitudes towards expanding ocean aquaculture and shipping increase social acceptance for new floating offshore wind power projects. By contrast, people who are positive towards increasing oil and gas exploration prefer postponing offshore wind power development until after 2030.

The main study limitation lies in the framing of the DCE, as explained in subsection 4.1. Furthermore, interacting indicators with the alternative specific constant in the mixed logit models offer useful policy insights. However, indicator variables face measurement errors and endogeneity issues. Hence, it is preferable to employ a hybrid mixed logit model. Though the measures used do not fulfil the requirement of exploratory factor analysis, a stage considered decisive for choosing a hybrid mixed model (Mariel and Meyerhoff, 2016).

Future research can include more measures to extract knowledge about people's attitudes towards sharing ocean space by the incumbent offshore wind and the conventional offshore industries. This could also be explored in a new DCE of ocean space with different uses, including preservation as an attribute. Similar to a study by Aanesen et al. (2015) that valued the preservation of cold-water corals versus oil and gas extraction and fisheries.

4.3 People, power and the ocean: Analysing public attitudes towards floating offshore wind power in Norway (Paper III)

Social acceptance of floating offshore wind power projects is likely to be influenced by people's relations to the ocean. Paper III maps attitudes towards floating offshore wind power projects in the context of ocean meanings and place attachment. To test the effect of policy framings, like Paper I above, respondents are randomly assigned to either electricity demand needs or climate objective framing. Furthermore, the paper dissects the role of underlying technology risks and benefits perceptions in shaping attitudes towards floating wind power technology.

Concretely, ocean meanings result in distinct attitudes towards offshore floating wind power, and place attachment has no effect. Unsurprisingly, people's perceptions of technology risks and benefits predict negative and positive attitudes towards floating offshore wind power. However, the impact of technology benefits perceptions on attitudes is noticeably larger than that of technology risk perceptions. Noteworthy, while the beauty meaning predicts positive attitudes for respondents under electricity and climate framing, other ocean meanings increase negative attitudes for respondents under climate objective framing. Moreover, attitudes towards floating offshore wind power do not differ based on proximity to the ocean, both in terms of residence and ownership of holiday homes.

The main study limitation lies in the use of a smaller number of measures of the ocean meanings and place attachment variables. Similar to Paper I, this paper blends general acceptance and specific acceptance.

Future studies should elicit attitudes towards far-shore wind power in the context of people-ocean relations.

4.4 Valuing externalities of offshore wind power: A review of discrete choice experiment studies (Paper IV)

DCEs can be used to elicit people's preferences for different characteristics of offshore wind power projects, including their potential negative and positive externalities. Researchers can create hypothetical wind power policy scenarios that allow individuals to choose between various project layouts.

Paper IV finds visibility attributes to be decisive for social acceptance. People have a higher WTP to avoid aesthetic impacts emanating from offshore wind. However, non-visibility attributes such as the effect on the marine environment and offshore activities can be as impactful. People prefer inconspicuous wind turbines, preserving marine ecosystems and local offshore industries. However, the effect of offshore wind power on the latter is diverse. While people's WTP reduces when the effect of offshore wind on the fishing industry is gauged, it remains positive in the context of marine tourism.

The central limitation of this paper is the small number of published papers included in the systematic review. However, the inferences seem plausible. Furthermore, a few preceding reviews have used even fewer studies (See Ladenburg and Lutzeyer, 2012; Knapp and Ladenburg, 2015; Wen et al., 2018).

Conducting a meta-analysis for the relevant attributes can offer more insights into people's tastes and preferences for offshore wind power. To accomplish this, more offshore wind DCE research has to be implemented to increase the number of data points.

5 Conclusion

This thesis uses a national DCE survey and a review of the existing literature to analyse and understand the social acceptance of offshore floating wind power technology and offshore wind. Specifically, Paper I delve into policy aspects of floating wind power, including technology innovation, utilizing domestic technology, and the use of electricity. Paper II focuses on the relationship between underlying attitudes towards expanding existing offshore industries and attitudes towards new floating offshore wind power projects. Paper III dissects people's meanings and attachment to the ocean and how these concepts shape their attitudes towards floating offshore wind power. Lastly, paper IV examines the relevant drivers of WTP for offshore wind power projects. The findings from the four papers provide a few relevant policy conclusions

Overall, Norwegians support the development of floating offshore wind power projects. The level of support does not vary between coastal and inland populations, but it is contingent on offshore wind power projects' characteristics, socio-demographics, people's technology risks and benefit perceptions, their meanings and attachment to the ocean, and their general beliefs about climate change.

Results from both the DCE studies (Paper I and II) and the review of thirteen DCE studies (Paper IV) support the assertion that future offshore wind DCE studies should be based on a thorough selection of attributes and their subsequent levels. The attributes descriptions and presentation should reflect all plausible characteristics of planned offshore wind power projects to provide policy-relevant external effects estimates. Furthermore, the cost attribute should be realistic, and the payment vehicle should be available to people, e.g., monthly electricity bills, and consequential both regarding policy implementation and payment. Then the marginal WTP estimates would be better fit as input to designing public subsidies for offshore wind and other government regulatory schemes.

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Papers

Paper I

Public support and opposition towards floating offshore wind power development in Norway[1]

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Highlights

- We use a choice experiment to elicit preferences for floating offshore wind
- Norwegians prefer projects connected to the domestic electricity grid
- Support increases with the share of domestic technology in the projects
- Support unaffected by projects' impact on future technology costs
- Opposition to offshore wind power associated with climate skepticism

Abstract

For countries like Norway, with abundant offshore wind resources and deep seas, floating wind power technology can play an essential role in the green energy transition. However, this technology is still immature, and the first utility-scale floating offshore wind power projects need substantial support for technology development to be commercially feasible. This study employs an online survey targeting the general population in Norway (N=1011) to investigate support and opposition towards the development of floating offshore wind power. The survey includes a discrete choice experiment focusing on policy-relevant factors, including the export of electricity, reducing domestic carbon emissions by electrifying offshore oil and gas platforms, impact on global technology cost trends, and involving domestic offshore industries as key players in the floating offshore wind sector. We find the highest support for developing projects that utilize technology from domestic offshore industries and projects connected to the domestic electricity grid. Projects aimed at reducing domestic carbon emissions by electrifying offshore oil and gas platforms are favored over those for exporting electricity to other countries. A significant impact on future technology costs does increase support for the project. Projects presented after a framing text focusing on meeting future electricity demand result in a higher willingness to pay for floating

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offshore wind projects than those presented after a framing text focusing on meeting climate objectives. Respondents opposing all the projects are likely climate skeptics and believe that project developers should bear all the project costs. Norway is expected to play a critical role in developing floating offshore wind power. However, the Norwegians demand clear national benefits to be willing to shoulder the cost of spearheading the development of floating offshore wind power. Understanding these preferences is vital for crafting energy policies aligning with public interests and rapidly integrating floating wind power into the green energy transition.

Keywords: floating wind power technology; offshore wind; discrete choice experiment; willingness to pay; social acceptance

1 Introduction

The offshore wind power industry is developing rapidly, driven primarily by the growing energy demand and the need to transition to low-carbon energy systems. Most offshore wind power projects are located in shallow waters and use lower-cost fixed-bottom technology (GWEC, 2022). Due to the abundant wind resources in areas with deep seas, several countries are now exploring projects using expensive floating wind technologies (GWEC, 2022). One of these countries is Norway, which has vast offshore wind resources in sea areas characterized by deep waters (Østenby, 2019). Utsira Nord, the pioneering offshore floating wind power area in Norway (Bru, 2020), has an average sea depth of 265 meters (NVE, 2023). The sea depth exceeds the 60-meter threshold for fixed-bottom foundations (Lopez et al., 2022). Hence, the projects built at Utsira Nord and other locations in Norwegian waters will use floating wind technology (NVE, 2023).

Floating wind technology is costly, and immature compared to conventional energy technologies (GWEC, 2022). In terms of power generation costs, the levellized cost of electricity (LCOE) of floating offshore wind power is above \$100/MWh, compared to fixed-bottom offshore wind (\$80/MWh) and onshore wind (\$40/MWh) (IRENA, 2022). It is difficult to predict future costs because market conditions, technology innovation trends, and sites' physical characteristics are inherently uncertain (Beiter et al., 2021). Still, developing an economically feasible floating offshore wind industry requires further innovations in dynamic high-voltage cables, improved installation methods, and mass production of floating platforms (James et al., 2018). Public financial support will likely play a pivotal role in expediting this evolution.

This paper sheds light on public support and opposition to subsidizing the development of floating offshore wind power in Norway. To achieve this objective, we analyse data from three parts of a representative online survey: (1) Likert scale attitude questions gauging respondents' positivity or negativity towards the Norwegian government facilitating the development of various energy technologies; (2) a discrete choice experiment (DCE) focusing on the development of floating offshore wind power, including a green tax on households to support the development; and (3) follow-up questions directed at status quo choosers in the DCE to determine their characteristics and reasons for not choosing any of the floating offshore wind power projects.

The literature utilizing DCE to evaluate the willingness to pay (WTP) for offshore wind power projects has been growing steadily (Ladenburg & Dubgaard, 2007; Krueger, Parsons, & Firestone, 2011; Westerberg, Jacobsen, & Lifran, 2013; Kim, Kim, & Yoo, 2019; Klain et al., 2020; Kim, Choi, & Yoo, 2021; Ladenburg & Skotte, 2022; Joalland & Mahieu, 2023). This paper contributes to this literature by focusing on public support of offshore wind using floating technology, an area barely touched upon by researchers. Furthermore, we add to the knowledge of WTP for offshore wind power projects by including two novel technology attributes, and energy versus climate framings to our DCE.

We include two novel technology-development related DCE attributes. The first attribute is the project's impact on future technology costs. The Global Wind Energy Council (GWEC) predicted that the global cost of installing floating offshore wind power would drop from above 100 $/MW in 2020 to 40 $/MW by 2030 (GWEC, 2020). Though this prediction is based on worldwide announced developments in floating offshore wind, the forecast remains uncertain, with 92.9% of the installations anticipated to occur in the second half of the decade. Moreover, GWEC's prediction for floating offshore wind became increasingly optimistic, jumping from a prediction of 6.5 GW by 2030 in their 2020 forecast to 16.5 GW in their 2021 forecast (GWEC, 2022). The change is attributed to a surge in planned offshore wind activities worldwide, with the announced Norwegian projects contributing to this increase. By the end of this decade, GWEC expects South Korea, Japan, Norway, France, and the United Kingdom to be market leaders for floating offshore wind (GWEC, 2022).

The Norwegian government's selection criteria for new wind power projects at Utsira Nord will prioritize projects demonstrating high innovation and advancement in floating technology (Norwegian Ministry of Petroleum and Energy, 2023). Besides deploying projects, Norway has financed research centers to boost innovation in floating wind technology (SINTEF, u.d.). Thus, Norway's offshore wind power activities may substantially contribute to the development of floating wind technology and significantly lower future technology costs worldwide. Existing offshore wind power DCE studies have not used the impact on technology costs trends as an attribute, but some studies imply in their attribute description that mass deployment of wind power projects would reduce future costs (Peri, Becker, & Talc, 2020).

The second novel technology development-related attribute is associated with the potential of utilizing technology from domestic offshore industries to develop an offshore wind power industry. Norwegian oil and gas companies are already diversifying into the offshore wind sector (Mäkitie et al., 2018) and supplying technologies such as floating platforms to significant offshore floating wind power development projects worldwide, including Hywind Scotland and Hywind Tampen (GWEC, 2022).

We include a size attribute of one to three projects, each of 500 MW, inspired by the plans for floating offshore wind power at Utsira Nord. We also feature a use of electricity attribute associated with transmission cables, whether they connect to the electricity grid in Norway, abroad, or Norway's offshore oil and gas fields. The latter attribute characteristic is novel to this study, and it is aimed at reducing domestic carbon emissions by electrifying the offshore oil and gas sector's production processes.

We use a split-sample information treatment before the DCE, presenting respondents with information focusing on either energy demand needs or climate objectives. With the growing energy demand (IEA, 2022) and the existential threat linked to climate change (Ripple et al., 2022), it is relevant to examine how framing energy policies influences public support. Both framing texts highlight the potential impacts of floating offshore wind power projects on the environment and other offshore industries.

Existing DCEs for offshore wind power examine how characteristics such as distance from the shore, number and height of turbines, ownership, and process fairness influence WTP (Krueger, Parsons, & Firestone, 2011; Westerberg, Jacobsen, & Lifran, 2013; Boyle et al., 2019; Voltaire & Koutchade, 2020; Ladenburg et al., 2020; Kim, Choi, & Yoo, 2021; Ladenburg & Skotte, 2022). However, factors related to visibility issues and other use values may be less relevant in most of Norway's new sea areas under consideration for the development of floating offshore wind power (NVE, 2023). Hence, we do not prioritize these factors in this study.

The pace of developing floating offshore wind in the Norwegian ocean space hinges on the political will to cover a substantial portion of the high development costs. This study investigates public preferences for floating offshore wind power development that will inform policy concerning offshore wind and shed light on the broader discussion about who should cover the green energy transition costs. While the potential for floating offshore wind power is immense, there needs to be public and political will to bear some of the development costs to realize the predicted rapid increase in floating offshore wind installed capacity in the coming years.

Organized into four remaining sections, the paper presents the methodology employed in this study, including data collection, survey implementation, and discrete choice experiment design in Section 2. Section 3 presents our findings on support and opposition towards floating offshore wind power development, while Section 4 discusses and compares our results with existing studies. Finally, we conclude the paper by summarizing our key findings and discussing their policy implications.

2 Methodology

2.1 Survey sample

We investigate Norwegians' support and opposition to the development of floating offshore wind power using an online survey conducted in November and December 2021. The Norwegian branch of the international market analysis agency Kantar implemented the survey. The Norwegian Centre for Research Data evaluated and gave guidance on the questionnaire concerning consent and general data protection regulations.

The study sample was recruited from Kantar's GallupPanelet, a Norwegian internet survey panel. Comprising approximately 40,000 regular participants, GallupPanelet is designed to reflect Norway's population in miniature. Recruitment is primarily from representative phone surveys, and the panel is certified according to ISO 26362:2009, which pertains to "Access panels in market, opinion, and social research - Vocabulary and service requirements" (Kantar, u.d.). As is standard for this type of survey panel, participants are awarded points based on the survey length. These points can be redeemed for gift items, gift cards, cinema tickets, or donated to a charitable cause.

Targeting 1000 complete responses, Kantar sent questionnaire invitations to 3,987 of their panel members, of whom 1,337 opened it. A response rate of 33.5% is on the lower side of what is usual in web surveys and might be a result of the time of year, survey length, and topic. During the period it was open, 1099 participants completed the questionnaire, resulting in a completion rate of 82%. We excluded 88 respondents who did not complete all the choice tasks. However, we conduct multiple imputations for other relevant variables (discussed in section 2.5). Thus, our analyses are based on data from 1,011 respondents, marginally exceeding our initial target of 1000 observations. Our sample size aligns with recent nationwide surveys employing DCE to study WTP for offshore wind power in South Korea and Japan, as documented by Kim et al. (2019) (N=1000), Kim et al. (2021) (N=1000), and Iwata et al. (2023) (N=900).

Table 1 summarizes the socio-demographics for the two framing subsamples, the pooled sample, and the Norwegian population. Notably, the pooled sample was not representative of the Norwegian population in terms of age, gender, and education levels. The older respondents (+60) are overrepresented, while younger respondents (under 30) are slightly underrepresented. The education level is somewhat higher than that of the population, which is common in online surveys (Liebe, Bartczak, & Meyerhoff, 2017; Linnerud, Dugstad, & Rygg, 2022). To adjust for this, we add sample weights provided by Kantar to our regressions. Kantar derives the weights by comparing the sample to the population on age, gender, and region.

We test for balance between the two framing sub-samples; electricity and climate, using a t-test for age ($p=0.51$) and Chi-square tests for gender ($p=0.07$) and education ($p=0.51$). The test results show that the two samples are balanced for these socioeconomic variables.

Table 1 Socio-demographics of subsamples and population

		Samples			Population
Variable		Electricity	Climate	Pooled	Norway
Gender	Male	56%	56%	56%	49%
	Female	44%	44%	44%	51%
Age	18-29	13%	15%	14%	20%
	30-44	23%	21%	22%	26%
	45-59	24%	28%	26%	26%
	60-89	40%	36%	38%	29%
Education	University degree	38%	38%	38%	35%

2.2 Attitude questions

Table 2 presents the Likert scale question we used to assess respondents' sentiments towards the Norwegian government's facilitating the development of various energy technologies. Our analysis covers the leading energy technologies used in Norway, such as hydropower, onshore wind, and oil and gas, as well as wave energy and offshore wind, both of which have vast potential in Norway (Christakos et al., 2020). In this question, we do not distinguish between fixed-bottom and floating technology for offshore wind. Furthermore, we do not include any information on cost per MW.

Table 2 Facilitating energy technologies and climate change questions

How positive or negative are you towards the Norwegian authorities facilitating the following developments? Five-point Likert scale from 1=very negative to 5=very positive.
Developing new oil and gas fields
Upgrading existing hydropower plants
Developing new hydropower plants
Developing new onshore wind power plants
Developing new offshore wind power plants
Developing new wave power plants
How much do you disagree or agree with the following statements? Five-point Likert scale from 1=strongly disagree to 5=strongly agree.
Climate change is one of the biggest problems facing humanity
Climate change is caused mainly by human activities
Climate change leads to significant negative consequences

Table 2 also presents a climate question with three statements adapted from Thøgersen et al. (2021), which asks respondents to indicate their agreement regarding the causal, attribution, and perceived consequences of climate change. We use the climate question to understand the reasoning behind the status quo choices in the DCE. For both questions, we presented the items in randomized order across respondents.

2.3 Design of the choice experiment

The choice experiment has two framings, two project alternatives, and a status quo alternative.

2.3.1 Electricity and climate framing

The respondents were randomly assigned into two groups: electricity and climate framings. The first group received information about expected future electricity demand needs, while the second group received information about the Paris Agreement.

Table 3 presents the electricity and climate framing texts used in the study. These framings were formulated based on the ongoing political discourses on enhancing energy security and reducing carbon emissions. As part of the updated Paris Climate Agreement in 2020, Norway aims to reduce its carbon emissions by 50-55% by 2030 compared to the 1990 levels and to become climate neutral by 2050 (Norwegian Ministry of Climate and Environment, 2021). At the same time, Norway's electricity demand is projected to increase by 15% by 2040, hence the need to increase energy production (NVE, 2020).

Table 3 Framing of the choice experiment

Framing	Information
Electricity	**Developing floating offshore wind power projects to meet electricity demand** According to the Norwegian Water Resources and Energy Directorate (NVE), the demand for electricity in Norway is expected to increase by 15% by 2040. A similar increase in electricity demand is expected in neighbouring countries.
Climate	**Developing floating offshore wind power projects to reduce greenhouse gas emissions** Norway is one of 197 countries that signed the Paris Agreement to reduce carbon emissions. Norway is committed to reducing its emissions in the years to come. To achieve net-zero emissions by 2050, countries must replace polluting energy sources with renewable energy sources.
Both	In 2020, the Norwegian authorities decided to open the sea areas Utsira Nord and Sørlige Nordsjø II for the development of wind power projects. The wind projects built where the oceans are deep will use new floating offshore wind power technology. The Norwegian government will, in the transition phase, give economic support for the development of these projects.
Electricity	The floating offshore wind power projects will help us meet the increasing electricity demand, but critics say the projects could affect the coast and seascapes, other industries, birds, and marine life.
Climate	The floating offshore wind power projects will help us meet the climate objectives, but critics say the projects could affect the coast and seascapes, other industries, birds, and marine life.

As most Norwegians have not encountered floating wind technology, we presented a drawing of three floating wind technology types before presenting the choice experiment. The drawing purposed to familiarize respondents with floating wind power technologies, and the drawing did not imply a visual representation of the wind power projects as commonly done when visual aspects are an important part of a DCE (e.g., Ladenburg & Dubgaard, 2007; Westerberg, Jacobsen, & Lifran, 2013; Hevia-Koch & Ladenburg, 2019; Klain et al., 2020). The drawing is presented in Figure A in the Appendix.

2.3.2 The DCE attributes

Table 4 presents the five DCE attributes, attribute description, and their levels. The DCE features project size and use of electricity attributes, two attributes related to technology development, and one payment attribute.

Table 4 Choice experiment attributes with levels and descriptions

Attribute	Levels	Description of attribute
Project size	500 MW, 1000 MW, 1500 MW	The most extensive proposed development has an installed capacity of 1,500 megawatts (MW), and 150 wind turbines in three areas, and will be able to provide electricity to 400,000 households. The development of 1000 MW will have 100 wind turbines in two areas. The 500 MW development will have 50 wind turbines in one area.
Share of Norwegian technology	25%, 50%, 75%	Norwegian companies operating in the oil and gas sector have knowledge and technology that can be adapted to the needs of floating offshore wind projects. To develop the Norwegian offshore wind sector, the proposed projects will use technology from Norwegian companies. The Norwegian technology share will be between 25% and 75%, while international companies will cover the rest.
Reduction in technology costs in 2030	10%, 20%, 30 %	The technology development in the proposed projects will result in between 10% and 30% lower installation costs for floating wind power projects planned after 2030. The overall effect of the technology development in these and similar projects in other countries is assumed to reduce the technology costs significantly. The more offshore wind projects being built now, the faster the costs will be reduced.
Use of electricity	Norway Oil and gas, Other countries	The projects are different in terms of who will use the electricity. They can either be connected to offshore oil and gas platforms, directly to the Norwegian power grid, or directly to the power grid in other countries via international submarine cables.
Increase in household's electricity bill for three years	10%, 15%, 20%, 25%, 30%, 35%	The projects have high development costs and need financial support to be realized. The financing of the projects will lead to an increase in the electricity bill for Norwegian households in the form of a green tax of between 10% and 35% for three years.

The project size and use of electricity attributes were adopted from available wind power studies. The two technology development attributes: (i)share of Norwegian technology, and (ii) reduction in technology costs by 2030, are novel to this study. All the attributes are adapted to fit Norwegian offshore wind power plans and market conditions, trends and predictions published by reputable organizations such as the Global Wind Energy Council (GWEC) and the International Renewable Energy Agency (IRENA). We formulated the cost attribute to convey the high costs of developing floating offshore wind technology to the respondents. However, the exact costs of such pioneering projects are highly uncertain, and the costs are unlikely to be presented as saliently as a green tax per household over three years.

2.3.3 Project size and use of electricity attributes

We adopted the project size and electricity use attributes from the wind power literature. For the project size attribute, see, e.g., Blondiau & Reuter (2019); Boyle et al. (2019); and Cranmer et al. (2023), and for the use of electricity attribute, see, e.g., Paasi (2003); Navrud & Bråten (2007); Brennan, Rensburg, & Morris (2017); Liebe, Bartczak, & Meyerhoff (2017); and Linnerud, Dugstad, & Rygg (2022). The use-of-electricity attribute includes one novel attribute level, electrifying the oil and gas platforms.

We described project size in terms of total installed capacity, number of turbines and locations. As aforementioned, the plans for the projects at Utsira Nord inspire the project size attribute's description and levels. This attribute has three levels, 500 MW, 1000 MW, and 1500 MW, corresponding to the three announced bids for Utsira Nord of 500 MW each (Norwegian Ministry of Petroleum and Energy, 2023). The lowest level, 500 MW, reflects predicted total installed capacity of floating wind power in Norway by 2030 (GWEC, 2020). We use a 10 MW turbine size to determine the number of turbines for each project size. The 10 MW turbine size falls within the available capacity range of 8-12 MW (IRENA, u.d.). We describe the 500 MW project as having 50 turbines in one area, the 1000 MW project as having 100 turbines in two areas, and the 1500 MW project as having 150 wind turbines in three areas. To make the project size numbers easier to interpret by the respondents, we translated the 1500 MW project into the average number of households that can be supplied with electricity from these offshore wind farms. The annual energy production of a 1500 MW wind farm is calculated as the total installed capacity multiplied by the capacity factor times the number of hours in a year, giving an expected annual energy production of 6.57 terawatt hours (TWh), based on an average capacity factor of 50% (IEA, 2019). In Norway, the average household consumes 16 MWh per year. Hence, a 1500 MW wind farm could provide electricity to around 400,000 million Norwegian households.

We specify that the projects differ with regards to where the electricity will be used. Preferences for connecting projects to domestic or foreign grids have been studied in the literature. However, the third attribute level, electrifying oil and gas platforms, is novel. Electrifying of oil and gas platforms is not new, but it remains a politically contentious topic in Norway. Norway operates over 90 offshore oil and gas platforms (Norwegian Petroleum, 2023), which use electricity to power equipment, pumps, and control systems. The electricity is generated on-site by burning natural gas or diesel fuel, resulting in CO2 emissions. Accordingly, the oil and gas sector contribute to 30% of Norway's total carbon emissions. Hence, cutting these emissions is vital for Norway to reach its climate objectives by 2030 (Norwegian Ministry of Climate and Environment, 2021). The Norwegian government has demonstrated its commitment to using floating offshore wind projects to reduce carbon emissions in the oil and gas sector by providing subsidies to Hywind Tampen (88MW), which now supplies 35% of the annual electricity demand for the five platforms at the Snorre and Gullfaks oil fields (Equinor, u.d.).

2.3.4 Novel attributes related to technology development

Share of domestic technology attribute is linked to the possibility of leveraging technology from existing offshore industries to develop an offshore wind sector (Norwegian Government, 2022; Norwegian Office of the Prime Minister, 2022). The oil and gas industry includes a broad range of suppliers providing technologies and services to oil and gas companies. With over half a century of offshore activities, the Norwegian oil and gas industry has extensive experience innovating and developing infrastructure relevant to offshore wind projects. For instance, Equinor, the largest Norwegian oil and gas company, developed the Spar Buoy floating technology in 2009, one of the main floating technology types used in offshore wind power projects (IRENA, 2016).

The share of domestic technology attribute has three levels, ranging from 25% to 75%. We based the levels on the capital expenditure (CAPEX) for the various floating offshore wind power components. We intentionally excluded the 100% level to account for components, such as wind turbines, currently not produced in Norway. According to the National Renewable Energy Laboratory, turbines account for 23.3%, while the balance-of-system (substructure and foundation, electrical infrastructure, installation) account for 61.4%, and the soft costs (commissioning, contingency, financing, insurance) account for 15.3% of the total CAPEX (Stehly & Duffy, 2022).

The reduction in technological cost attribute is based on learning by doing and the expected growth in the floating offshore industry by 2030 (GWEC, 2022). The attribute levels are based on observed (IRENA, 2020; Wiser et al., 2020) and predicted cost reduction trends in the offshore industry (GWEC, 2022). Between 2010 and 2020, the observed cost reductions for fixed-bottom offshore wind ranged from 16-32% per doubling of installed capacity (IRENA, 2020; Wiser et al., 2020). There are currently few examples of floating offshore wind power projects in operation. However, Equinor, a pioneer developer of offshore wind power projects predicts a 40% reduction in CAPEX per MW between Hywind Scotland (installed in 2017) and Hywind Tampen, completed in 2023 (Equinor, u.d.). At the time of the survey design, the global installed floating offshore wind power capacity was projected to increase from 66 MW in 2020 to 6200 MW in 2030 (GWEC, 2020). Consequently, a 1,500 MW project would account for 24% of the expected installed capacity by 2030. Therefore, these projects would be critical in technology development and subsequent cost reductions in the coming years. The three attribute levels, 10%, 20%, and 30%, represent a low, medium, or high impact on technology cost trends from these projects. However, there are significant uncertainties connected to forecasting the total installed capacity by 2030. Similarly, the impact of Norwegian projects on cost trends is unknown and potentially contingent on how early these projects are realized. Additionally, the effects on cost trends might be more pronounced locally than globally.

2.3.5 Choice experiment payment vehicle

To estimate WTP, a DCE must have a payment vehicle. We use an increase in the household's electricity bill in the form of a three-year green tax as the payment vehicle. The choice of payment vehicle builds on offshore wind power studies using taxes (Börger, Hooper, & Austen, 2015; Kim, Kim, & Yoo, 2019; Kim, Choi, & Yoo, 2021) and an increase in the electricity bill (Ladenburg and Dubgaard, 2007; Krueger et al., 2011; Klain et al., 2020; Ladenburg et al., 2020; Iwata et al., 2023; Joalland & Mahieu, 2023). The three-year green tax highlights the high subsidies needed to develop Norway's first utility-scale floating offshore wind power projects before 2030. However, it is unlikely that the Norwegian government will use a three-year green tax on households' electricity bills to finance subsidies for the development of floating offshore wind. The payment vehicle closely resembles that used by Krueger et al. (2011), where a three-year monthly addition to the electricity bill and the option of choosing no wind power were featured. We discuss the possible effects of the choice of payment vehicle in the discussion and limitation section.

We defined six levels of relative increases like existing studies (Longo, Markandya, & Petrucci, 2008; Kosenius & Ollikainen, 2013; Martínez-Cruz & Núñez, 2021). The average electricity bill in Norway was approximately NOK 18000 per year in 2020. Hence, our choice of the six levels ranging from 10 to 35% increase corresponds to an annual increase of NOK 1800 to 6400, or NOK 5300 to 18,900 over three years. All monetary values in the paper are represented in the local currency, Norwegian Kroner (NOK). At the time of the survey, the exchange rate was at NOK 10 to Euro 1.

The subsidy level for the first utility-scale floating offshore wind project in Norway is highly uncertain and will be based on a qualitative competition followed by negotiations with the Norwegian government (Norwegian Ministry of Petroleum and Energy, 2023). Using the NOK 2.3 billion subsidy granted to the recently completed floating offshore wind farm Hywind Tampen (88 MW) as a benchmark (Equinor, u.d.), a 1500 MW project with the same subsidy level would require a subsidy of NOK 39 billion, which would result in a three-year 30% green tax on households' electricity bill. Assuming the project would require lower subsidies per MW, we include four levels below a 30% increase and one level above, representing subsidies from NOK 13 to 47 billion, respectively. In 2023, the Norwegian government announced a subsidy cap of NOK 23 billion for the first 1400-1500 MW fixed-bottom offshore wind tender (Norwegian Ministry of Petroleum and Energy, 2023). The cost estimates for floating offshore wind are significantly higher than for fixed-bottom offshore wind (IRENA, 2022). Hence, it is expected that the subsidy level for the first floating offshore utility-scale wind farm is higher than the subsidy level of the first fixed-bottom project.

2.3.6 Experimental design

Using the attributes presented in Table 3, we created a D-efficient design (Rose et al., 2008) using Ngene software (Choice Metrics, u.d.). Efficient designs are increasingly used as they produce lower standard errors and require smaller sample sizes than orthogonal designs (Rose et al., 2008).

We specified the design with a Multinomial Logit model (MNL) with zero priors (Bliemer & Collins, 2016). The attributes were linearly coded, except for the use of the electricity attribute, which is dummy coded. The design included a constraint reflecting the high costs of developing new technology. Hence, within the choice tasks, the project alternative with the highest percentage reduction in technology costs by 2030 also had the highest green tax. The DCE comprised 18 choice tasks split into three blocks, and each choice task had two project alternatives and a none-of-these alternative. The choice cards were randomized across participants in each block and within framing to reduce potential sequence biases. We ask the respondents, "Which alternative do you prefer?". Figure 1 shows a sample of a choice card.

	OFFSHORE WIND 1	OFFSHORE WIND 2	NONE OF THESE
Project size	500 MW	1500 MW	No new Norwegian offshore wind power projects before 2030
Share of Norwegian technology	25%	50%	
Reduction in technology costs by 2030	30%	30%	
Use of electricity	Norwegian oil and gas sector	Transfer to other countries	
Increase in household electricity bill for three years	20%	30%	

Figure 1 Choice card example

2.4 Econometric model

We estimate a mixed logit model in the WTP space (Train & Weeks, 2005). The model was used recently to estimate WTP for offshore wind power by Ladenburg and Skotte (2022). The WTP space specification enables us to estimate marginal WTP directly as parameters. Thereby, we avoid potential problems with calculating WTP as ratios in the preference space model, such as undefined first and second moments (Daly, Hess, & Train, 2012) and WTP estimates with implausible signs or magnitudes (Hensher & Greene, 2011).

To estimate the mixed logit model, we first convert the cost variable "Increase in household's electricity bill for three years" to absolute monthly values by multiplying the percentage increase from the chosen alternative with the respondent's stated average monthly electricity bill. The monthly electricity bill is an interval variable with seven levels ranging from below NOK 300 to above NOK 3000 per month. We use the midpoints of the categories below 3000 and the exact values for those reporting electricity bills >3000. As a result, the parameter estimates in our analysis are monthly WTP in NOK. The cost variable indicated that the electricity bill would increase for three years; thus, the total WTP is calculated by multiplying the resulting WTP by 36 months.

The DCE approach is based on random utility theory, where individuals choose an alternative that maximizes their utility (McFadden, 1974). For the mixed logit model, under the assumption of heterogeneous preferences, the utility for an individual n choosing alternative j at choice situation t is assumed to be linear, made up of a deterministic and random part, and can be written as equation (1).

$$U_{njt} = \alpha_n C_{njt} + \beta_n V_{njt} + \varepsilon_{njt} \quad (1)$$

Where α_n is a cost parameter and β_n a vector parameter for non-cost attributes, e.g., project size and share of domestic technology. The error term ε_{njt} is assumed to be independent and identically distributed with an extreme value distribution, and its variance is unknown across individuals, periods, and samples (Train, 2003; Fiebig et al., 2009). We normalize the variance; thus, the new error term ε_{njt} is i.i.d extreme value distributed with a constant variance $\pi^2/_6$. Utility specification in equation (1) is in preference space. In the willingness-to-pay space, we respecify equation (1) as equation (2) below. The WTP is thus defined directly as $\rho = \frac{\beta}{\alpha}$ (Train and Weeks, 2005).

$$U_{njt} = -\alpha_n \sigma\left(C_{njt} - \rho_n V_{njt}\right) + \varepsilon_{njt} \quad (2)$$

where σ is the scale parameter and ρ is a vector of WTP estimates for the attributes. Cost and scale parameters cannot be identified separately. However, we can determine the relative scale parameter between samples. When pooling the two sub-samples, we estimate a relative scale factor μ (Swait & Louviere, 1993; Sandorf, Aanesen, & Navrud, 2016). The difference in scales is determined by fixing the scale of one group, μ_1 equal to unity (electricity framing sub-sample), and calculating the relative scale size of the other group (climate framing sub-sample). In other words, we normalize one group's error variance relative to the other. We let $\sigma = f_1 + f_2 * {}^{\mu_2}/_1$ where μ_2 is the relative scale for the climate sub-sample, and f_1 and f_2 are dummies indicating whether a respondent belongs in the electricity or climate sub-sample, respectively (Sandorf, Aanesen, & Navrud, 2016). $\mu_2 > 1$ implies that respondents under the climate framing have smaller error variance, and thus, their decisions to a larger degree are affected by observed factors.

Using equation (2), we specify models for electricity, climate, and pooled data sets, with random parameters, lognormal distribution for cost, α, and normal distribution for non-cost attributes, ρ (Train, 2003; Daly, Hess, & Train, 2012). The joint density is unknown and is given by $f(\theta_n|\Omega)$, where θ_n is a vector of random parameters, and Ω captures the mean and variances of their distribution. Given our assumptions, the unconditional probability of the six repeated choices is estimated using the integral over the product of all possible values of $\hat{\alpha}_n$ and $\hat{\rho}_n$.

$$Pr(y_n|C_n, V_n, \Omega) = \int \prod_{t=1}^{6} Pr\left(j_{nt}|\hat{\alpha}_n, \hat{\rho}_n, C_{njt}, V_{njt}\right) f(\theta_n|\Omega) d(\theta_n) \quad (3)$$

The integral in equation (3) is not a closed form and is thus transformed into a logarithmic form and solved by a simulated log-likelihood estimator (Train, 2003)

$$logL = \int \prod_{t=1}^{6} Pr\left(j_{nt}|\hat{\alpha}_n, \hat{\rho}_n, C_{njt}, V_{njt}\right) f(\theta_n|\Omega) d(\theta_n) \quad (4)$$

We estimate all the models using 1000 modified Latin hypercube sampling draws (Hess, Train, & Polak, 2006) in R 4.2.1 using the Apollo package version 0.2.7 (Hess & Palma, 2019). We apply individual-level sample weights in our models to correct for the lack of sample representativeness in socio-demographics.

2.5 Imputation of missing values

The dataset contains missing values for several variables, including monthly electricity bills, attitudes towards different energy technologies, climate change beliefs, and attribute importance. The percentage of missing data is less than 10% for each variable, though approximately 30% of the respondents have a missing observation for at least one of the relevant variables. Based on a probit model, where a respondent with missing observation equals one, with social demographics as covariates, we find no discernible pattern in the missingness. Therefore, we assume that the data are 'missing at random' (Rubin, 1976). Hence, multiple imputations can be used to fill in the missing values.

We use the multivariate imputation via the chained equations procedure in Stata 17. We employ the predictive mean matching method to fill in the missing values and generate 20 datasets. Plausible values for missing observations are estimated based on the ten nearest neighbours (Morris, White, & Royston, 2014). We use the weighted average of the resulting imputed values to create a single value for the electricity bill variable and run a single mixed logit model in Apollo in R. For the binary logit models discussed in the status quo choosers sub-section, we pool the 20 generated data sets following Rubin's rules (Stata, 2023)

3 Results

First, we present findings on respondents' attitudes towards the Norwegian government facilitating the development of various energy technologies. Next, we report the estimated WTP values for the floating offshore wind power projects. Finally, we explore the reasoning and characteristics of respondents who consistently chose the "no-new-floating-offshore-wind-project-before-2030" alternative, as determined by the follow-up questions.

3.1 Attitudes towards the development of new energy projects

Table 5 presents the mean scores for questions assessing attitudes towards the Norwegian government facilitating new energy projects. The results indicate that Norwegians are most positive about upgrading existing hydropower plants. This is unsurprising as hydropower is Norway's primary energy source, providing low-cost and low-carbon energy. With their greater environmental impact, building new hydropower plants is less favored than upgrading existing ones. Respondents prefer offshore wind to onshore wind. Moreover, respondents show a stronger preference for developing wave energy and offshore wind than establishing new offshore oil and gas fields. Collectively, these results suggest that respondents prefer minimal environmental intrusion and low-carbon technologies.

Table 5 Attitudes towards developing different energy technologies

	Full	Gender		Age		Education	
		Male	Female	≦ 44 years	≧ 45 years	No University	University
Developing new oil and gas fields	3.11	3.41***	2.84***	2.94***	3.28***	3.30***	3.05***
Upgrading existing hydropower plants	4.51	4.73	4.34	4.40***	4.65***	4.51	4.60
Developing new hydropower plants	3.83	3.98***	3.66***	3.90	3.80	3.83	3.84
Developing new onshore wind power plants	2.82	2.87	2.74	2.95*	2.74*	2.73*	2.88*
Developing new offshore wind power plants	3.78	3.91**	3.67**	3.80	3.81	3.66***	3.92***
Developing new wave energy plants	4.00	4.09*	3.96*	3.94*	4.08*	3.99	4.10
Number of observations	1011	566	445	365	646	442	569

*Notes: Respondents' attitudes towards the Norwegian government facilitating each energy technology were measured on a 5-point Likert scale, where one represents 'very negative' and five represents 'very positive.' Mean scores for the entire sample are weighted. ***0.001, **0.01, and *0.05 indicate statistically significant differences in means between socioeconomic groups (e.g., respondents with no university vs. those with university-level education) based on t-tests.*

Based on a t-test for the pooled sample, the differences in attitudes towards the various energy technologies are statistically significant except for the difference between developing new hydropower and offshore wind power. In addition, we observe statistically significant differences ($p<0.01$) in mean scores for various technologies across socio-demographics. Generally, males are more positive towards developing new energy projects than females. Older participants favor developing oil and gas, upgrading hydropower, and developing wave energy and are less positive about onshore wind power than their younger counterparts. Respondents with a university education are less positive towards developing oil and gas and more positive about onshore and offshore wind and wave energy than those with less education.

3.2 Marginal WTP estimates.

Table 6 displays the weighted marginal WTP estimates for electricity and climate subsamples and the pooled sample. When discussing the results, we primarily focus on the pooled data, except when comparing WTP between the two framings. According to the choice pattern for the pooled sample, alternative 1, alternative 2, and 'none of these' are selected 36%, 32%, and 32% of the time, respectively.

The alternative specific constant (ASC) represents the WTP difference between the status quo alternative (no new floating wind project before 2030) and the base project (500 MW, 25% share of Norwegian technology, 10% reduction in technology costs, and use of electricity in other countries). The negative WTP for ASC indicates that the average respondent has a positive WTP for the base project. The monthly WTP for electricity, climate, and the pooled data models base project is NOK 698, NOK 427, and NOK 524, respectively. Focusing on meeting future electricity demand results in higher WTP than meeting climate objectives. The ASC's high standard deviation suggests high variation in preferences when comparing the status quo to the project alternatives.

The WTP estimates for connecting the offshore wind power projects to the domestic electricity grid or offshore oil and gas platforms are calculated relative to connecting the projects to electricity grids in other countries. Both WTP estimates are positive, indicating that the average respondent is less willing to support projects connected to a foreign electricity grid than those supplying electricity to oil and gas platforms or the domestic electricity grid. In all three models, connecting to a foreign grid versus the domestic grid results in the largest intra-attribute difference in WTP. The marginal WTP for the use of electricity in Norway in the pooled sample is NOK 352.

Respondents prefer a higher share of domestic technology. The marginal WTP estimates for 50% and 75% domestic technology, relative to the base project's 25%, are NOK 80 and 237, respectively. The preference for a higher share of domestic technology may suggest that the respondents are willing to support their local offshore supply industry.

Project size is less important than the use of electricity and the share of domestic technology. Respondents prefer to pay for the 1000 MW and 1500 MW projects to the 500 MW project. In the pooled sample, the marginal WTP estimate is NOK 112 and NOK 105 for 1000 MW and 1500 MW, respectively.

Table 6 Marginal willingness to pay for offshore wind project attributes for the electricity, climate, and pooled samples

	Electricity		Climate		Pooled	
Attributes and Levels	WTP (s.e.)	St. dev. (s.e.)	WTP (s.e.)	St. dev. (s.e.)	WTP (s.e.)	St. dev. (s.e.)
ASC	-698.56**	2032.55**	-427.56**	1177.80**	-524.48**	1618.35**
	(115.42)	(189.79)	(33.37)	(67.61)	(64.85)	(133.64)
Project Size-1000 MW	131.73*	62.15	70.97*	59.10**	112.13**	92.04*
	(48.90)	(84.28)	(24.78)	(12.38)	(25.73)	(40.58)
Project Size-1500 MW	79.97*	231.52**	101.06**	308.75**	105.28**	305.45**
	(35.89)	(41.14)	(24.67)	(25.91)	(26.76)	(37.39)
Technology share-50 %	146.49**	239.62**	36.47*	5.94	80.32*	9.79
	(44.19)	(69.60)	(22.37)	(20.85)	(31.44)	(58.53)
Technology share-75 %	302.94**	365.87**	165.97**	128.27**	237.50**	260.37**
	(41.84)	(53.64)	(18.48)	(13.22)	(24.68)	(31.34)
Technology cost-20 %	-88.67	3.02	-35.45	40.28*	-48.09	146.95*
	61.16	(53.64)	(23.89)	(16.35)	(31.70)	(53.54)
Technology cost-30 %	-117.99*	315.15**	-43.15*	229.44**	-77.79*	321.10**
	(40.54)	(57.01)	(20.86)	(20.15)	(30.72)	(48.13)
Use of electricity-oil and gas	69.09*	114.12*	85.91*'	227.50	84.31**	179.34**
	(30.23)	(54.91)	(26.69)	(23.47)	(21.73)	(27.97)
Use of electricity-Norway	366.23**	391.00**	320.67**	273.84	352.28**	381.72**
	(45.85)	(46.32)	(33.35)	(22.00)	(30.15)	(36.98)
Relative scale					1.11	
Adj. Rho-squared	0.29		0.29		0.29	
Log-likelihood	-2301.99		-2421.99		-4759.46	
Number of observations	2928		3138		6066	

*Notes: ** 0.01%, * 0.05%. Technology share is the share of Norwegian technology, and technology cost is the reduction of technology cost by 2030. The attribute base levels are project size, 500 MW, share of Norwegian technology, 25%, reduction in technology costs by 2030, 10%, and use of electricity in other countries. NOK 10 equaled Euro 1 in the survey period.*

The attribute reduction in technological costs by 2030 yields mixed results. There is no significant difference between the base level, 10%, and the mid-level, 20%. However, the 30% reduction in technology cost has a significantly lower WTP than the base level. This indicates that, given our framings, project descriptions, and choice of payment vehicle, the respondents are unwilling to pay more for the projects to substantially reduce future technology costs.

Summing up all the preferred characteristics for the pooled sample in The WTP estimates for connecting the offshore wind power projects to the domestic electricity grid or offshore oil and gas platforms are calculated relative to connecting the projects to electricity grids in other countries. Both WTP estimates are positive, indicating that the average respondent is less willing to support projects connected to a foreign electricity grid than those supplying electricity to oil and gas platforms or the domestic electricity grid. In all three models, connecting to a foreign grid versus the domestic grid results in the largest intra-attribute difference in WTP. The marginal WTP for the use of electricity in Norway in the pooled sample is NOK 352.

Respondents prefer a higher share of domestic technology. The marginal WTP estimates for 50% and 75% domestic technology, relative to the base project's 25%, are NOK 80 and 237, respectively. The preference for a higher share of domestic technology may suggest that the respondents are willing to support their local offshore supply industry.

Project size is less important than the use of electricity and the share of domestic technology. Respondents prefer to pay for the 1000 MW and 1500 MW projects to the 500 MW project. In the pooled sample, the marginal WTP estimate is NOK 112 and NOK 105 for 1000 MW and 1500 MW, respectively.

Table 6, a 1000 MW project size, 75% domestic technology share, 10% impact on technology cost, and connection to the Norwegian electricity grid, result in a WTP of NOK 702 compared to the base alternative, and NOK 1227 compared to no new floating offshore wind before 2030, per household per month. For the least preferred alternative, the WTP compared to no new floating offshore wind before 2030 is NOK 447 per household per month. Given our choice of payment vehicle, this indicates a WTP for new offshore floating wind power of between NOK 40 and 110 billion. The WTP values are significantly higher than the subsidy cap of NOK 23 billion used in the first fixed-bottom tender planned in 2023. Given these numbers, it is essential to remember the inflating effect of the hypothetical bias in surveys. We also note that the adjusted rho-squared value is 0.29, which indicates that our model has some explanatory power, but it also implies that a substantial portion of the variability in the WTP remains unexplained.

The attribute importance ranking presented in Table A in the Appendix supports the main results of the DCE. The ranking reveals that the increase in the household's electricity bill attribute was the most important, followed by the use of electricity, share of Norwegian technology, reduction in technology cost by 2030, and project size attributes.

For robustness checks, the Appendix includes several tables presenting results from various estimation methods. Table B provides marginal WTP estimates, unweighted and without imputations, estimated using the same mixed logit model in WTP space across the three samples as in Table 6. Table C presents marginal WTP estimates for the pooled data, unweighted and utilizing imputed data but excluding status quo respondents. Lastly, Table D contains marginal WTP estimates, weighted and with imputations, estimated using an MNL model in WTP space over the same three samples as those in Table 6. The overall results remain stable across these estimations, with some variations in the overall WTP levels. The most notable difference can be observed in the attribute representing a 20% reduction in technology cost by 2030—an attribute ranked low in importance according to Table A. In Table 6, this attribute is positive and significant at a 5% level, while in Tables B and C, it is insignificant, and in Table D, it is negative and significant at a 1% level. There are some changes in significance levels for the other attributes but no changes in signs. The results from Tables B, C, and D for the technology cost trend attribute reinforce the participants' unwillingness to shoulder the cost of a large impact on future technology cost trends.

3.2 WTP differences between framings

Using the relative scale factor defined in the pooled model, we observe a slight but significant difference between respondents in the two frames. The climate frame has a relative scale factor >1, indicating that respondents in this frame have a smaller error variance. This implies that choices for respondents in the climate framing are more influenced by factors incorporated in the model (Swait & Louviere, 1993).

To test whether WTP for the respondents differs due to framing, we compare the WTP estimates using the complete combinatorial test of difference in empirical WTP distributions (Poe, Giraud, & Loomis, 2005). The results suggest that WTP estimates for the share of technology, specifically 50%, differ significantly between the two framings ($p<0.05$). However, the difference in WTP between the framings should be interpreted with caution because Norway was experiencing anomalous electricity prices, accentuating the urgency of fulfilling the growing energy demand needs.

3.3 Status quo choosers

Based on the pooled sample, 18% of the respondents chose the status quo alternative of no new floating offshore wind power project before 2030. Following recommendations by Meyerhoff and Liebe (2008), we included follow-up questions to determine their reasons for choosing the status quo. Table 7 presents the four statements and the percentage of the 182 status quo choosers that choose each of the four statements. The results show that most status quo respondents chose the status quo alternative due to the perceived impact of wind power projects on marine life and the cost implications for Norwegian households.

Table 7 Reasons for choosing the none-of-these alternative in all choice tasks

Reason	Pooled	Electricity	Climate
The developers should cover all the costs related to offshore wind power development	37%	38%	36%
Offshore wind power projects will destroy birds and marine life	51%	46%	55%
I can not afford to pay more for electricity	41%	39%	43%
Norwegian households should not cover the costs of developing offshore wind power projects	67%	65%	67%
N	182	85	97

Note: The results are based only on the respondents who chose the status quo alternative for all the six choice cards (n=182). The respondents could choose more than one statement.

To gain insight into the characteristics of the status quo choosers, we estimate four binary logit models using the entire sample (N=1011). The binary dependent variable in these models equals one for the status quo choosers. Model 1 incorporates social demographics. Model 2 includes social demographics and attribute importance. Model 3 further expands to incorporate climate change beliefs. Lastly, Model 4 includes all the variables from the previous models, as well as the framing variable.

Table 8 Determinants of status quo choosers: a binary logit model analysis

Variables	Model 1	Model 2	Model 3	Model 4
Social demographics				
Age	-0.006	0.003	0.002	0.002
Education	-0.085	-0.056	-0.016	-0.016
Male	-0.226	-0.141	0.005	0.005
Attribute importance				
Project size		-0.048	-0.010	-0.010
Share of Norwegian technology		-0.716	-0.611	-0.611
Reduction in technology cost by 2030		-0.687	-0.607	-0.607
Use of electricity		-1.000*	-0.882*	-0.882*
Climate change beliefs				
Climate change is one of the biggest problems facing humanity			-0.286*	-0.286*
Climate change is caused mainly by human activity			-0.181*	-0.181
Climate change will lead to significant negative consequences			0.060	0.060
Electricity framing				-0.002
Pseudo R^2	0.005	0.055	0.108	0.112
No. of observations	1011	1011	1011	1011

*Note: **0.01, *0.05. Age, Education, and Male are dummy variables. Age is set to one for respondents 45 years and above, Education for those with a university degree, and Male for male respondents. Attribute importance variables are measured on a 5-point Likert scale from 'not important at all' to 'very important' and calculated relative to the household cost attribute. Climate change beliefs variables are measured on a 5-point Likert scale from 'strongly disagree' to 'strongly agree.' Electricity framing is a dummy variable equal to 1 for respondents in the electricity framing.*

Only attribute importance and climate change beliefs are significant determinants of status quo choosers. Respondents who do not believe climate change is one of humanity's biggest problems, primarily driven by human activity, tended to opt for the status quo. Respondents who rank the 'use of electricity' attribute as important are less likely to be status-quo choosers. Notably, the largest model, Model 4, has a pseudo R-square value of 0.12, which indicates that the model provides some insight into the relationship between the predictors and the response, however, a significant amount of variance remains unexplained.

Excluding the status-quo choosers from the WTP mixed logit model results in some changes. For the least important attribute, according to Table A in the Appendix, the project size, we see a change in order where the largest project size, 1500MW, is now the most preferred. For the other attributes, there are size changes but not order changes in the WTP for the attribute levels. Domestic use of electricity and a 75% share of domestic technology are still the dominant factors. See Table C in the Appendix.

4. Discussion

We begin by contextualizing our findings within the broader literature and then delve into their implications for the development of floating offshore wind power in Norway. The findings of our study suggest that the public supports the deployment of floating offshore wind power technology. The finding is consistent with previous studies that show general support for emerging energy technologies, including wave energy (Heras-Saizarbitoria, Zamanillo, & Laskurain, 2013) and power-to-gas (Azarova et al., 2019). However, this finding is not guaranteed, as studies also find negative attitudes towards emerging energy technologies such as bioenergy (Upreti & Van Der Horst, 2004; Soland, Steimer, & Walter, 2013; Schumacher et al., 2019).

Our use-of-electricity finding aligns with previous studies indicating that individuals often prefer local electricity consumption to export (Paasi, 2003; Navrud & Bråten, 2007; Brennan, Rensburg, & Morris, 2017; Bidwell, Firestone, & Ferguson, 2022; Linnerud, Dugstad, & Rygg, 2022). This preference for local resource use may stem from a sense of regionalism and the belief that those bearing the projects' cost and environmental impact should benefit from the produced electricity.

Electrifying oil and gas installations is primarily relevant to countries with oil and gas industries. However, the broader issue of a country or industry-level carbon emissions reduction remains a central focus in climate discourses and has been examined directly through attribute descriptions or as an attribute in prior studies (Linnerud, Dugstad, & Rygg, 2022; Iwata, Kyoi, & Ushifusa, 2023). Our results indicate that Norwegians prefer using electricity from floating offshore wind projects to mitigate carbon emissions from the domestic oil and gas sector instead of exporting it so that other countries can reduce their carbon emissions.

Our design and findings should be viewed from the perspective of the recent development and public discourse on offshore wind in general and the possibility of developing floating offshore wind power in Norway before 2030. The allocation of the three pioneering projects at Utsira Nord will be based on qualitative criteria due to the uncertainty inherent in the immature floating wind power technology. The criteria include the cost level for 2030, innovation and technological development, implementation ability, sustainability, and a positive local impact. The three applicants with the highest score on these criteria will be awarded a project area and enter into negotiations with the Norwegian government (Norwegian Ministry of Petroleum and Energy, 2023).

Unlike the Utsira Nord qualitative competition, the first tender for a Norwegian utility scale fixed-bottom wind power project at Sørlige Nordsjø II will operate under an English auction format, accepting bids as a fixed electricity price for a 15-year term without any adjustments for inflation (Norwegian Ministry of Petroleum and Energy, 2023). This tender may provide some insights into what is expected from the government regarding its position in the Utsira Nord negotiations. The Sørlige Nordsjø II tender covers offshore wind power projects ranging from 1400-1500 MW, similar to the total size for Utsira Nord. The tender will utilize a double differentiation price contract, incorporating a subsidy cap of NOK 23 billion, with the realized subsidy value depending on inflation and changes in electricity prices over the contract period.

The NOK 23 billion subsidy cap for the fixed-bottom wind power projects at Sørlige Nordsjø II equals NOK 9200 for every Norwegian household. Considering the significantly higher LCOE for floating offshore wind power compared to the fixed-bottom (IRENA, 2022), we anticipate subsidy levels significantly above NOK 23 billion if the first Norwegian utility-scale 1500 MW floating offshore wind projects are realized before 2030. The subsidy levels used in our survey correspond to a range from NOK 13 to 47 billion, with a mean 30% above the NOK 23 billion subsidy cap used in the tender for the fixed-bottom offshore wind project in phase 1 of Sørlige Nordsjø II. The WTP results indicate that the Norwegian population is willing to pay the substantial costs associated with developing the first utility-scale offshore floating wind power projects. However, this willingness depends on the characteristics of the projects, and the results might be inflated due to the hypothetical bias often present in surveys.

The three levels used for the use-of-electricity attribute, (i)Norwegian electricity grid, (ii) foreign electricity grids, and (iii) oil and gas installations, offer a simplified view of actual electricity connection possibilities. First, a project can be connected to multiple grids, especially if it is located in waters near other countries. Second, connecting solely to oil and gas installations is improbable for utility-scale wind power projects like those planned for Utsira Nord and Sørlige Nordsjø II. Instead, electrifying oil and gas installations will likely arise from smaller projects, such as Hywind Tampen, located near the oil and gas platforms, or through a blend of connections involving domestic and international electricity grids. Third, connecting to the Norwegian grid does not imply exclusive use in Norway. The Norwegian electricity grid is connected to neighbouring countries through 18 terrestrial and submarine cables (Hofstad, Askheim, & Rosvold, 2022). Hence, electricity generated in Norway can, to some degree, be used in neighbouring countries.

Phase 1 of Sørlige Nordsjø II will be connected solely to the Norwegian electricity grid, reducing the income potential and increasing the need for subsidies (Norwegian Ministry of Petroleum and Energy, 2023). Utsira Nord is much closer to the Norwegian coast than Sørlige Nordsjø II. Therefore, it is likely that projects developed in this area will feed into the Norwegian electricity grid. This aligns with respondents' preferences in our survey; connecting to the Norwegian electricity grid is the characteristic with the highest impact on the WTP for floating offshore wind power projects.

The government's financing of the subsidies will likely be less salient to the consumers than the payment vehicle used in our survey, and the subsidy may be a combination of short and long-term payments. The saliency of our choice of payment vehicle is likely to reduce the WTP for new floating offshore wind projects. Working in the opposite direction, the hypothetical bias is likely to inflate the WTP estimates. Which of these effects is the largest, we do not know.

An essential consideration in planning the first utility-scale floating wind power project in Norwegian waters is the trade-off between cost and the potential contribution to technological innovation and the development of a domestic supply industry. Postponing the projects for a few years could allow floating wind platforms to mature, likely reducing the project's cost. However, this delay might also diminish the project's impact on the global cost trend for floating offshore wind and lessen the domestic industry's possbility to develop expertise in the early stages. Our survey reveals that the Norwegian respondents do not value the first of these technological impacts; the effect on cost trends, which might suggest that they prefer to wait. However, the second impact, concerning the benefits to the domestic offshore wind power industry, significantly increases the willingness to support the projects. Given the political debate surrounding the high cost of Sørlige Nordsjø II, it may be challenging to secure political support for an even larger subsidy for realizing a floating offshore wind project at Utsira Nord before 2030. A politically more feasible solution can be to postpone one or more of the three 500 MW areas planned for Utsira Nord until the mid-2030s.

The study reveals that the respondents are unwilling to pay for the projects to substantially impact future technology costs. This suggests that, given our project descriptions and choice of payment vehicle, respondents are unwilling to finance global technology development. This may indicate that individuals weigh the immediate loss in the form of an increase in electricity bills as more significant than the uncertain future gain resulting from the potential reduction in technology costs. Respondents may also view the distribution of costs and benefits as inequitable, whereby the Norwegians pay for technology development (costs), while the reduction in technology costs (benefits) is felt globally. Given our respondents' preferences for connecting to the domestic electricity grid and use of domestic technology, the technology cost result might have been different if the future technology cost attribute was presented as a domestic technology cost reduction, hence likely to affect domestic industries' competitiveness and employment.

Electrifying oil and gas installations to decrease the significant point emissions from these facilities has garnered considerable attention in Norway. Since 30% of Norway's total carbon emissions stem from oil and gas fields, electrifying these sites is crucial for Norway to meet its climate objectives without reducing oil and gas exports in the coming years. The Norwegian government has recently backed the electrification of the offshore oil and gas field Johan Sverdrup with electricity from the Norwegian mainland and the development of the Hywind Tampen offshore wind project, which is exclusively connected to offshore oil and gas platforms (Equinor, u.d.; Bjelland & Røli, 2023). In addition, the government has greenlit the controversial electrification of Melkøya, a major gas installation on Norway's Arctic coast (Regjeringen, 2023). Critics of the electrification plans argue that such actions extend Norway's dependence on oil and gas and reduce electricity available for other industries. Additionally, they argue that these initiatives are greenwashing, asserting that they mask the broader environmental consequences of fossil fuel exploitation without effecting substantial change (Bjelland & Røli, 2023; Bjerkholt, 2023). Despite its controversy, our respondents favor electrifying Norwegian oil and gas installations over exporting electricity.

The sentiments and implications found in our study apply to Norway's unique energy landscape, industrial capabilities, and public priorities. While some aspects, such as preferences for developing domestic technology and local electricity consumption, resonate with other contexts, caution must be exercised when generalizing these findings. Different socioeconomic conditions, energy needs, environmental priorities, and cultural perceptions of renewable energy might lead to diverging attitudes and acceptance levels. For example, a country with a less developed offshore industry might not perceive the development of domestic technology as a consequence of offshore wind power development. Similarly, countries with different energy export and import dynamics might have varying preferences for local versus global utilization of renewable energy sources.

5. Limitations

While our study provides valuable insights, it is important to acknowledge some limitations.

Our data is sourced from a survey, so it is subject to inherent survey-related challenges. The representativeness of the panel members is a concern, considering the response rate of 33.5% and the completion rate of 82%. This means that only one in four individuals who received an invitation to the survey completed it before we achieved our target of 1,000 usable responses. Other survey-related challenges include the potential overestimation of WTP due to hypothetical and social desirability biases. The absence of tangible economic consequences in a survey setting can make participants more liberal in expressing their WTP. Additionally, reliance on self-reported figures, such as the average monthly electricity bill used in our WTP calculations, introduces room for error. It is uncertain, however, whether this latter skews the average in a specific direction. The same is the case for the timing of the survey. During the fall and winter of 2021, electricity prices surged, there was significant media coverage regarding the energy shortage in Europe, and Norway introduced electricity subsidies to cushion the impact of rising costs on households and businesses. The exact influence of this confluence of events on the survey responses remains uncertain.

As discussed in the previous sections, a limitation of our study lies in the choice of payment vehicle. As there were no existing utility-scale floating offshore wind projects on which to base the subsidy level and payment vehicle, the subsidy used in the survey was formulated akin to the model used for Hywind Tampen, where the subsidy is disbursed in the project development phase. Recent indications of what to expect for subsidy schemes for utility-scale offshore wind projects come from the plans for phase 1 of the Sørlige Nordsjø II tender. Here, the subsidy depends on the market price for electricity in the years after the project has started its operations, potentially lasting for 15 years (Norwegian Ministry of Petroleum and Energy, 2023).

The government's choice of tailoring the payments closer to the life span of the technology and offshore wind market conditions, is likely to make the annual subsidy smaller than in the three-year green tax used in our survey. Opting for a different payment duration — more aligned with paying for a continuous service rather than supporting the development of a project — might have influenced the WTP values. However, the deflating effect of the saliency of our three-year green tax is likely to be counteracted by the hypothetical bias in survey studies, typically inflating the WTP estimates. The interaction between these conflicting effects and which of them predominates is an ambiguity we cannot resolve with the data and design employed in this study.

Our survey, while informed by the specifics of Utsira Nord, does not explicitly focus on this particular location and thus blends elements of general and specific acceptance. As a result, location-specific factors that can significantly shape public acceptance may not be fully considered within the survey's design. While this broad societal approach aids in assessing national-level policies and strategies on the renewable energy transition, it might overlook the nuances that individual project characteristics may bring to public acceptance (Bell, Gray, & Haggett, 2005).

Wind power projects' visual impact and proximity to the coastline can strongly influence public acceptance (Westerberg, Jacobsen, & Lifran, 2013; Wen, Dallimer, Carver, & Ziv, 2018; Ladenburg & Skotte, 2022). Our choice experiment focused on other factors and did not include distance from shore or visual impact as attributes. Furthermore, we did not utilize visual aids, such as pictures or diagrams, to illustrate the size of the wind projects, which could have provided respondents with a better understanding of the scale of these projects.

The planned floating wind power projects at Utsira Nord will be highly visible to the 188 inhabitants of the island of Utsira. The same can be concluded for the impact of onshore infrastructure needed for most offshore projects. Recent research indicates that static visuals in social acceptance studies can result in too high social acceptance, especially among respondents who have never interacted with offshore wind parks or the supporting infrastructure (Cranmer et al., 2022). We do not include visualizations in our study.

Concerning the sample's location relative to the ocean, it is worth noting that all Norwegian municipalities with more than 100,000 inhabitants and 67 of the country's 100 largest municipalities are located along the coastline, bordering either the sea or a fjord (Statistics Norway, u.d.). However, none of the 20 Norwegian sea areas currently under consideration for developing offshore wind farm projects will be visible from densely populated areas. Fifteen of the 20 ocean areas are over 50 kilometers from the Norwegian mainland (NVE, 2023). Hence, it is reasonable to believe that the visual impacts of most offshore wind power projects will be minor, but not negligible, on the majority of Norwegians.

Our study does not include explicit variation in environmental attributes, such as impacts on marine life, which are studied and found impactful on WTP in other wind power studies (Börger et al., 2015; Klain et al., 2020; Kim, Choi & Yoo, 2021; Iwata et al. 2023; Joalland and Mahieu, 2023). The absence of explicit variations in environmental attributes was due to the focus on technology and limited literature on the environmental impacts of floating offshore wind projects. As the floating offshore wind industry develops, environmental impacts could become more salient and influential in public discourses and opinions.

6. Conclusions and Policy Implications

The impact of developing the first utility-scale offshore floating wind projects transcends electricity production. It is primarily a technology development initiative, a proof of concept, and an example for others. The successes and learnings from these early projects will play a critical role in stimulating the growth of a floating offshore wind industry and influencing the costs of subsequent developments worldwide.

This paper uses a national survey to examine public support and opposition to developing floating offshore wind power in Norway before 2030. Using Likert scale attitude questions, we assess attitudes towards the Norwegian government's facilitating the development of various energy technologies. We find that developing offshore wind is significantly more popular than onshore wind and new oil and gas fields. Furthermore, offshore wind is as popular as developing new hydropower plants but lags behind upgrading existing hydropower facilities.

Our DCE reveals that public support for new floating offshore wind power projects is contingent on the projects' connecting to the domestic energy grid and their use of domestic offshore technology. Additionally, respondents prefer projects that reduce domestic carbon emissions over those that export electricity. We also observe low interest in projects developed to significantly impact technology cost trends, which may suggest a preference for waiting for the technology to mature through projects developed in other countries. Our study also reveals that using a future energy demands framing results in higher public support for the development of floating offshore wind than climate goals framing. Lastly, we identified a mixture of economic and environmental concerns among those who opposed floating offshore wind power projects, with climate skepticism being a notable contributing factor.

To secure substantial domestic public support during this early phase when large subsidies are necessary, floating offshore wind projects should prioritize connecting to the domestic energy grid and using domestic technology. However, focusing on domestic energy needs and industry development also brings significant costs and trade-offs. For example, connecting the offshore wind projects only to the Norwegian electricity grid could yield lower revenues, thereby requiring higher subsidies for the projects to be economically viable than if they were also connected to other grids.

Norway's initiatives to electrify oil and gas installations underscore its dedication to reducing the significant oil and gas sector emissions. While critics argue that such efforts might sidetrack the green transition and merely extend the country's dependence on fossil fuels, our results reveal a public preference for supporting projects aimed at electrifying oil and gas installations to those aimed at electricity export. In other words, projects that lead to emission reductions within Norway are favored over those reducing emissions in other countries.

Regarding technology, the wind power sector in Norway is still relatively novel and small-scale. Hence, a significant share of the components for offshore floating wind projects will likely be sourced from international companies. Therefore, ensuring that domestic supply industries reap the benefits of the large-scale floating offshore wind power development planned in Norway might be challenging.

Considering the limited production that can be expected from upgrading existing hydropower plants, environmental constraints facing new hydropower, large land requirements for solar power, the lack of breakthrough in wave energy, and the unpopularity of onshore wind and new oil and gas, offshore wind is essential in Norway’s green energy transition. However, this might change as Norwegians become more aware of the high costs associated with offshore wind compared to solar power and onshore wind. Furthermore, before offshore wind power can be extensively deployed along Norway's long coastline, further research is required to understand its environmental implications, impact on fisheries and other industries, and potential visibility issues. Accentuating these issues can alter the preferences towards offshore wind.

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Appendix

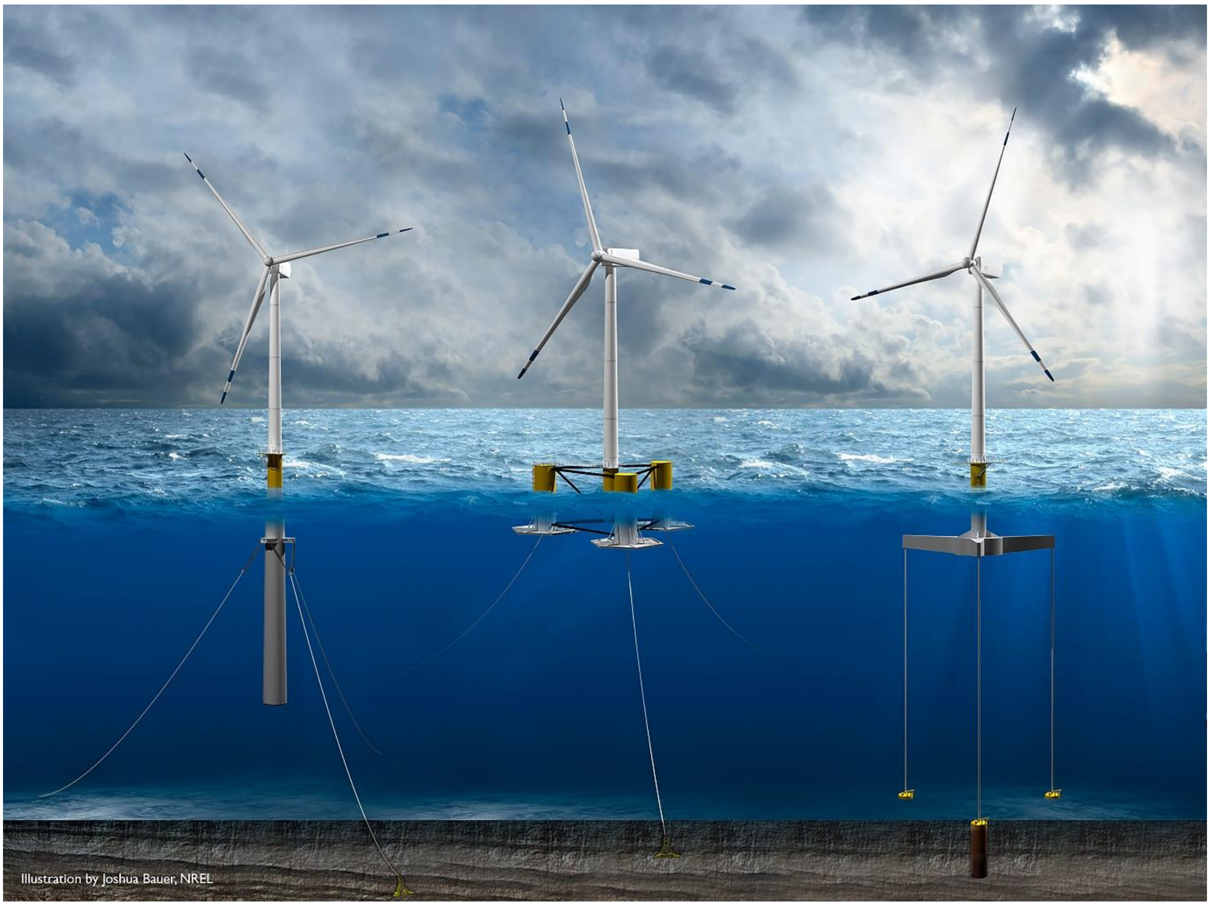

Figure A Illustration of floating wind power technology
Credit: Illustration by Joshua Bauer, NREL.

Table A Ranking of the importance of the choice attributes — weighted means

	Full	Gender		Age		Education	
Attribute		Male	Female	≦ 44 years	≧ 45 years	No University	University
Project size	2.77	2.86	2.72	2.73	2.84	2.74*	2.85*
Share of Norwegian technology	3.23	3.44	3.34	3.08**	3.58**	3.35	3.44
Reduction in technology cost by 2030	2.96	3.08	2.97	2.77**	3.17**	3.00	3.04
Use of electricity	3.69	3.68	3.80	3.64*	3.79*	3.69	3.77
Increase in household's electricity bill for three years	3.76	3.92	3.79	3.95	3.78	3.86	3.94

*Notes: Respondents evaluated each attribute's importance using a 5-point Likert scale, where one represented 'not important' and five represented 'very important.' ** 0.01% and * 0.05% indicate statistically significant differences between socioeconomic groups (e.g., respondents with no university vs. university-level education) based on t-tests.*

Table B Marginal Willingness-to-Pay — unweighted and using non-imputed data

	Electricity		Climate		Pooled	
Attributes and Levels	WTP (s.e.)	St. dev. (s.e.)	WTP (s.e.)	St. dev. (s.e.)	WTP (s.e.)	St. dev. (s.e.)
ASC	-648.76** (88.74)	2143.34** (204.70)	-329.86** (48.39)	1532.5** (135.61)	-435.04** (79.21)	1640.89** (161.46)
Project Size-1000 MW	212.68** (42.92)	47.15 (43.03)	152.80** (32.96)	143.15** (34.29)	169.03** (34.23)	42.23 (67.08)
Project Size-1500 MW	80.17* (33.85)	333.44** (51.62)	81.04** (25.04)	373.03** (36.83)	95.49** (30.09)	357.92** (45.78)
Technology share-50 %	143.69* (50.36)	166.69** (35.76)	31.06 (34.82)	7.13 (29.73)	86.73* (37.02)	81.59 (63.48)
Technology share-75 %	327.30** (40.50)	408.73 ** (48.51)	179.48** (28.25)	222.90** (34.19)	252.28** (28.62)	273.49** (37.83)
Technology cost-20 %	34.86 (44.01)	152.31** (38.07)	-19.20 (33.84)	194.64** (35.40)	11.86 (32.20)	-86.35 (73.21)
Technology cost-30 %	-124.64* (43.45)	381.89** (59.65)	-84.59* (37.71)	387.33** (36.74)	-96.85* (35.60)	368.64** (59.30)
Use of electricity-oil and gas	167.13** (29.73)	90.15** (24.76)	139.12** (24.37)	248.12** (27.56)	156.63** (24.78)	199.38** (37.02)
Use of electricity-Norway	425.92** (43.49)	519.72** (56.06)	423.25 ** (35.09)	384.13** (37.43)	453.33** (38.76)	423.22** (47.81)
Relative scale					0.97252**	
Adj. Rho-squared	0.307		0.299		0.303	
Log-likelihood	-2054.65		-2116.91		-4197.57	
Number of observations	2418		2556		4974	

*Notes: ** 0.01%, * 0.05%. Respondents without the monthly electricity bill are excluded. The sample size is 918 respondents. Technology share is the share of Norwegian technology, and technology cost is the reduction of technology cost by 2030. The attribute base levels are project size equal to 500 MW, the share of Norwegian technology equal to 25%, reduction in technology costs by 2030 equal to 10%, and use of electricity equal in other countries. NOK 10 equaled Euro 1 in the survey period.*

Table C Marginal Willingness-to-Pay – unweighted and using imputed data without status quo respondents

	Pooled	
Attributes and Levels	WTP (s.e.)	St. dev. (s.e.)
ASC	-2.62** (19.23)	2.69** (0.18)
Project Size-1000 MW	60.49** (18.94)	2.03 (24.98)
Project Size-1500 MW	97.66** (21.95)	265.77** (29.91)
Technology share-50 %	89.13* (25.34)	14.39 (50.81)
Technology share-75 %	206.70** (19.17)	207.64** (27.14)
Technology cost-20 %	-47.37 (23.28)	63.14 (36.28)
Technology cost-30 %	-45.14* (19.92)	0.00** (24.54)
Use of electricity-oil and gas	84.72* (17.78)	141.18** (32.42)
Use of electricity-Norway	337.67** (23.63)	239.11** (27.01)
Relative scale	0.97252**	
Adj. Rho-squared	0.2186	
Log-likelihood	-4227.52	
Number of observations	4974	

*Notes: ** 0.01%, * 0.05%. The ASC is estimated in preference space, excluding status quo choosers. The sample size is 829 respondents. Technology share is the share of Norwegian technology, and technology cost is the reduction of technology cost by 2030. The attribute base levels are project size equal to 500 MW, the share of Norwegian technology equal to 25%, reduction in technology costs by 2030 equal to 10%, and use of electricity equal in other countries. NOK 10 equaled Euro 1 in the survey period.*

Table D Marginal Willingness-to-Pay — weighted, with imputed data, using an MNL model

	Electricity	Climate	Pooled
Attributes and levels	WTP (s.e)	WTP (s.e)	WTP (s.e)
ASC	94.43 (110.65)	70.92 (71.83)	86.40 (64.15)
Size-1000 MW	236.55* (94.00)	237.49** (63.20)	243.87** (55.28)
Size-1500 MW	144.96* (87.00)	248.45** (60.50)	214.15** (51.56)
Technology share-50 %	330.55** (108.58)	62.08 (66.42)	164.36* (59.22)
Technology share-75 %	684.52** (120.47)	327.78** (55.81)	475.32** 58.69
Technology cost-20 %	-325.73* (128.45)	-135.37* (74.85)	-219.00** (69.43)
Technology cost-30 %	-413.19** (114.29)	-229.95** (65.25)	-311.17** (61.43)
Use of electricity-oil and gas	166.81* (80.97)	147.14* (52.53)	159.09** (46.36)
Use of electricity-Norway	743.38** (122.06)	543.37** (69.21)	636.65** (66.61)
Relative scale			1.014
Adj. Rho-squared	0.054	0.0523	0.0517
Log-likelihood	-3092.34	-3254.49	-6355.41
Number of observations	2928	3138	6066

*Notes: ** 0.01%, * 0.05%. The sample size is 1011 respondents. Technology share is the share of Norwegian technology, and technology cost is the reduction of technology cost by 2030. The attribute base levels are project size equal to 500 MW, the share of Norwegian technology equal to 25%, reduction in technology costs by 2030 equal to 10%, and use of electricity equal in other countries. NOK 10 equaled Euro 1 in the survey period.*

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Credit author statement

Sharon Nytte: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing. **Frode Alfnes**: Conceptualization, Methodology, Writing - Review & Editing, Supervision, Project administration, Funding acquisition. **Silja Korhonen-Sande**: Conceptualization, Writing - Review & Editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could potentially influence the work and findings in this paper.

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Paper II

Social acceptance of new floating offshore wind power: Do attitudes towards existing offshore industries matter?[1]

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Highlights

- Examining drivers for attitudes towards new floating offshore wind
- Discrete choice experiment used to determine willingness to pay
- Attitudes towards oil and gas and ocean aquaculture are important determinants
- Positive attitudes towards expanding ocean aquaculture increase social acceptance
- Positive attitudes towards expanding oil and gas extraction reduce social acceptance

Abstract

The exploitation of ocean-based wind energy resources is predicted to increase rapidly in the coming decades. Introducing offshore wind power will intensify the use of ocean space and could engender conflicts with conventional offshore industries, reducing its social acceptance. We conduct a discrete choice experiment and compute Norwegians' willingness to pay (WTP) for floating offshore wind farms to test whether their attitudes towards existing offshore industries affect their acceptance of this new energy technology. Results show that people's attitudes towards expanding the existing offshore industries including oil and gas extraction, ocean aquaculture, tourism, and shipping combined with socio-demographic characteristics are robust indicators for their acceptance of new floating offshore wind power projects. Notably, positive attitudes towards advancing ocean aquaculture and tourism boost social acceptance of new floating offshore wind power projects. By contrast, respondents who are positive about broadening oil and gas extraction activities are less willing to pay for new floating offshore wind power projects. As the Norwegian government will likely utilize public funds for upcoming floating offshore wind power projects, it

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is pertinent to comprehend the determinants of public acceptance of this new renewable technology to ease its implementation.

Keywords: offshore wind; floating technology; offshore industries; social acceptance; discrete choice experiment; willingness to pay.

1 Introduction

The ocean and sea space are akin to other resource-rich spaces, and thus, their operation is marred with similar challenges (Steinberg, 2001). Offshore industries share not only space but also compete for natural resources, supply chains, human resources, and technology. The deployment of offshore wind power projects is predicted to increase rapidly in the coming decades (IEA, 2022). Inaugurating offshore wind power projects will undoubtedly intensify the use of the ocean and sea space and, in turn, heighten competition between the new entrant and the conventional offshore industries. This assertion is especially relevant for countries like Norway, which have various offshore industries such as oil and gas extraction, carbon capture and storage (CCS), tourism, aquaculture, and shipping, and plans to establish an offshore wind power industry. Moreover, offshore wind power projects are likely to use floating platforms such as Spar Buoy and Submersible, commonly applied in the aquaculture and oil and gas sectors (Mäkitie et al., 2018).

Offshore wind power, especially floating technology, is not well known among the Norwegian population. Therefore, a survey to map their attitudes towards floating offshore wind was necessary to not only dissect their current knowledge but also to provide information about this technology. Furthermore, we sought to map Norwegians' attitudes towards expanding the existing offshore industries to understand better how their preferences for floating offshore wind have been formed. People's perceptions and preferences for or against such new technologies are based on the features of the new development itself. Furthermore, Bauer and Gaskell (1999) and Wagner and Kronberger (2001) argue that people's attitudes towards new developments could also be biased by their knowledge of or experience with similar existing structures. This would in our case be oil and gas extraction, ocean aquaculture, tourism, and shipping.

The existing literature applying discrete choice experiments (DCEs) to examine households' willingness to pay (WTP) for offshore wind farms accentuates their visibility from the shore and the aesthetic impacts (Ladenburg and Dubgaard, 2007; Krueger et al., 2011; Westerberg et al., 2013; Dalton et al., 2020; Lutzeyer et al., 2018; Kim et al., 2019; Ladenburg et al., 2020; Kim et al., 2021; Ladenburg and Skotte, 2022), impact on the marine environment (Börger et al., 2015; Kermagoret et al., 2016; Kim et al., 2019; Klain et al., 2020), as well as possible ownership (Linnerud et al., 2022; Vuichard et al., 2022) and conflicts that may occur in this use of ocean space (Westerberg et al., 2013; Dalton et al., 2020; Joalland and Mahieu, 2023).

Studies evaluating the effect of offshore wind farms on other industries and users of the ocean space feature residents' and tourists' WTP for visiting areas with turbines in view at varying distances from the shoreline. The overall impression is that visual disamenities that are substantial for near-shore wind turbines, become smaller with increased distance, and eventually, the WTP becomes zero or even positive (Ladenburg and Dubgaard, 2007; Krueger et al., 2011; Westerberg et al., 2013; Lutzeyer et al., 2018). In Ireland, recreational boaters prefer to pay more to avoid areas with offshore wind farms (Börger et al., 2020). Furthermore, attitudes towards offshore wind are influenced by their impact on job opportunities in the maritime sector, the availability of fresh seafood, and their impact on recreational activities (Joalland and Mahieu, 2023). However, to our knowledge, no study has assessed how households' acceptance of new floating offshore wind power projects relates to their attitudes towards expanding existing offshore industries.

We argue that positive attitudes towards expanding existing offshore industries can predict people's acceptance of a new one, such as floating offshore wind power. Our assumption is based on the renowned characterisation that the ocean is a resource that should be consumed (Steinberg, 2001). Studies show that people support ocean-based renewable energy technologies such as wave, tidal, and wind on the premise that the ocean is a resource (Devine-Wright, 2011; Bidwell, 2017; Johnson and Braverman, 2020; Bidwell, 2023).

Earlier scholars contend that one industry's use of ocean space can be interpreted and understood in the context of other uses (Hugill, 1993). This calls for an in-depth analysis of people's attitudes towards floating offshore wind power in the context of the 'blue-economy-blue-energies' nexus.

This study explores four main research questions: (i) Do people's attitudes towards expanding existing offshore industries predict attitudes towards developing new floating offshore wind power projects? (ii) Are socio-demographics significant determinants of attitudes towards developing new floating offshore wind power projects? (iii) Do positive attitudes towards expanding different offshore industries influence people's WTP for new floating offshore wind power development? (iv) Do people's socio-demographic characteristics influence their WTP for new floating offshore wind power development?

The remainder of this paper is organized as follows: Section 2 describes survey implementation and the econometric approach. Section 3 presents the data analyses and results. Section 4 discusses the results and draws comparisons with previous studies, while section 5 concludes.

2 Methods

2.1 The Norwegian Context

Norway is arguably known for its offshore industries. Norway is the largest oil and gas producer in Western Europe, one of the world's leading exporters of aquacultural products, and a front-runner in the development of offshore CCS technology (Norwegian Government, 2023).

Additionally, Norway is a pioneer in innovating solutions for zero and low-carbon shipping vessels (Tenold, 2019).

Offshore industries and related industries accounted for more than 60% of export earnings and 10% of employment in Norway in 2019 (DNB, 2021). The bulk of the export value accrued from the oil and gas sector, followed by shipping, aquaculture, fisheries, and tourism (DNB, 2021).

Due to the abundant offshore wind resources in Norway, coupled with a colossal ocean area, offshore wind is seen as an integral source of renewable energy. The Norwegian government has recently opened several ocean areas for installing offshore wind power projects (Norwegian government, 2023). For faster project deployment, the offshore wind industry will bank on technology, market skills and workers' competence from existing offshore industries. For instance, the oil and gas extraction and ocean aquaculture sectors use floating platforms that are relevant to the offshore wind power industry (Mäkitie et al., 2018). On the other hand, offshore wind can electrify traditional offshore industries directly by connecting transmission cables to offshore oil and gas platforms, such as in the case of the Hywind Tampen wind power project in Norway, or indirectly by generating green hydrogen that can be used in ships.

Public financing and the use of subsidies are essential if Norway is to realize its offshore wind power project goal of 30 GW by 2040. Though Norwegian companies have a glaring advantage concerning technical know-how and skills (Mäkitie et al., 2018), Norway still contends with the high installation costs for floating offshore wind power projects (IRENA, 2022). So far, subsidies have been proffered to the inaugural floating wind power project, Hywind Tampen. However, the use of subsidies, though prevalent in some offshore industries, including tourism, is not commonplace for the oil and gas industry. However, the oil and gas sector administers a 'special petroleum tax', which a few analysts categorize as subsidies (Aarsnes and Lindgren, 2012).

2.2 Data collection and survey implementation

Data were collected using an online survey conducted in November and December 2021 by an international survey company, Kantar. The survey was first sent to the Norwegian Centre for Research Data to examine and provide instructions for consent and data protection.

Kantar has an online panel of 40,000 adult Norwegian respondents representative of the Norwegian population. The respondents are recruited beforehand to participate in online surveys. Kantar sent the questionnaire to 3987 respondents randomly selected from the online panel. Out of 3987 respondents, 1337 opened the survey, and 1099 questionnaires were returned, which equals an 82% completion rate.

The survey began by informing the respondents that their participation would help map Norwegians' perceptions towards offshore wind power. To eliminate hypothetical bias, the respondents are informed that their responses are consequential, as they could potentially inform energy policies for the development of offshore wind power in Norway. The respondents are also informed that offshore wind power projects located in the deep Norwegian seas will use floating wind technology. They are further informed that the projects using floating wind technology would be expensive, thus necessitating government financial support. Finally, the respondents were informed about the critics' claims that these wind farms may kill birds, destroy marine life, and lead to conflicts with existing offshore industries. Then, the survey presented a drawing of floating wind power technology types (see Figure A in the Appendix) and the DCE described in subsection 2.3. After that, the survey asked attitudinal questions eliciting attitudes towards floating offshore wind power and offshore industries, described further in subsection 2.4. Lastly, socio-demographics such as age, gender, level of education, and income were collected, and respondents were also asked to indicate whether they resided along the coast.

2.3 The discrete choice experiment

The DCE was characterised by two offshore wind project alternatives, an 'opt-out' alternative, four attributes with three levels each and a cost attribute with six levels. The non-cost attributes and corresponding levels are adopted from (i) existing literature, e.g., project size and the use of electricity, (ii) Norwegian offshore wind plans, and market conditions, e.g., share of Norwegian technologies, (iii) expert prediction of technology development and cost reductions, e.g., reduction in technology costs in 2030. The attributes and levels are presented in Table 1. For a more detailed description of the attributes, and the main results from the DCE part of this survey; see Nytte et al., (2024).

Table 1 Description of DCE attributes and their levels

Attribute	Description	Levels
Project size	Size of the project in MW, and the number of turbines per project	500 MW, 1000 MW, 1500 MW
Share of Norwegian technology	Percentage share of Norwegian technology used in proposed projects	25%,50%, 75%
Reduction in technology costs in 2030	Contribution of projects to the future reduction in technology costs by 2030	10%, 20%, 30 %
Use of electricity	Where the produced electricity is consumed; in Norway, to electrify the offshore oil and gas extraction, or exported to other countries	Norway, Oil and gas, and Other countries
Increase in household's electricity bill for three years	The percentage increase in the household's annual electricity bill paid as a green subsidy	10%, 15%, 20%, 25%, 30%, 35%

Note: Project sizes 500MW,1000MW and 1500MW are referred to as small-size, medium-size and large-sized projects, respectively.

2.3.2 Design of the DCE

We used a D-efficient design and zero priors as recommended by Bliemer and Collins (2016). Using Ngene software, and a Multinomial Logit Model (MNL) design, we search for optimal combinations of the attribute levels. Apart from the use of electricity attributes, the attributes are continuous variables, and their levels are coded linearly. Ngene generates 18 choice tasks, which are grouped into three blocks. Therefore, each respondent was given six choice cards. Each choice card had two project alternatives and a status quo alternative. To reduce sequential bias, the choice cards are randomized across respondents in each block.

In the DCE design, we specified higher reductions in technology costs to be associated with higher percentage annual increases in household electricity bills. The specification is guided by the underlying condition for new technologies, whereby cost reduction is proportionate to an increase in production and mass deployment. Thus, more project financing, implying faster project deployment, is required in the initial phases to catalyse technology innovation and development. An example of a choice card is shown in Figure 1.

	OFFSHORE WIND 1	OFFSHORE WIND 2	NONE OF THESE
Project size	500 MW	1500 MW	No new Norwegian offshore wind power projects before 2030
Share of Norwegian technology	25%	50%	
Reduction in technology costs by 2030	30%	30%	
Use of electricity	Norwegian oil and gas sector	Transfer to other countries	
Increase in household electricity bill for three years	20%	30%	

Figure 1 Choice card–an example

2.4 Questions eliciting underlying attitudes towards offshore industries

Table 2 presents the questions used to elicit attitudes towards developing floating offshore wind power projects, wave power plants, and expanding existing offshore industries. The questions measuring attitudes towards offshore industries were randomized across respondents.

Table 2 Questions eliciting attitudes towards new floating offshore wind power and expanding offshore industries

Variable/s	Question
Floating wind power	How positive or negative are you towards the development of floating offshore wind power projects?
Wave energy	How positive or negative are you towards the Norwegian authorities facilitating the development of new wave power plants?
Offshore industries	Many industries would like to use Norwegian sea areas. How positive or negative are you about the further expansion of the following industries in the Norwegian Sea and Ocean areas? (i) Oil and gas (ii) Shipping (iii) Tourism (iv) Aquaculture, and (v) Carbon capture and storage

Note: All variables are measured on a 5-point Likert scale ranging from 1=very negative to 5=very positive.

2.5 Sample composition

Table 3 gives a summary of the socio-demographics of the sample and the Norwegian population. Out of 1099 returned questionnaires, we excluded 88 respondents who did not complete all the choice tasks. However, we included respondents who skipped or chose 'I don't know' responses to relevant variables used in the analysis. We treated the 'I don't know' responses as missing values, similar to skipped questions. Hence, we perform multiple imputations, which we discuss in the multiple imputations subsection 2.6.3.

To this end, our primary analyses are based on 1011 respondents. Comparing the socio-demographics between the sample and the Norwegian population, we observe that male and older people (between 60-89 years) are overrepresented, while female and younger people (between 18-29 years) are underrepresented in the sample. The education level is higher in the sample than in the national population. Notably, the respondents are well spread out across geographical regions. To control for sample non-representativeness, we include socio-demographics in our ordinal logistic models and sampling weights provided by the survey company, Kantar, in the mixed logit models.

Table 3 Socio-demographics of sample and population

Variable		Sample	Norway
Gender	Male	55%	49%
	Female	45%	51%
Age (years)	18 – 29	15%	20%
	30 – 44	23%	26%
	45 – 59	28%	26%
	60 – 89	34%	29%
Education	Primary	7%	25%
	Secondary	56%	40%
	University	37%	35%
Income	>300,000	17%	Median
(NOK)	300,000 – 499,999	33%	550,000
	500,000 – 699,999	25%	Mean
	700,000 – 999,999	11%	610,000
	≦1,000,000	3%	
	No response	11%	
Geography	Eastern Norway	34%	36%
	South−East Norway	8%	8%
	Western Norway	16%	16%
	Agder and Rogaland counties	14%	14%
	Middle and Northern Norway	27%	24%
Coast	Reside along the coast	52%	

Notes: 1 NOK = 0.1 USD. Income is the annual personal gross income in NOK. The percentages for coast variables are based on the number of respondents who indicated 'yes' for living along the coast. Statistics for the Norwegian population are based on Statistics Norway www.ssb.no.

2.6 Modelling approach and variable specification

2.6.1. Ordinal logistic regression

We employed ordinal logistic regression to predict households' attitudes towards new floating offshore wind power. The dependent variable captures general attitudes towards floating offshore wind power, measured by a 5-point Likert scale. The predictor variables featured include underlying attitudes towards expanding existing offshore industries, which are also measured by a 5-point Likert scale, and socio-demographic variables, comprising categorical variables, gender and level of education, and the continuous variable age. The specification is thus:

$$logit\big(P(Y \leq j)\big) = \beta_{j0} + \beta_1 O_i + \beta_2 D_i + \varepsilon_i \tag{1}$$

The equation models the probability of the dependent variable falling into a specific category based on the values of predictor variables. P(Y≤j) represents the probability that the dependent variable

Y falls into one of the categories less than or equal to j, where j is an integer representing the ordered Likert scale categories in Y. O_i is a vector for attitudes of existing industries, D_i is a vector for socio-demographics (female, university education, and age), and ε_i is the error term.

2.6.2 Mixed logit model

We use a mixed logit model to calculate households' WTP for developing new floating offshore wind power contingent on their underlying attitudes towards expanding existing offshore industries. Although a hybrid mixed logit could have captured better the heterogeneity relevant to policy formulation (Mariel and Meyerhoff, 2016), the model was not applicable in our case, due to the constructs failing to fulfil the requirements of exploratory multivariate analysis.

The mixed logit is founded on the MNL model (McFadden, 1974), which is based on consumer demand theory (Lancaster, 1966) and random utility theory (Thurstone, 1927). The mixed logit model is commonly used to analyse DCE data as it allows for the researcher to capture heterogeneous preferences and it avoids the independence of irrelevant alternatives (IIA) assumptions (Revelt and Train, 1998). All the mixed logit models reported in this paper are estimated in R 4.3.2 using the Apollo package version 0.2.9 (Hess and Palma, 2019) using 1000 Sobol draws as recommended by Mariel et al. (2021).

In the DCE study, each respondent was given 6 choice tasks. The utility derived by respondent n, choosing alternative i in choice situation t is assumed to be linear and comprises a deterministic and stochastic part and can be written as Equation 2.

$$U_{nit} = \sigma\left[\alpha_n C_{nit} + \beta_{n,x} X_{nit} + \gamma \mathrm{OFF}_n\right] + \varepsilon_{nit} \tag{2}$$

Where X is a vector of non-cost attributes including the alternative specific constant (ASC), C is the percentage increase in annual household bill, α is the fixed cost parameter, σ is the scale parameter and ε_{njt} is the error term that is assumed to be independent and identically distributed (i.i.d) following a type I extreme value distribution with a constant variance $\pi^2/6$.

The model specification indicates that utility for offshore wind projects is contingent on attitudes towards expanding existing offshore industries We create four indicator variables, equal to 1 if a respondent is 'very positive' or 'positive' towards each of the existing industries; oil and gas, shipping, tourism or aquaculture (see Table 5). Thus, OFF is a vector for the interaction effects of attitudes towards offshore industries and social demographics denoted as $> \gamma$.

In the willingness-to-pay space, WTP values for the attributes X_{nit} are calculated directly as $\rho = \beta/\alpha$. Estimating WTP in willingness-to-pay-space helps avoid magnitude and sign issues that may occur in the preference space(Daly et al., 2012). The utility function in (2) is rewritten as equation (3) below, and the cost parameter is inserted separately as α_n and is negative.

$$U_{nit} = -\sigma\alpha_n[C_{nit} - \rho X_{nit}] + \varepsilon_{nit} \qquad 3$$

We assume the parameters, ρ and α to have a normal and log-normal distribution, respectively (Train, 2009). The joint density is given as $f(\varphi \mid \phi)$, where φ captures the parameters' mean and variances and ϕ captures the means and variances of unobserved factors. Given this specification, the unconditional probability is given by an integral over all possible values of $\hat{\alpha}_n$.and $\hat{\rho}_n$.

$$\Pr(y_n \mid C_n, X_n, \Omega) = \int \prod_{t=1}^{T} Pr(j_{nt} \mid \hat{\alpha}_n, \hat{\rho}_n, C_{njt,} X_{njt}) f(\varphi \mid \phi_n) d(\varphi) \qquad 4$$

The unconditional probability is converted into a logarithmic form aggregated over the whole sample and the integral is solved by a simulated maximum likelihood estimator (Train, 2009).

2.6.3 Multiple Imputations

From an original sample of 1099 respondents, 227 respondents chose the 'I don't know' response or skipped questions for relevant variables used in this paper. In our primary analyses, we excluded 88 respondents who did not complete all the choice tasks: thus, remaining with 1011 respondents. Out of the 1011 respondents, 5% either chose 'I don't know' or skipped questions for important variables. However, a higher percentage of respondents, 9% and 14% have missing values for the electricity bill and CCS variables, respectively.

First, we test the pattern of missingness using Little's chi-squared test for missing completely at random (Little, 1988), and based on the non-significant results, we conclude that the data is missing at random. Based on the missing at-random assumption, multiple imputations can be used to fill the missing values. Second, we use all relevant variables, including socio-demographics in our imputation model. Lastly, we employ the multivariate imputations by chained equations in Stata 17 to fill in the missing observations. We generate a set of 20 data sets based on 10 nearest neighbours (Morris et al., 2014).

When running ordinal logistic and linear regression models, the data sets are pooled following Rubin's rules (Rubin, 1987), whereby parameters and standard errors are adjusted to cater for variability between the imputations. However, the Apollo package in R used for estimating the mixed logit models does not cater for multiple imputations. Hence, we calculate one value equivalent to the weighted average electricity bill for each individual with missing observations based on the 20 different generated data sets.

3. Results

3.1. The use of ocean and sea space

Based on responses to questions eliciting Norwegians' attitudes towards the expansion of offshore industries and the development of ocean-based renewable energy, we present the weighted mean scores for each of the offshore industries for the full sample in Table 4. We find respondents to be more positive towards developing wave energy, followed by shipping, and then floating offshore wind power. In addition, respondents prefer utilizing the ocean for CCS to increasing oil and gas extraction activities. Using t-tests, we determine whether the differences in mean distributions for the offshore industries and ocean-based energy technologies differ. We find that the mean scores vary significantly across the offshore industries, aside from that of floating offshore wind and tourism. We also calculate and present mean scores for the different offshore industries and energy sources across socio-demographics such as age (below and above 60 years), education (university or without university degree) and gender. Using t-tests, we find significant differences in attitudes towards all the offshore industries and ocean-based renewable energy sources between the socio-demographics.

Table 4 Means of variables for existing offshore industries and new ocean-based renewable energy technologies based on imputed data

	Full	Gender		Age		Education	
		Male	Female	≦ 59 years	≧ 60 years	No university	University
Wave energy	4.00	4.08	3.96	3.96	4.16	3.98	4.11
Shipping	3.80	4.02	3.65	3.70	4.12	3.90	3.79
Floating wind power	3.56	3.71	3.43	3.55	3.65	3.45	3.80
Tourism	3.54	3.70	3.44	3.51	3.72	3.65	3.49
Aquaculture	3.26	3.35	3.18	3.23	3.35	3.32	3.21
Carbon capture and storage	3.29	3.56	3.00	3.27	3.40	3.19	3.52
Oil and gas	3.10	3.36	2.86	3.11	3.21	3.33	2.86
No. of observations	1011	566	445	632	379	624	387

Notes: Respondents' attitudes towards offshore industries expanding their activities on the Norwegian ocean waters were measured on a 5-point Likert scale, where one represents 'very negative' and five represents 'very positive.' The mean scores for the full sample are weighted.

We determined respondents' attitudes towards developing the four main offshore industries in Norway. The share of respondents who are either positive, neutral or negative towards the existing offshore industries is given in Table 5. Combining the 'very positive' and 'positive' columns, 69%, 57%, 49% and 43% of the respondents are positive towards expanding shipping, tourism, aquaculture, and oil and gas activities in the Norwegian ocean space, respectively. We created dummy variables representing positive responses for each of the existing industries and used these variables in the mixed logit models discussed in subsection 3.3.

Table 5 Percentage of respondents who choose very negative, negative, neutral, positive, or very positive for each of the existing offshore industries

	Shipping	Tourism	Aquaculture	Oil and gas
Very negative	2%	1%	8%	14%
Negative	7%	12%	18%	17%
Neutral	22%	28%	25%	26%
Positive	42%	41%	36%	28%
Very positive	27%	16%	13%	15%

Note: Respondents' attitudes towards offshore industries expanding their activities on the Norwegian ocean waters were measured on a 5-point Likert scale, where one represents 'very negative' and five represents 'very positive'

3.2 Determinants of attitudes towards the exploitation of offshore wind

We evaluate whether attitudes towards existing offshore industries influence attitudes towards the development of new floating offshore wind using ordinal logistic regression. Attitudes towards floating offshore wind power and existing offshore industries were measured using a 5-point Likert scale. We excluded CCS in the subsequent analyses because it is primarily linked to the oil and gas industry. Furthermore, there is limited information on its contribution to revenue, employment and tax, hence, we did not classify it as a main offshore industry. We included categorical variables for females, and respondents with a university degree, while age is continuous. The odds ratios and standard errors (in parenthesis) are presented in Table 6. A positive odds ratio indicates that a change in the independent variable is positively associated with positive attitudes towards floating offshore wind power.

Based on the results, university-educated people are more likely to be positive towards floating offshore wind power, while females are less likely to be positive. People who are positive towards expanding aquaculture activities are more positive towards developing new floating offshore wind power, while those who are positive towards expanding oil and gas extraction are less positive.

Table 6 Determinant of attitudes towards developing new floating offshore wind power

	Ordered logit model
Variables	Odds ratio (s.e)
Socio-demographics	
Age	0.00(0.04)
Female	−0.52**(0.12)
University	0.57**(0.12)
Offshore industries	
Oil and gas	−0.15*(0.06)
Shipping	0.07(0.09)
Tourism	0.09(0.08)
Aquaculture	0.28**(0.06)
Pseudo R^2	0.07
No. of observations	1011

*Note: **0.01, *0.05 significance level. Ordered logit model run on imputed data.*

Attitudes for both dependent (floating wind power) and independent variables (offshore industries) are measured by a 5-point Likert scale ranging from 'very negative' to 'very positive'. Age is continuous while female and university are dummy coded equal 1 for female and for university education, respectively.

3.3 Marginal WTP estimates

We provide the marginal WTP estimates in this subsection. The project size, share of Norwegian technology, reduction in technology cost by 2030 and cost attributes are continuously coded, while the project size and use of electricity attributes are dummy-coded. The WTP estimates for the dummy coded variables are calculated relative to the base levels, 500MW project size and use of electricity in other countries, while the continuous variables are interpreted as an increase in the share of Norwegian technology and an increase in the reduction in technology costs.

We find that respondents have positive WTP for increasing the project size to 1000MW and 1500MW, relative to the 500MW base level and for supplying the produced electricity to mainland Norway. While the respondents have a positive WTP for increasing the share of Norwegian technology, they have a negative WTP for reducing future technology costs. The ASC is statistically significant and negative with a large standard deviation. This indicates that the respondents support the development of new floating offshore wind power projects, the base level, compared to postponing the development until after 2030. The cost coefficient in the mixed logit model is significant with a negative sign.

Table 7 Marginal WTP estimates for floating offshore wind power projects

	Mixed Logit	
	Coeff (s.e)	Std.dev(s.e)
ASC	−395.71**	1164.89**
	(34.18)	(65.61)
Project size −1000 MW	74.85**	30.73**
	(18.13)	(31.36)
Project size−1500 MW	90.94**	244.99**
	(16.00)	(21.78)
Share of Norwegian technology	3.48**	5.52**
	(0.38)	(0.36)
Reduction in technology cost by 2030	−2.35**	9.70**
	(0.99)	(0.93)
Use of electricity−Offshore oil & gas	73.32**	157.32**
	(15.89)	(216.89)
Use of electricity−Mainland Norway	299.48**	267.22**
	(211.86)	(21.31)
Cost	3059.84**	
	(271.84)	
Log-likelihood	−4717.61	
Adj. R-squared	0.2949	
BIC	9574.6	
No. of observations	6066	

*Note: **0.01, *0.05 significance level. Mixed logit results based on imputed data*

The project size and use of electricity attributes are dummy coded, and their base levels are project size, 500 MW and use of electricity, in other countries.

3.4 Effect of offshore industries and social demographics on WTP

We focused on the four major offshore industries in Norway based on their contribution to the economy in terms of revenue, and employment (Norwegian Government, 2023), hence we excluded CCS. We interact the four dummy variables representing the dummy variables for each industry with the ASC and use a mixed logit model, herein referred to as OFFSHORE. The results for the OFFSHORE model are presented in Table 8.

We observe that respondents who are positive towards expanding oil and gas oppose new floating offshore wind power. By contrast, respondents who are positive towards expanding both ocean aquaculture and tourism activities support the development of floating offshore wind power projects before 2030.

WTP for offshore wind power projects can also vary across socio-demographics. Therefore, we interacted ASC with the dummy variables for university education, females and continuous variable for age and used the mixed logit model, DEMOGRAPHICS presented in Table 8. We find that university-educated respondents support the development of new floating offshore wind power compared to the general population.

Table 8 The effects of attitudes towards expanding offshore industries and socio-demographics on the willingness-to-pay (WTP) for developing new floating offshore wind power projects

	OFFSHORE		DEMOGRAPHICS	
	WTP(s.e)	Std.dev(s.e)	WTP(s.e)	Std.dev(s.e)
ASC * Oil & gas	648.65**			
	(86.14)			
ASC * Aquaculture	−502.52**			
	(56.82)			
ASC * Tourism	−139.96**			
	(46.63)			
ASC * Shipping	−42.87			
	(51.49)			
ASC * Age			−1.29	
			(1.57)	
ASC * Female			−22.56	
			(43.85)	
ASC * University			−320.02*	
			(47.58)	
ASC	−333.16**	1232.68**	−290.47**	1253.06**
	(48.70)	(120.37)	(93.97)	(70.81)
Project size – 1000MW	87.54**	7.87	89.08**	11.21
	(18.70)	(23.92)	(20.03)	(33.26)
Project size – 1500MW	108.19**	248. 75**	101.46**	255.53**
	(16.22)	(27.14)	(17.53)	(25.31)
Share of Norwegian technology	3.83*	5.60**	4.12**	5.49**
	(0.40)	(0.69)	(0.39)	(0.45)
Reduction in technology cost by 2030	−2.16**	12.14**	−3.59**	14.62**
	(1.24)	(1.26)	(0.12)	(1.25)
Use of electricity−Offshore oil & gas	79.23**	140.34**	81.40**	151.66**
	(15.85)	(25.51)	(17.87)	(22.50)
Use of electricity−Mainland Norway	305.19**	277.87**	315.52**	316.27**
	(229.05)	(26.38)	(23.33)	(23.13)
Cost	−61.72**	101.58**	−64.91**	96.18**
	(10.35)	(13.98)	(9.29)	(13.52)
Log-likelihood	−4696.92		−4745.15	
Adj. R-squared	0.2974		0.2957	
BIC	9568.04		9584.28	
No. of observations	6066		6066	

*Note: **0.01, *0.05 significance level. Mixed logit results based on imputed data*

The project size and use of electricity attributes are dummy coded, and their base levels are project size, 500 MW and use of electricity, in other countries. Age is continuous while female and university are dummy coded equal 1 for female and for university education, respectively.

3.5 Heterogeneity analyses

Attitudes towards offshore wind power may vary across regions (Firestone et al., 2012). We calculated the mean scores for attitudes towards developing new floating offshore wind power and expanding offshore industries across regions (See Table A in the Appendix). A chi-square distribution test confirms that attitudes towards expanding oil and gas extraction, shipping, and aquaculture vary significantly across regions. We control for regional differences by running linear regression models for each of the six regions of Norway. The results are presented in Table B in the Appendix. We find that the attitudes of respondents in five regions (Southeast Norway, Agder and Rogaland counties, Western Norway, Middle Norway, and Northern Norway) are more influenced by their socio-demographic characteristics than their underlying attitudes towards expanding existing industries. By contrast, the attitudes of respondents residing in Eastern Norway are solely influenced by their underlying attitudes towards expanding existing industries. Notably, people having positive attitudes towards ocean aquaculture also have positive attitudes towards floating offshore wind in three of the six regions (Eastern, Middle and Northern Norway), the two latter regions also have most of the current aquaculture in the fjords

Besides, attitudes may also differ between coastal and non-coastal communities. We ran linear regression models separately for coastal and non-coastal communities (see Table C in the Appendix). In both subsamples, positive attitudes towards ocean aquaculture result in positive attitudes towards floating offshore wind. The results for social-demographic variables are mixed. Highly educated people in the coastal subsample, but not in the non-coastal subsample, are significantly more positive towards new floating offshore wind power; and females living on the coast are significantly more negative towards offshore wind than men, while the opposite is true for the non-coastal communities.

3.6 Robustness checks

The study controls for the results by conducting robustness checks; (i) reproducing the results presented in Table 6 using a different regression method, (ii) reproducing the results in Table 8 using MNL models, (iii) using the sample with full information, (N=872), before multiple imputations and; (a) testing and controlling for potential bias to the results, in case missing responses were not random, and (b) using inverse probability weights to test and control for potential bias in the ordinal logistic regressions. The results of the robustness checks are presented in Tables D−F in the Appendix.

First, we reproduce the results presented in Table 6 using the ordinary least squares regression model. The results are comparable for ordinal logistic regressions and linear regression models regarding predictors, direction and the level of significance.

Second, assuming homogeneous preferences across the population, we use the MNL models in place for mixed logit models. We observe that the signs of the means remain the same, apart from the ASC which is now positive and significant. Indicating that under the assumption of homogenous preferences, respondents are unwilling to support the development of new floating offshore wind power before 2030.

Third, we test for attrition bias considering the original sample(N=1099); reduced to 872 respondents when we excluded 'I don't know' responses and respondents who skipped relevant questions, including the choice tasks. Comparing the socio-demographics for the original and reduced samples using t-test and chi-squared tests, we observed that the samples were statistically different in terms of age, gender, and education level. However, the two samples are comparable in terms of education and geographical location. Based on the Little test performed in the multiple imputation's subsection 2.6.3 above, the data is assumed missing at random. Hence, we run a probit model that predicts the probability of a respondent not being in the full sample, using the dummy dependent variable for respondents that are excluded from the primary analyses with social demographics as additional covariates. We generate inverse probability weights; a reciprocal of the predicted probability of the sample having complete records. Thereafter, we use the generated weights as additional covariates in the ordinal logistic models. We observe that the inverse probability weights are not statistically significant. Hence, we conclude that there is no attrition bias.

4. Discussion

The results show that Norwegians are generally positive towards new ocean-based technologies such as floating wind technology and wave energy. The positive attitudes are observed in previous studies for wave energy (Heras-Saizarbitoria et al., 2013), power-to-gas (Azarova et al., 2019), tidal (Devine-Wright, 2011), and hydrogen (Schönauer and Glanz, 2022). Norwegians are more positive towards moving energy projects offshore and to remote locations away from where people live, mirroring the results reported by Linnerud et al. (2022). Interestingly, the respondents are more positive towards wave energy than floating offshore wind, despite both technologies having a huge potential (Christakos et al., 2020) and being novel where only prototypes of each had been developed in Norway (at the time this survey was conducted). However, while floating technology is gaining interest in Norway, the interest in wave energy declined years ago due to technical challenges and organisational capacity (Christiansen and Buen, 2002). The less positive attitudes towards floating offshore wind power compared to wave energy are likely influenced by negative experiences from exposure to and experience with onshore wind farms both directly (turbines) and indirectly via social media (Dugstad et al., 2020; Simonsen, 2022).

The respondents are positive towards expanding existing offshore industries, especially shipping and tourism. Overall, the positive attitudes towards expanding existing offshore industries can be explained by the perceived economic benefits such as job creation, tourist attraction, revenue, and energy (Lahn, 2019). However, negative attitudes may stem from environmental effects, greenhouse gas emissions and potential competition in the use of ocean space (Mather and Fanning, 2019).

Specifically, the respondents are more positive towards expanding shipping, and tourism, compared to other existing offshore industries. This is not surprising as the ocean is primarily viewed as a transport hub (Steinberg, 2001); and as the tourism industry has grown significantly, increasing people's interactions with the ocean and seascapes. The respondents view the use of the Norwegian continental shelf for CCS positively, akin to findings by earlier studies in Norway (Tjernshaugen, 2010). The respondents support the government's initiative to meet its climate goals or 'lengthen' its oil production using CCS to contain production-related emissions from the oil and gas sector. By contrast, the respondents are negative towards expanding oil and gas extraction on the Norwegian continental shelf. This means they support reducing the number of exploration licenses, and gradual divestment from the sector to manage the 'imminent' decline of the fossil fuel industry (Lahn, 2019). Lastly, lower positivity towards expanding ocean aquaculture compared to tourism and shipping may stem from the perceived large ecological footprint of aquaculture in Norwegian fjords and scepticism by non-beneficiaries (Krøvela et al., 2019; Aanesen et al., 2023).

In the following subsections, we discuss the results in light of our four research questions.

4.1 Attitudes towards existing offshore industries

Using ordinal logistic regression models, we find that underlying attitudes towards expanding oil and gas extraction and ocean aquaculture are significant predictors of people's attitudes towards the development of new floating offshore wind power. Oil and gas and ocean aquaculture industries contribute significantly to the Norwegian economy; hence it is likely that the respondents are positive towards the new offshore wind power industry, because of the perceived economic benefits such as employment (Kallbekken and Sælen, 2011). Most importantly, people who are positive towards ocean aquaculture and tourism, are significantly more positive towards new floating offshore wind projects. This might be due to ocean aquaculture and floating offshore wind power sharing the same technology, including floating platforms (Mäkitie et al., 2018). The tourism industry in Norway receives subsidies, like the new offshore wind power industry. However, the former is run by municipal governments, unlike the latter where the first existing project, Hywind Tampen, is managed at a national level. It may be possible that people who are positive towards expanding tourism are positive towards developing the offshore wind industry because the turbines can influence tourism positively. However, the effect of offshore wind power on tourism is inconsistent in the literature (Smythe et al., 2020; Machado and Andrésb, 2023).

On the contrary, people who are positive towards expanding oil and gas extraction are less positive towards the development of new floating offshore wind power projects. This may stem from the perceived competition between the two industries. Offshore wind power is predicted to replace the oil and gas industry as a new revenue source and to offer employment opportunities to 'stranded' workers, especially as countries increasingly reduce investments in fossil fuels (Lahn, 2019).

4.2 Impact of attitudes towards existing offshore industries on WTP

Based on the interactions between the ASC and dummy variables capturing positive attitudes towards expanding different offshore industries, we find that a positive outlook for expanding oil and gas and shipping activities impacts social acceptance, by either opposing or supporting new floating offshore wind power, respectively. The Norwegians may perceive aquaculture and floating offshore wind power as non-competing in terms of location, technology, and purpose but rather complementary. Aquaculture is concentrated in Northern Norway and along the west coast, while the proposed offshore wind power projects are to be sited in the open seas in southern and western Norway (Norwegian Government, 2023). Second, the aquaculture industry intends to reduce its carbon emissions through electrification and the use of low-carbon fuels in its operations. Offshore wind power can be an important energy source to achieve this objective in the ocean aquaculture sector. Third, the aquaculture industry also uses floating platforms (Afewerki et al., 2022), which are also applicable to the offshore wind industry. Offshore wind and offshore aquaculture farms are mutually beneficial in terms of local use of electricity and reducing the carbon footprint of aquaculture.

Besides the 'competition' that may exist between oil and gas and offshore wind power, the two industries can be complementary in terms of technology, skills, and electrification to reduce the carbon footprint of oil and gas extraction activities. However, the respondents do not seem to support this, as those who are positive about expanding oil and gas extraction activities oppose developing new floating offshore wind power projects.

4.3 Socio-demographics as determinants of attitudes and WTP

The effect of socio-demographics on attitudes and WTP for wind power projects is inconsistent in the literature. In concert with existing research (Langer et al., 2018; Boudet, 2019), we find highly educated respondents to be more positive towards developing floating offshore wind power. By contrast, female respondents are negative towards new floating offshore wind power. However, only education influences WTP for new floating offshore wind power. Unlike other studies, age and gender does not influence WTP. For instance, Ladenburg and Dubgaard (2007) and

Westerberg et al. (2023) found older samples to be less favourable towards offshore wind farms mainly due to visual factors. By contrast, Ladenburg and Skotte (2022) found WTP to increase with an increase in age. Moreover, Krueger et al. (2011) found males to be less favourable towards offshore wind power than females in their ocean segment; one of the three latent groups.

4.4 Heterogeneity analyses

Although respondents are generally positive towards new floating offshore wind power projects, and their attitudes are predicted by the same factors, we observe some differences across regions. For instance, respondents in Eastern Norway are more positive towards new floating offshore wind than other regions. This is observed by earlier onshore wind power studies conducted in Norway (e.g., Dugstad et al., 2020), and may stem from the very few wind turbines in Eastern Norway. Hence Eastern Norway respondents' attitudes to new offshore wind power may not be influenced by exposure to disammenities emanating from onshore wind turbines. Thus, they may prioritize enhancing energy security, a decisive factor for accepting new offshore wind farms as documented by other studies (e.g., Firestone et al., 2012). In contrast, less positive attitudes towards offshore wind in other regions may stem from perceived distributional injustices, whereby a few regions incur the disammenity and external costs of wind power, whereas the whole country benefits in terms of increased electricity production (see Bidwell et al., 2023).

5. Conclusion

We used a national survey to evaluate the social acceptance of floating offshore wind power. The study addresses four main research questions: (i) Can people's attitudes towards expanding existing offshore industries predict attitudes towards developing new floating offshore wind power? (ii) Do socio-demographic characteristics affect people`s attitudes towards new floating offshore wind power? (iii) Do attitudes towards expanding different offshore industries influence people's willingness to pay for floating offshore wind power? and (iv) Do people's socio-demographics influence their willingness to pay for new floating wind power projects?

Based on ordinal logistic regressions, underlying attitudes towards expanding oil and gas extraction, ocean aquaculture and people's characteristics are significant predictors of attitudes towards new floating offshore wind power. Based on the mixed logit models, we find that positive attitudes towards expanding ocean aquaculture, tourism, and oil and gas activities significantly influence WTP for the development of floating offshore wind power projects. Lastly, we find that education is a consistent predictor of attitudes towards the development of new floating offshore wind power projects.

The results indicated the importance of informing people about new technologies and engaging with the public to understand their preferences for the use of ocean space. This also shows that gaining trust through information sharing and consultation with the general public will be pertinent for successful project implementation.

Furthermore, the Norwegian government needs to increase the dialogue with experts from existing offshore industries and the offshore wind industry to map out offshore resources and plan the use of ocean space, matching industries to ocean areas with optimal resources for each industry. The government can develop strategies and regulations that promote and govern space-sharing between offshore industries to avoid future conflicts. To circumvent conflicts and possible wind power project delays due to social acceptance problems, the Norwegian government should formulate policies that allow for seamless integration between the offshore wind industry and existing offshore industries.

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Appendix

Figure A Picture depicting types of floating wind power technology

Note: Illustration by Joshua Bauer, NREL

Table A Attitudes toward expanding existing offshore industries and developing new ocean-based renewable energy technologies across regions

	Full	Eastern	Southeast	Western	Agder & Rogaland	Middle	Northern
Wave energy	4.00	4.04	3.93	4.02	4.04	4.07	4.04
Shipping	3.80	3.81	3.94	3.92	4.04	3.70	3.88
Floating offshore wind	3.56	3.67	3.60	3.59	3.60	3.52	3.38
Tourism	3.54	3.64	3.67	3.55	3.69	3.50	3.43
Aquaculture	3.26	3.39	3.44	3.15	3.26	3.30	2.99
Carbon capture and storage	3.29	3.40	3.30	3.43	3.32	3.15	3.18
Oil and gas	3.10	3.01	3.31	3.11	3.49	3.18	3.02
No. of observations	1011	342	80	161	143	174	111

Note. The regions are grouped based on Norwegian counties. The eastern region includes Oslo and Viken, the Southeast is Vestfold and Telemark, the Western region includes Vestland and More and Romsdal, the Middle region, comprises Innlandet, and Trondelag and the Northern comprises, Nordland, Troms and Finnmark counties.

Table B Determinants of attitudes towards exploitation of floating offshore wind power across regions in Norway based on linear regression models

	Eastern	Southeast	Western	Agder & Rogaland	Middle	Northern
Variables	Coeff(s.e)	Coeff(s.e)	Coeff(s.e)	Coeff(s.e)	Coeff(s.e)	Coeff(s.e)
Constant	2.95**(0.39)	3.85**(0.94)	3.42**(0.56)	3.22**(0.56)	3.72**(0.63)	2.77**(0.72)
Socio demographics						
Age	−0.03(0.13)	0.48(0.29)	0.24(0.19)	−0.04(0.20)	−0.07(0.20)	0.15(0.25)
Female	−0.07(0.13)	−0.32(0.29)	−0.49*(0.19)	0.57*(0.19)	−0.41*(0.19)	0.05(0.25)
University	0.28(0.13)	0.69*(0.33)	0.42*(0.19)	0.53*(0.18)	0.07(0.21)	0.63*(0.25)
Offshore industries						
Oil and gas	−0.19*(0.06)	0.11(0.15)	−0.14(0.10)	−0.15(0.10)	−0.13(0.09)	0.17(0.11)
Shipping	0.07(0.10)	−0.25(0.23)	0.13(0.14)	0.15(0.13)	−0.07(0.14)	0.07(0.16)
Tourism	0.13(0.09)	0.07(0.23)	−0.08(0.12)	0.08(0.12)	0.13(0.13)	−0.15(0.15)
Aquaculture	0.16*(0.06)	0.03(0.18)	0.26*(0.09)	0.17(0.09)	0.24*(0.10)	0.01(0.11)
Adjusted R^2	0.05	0.01	0.11	0.15	0.04	0.02
No. of observations	342	80	161	143	174	111

*Note: **0.01, *0.05 significance level. Attitudes for both dependent and independent (offshore industries) variables are measured by a 5-point Likert scale ranging from 'very negative' to 'very positive'. Age is continuous while female and university are dummy coded equal 1 if the respondent is female and has a university education. The regions are grouped based on Norwegian counties. The eastern region includes Oslo and Viken, the Southeast is Vestfold and Telemark, the Western region includes Vestland and More and Romsdal, and the Middle region, comprises Innlandet, Trondelag and the Northern region comprises, Nordland, Troms and Finnmark counties. The data is imputed.*

Table C Determinant of attitudes towards exploitation of floating offshore wind power for coastal and non-coastal subsamples based on linear regressions

	Coastal respondents	Non-coastal respondents
	Coeff(s.e)	Coeff(s.e)
Constant	3.16**(0.35)**	3.34**(0.35)
Socio-demographics		
Age	0.00(0.00)	0.00(0.00)
Female	−0.25*(0.11)	0.34**(0.11)
University	0.49**(0.11)	0.27(0.11)
Offshore industries		
Oil and gas	−0.09(0.05)	−0.10*(0.05)
Shipping	0.02(0.08)	0.08(0.08)
Tourism	−0.00(0.07)	0.07(0.07)
Aquaculture	0.17**(0.05)	0.18*(0.07)
Adjusted R^2	0.08	0.07
No. of observations	515	496

*Note: **0.01, *0.05 significance level. Attitudes for both dependent and independent (offshore industries) variables are measured by a 5-point Likert scale ranging from 'very negative' to 'very positive'. Age is continuous while female and university are dummy coded equal 1 if a respondent is female and has a university education.*

Table D Determinant of attitudes towards developing floating offshore wind power based on ordinary least squares regression model

	Floating offshore wind power
	Odds ratio(s.e)
Socio-demographics	
Age	−0.02(0.00)
Female	−0.12**(0.13)
University	0.16**(0.14)
Offshore industries	
Oil and gas	−0.10*(0.12)
Shipping	0.03(0.01)
Tourism	0.03(0.01)
Aquaculture	0.17**(0.16)
Adjusted R^2	0.16
No. of observations	1011

*Note: **0.01, *0.05 significance level. Attitudes for both dependent and independent (offshore industries) variables are measured by a 5-point Likert scale ranging from 'very negative' to 'very positive'. Age is continuous while female and university are dummy coded equal 1 if a respondent is female and has a university education.*

Table E The effects of attitudes towards the expansion of offshore industries and socio-demographics on the willingness-to-pay (WTP) for developing new floating offshore wind power projects based on multinomial logit model

	MNL without interactions	OFFSHORE	DEMOGRAPHICS
		WTP	WTP
ASC * Oil & gas		384.47**	
		(51.07)	
ASC * Aquaculture		−397.97**	
		(50.07)	
ASC * Tourism		−127.48*	
		(43.26)	
ASC * Shipping		−49.92	
		(47.27)	
ASC * Age			−1.41
			(0.10)
ASC * Female			4.64
			(34.08)
ASC*University			−201.49**
			(38.16)
ASC	96.92**	221.54**	239.12 **
	(52.29)	(62.85)	(76.22)
Project size – 1000MW	143.79**	154.08**	142.62**
	(33.32)	(34.76)	(33.25)
Project size – 1500MW	139.78**	140.89**	139.93**
	(26.99)	(27.81)	(26.92)
Share of Norwegian technology	6.59**	6.76**	6.57**
	(0.66)	(0.69)	(0.66)
Reduction in technology cost by 2030	−8.54**	−9.05**	−8.50**
	(1.79)	(1.88)	(1.79)
Use of electricity−Offshore oil & gas	127.14**	130.02**	126.82**
	(29.54)	(30.45)	(29.47)
Use of electricity−Mainland Norway	449.30**	460.42**	448.94**
	(36.09)	(37.88)	(36.09)
Cost	16.54**	−16.10**	−165.94**
	(1.15)	(1.16)	(11.63)
Log-likelihood	−6311.36	−6220.02	−4745.15
Adj. R-squared	0.059	0.072	0.0608
BIC	12692.4	12544.56	12685.16
No. of observations	6066	6066	6066

*Note: **0.01, *0.05 significance level. Results based on imputed data*

The use of electricity attribute is dummy coded, and its base level is the use of electricity in other countries.

Age is continuous while female and university are dummy coded equal 1 for female and for university education, respectively.

Table F Determinant of attitudes towards exploitation of floating offshore wind power. Inverse probability weights were included as additional covariates to control for attrition bias.

	Floating offshore wind power
	Odds ratio(s.e)
Inverse probability weights	0.99(0.10)
Socio-demographics	
Age	1.00(0.01)
Female	0.54(0.17)
University	1.85**(0.37)
Offshore industries	
Oil and gas	0.88*(0.06)
Shipping	1.07(0.10)
Tourism	1.10(0.09)
Aquaculture	1.31**(0.08)
Pseudo R^2	0.03
No. of observations	872

Paper III

People, power and the ocean: Analysing public attitudes towards floating offshore wind power in Norway[1]

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Highlights

- National-level analysis of attitudes towards floating offshore wind power
- Respondents were randomly assigned to either electricity or climate framing
- Positive attitudes increase when the ocean landscape is viewed as beautiful
- Ocean meanings are stronger predictors of negative attitudes in the climate framing
- Technology risks and benefits are the most important predictors of attitudes

Abstract

Research on ocean meanings and place attachment has advanced the understanding of social acceptance of offshore wind power projects. However, existing studies focus mostly on ocean meanings and place attachment in the context of offshore wind power in general, coastal communities and specific locations at the coast. This focus limits the generalizability of the findings to wind power projects that use floating wind power technology and have cost-benefit implications for the general population. Using a national sample, this study evaluates the influence of ocean meanings, place attachment and technology risk and benefit perceptions on attitudes towards floating offshore wind power technology in Norway. To test the effect of policy framing, respondents are randomly assigned to either an electricity demand framing or a climate objective framing. Results show that respondents who perceive the ocean as beautiful are positive towards floating offshore wind power. The attitudes of respondents in the climate framing are more negatively influenced by ocean meanings than those in the electricity framing. Notably, underlying risk and benefit perceptions of floating wind power technology are the most significant predictors of attitudes.

Keywords: Ocean meanings, place attachment, policy framing, floating wind power technology, offshore wind

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1 Introduction

The ocean is a unique place with specific qualities (Gee, 2010). Compared with the mainland, which has undergone huge transformations and been conquered by humans, the ocean is valued for its wilderness, richness in biodiversity and aesthetic value (Klain et al., 2014). People continually interact with the ocean and feel protective about it (Gelcich et al., 2014), and the ocean remains instrumental in human history, as well as in the development of science and languages (Mentz, 2009; Alaimo, 2019). The ocean is an important source of food, a place for inspiration and a transport hub (Steinberg, 2001; Longo and Clark, 2016). Notably, the ocean has abundant energy resources that are now increasingly exploited (GWEC, 2022). For instance, the Norwegian government recently opened more ocean and sea areas for developing wind power projects (Norwegian Government, 2023). The growth of offshore wind power projects will likely transform the ocean landscape and seascapes and reshape the way people perceive the ocean.

This study focuses on two socially constructed concepts, place meanings and place attachment, which make up the concept of 'sense of place' (Tuan, 1974). Place meanings are cognitive or evaluative beliefs that reflect the physical characteristics and social and cultural importance of a place to an individual or a group (Manzo, 2005; Stedman, 2003). Place attachment is defined as the relationship people develop with their environment (Greider and Garkovich, 1994). An important distinction between the two concepts is that place attachment involves an emotional bond between people and the environment (Manzo, 2005), while place meanings are based on descriptive elements. However, place meanings and place attachment are interrelated, as people are attached to the meanings they ascribe to a place rather than the place itself (Stedman, 2003). The study uses ocean meanings and place attachment henceforth.

Several studies confirm that ocean meanings and place attachment influence people's attitudes towards offshore wind power projects. People oppose wind power projects when they hold strong meanings and attachments to the ocean landscape and seascapes (Westerberg et al.,2013; Bidwell, 2017; Firestone et al., 2018; Devine-Wright and Wiersma, 2020; Lamy et al., 2020; Russell et al., 2020; Bidwell et al., 2023; Bingaman et al., 2022). However, existing studies highlight community-level acceptance of offshore wind power projects located at specific locations along the coast. There has been limited interest in understanding the influence of meanings and attachment to the ocean on the socio-political acceptance of floating offshore wind power projects.

Wüstenhagen, et al. (2007) conceptualized social acceptance into three dimensions, socio-political, community and market acceptance. Socio-political acceptance is concerned with how the general public, key stakeholders and policymakers view energy policies and technologies, including offshore wind power. Researchers have discovered a so-called social gap between the widespread general acceptance of renewable energy and the low deployment of energy projects (Bell et al., 2005), which is explained by the distinct approaches for examining socio-political and community acceptance. A review by Batel (2020) classifies studies into three waves, conditional on the period of publication and their approach to examining social acceptance. The first and second waves of the social acceptance literature delve into the now-debunked *not-in-my-backyard* explanation of opposition to energy projects. However, recent literature, referred to as the third wave seeks to analyse specific responses such as support (Dermont et al., 2017), and distinct from the first and second waves, it questions whether opposition towards renewable energy should be minimized (for a review, see Wolsink, 2018; Batel, 2020). Alternatively, this third-wave literature dissects power relations and how they shape attitudes towards renewable energy technologies, and their deployment (Kropp, 2018; Sovacool and Brisbois, 2019). While there is extensive literature on community-level acceptance, there is limited research on public acceptance of energy projects in the context of people–ocean relations. Thus, this will be addressed in this study.

Offshore wind power projects are realized using either fixed-bottom or floating wind technology. The choice of technology is informed by the water depth, with 60 m being the threshold for fixed-bottom technology (NREL, 2023). In the Norwegian context, the average water depth for the oceans and seas is greater than 60 m, apart from the North Sea, which is roughly 60 m. Consequently, most of the Norwegian offshore wind projects will use floating wind technology. Based on the planned offshore wind power projects, a few projects will be located at least 20 km from the Norwegian mainland (e.g., Utsira Nord and Vestvind A), while the majority will be installed more than 40 km from the mainland (e.g., Sørlige Nordsjø II and Hywind Tampen) (NVE, 2023). Contingent on the distance from the coastline, offshore wind power projects can be considered either near-shore or far-shore.

Unlike fixed-bottom, floating wind technology is expensive (GWEC, 2022), and fairly recent, as perceived by the general population, but is not necessarily new to experts or policymakers. The possible lack of knowledge about floating wind technology can affect people's perceived risks and benefits (Ajzen, 1991; Huijts et al., 2012), as they may rely on their general attitudes towards technology or prior experiences with similar technologies. Existing studies elicit attitudes towards the two technologies, fixed-bottom and floating, under the umbrella term 'offshore wind'. Based on the premise that attitudes towards technology depend on the type of technology and context (Frewer et al., 1998), it is pertinent to explore people's attitudes towards floating wind technology specifically.

The spatial nature of offshore wind power projects in a country with extensive coastlines, like Norway necessitates a national-level approach to examining people-ocean relations. First, Norway's plans for meeting national electricity demand and mitigating climate change entail inaugurating several offshore wind power projects. Second, these projects are likely to rely on public financing, until floating wind technology reaches commercial feasibility. In terms of development and operations, these projects are constructed by national or multinational companies, and they are often overseen by the state. The impacts of far-shore floating wind power projects may be felt by local communities, which will host complementary infrastructure including transmission lines and substations or encounter changes in electricity prices (Wolsink, 2018). However, deploying offshore wind has far-reaching effects affecting locals and non-locals alike, including those using the ocean and sea space for recreation and fishing (Haggett, 2008). Possible consequences of the presence of turbines include overcrowding, displacement, reduced incomes, and higher fuel expenditure due to the rerouting of vessels (Chaji and Werner, 2023).

This national-level significance of both the costs and benefits of offshore floating wind power projects is demonstrated by Hywind Tampen. This groundbreaking project supplies electricity to offshore oil and gas platforms, effectively mitigating carbon emissions emanating from these installations. The Norwegian government has provided substantial subsidies amounting to 2.3 billion Norwegian kroner (Equinor, 2022). Furthermore, the key project features, including operation, installation and components are contracted to either national or international companies including Aker Solutions, Siemens Gamesa and Subsea 7. Hence, examining the social-political acceptance of new floating offshore wind power projects is of great interest.

Social-political acceptance is influenced by factors such as people–place relations (Devine-Wright, 2011; Devine-Wright and Howes, 2010; Bidwell, 2017; Lamy et al., 2020; Bidwell et al., 2023; Bingaman et al., 2022) and other contextual factors such as type of technology and its perceived risks and benefits (Frewer et al., 1998; Contu et al., 2016; Groot et al., 2020; Linzenich et al., 2020) and framing of energy policies (Eaton et al., 2013; Walker et al., 2014; Feldman and Hart, 2018; Hazboun et al., 2019; Wolsink, 2020; Bollman, 2022)

Therefore, this study aims to answer four main research questions: (i) Do Ocean meanings influence attitudes towards floating offshore wind power? (ii) Does place attachment influence attitudes towards floating offshore wind power? (iii) Do risk and benefit perceptions of floating wind power technology matter? (iv) To what extent do attitudes differ due to policy framing?

The findings are based on a nationwide survey, administered to Norwegian adult respondents by an international survey company, Kantar. The study randomly splits the respondents into two subgroups, and the respondents are given information for one of each framing highlighting the objective to develop floating offshore wind power to either meet electricity demand or climate objectives.

Exploring energy policy framing is timely and relevant today, as there has been an energy crisis in Europe since 2021 (IEA, 2022), induced primarily by the Russian–Ukrainian war (IRENA, 2023) and aggravated by apparent extreme weather changes (UNFCCC, 2022) and ever-increasing energy demand. Considering Norway has deep coastlines compared with other countries, increasing energy supply while reducing carbon emissions will require Norway to adopt expensive but necessary technology pathways including floating wind power technology. The ocean, similar to the land, has abundant energy sources, but it also faces climate change problems that will affect its ability to sustain marine life (IPCC, 2019) and other uses related to the blue economy (Bruno et al., 2018). However, introducing wind power projects may also harm the marine environment (Klain et al., 2020; Lloret et al., 2022). This falls under the 'green versus green' controversy, which is studied extensively in the context of onshore wind (Warren et al., 2005; Rygg, 2012; Wang and Wang, 2015). The 'green versus green' controversy pertains to the development and the conservation of the landscape. In the development of renewable energy projects, the costs (e.g., biodiversity) and the benefits (e.g., green energy) have to be balanced. Depending on the costs and benefits, pro-environmentalists may either support, oppose or remain neutral towards specific projects (Warren et al., 2005; Rygg, 2012; Wang and Wang, 2015).

2 Literature Review

The aforementioned factors for people-place relationships, technology risks and benefits, and policy framing have previously not been studied in the context of floating wind power technology. This study aims to fill this gap. The literature review in the subsequent subsections is thus informed by these factors and compares findings from other ocean-based renewable energy technologies.

2.1 Concept of place

A place is an important concept in human geography (Kaltenborn and Williams, 2002), environmental psychology (Williams and Vaske, 2003), and sociology and refers to space that has become meaningful through emotions, social bonds, feelings and lived experiences (Tuan, 1977; Stedman, 2003).

A place can be perceived as one specific location or region or can extend over various scales (Jessop et al., 2008). Individuals can form meanings about imagined places, as well as places they have lived (Gustafson, 2009) and visited for recreation and tourism (Williams and McIntyre, 2011). People can get attached at different scales: locally, regionally and globally (Gustafson, 2009; Lewicka, 2011; Devine-Wright and Batel, 2017; Sebastien, 2020).

The ocean as a place exhibits the three elements crucial for meaning-making (Agnew, 1987). Agnew (1987) argues that a place is a *locale*, a possibility of social interactions, either formal or informal, a *location*, a geographical area where cultural and economic factors can operate on a wider scale, and a *sense of place*, a feeling of belonging towards a spatial setting, and it comprises both place meanings and place attachment (Jorgensen and Stedman, 2001; Trentelman, 2009). To capture the meaning of a place, studies need to consider all three dimensions (Agnew and Duncan, 2014). In most studies, however, one of the three elements tends to dominate (Gustafson, 2001). The ocean area surrounding Norway is geographically located, *location*, and is a setting for human interaction, *locale*, where people can form meanings, i.e., natural beauty, pristineness, intrinsic, exploration and a place for inspiration, and can get attached to these meanings.

In contrast to ocean meanings, place attachment is characterised by place identity and place dependency. While identity refers to the way people connect a place's physical attributes to their own identity (Proshansky et al., 1983), dependence refers to the ability of a place to meet certain needs (Vaske and Kobrin, 2001). The ocean offers an opportunity to reflect, introspect and understand oneself, which can contribute to a person's identity (Manzo, 2005). This paper accentuates the identity aspects of place attachment (Stedman, 2003).

2.2 Social acceptance of marine renewable energy projects in the context of people-place relations.

Due to the extensive literature on community-level acceptance, but limited research on public acceptance of energy projects in the context of people–ocean relations, this section blends studies eliciting general acceptance and specific acceptance. Noteworthy, some researchers, though interested in community-level acceptance, measure people's meanings and attachment to the ocean as a whole or in multiple ways (Bidwell, 2017; Devine-Wright and Batel, 2017; Russell et al., 2020).

Research reveals that ocean meanings and place attachment influences acceptance of ocean-based energy technologies including wave (McLachlan, 2009), tidal (Devine-Wright, 2011) and wind (Devine-Wright and Howes, 2010; Westerberg et al., 2013; Bidwell, 2017; Firestone et al., 2018; Russell et al., 2020; Lamy et al., 2020; Bidwell et al., 2023; Bingaman et al., 2022). However, social acceptance varies significantly across ocean landscapes. People reject projects when they perceive the seascape and ocean landscape as pristine and beautiful (Westerberg et al., 2013; Bidwell, 2017; Devine-Wright and Wiersma, 2020; Russell et al., 2020; Lamy et al., 2020).

The resistance arises because introducing new energy projects threatens a place's conventional meanings and disrupts place attachment., consequently invoking negative emotions such as grief and loss, leading to place-protective behaviour (Devine-Wright and Howes, 2010; Devine-Wright, 2011; Bidwell, 2017; Devine-Wright and Wiersma, 2020; Speller and Twigger-Ross, 2009). By contrast, projects are more acceptable when a landscape is perceived as ghastly or 'abandoned' or industrialized (Gee, 2010)

Strong place attachment or ocean meanings do not necessarily result in negative attitudes towards energy projects. Energy projects can be accepted if they are perceived to advance the ocean landscape, improve the economic conditions of a place or align with the meanings bestowed on a place (Devine-Wright, 2009; Bates and Firestone, 2015; Bailey et al., 2021) For instance, in Northern Ireland, people's interpretation of the ocean (e.g., the ocean as a resource) and a given technology (e.g., tidal energy as pioneering) increased positivity for tidal energy (Devine-Wright, 2011).

The literature shows that besides people-ocean relations, context is important in understanding people's reactions towards energy projects. To deepen the understanding of people–ocean relations and social acceptance, this study focuses on a different geographical context, the whole ocean, and a different energy technology (*floating wind technology*).

2.2 Technology risks and benefits

Attitudes towards a given technology are governed by its perceived risks and benefits. Risk perception is subjective and informed by the physical features of the object and an individual's characteristics (Fischhoff et al., 1993).

Existing studies focus on the role of perceived technology benefits and risks of different energy technologies, including nuclear power and wind turbines in determining social acceptance (Contu et al., 2016; Groot et al., 2020; Linzenich et al., 2020). The consistent finding is that a higher technology risk perception reduces social acceptance, while a higher technology benefit perception increases it. However, the extent to which underlying risks and benefits influence social acceptance varies across technology types. Moreover, there are currently no studies that have studied this concept in the context of floating wind technology.

The risks and benefits of new technologies such as floating wind technology are relatively unknown among the general population; thus, their viewpoints are highly unpredictable (Bush and Hoagland, 2016). Floating wind technology is presented by energy experts as necessary for tapping rich offshore wind resources in deep sea waters, but also costly (GWEC, 2022) and could affect marine life and other offshore industries (Davis et al., 2016; Klain et al., 2020; Maxwell et al., 2022). Yet, earlier studies found people to be positive towards high-application technologies that are considered necessary and beneficial, even if they are risky (Frewer et al., 1998; Clark et al., 2016).

2.3 Framing

Framing is defined as a mental system of beliefs, perceptions and valuations social actors use to interpret their worlds (Schoen and Rein, 1994). Framing accentuates certain interpretations of a complex problem while debilitating others. Psychologically, framing aids in fast decision-making by acting as a mental shortcut (Tversky and Kahneman, 1974). In energy discourses, the use of framing is direct, specific and aimed at eliciting attitudes towards specific energy technologies and policies (Burke, 2018). Framing is characterised by: (i) 'diagnosis', a problem to be solved, either meet the electricity needs or climate objectives, (ii) 'prognosis', a possible solution, including floating offshore wind power and (iii) 'motivation', justification for the solution, such as based on technology risks and benefits.

The study focuses on the way framing is used in the context of renewable energy (see Eaton et al., 2013; Walker et al., 2014; Wolsink, 2020) Based on the existing literature, frames aimed at developing renewable energy projects to achieve energy security, energy independence and community benefits receive the broadest support, unlike those aimed at meeting climate benefits (Walker et al., 2014; Feldman and Hart, 2018; Hazboun et al., 2019; Bollman, 2022). This study examines two policy framings: (i) meeting electricity needs and (ii) achieving climate objectives in the context of floating wind technology.

3 Data and Methods

3.1 Survey

At the start of the survey, the respondents were informed that their participation would aid in mapping Norwegians' attitudes towards offshore wind power. They were also informed that their responses might influence the formulation of offshore wind power energy policies. The respondents were then randomly split into two groups, and each group was presented with one of the two framing texts, to develop offshore wind power to either meet increasing energy demands (electricity framing) or meet climate objectives (climate framing) see Table 1.

Table 1 Text used in the survey to describe the two policy framings. Respondents were given either the Electricity or the Climate framing

Framing	Information
Electricity	According to the Norwegian Water Resources and Energy Directorate (NVE), the demand for electricity in Norway is expected to increase by 15% by 2040. A similar increase in electricity demand is expected in neighbouring countries. In 2020, the Norwegian authorities decided to open the sea areas Utsira Nord and Sørlige Nordsjø II for the development of wind power projects. The wind projects where the oceans are deep will use new floating offshore wind power technology. The Norwegian government will give economic support for the development of these projects in the transition phase. The floating offshore wind power projects will help us meet the increasing electricity demand, but critics say the projects could affect the coast and seascapes, other industries, birds and marine life.
Climate	Norway is one of the 197 countries that signed the Paris Agreement to reduce carbon emissions. Norway is committed to reducing its emissions substantially in the years to come. To achieve net-zero emissions by 2050, countries must replace polluting energy sources with renewable energy sources. In 2020, the Norwegian authorities decided to open the sea areas Utsira Nord and Sørlige Nordsjø II for the development of wind power projects. The wind projects where the oceans are deep will use new floating offshore wind power technology. The Norwegian government will give economic support for the development of these projects in the transition phase. The floating offshore wind power projects will help us meet the climate objectives, but critics say the projects could affect the coast and seascapes, other industries, birds and marine life.

To familiarize the respondents with the technology, a drawing depicting types of floating wind power technology was shown to them (See Figure A in the Appendix). Thereafter, the respondents were presented with questions measuring ocean meanings, place attachment and technology benefits and risks (these are described further below). The respondents were asked to indicate whether they reside or own a holiday home along the coast. Residence and homeownership at the coast are measured by binary responses, yes or no. In addition, the survey included socio-demographics including gender, age, education, and income.

The survey was sent to a sample representative of the Norwegian adult population (i.e., 18 years and above) in November and December 2021 by an international survey company, Kantar. Kantar has an internet survey panel, made up of adult respondents who are recruited through other phone and mail surveys. The individuals indicate a willingness to participate in various surveys. Currently, the panel consists of approximately 40,000 individuals, who are representative of the adult population in terms of gender, age, location and education level.

Initially, Kantar contacted and sent out the survey to 3987 randomly selected respondents from their panel, of which 1337 opened the survey. Out of this, a total of 1099 respondents completed the survey. The number of respondents in the electricity and climate subsamples is 527 and 572, respectively. Sample weights are provided by the survey company, Kantar. Kantar created the weights by comparing the sample with the population based on age, gender and location.

3.1.1 Summary statistics

Table 2 shows the sample composition in terms of socio-demographics for the electricity and climate framing subsamples, the samples: sample I (N=1099) and sample II (N= 794), and the Norwegian population.

Table 2 Socio-demographics for electricity and climate subsamples, full sample and the Norwegian population.

Electricity, Climate and Sample I include all the respondents, while Sample II exclude respondents that had missing observations on relevant variables.

Variable	Description	Electricity N= 527	Climate N=572	Sample I N=1099	Sample II N=794	Norway
Gender	Male	61%	60%	55%	60%	51%
	Female	39%	40%	44%	40%	49%
Age	18–29	12%	13%	14%	13%	20%
	30–44	24%	19%	21%	21%	26%
	45–59	25%	29%	26%	28%	26%
	60–89	39%	39%	39%	38%	28%
Education	Primary education	6%	8%	7%	7%	25%
	Secondary education	55%	55%	56%	55%	40%
	University	39%	37%	37%	38%	35%
Income (NOK)	<400,000	15%%	17%%	17%	16%	Mean
	400,000–599,999	14%	19%	15%	16%	610,000
	600,000–799,999	19%	21%	18%	20%	Median
	≥800,000	41%	38%	38%	39%	550,000
	Did not indicate	11%	11%	11%	11%	
Residence	Live along the coast	52%	56%	52%	54%	
Ownership	Own a holiday home	18%	25%	19%	22%	

Note. The values for residence and ownership are based on the number of respondents who indicated 'yes' for living or owning a holiday home along the coast. Statistics for the Norwegian population are based on Statistics Norway www.ssb.no.

Comparing the sample before deleting respondents with missing observations, N=1099, and the Norwegian population, the proportion of males is higher than that of females, and older respondents are slightly overrepresented, while younger respondents are slightly underrepresented. Education levels are higher in the sample, which is typical for online surveys (Linnerud et al., 2022). Over 50% of respondents who indicated their income earn 600,000 NOK and above per annum. A total of 52% and 19% of the sample live and own a holiday home at the coast, respectively. Less than 2% in both framings did not indicate whether they live and own a holiday home along the coast. Based on a two-sample t-test and chi-square test, the electricity and climate subsamples are not statistically different in terms of socio-demographics.

3.1.2 Variables

The independent variables are ocean meanings, place attachment and technology risks and benefits, and additional covariates are socio-demographics. The dependent variable is attitudes towards floating offshore wind power.

Attitude towards floating offshore wind power is measured using one statement, 'How positive or negative are you towards the development of floating offshore wind power projects?'. The statement captures a general attitudinal disposition, either positive or negative, considered part of social acceptance (Upham et al., 2015; Hoen et al., 2019). The responses were captured by a 5-point Likert scale, with 1 representing 'very positive' and 5 'very negative', and 'I do not know' at the end to avoid forced responses.

The ocean meanings statements are developed based on landscape values defined by Brown and Raymond (2007). Their statements are created for the lake environment, but they have been redefined and used for ocean landscapes (Wynveen and Kyle, 2015; Bidwell, 2017). The respondents were asked to think about the ocean area surrounding Norway when choosing their responses. The statements include 'I think of the ocean as a place of inspiration'. Focusing on the ocean area as a whole without distinguishing between the different oceans and seas surrounding the Norwegian mainland (e.g., the Atlantic Ocean, Barents Sea, Norwegian Sea, North Sea and Skagerrak Sea) is plausible on the premise that naming and creating ocean boundaries is somewhat arbitrary and boundary lines drawn within the ocean regions can be difficult to interpret by laypersons (Lewis and Wigen, 2010).

The study uses three statements from Stedman (2006) to measure place attachment. The statements are used to elicit people's attachment to the lake, but the statements have also been applied to marine settings (Bidwell, 2017). Respondents were asked whether they agreed or disagreed with statements about the Norwegian ocean area. The statements include 'I miss the ocean when I am away too long' and 'The ocean is my favourite place to be'. The people who are attached to a place exhibit an increased need for proximity to the place at the behavioural level, and this is reflected by the statements used in this study.

Floating wind power technology is costly, and can be risky (GWEC, 2022). It can also harm the environment (Maxwell, et al., 2022), and is thus seen as controversial within the 'green versus green' lens (Wang and Wang, 2015). In contrast, the technology is necessary for deep seas (GWEC, 2022), it is beneficial for enhancing energy security, and it is good for the environment because it aids in cutting carbon emissions. Conditional on these perceived risks and benefits, the paper uses six statements adopted from Frewer et al. (1998). Frewer et al. (1998) employ different characteristics to elicit attitudes towards different technologies across various disciplines. The respondents were asked to rank the extent to which they thought floating wind power technology to be either necessary or controversial. The weighted means and standard deviations for the statements based on 794 respondents are given in Table 3.

Table 3 Weighted means and standard deviations for variables for the Full sample, Electricity and Climate sub-samples.

	Full (N=794)		Electricity (N=379)		Climate (N=415)	
Variable	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
Attitudes towards floating offshore wind power	3.59	1.20	3.58	1.21	3.60	1.22
Ocean meanings						
A beautiful place to look at	4.63	0.68	4.67	0.71	4.59	0.73
A place for recreation	4.37	0.83	4.39	0.90	4.35	0.92
A place for relaxation	4.25	0.93	4.28	0.95	4.22	0.96
A place of inspiration	4.12	0.95	4.14	0.96	4.09	0.98
A home for wild animals	4.35	0.92	4.37	0.91	4.32	0.94
A place for pristine nature	3.96	1.02	3.95	1.04	3.96	1.03
A place with intrinsic value	4.20	0.94	4.19	0.96	4.21	0.92
Place attachment						
I miss the ocean when I am away	3.55	1.26	3.63	1.23	3.51	1.27
The ocean is my favourite place	3.27	1.24	3.31	1.21	3.24	1.22
I feel happiest when I am at the coast	3.89	1.16	3.94	1.11	3.86	1.14
Technology benefits						
Floating wind technology is…						
Necessary	3.61	1.15	3.65	1.23	3.57	1.18
Beneficial	3.58	1.13	3.59	1.22	3.57	1.11
Good	3.54	1.15	3.51	1.11	3.56	1.14
Technology risks						
Floating wind technology is…						
Controversial	3.51	0.94	3.50	0.94	3.51	0.97
Can affect the environment	3.52	1.00	3.50	1.00	3.54	1.00
Risky	3.26	1.03	3.26	1.03	3.26	1.05

Note: All the variables are measured on a 5-point Likert scale. The score for the attitudes towards floating offshore wind power ranges from 1 'very negative' to 5 'very positive'. For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'. For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'. Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis (see the percentage of respondents for each of the variables in Table A in the Appendix).

The respondents have strong meanings about the ocean, but they are slightly attached to the ocean and hold moderate perceptions about the risks and benefits of floating wind power technology. Based on a Mann–Whitney–Wilcoxon two-sample test, the mean distribution for the two subsamples does not differ significantly across variables.

Table A in the Appendix presents the percentage of respondents who skipped or chose 'I don't know' as the response for each of the variables. In general, the percentage of respondents who skipped or chose the 'I don't know' response does not differ across the two subsamples, electricity and climate. Less than 1% skipped the questions, and less than 2% chose the 'I don't know' response for all the variables, apart from the technology risk and benefit variables, for which between 6% and 13% chose the 'I don't know' option. The high percentage of 'I don't know' choosers for the technology risk and benefits questions may stem from the 'low' level of knowledge about floating wind power technology among the respondents. Even though the study does not test respondents' knowledge levels, this may be implied because floating wind power technology is fairly recent (GWEC, 2022).

3.4 Methods

3.4.1 Logistic regression

The ordinal logistic model calculates the probability of a given outcome measured on an ordinal scale (McCullagh, 1980), given a set of independent variables (Walker and Duncan, 1967), using equation 1:

$$logit\big(P(Y_i \leq j)\big) = \beta_{j0} + \beta_j Z_i + \varepsilon_i \qquad 1$$

where $j = 1 \dots, J - 1,$ and P are predictors. Y_i is the dependent variable measuring attitudes towards floating offshore wind power projects, Z_i is a vector of independent variables, β_j are parameters to be estimated, i identifies the respondent and ε is the disturbance term. All the regression models incorporate age, education and gender as additional covariates to control for the non-randomness of the sample and possible correlation between socio-demographics and the dependent variable. All the analyses are conducted using Stata 17.

Using the Brant test (Brant, 1990), a few variables violate the proportional odds assumption at a marginal level of statistical significance (95%). Therefore, the study re-runs a generalised ordered logit model (Williams, 2006). The results for the models run using an ordinal logistic regression and a generalised ordered logistic regression (across categories) on the full data show no large differences in terms of signs and levels of significance; however, the effect sizes differ. The results of the generalised logistics regression models on the full sample are presented in Table B. The model does not perform well in terms of convergence and probability values for the other subsamples; hence, the study presents results for the ordinal logistic regression and linear regression (discussed in Section 3.2.2).

To test for heterogeneity in attitudes among the sample, the study runs models for subsamples: (i) people who reside on the coast and (ii) people who own a holiday home on the coast. Attitudes can vary between local communities and the general public (Wüstenhagen et al., 2007), and between residents, holiday home owners and tourists (Bidwell, 2023). The results are presented in the Appendix (Tables A and B).

3.4.2 Robustness checks

The study controls for the robustness of the results by: (i) using a different statistical method, (ii) checking whether non-response to the variables was random, (iii) testing and controlling for potential bias to the results, in case missing responses were not random, (iv) correcting for the potential bias in the regressions, and (v) performing multiple imputations and re-running the models for the full sample and electricity and climate subsamples.

First, the study treats the dependent and independent variables as continuous and independent of the frequency distribution (Robitzsch, 2020). Thus, linear regression is used, and the models are re-run for the full sample, electricity and climate subsamples. The results from the linear regression models are comparable to those from ordinal logistic regression models.

Focusing on missing data, the study includes dummy variables, which are set equal to one if the response is missing. Based on a t-test for the dummy variables and dependent variable together with the other covariates, the pattern of the missing data is checked, and the assumption is that missing data are random. To control for any potential bias, a probit model is run, with a dummy dependent variable for the respondents that are deleted from the sample and using socio-demographics as covariates. The inverse Mills ratio (IMR) is generated from the probit model. Following the procedure from the Heckman model, the IMR is used as an additional covariate in the ordinal logistic models. The IMR is not statistically significant for the model with full predictors. Hence, there is no attrition bias.

Treating the 'I don't know' and skipped responses as missing data, the study includes dummy variables, which are set equal to one if the response is missing. Based on a t-test for the dummy variables and dependent variable together with the other covariates, the pattern of the missing data is checked, and the conclusion is that missing data are random. Hence, multiple imputations can provide unbiased estimates (Rubin, 1976). The paper uses multivariate imputations by chained equations in Stata 17 to fill in the missing values. Using predictive mean matching for the continuous variables and the logit method for the binary variables, along with a set of 10 donors as recommended by Morris et al. (2014), 20 datasets are generated. The datasets are pooled following Rubin's rules (Rubin, 1987), and ordinal logistic regression models are estimated for the full sample and climate and electricity subsamples.

Lastly, the study codes the 'I don't know' responses as the midpoint 3 for each of the variables measured on a 5-point Likert scale and rerun the model for the full sample. The results of the robustness checks are presented in the Appendix (Tables E–I).

4. Results

4.1 Determinants of attitudes towards floating offshore wind power

Table 4 presents the coefficients and the p-values of the determinants of attitudes towards floating offshore wind power for the full sample. Using variance inflation factor criteria, the independent variables are first checked for multicollinearity. All the variables have a variance inflation factor below 10. Following Russell et al. (2020), each statement for ocean meanings, place attachment and technology benefits and risks are added separately to the models as an independent variable.

Model I includes the socio-demographic variables. The variables are dummy coded, whereby male respondents who are 44 years old and above and those with a university education equal one. Being male and university-educated significantly increases positivity towards floating offshore wind. The pseudo-R^2 is 2%.

Model II captures the seven statements for ocean meanings. Only the 'ocean is a beautiful place to look at' (β =.409, $p<0.01$), 'a place of inspiration' (β= -.229, $p<0.05$), and 'a place for pristine nature' (β= -.465, $p<0.001$) characteristics of the ocean are statistically significant. While the 'beauty' meaning of the ocean increases positive attitudes, the inspiration and pristine meanings increase negative attitudes towards floating offshore wind power. The pseudo-R^2 increases by 3%.

Model III incorporates the three statements for place attachment. Male and university-educated respondents have more predicting power. Statements for place attachment are not statistically significant. The beauty, inspiration and pristine meanings of the ocean maintain their predictive power and level of significance. The pseudo-R^2 increases by only 0.1%.

Finally, Model IV integrates statements for underlying perceptions about floating wind power technology risks and benefits. All the technology benefit statements and two of the three technology risk statements (excluding 'controversial') are highly statistically significant ($p<0.001$). Respondents are positive they perceive floating wind power as beneficial, necessary and good. By contrast, they are negative when they view this technology, as both risky and could affect the environment. Notably, the place attachment statement 'I feel happiest when I am at the coast' is now a marginally significant predictor of positive attitudes (β =.196, $p<0.05$). In addition, male and university-educated remain significant predictors of attitudes. However, the ocean meanings, ‘a place of inspiration’ and ‘a place of pristine nature’ are no longer significant predictors of attitudes in this model. The pseudo-R^2 increases to 38%, which is a good fit for the data.

Table 4 Results for ordinal logistic regression models showing determinants of attitudes with socio-demographics as additional covariates.

	Model I		Model II		Model III		Model IV	
Independent variable	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value
Socio-demographics								
Male	**.500**(.134)	.000	**.348**(.137)	.012	**.322**(.140)	.022	**.390**(.161)	.016
University	**.652**(.136)	.000	**.713**(.138)	.000	**.712**(.140)	.000	**.440**(.160)	.006
Age	−.070(.140)	.617	−.121(.144)	.400	−.104(.144)	.470	−.252(.167)	.132
Ocean meanings								
A beautiful place to look at			**.409**(.126)	.001	**.396**(.126)	.002	**.596**(.150)	.000
A place for recreation			.037(.108)	.734	.041(.109)	.705	−.058(.129)	.652
A place for relaxation			−.041(.096)	.667	−.023(.098)	.817	**−.299**(.114)	.009
A place of inspiration			**−.229**(.095)	.015	**−.207**(.096)	.032	−.188(.112)	.093
A home for wild animals			−.017(.084)	.833	−.027(.085)	.751	.028(.099)	.774
A place for pristine nature			**−.462**(.079)	.000	**−.465**(.079)	.000	−.158(.089)	.077
A place with intrinsic value			−.025(.092)	.783	−.014(.093)	.882	−.014(.106)	.894
Place attachment								
I miss the ocean when I am away					.066(.088)	451	−.013(.102)	.898
The ocean is my favourite place					−.159(.096)	.097	−.082(.109)	.455
I feel happiest when I am at the coast			.		.033(.081)	.682	**.196**(.094)	.036
Technology benefits								
Floating wind technology is…								
Necessary							**.645**(.134)	.000
Beneficial							**.926**(.176)	.000
Good							**.792**(.158)	.000
Technology risks								
Floating wind technology is …								
Controversial							.009(.095)	.925
Can affect the environment							**−.337**(.102)	.001
Risky							**−.376**(.102)	.000
Pseudo-R^2	0.016		0.045		0.046		0.382	
No. of respondents	794		794		794		794	

Note: All the variables are measured on a 5-point Likert scale. The score for the attitudes towards floating offshore wind power ranges from 1 ‘very negative’ to 5 ‘very positive’. For ocean meanings and place attachment, the score ranges from 1 ‘strongly disagree’ to 5 ‘strongly agree’. For technology benefits and technology risks, the score ranges from 1 ‘to a very small extent’ to 5 ‘to a very large extent’.

4.2 Effect of policy framing on attitudes

The study analyses the difference in attitudes towards floating offshore wind power between electricity and climate framing. Using a likelihood-ratio Chow test for differences in coefficients between the composite models for the full sample and the electricity and climate subsamples, the null hypothesis is rejected at the 0.05 level of significance. Using Pearson correlation to test for the relationship between the dummy variable for electricity framing and other covariates, the test finds no significant relationship. Thereafter, the ordered logistic regression models are re-run for the two subsamples. The resulting odds ratios and p-values are given in Table 5.

Table 5 Ordinal logistic regression models for the attitudes towards floating offshore wind power: separately for the two energy policy framings.

	Electricity		Climate	
Independent variable	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value
Socio-demographics				
Male	.320 (.228)	0.159	**.501** (.241)	.037
University	**.447** (.225)	0.047	**.503** (238	.035
Age	−.091 (.236)	0.700	−.455 (.252)	.071
Ocean meanings				
A beautiful place to look at	**.464** (.220)	.035	**.728** (.216)	.001
A place for recreation	−.274 (.192)	.192	.127 (.183)	.487
A place for relaxation	−.052 (.170)	.758	**−.520** (.163)	.001
A place of inspiration	−.035 (.164)	.832	**−.343** (.159)	.031
A home for wild animals	.117 (.150)	.436	−.010 (.139)	.939
A place for pristine nature	−.034 (.132)	.798	**−.289** (.126)	.022
A place with intrinsic value	−.187 (.158)	.238	.086 (.151)	.570
Place attachment				
I miss the ocean when I am away	.160 (.162)	.319	−.102 (.140)	.464
The ocean is my favourite place	−.244 (.168)	.147	−.007 (.154)	.965
I feel happiest when I am at the coast	.192 (.143)	.181	.230 (.131)	.079
Technology benefits				
Floating wind technology is…				
Necessary	**1.00** (.190)	.000	.281 (.206)	.171
Beneficial	**.756** (.235)	.001	**1.213** (.275)	.000
Good	**.475** (.209)	.023	**1.272** (.250)	.000
Technology risks				
Floating wind technology is…				
Controversial	.080 (.132)	.544	**−**.047 (.141)	.735
Can affect the environment	**−.385** (.136)	.005	**−.332** (.149)	.026
Risky	−.269 (.142)	.057	**−.470** (.154)	.002
Pseudo-R²	0.357		0.453	
No. of observations	379		415	

Note: All the variables are measured on a 5-point Likert scale. The score for the attitudes towards floating offshore wind power ranges from 1 'very negative' to 5 'very positive'. For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'. For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'. Numbers in bold are significantly different from zero at the 5 % level (or lower).

Only the 'ocean is a beautiful place to look at' is a significant predictor of positive attitudes in both framings, though the effect size and the level of significance are higher under the climate framing (β =.728, $p<0.01$) than electricity framing (β =.464, $p<0.05$). The other ocean meanings, including 'a place for relaxation', 'a place of inspiration', 'a home for wild animals' and 'a place for pristine nature' only significantly predict negative attitudes for respondents in the climate framing. The technology benefits' perception 'beneficial' and 'good' are significant predictors of positive attitudes in both framings. Though the 'necessary' characteristic predicts positive attitudes in electricity framing, it does not predict attitudes in climate framing. The two technology risk statements 'can affect the environment' and 'risky' increase negative attitudes for respondents in the climate framing. Only the technology risk statement 'can affect the environment' increases negativity towards floating offshore wind power technology for respondents in both the electricity and climate framings.

5 Discussion

This study evaluated: (i) if ocean meanings influence attitudes towards floating offshore wind power, (ii) if place attachment influences attitudes towards floating offshore wind power, (iii) if risk and benefit perceptions of floating wind power technology matter and (iv) if attitudes towards floating wind power technology differ due to policy framing. The findings addressing each of the research questions are discussed in this section.

5.1 Influence of ocean meanings on attitudes

This study reveals that ocean meanings predict people's attitudes towards floating offshore wind power. The ocean is 'beautiful to look at' and the ocean is 'a place for relaxation' meanings predict positive and negative attitudes, respectively. It seems that floating wind technology is consistent with the 'beautiful' meaning of the ocean. However, people seem to view the ocean as a place to unwind and relax; hence, the presence of turbines is incompatible with the 'a place for relaxation' belief.

In contrast, place attachment is not critical in explaining attitudes towards floating offshore wind power projects. Bidwell (2017) finds ocean meanings and individual characteristics to be stronger predictors of attitudes than place attachment. However, he evaluates specific acceptance and measures place attachment to a specific location at the coast. The existing literature measuring place attachment at a distal scale suggests that place attachment can weaken (Vorkin and Riese, 2001; Gustafson, 2009) or strengthen (Devine-Wright and Bates, 2017) with a rise in the geographical scale and that the different levels of attachment can distinctly influence people's opinions about developing renewable energy.

5.2 Do perceived technology risks and benefits matter?

Underlying risk and benefit perceptions of floating wind power technology matter. Consistent with the literature (Groot et al., 2020; Contu et al., 2016; Frewer et al., 1998), the perceived benefits and risks predict positive and negative attitudes towards floating offshore wind power, respectively. The respondents' benefit perceptions of floating offshore technology are moderately high, despite the assumption that this technology is relatively unknown. Their benefits perceptions may be linked to subconscious technology optimism, which is commonplace for modern, new and high-application technologies (Frewer et al., 1998; Clark et al., 2016). Frewer et al. (1998) suggest that social acceptance is driven by the perceived technology benefits and that people are more concerned with the benefits accrued to technology than its risks, so long as the risks are not too unbearable.

Floating wind technology is also perceived as risky, and this could perhaps be in terms of both cost and its probable effect on the environment (Davis et al., 2016; Maxwell et al., 2022). Unsurprisingly, people believe that floating wind technology can be both risky and beneficial, as this belief is common for new technologies that are less known (Bush and Hoagland, 2016). The risky perceptions of floating wind technology may also be informed by prior negative experiences with similar technologies, such as fixed-bottom technology applied in onshore and offshore wind power projects.

5.3 Variation in attitudes due to policy framings

Determinants of attitudes between the two policy framings differ. Ocean meanings and place attachment seem to significantly influence the attitudes of respondents in the climate framing than those in the electricity framing. Ocean meanings result in mostly negative attitudes towards floating offshore wind power, particularly in climate framing, consistent with earlier research (Firestone and Kempton, 2007; Gee, 2010; Bidwell, 2017; Devine-Wright and Wiersma, 2020). Researchers observe that strong place meanings could derail climate mitigation efforts because people prefer to maintain conventional place meanings rather than developing renewable energy (Devine-Wright and Howes, 2010). This is despite the destruction of the ocean landscape that may occur because of climate change-induced weather changes. The study finds that ocean meanings become less influential on attitudes towards projects aimed at meeting electricity needs.

The necessary technology characteristic is a significant predictor of attitudes for respondents in electricity framing only. This implies that respondents view floating wind technology as necessary for tapping wind resources in the deep seas. Other characteristics such as 'beneficial' and 'good' are stronger predictors of attitudes in climate framing than in electricity framing. This signifies that respondents in the climate framing perceive floating wind technology as both good and beneficial to the environment and maybe not as necessary. The 'not necessary' attitude may stem from the perceived lack of efficacy of wind power in substantially reducing carbon emissions (Donald et al., 2022). The underlying technology risk perceptions do not significantly induce heterogeneity in attitudes across the two framings.

5.4 Study limitations

First, the survey mentions the Utsira Nord and Sørlige Nordsjø II projects. Although the purpose of including these projects is to inform the respondents about current development plans in the floating offshore wind power sector, we cannot exclude the possibility that the measurement mixes general acceptance and specific acceptance. Studies document that people are generally positive about renewable energy projects but less positive towards specific projects (e.g., Bell et al., 2005; Wüstenhagen et al., 2007).

Second, the measurement of the concepts requires further attention. Although the study elicits general attitudes towards floating offshore wind power, revealed by either the positive or negative responses, future research should include more questions (see Bauwens and Devine-Wright, 2018) or dimensions (see Russell and Firestone, 2022) to uncover people's complex attitudes towards energy projects.

Third, the study includes pertinent ocean meanings including aesthetics, relaxation, and the natural environment; it excludes other dimensions that can improve our understanding of social acceptance of offshore wind power. Place meaning dimensions, e.g., social bonding, place of escape and economic development are seen to shape attitudes towards the development of energy infrastructure (Steinberg, 2001; Wynveen and Kyle, 2015). Furthermore, the statement 'the ocean is a beautiful place to look at' fuses beauty with virtual aesthetics, thus disregarding other senses, and the beauty of landscapes can be interpreted based on biology or cultural norms (Jorgensen, 2011). Similarly, increasing the number of place attachment questions and including place dependency statements could have improved the reliability of the findings.

Finally, the study focuses on the ocean and sea area surrounding Norway as a whole. Previous studies have shown that individuals can have meanings and get attached to larger geographical areas regionally and even globally (Lewicka, 2011; Devine Wright and Bates, 2017), and this can influence their attitudes towards complex problems, including climate change and climate-related policies, i.e., the development of renewable energy. However, measuring only distal level place meanings and place attachment may discriminate against some individuals (Devine-Wright et al., 2015). Hence, future research should measure people–place relations at different scales.

6 Conclusion

Interest in offshore wind power is growing rapidly around the world. With the recent extreme weather changes and energy crises, the need to develop more renewable energy projects is essential. This study uses a national-level survey and ordinal logistic regression to determine people's attitudes towards floating offshore wind power projects. Based on the four main research questions, the study finds dimensions of ocean meanings to influence the attitudes towards floating offshore wind power. Second, technology risk and benefit perceptions are important predictors of attitudes. Finally, attitudes towards floating offshore wind power projects vary significantly between respondents in electricity and climate framings, especially in the context of ocean meanings and place attachment.

Policymakers and project developers may need to demonstrate to the general public that floating offshore wind power projects will advance the ocean landscape, rather than derail it. Moreover, the government needs to initiate dialogue and validate people's values by integrating ocean meanings into the project planning and implementation process.

Policymakers may need to increase public awareness of floating wind power technology costs and benefits to reduce any preconceived notions resulting from a lack of knowledge that may affect social acceptance.

Energy policy framings matter. Although enhancing energy security and meeting climate needs are a priority for policymakers and project developers alike, the emphasis on meeting electricity demand may reduce the negative attitudes towards floating offshore wind power.

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Appendix

Figure A Picture depicting types of floating wind power technology
Note: Illustration by Joshua Bauer, NREL

Table A: Results for the percentage of respondents who skipped or chose the 'I don't know' response for each of the variables in the electricity and climate subsamples and the full sample.

	Electricity		Climate		Full	
Variable	Missing	I don't know	Missing	I don't know	Missing	I don't know
Attitudes towards floating offshore wind power	0.1%	2.8%	0.1%	2.8%	0.1%	2.8%
Ocean meanings						
A beautiful place to look at	0.2%	0.8%	0.2%	0.8%	0.2%	0.8%
A place for recreation	0.3%	0.8%	0.3%	0.8%	0.3%	0.8%
A place for relaxation	0.3%	1.4%	0.3%	1.4%	0.3%	1.4%
A place of inspiration	0.4%	1.9%	0.4%	1.9%	0.4%	1.9%
A home for wild animals	0.6%	1.7%	0.6%	1.7%	0.6%	1.7%
A place for pristine nature	0.2%	1.0%	0.2%	1.0%	0.2%	1.0%
A place with intrinsic value	0.3	0.94	0.3	0.94	0.3	0.94
Place attachment						
I miss the ocean when I am away	0.3%	1.8%	0.3%	1.8%	0.3%	1.8%
The ocean is my favourite place	0.5%	1.0%	0.5%	1.0%	0.5%	1.0%
I feel happiest when I am at the coast	0.2%	1.0%	0.2%	1.0%	0.2%	1.0%
Technology benefits						
Floating wind technology is…						
Necessary	0.0%	7.4%	0.0%	8.2%	0.0%	6.9%
Beneficial	0.0%	7.0%	0.2%	6.6%	0.1%	6.8%
Good	0.0%	7.0%	0.2%	8.2%	0.1%	7.6%
Technology risks						
Floating wind technology is…						
Controversial	0.2%	8.5%	0.0%	8.7%	0.1%	8.6%
Can affect the environment	0.0%	8.0%	0.0%	10.0%	0.0%	9.0%
Risky	0.2%	11.2%	0.0%	13.5%	0.1%	12.4%

Note: A total of 28% of the respondents in the two subsamples, electricity and climate, either skipped or chose the 'I don't know' response overall.

Table B: Results for ordinal logistic regression models for showing differences in determinants of attitudes between respondents who do /do not live along the coast.

	Coast		Non-coast	
Independent variable	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value
Socio-demographics				
Male	**–.523** (.227)	.021	–.305 (.240)	.205
University	**.473** (.220)	.031	.410 (.248)	.098
Age	–.225 (.230)	.329	–.359 (.255	.158
Ocean meanings				
A beautiful place to look at	.305 (.215)	.156	**.960** (.223)	.000
A place for recreation	.069 (.198)	.725	–.208 (.188)	.267
A place for relaxation	**–.406** (.162)	.012	–.180 (.168)	.283
A place of inspiration	.126 (.154)	.411	**–.602** (.171)	.000
A home for wild animals	.183 (.140)	.191	–.196 (.147)	.182
A place for pristine nature	**–.235** (.117)	.045	–.064 (.146)	.658
A place with intrinsic value	–.046 (.155)	.898	–.039 (.158)	.805
Place attachment				
I miss the ocean when I am away	–.121 (.134)	.447	.101 (.169)	.552
The ocean is my favourite place	–.031 (.145)	.856	–.333 (.181)	.066
I feel happiest when I am at the coast	.051 (.136)	.780	**.451** (.139)	.001
Technology benefits				
Floating wind technology is…				
Necessary	**.554** (.182)	.001	**.775** (.208)	.000
Beneficial	**.986** (.257)	.000	**.866** (.254)	.001
Good	**.898** (.237)	.000	**.762** (.225)	.001
Technology risks				
Floating wind technology is…				
Controversial	–.066 (.125)	.435	.121 (.149)	.418
Can affect the environment	–.249 (.137)	.086	**–.455** (.148)	.002
Risky	**–.344** (.138)	.014	**–.371** (.158)	.019
Pseudo R^2	0.407		0.393	
No. of respondents	429		357	

Note: The coast sample captures the respondents who indicated that they reside at the coast (chose 'Yes'). All the variables are measured on a 5-point Likert scale. For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'. For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'
For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'. Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis (see the percentage of respondents for each of the variables in Table A). Eight respondents did not indicate whether they own or do not own a holiday home at the coast; therefore, they are excluded from the analysis.

Table C: Results for ordinal logistic regression models showing differences in determinants of attitudes between respondents who own or do not own a holiday home at the coast.

	Holiday home		No holiday home	
Independent variable	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value
Socio-demographics				
Male	–.336 (.415)	.416	**–.419** (.182)	.021
University	–.057 (.389)	.883	**.193** (.183)	.001
Age	–.648 (.436)	.137	–.137 (.185)	. 455
Ocean meanings				
A beautiful place to look at	**.**572 (.386)	.138	**.587** (.164)	.000
A place for recreation	.323 (.327)	.324	–.130 (.141)	356
A place for relaxation	–.411 (.297)	.167	**–.294** (.127)	.021
A place of inspiration	–.225 (.282)	.424	–.181 (.126)	.151
A home for wild animals	–.000 (.235)	1.000	.016 (.112)	.882
A place for pristine nature	–.319 (.246)	.194	–.092 (.098)	.350
A place with intrinsic value	–.243 (.285)	.395	.045 (.119)	. 708
Place attachment				
I miss the ocean when I am away	.034 (.232)	.882	–.025 (.119)	. 837
The ocean is my favourite place	–.262 (.278)	.345	–.060 (.124)	. 634
I feel happiest when I am at the coast	.040 (.255)	.876	**.220** (.104)	.034
Technology benefits				
Floating wind technology is…				
Necessary	**1.026** (.351)	.003	**.596** (.159)	.000
Beneficial	**1.354** (.479)	.005	**.884** (.197)	.000
Good	**.777** (.381)	.041	**.804** (.182)	.000
Technology risks			.	
Floating wind technology is…				
Controversial	–.409 (.251)	.103	–.095 (.107)	.373
Can affect the environment	**–.833** (.246)	.001	**–.258** (.112)	.020
Risky	–.173 (.260)	.506	**–.410** (.113)	.000
Pseudo R²	0.527		0.366	
No. of respondents	172		617	

Note: All the variables are measured on a 5-point Likert scale. For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'.

For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'.

For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'.

Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis (see the percentage of respondents for each of the variables in Table A). Five respondents do not indicate whether they own or do not own a holiday home on the coast; therefore, they are excluded from the analysis.

Table D: Results for linear regression models showing determinants of attitudes.

Independent variable	Model I		Model II		Model III	
	Coeff (s.e.)	P-value	Coeff (s.e.)	P-value	Coeff (s.e.)	P-value
Intercept	4.436	.000	4.516	.000	1.632 (.247)	.000
Socio-demographics						
Male	**–.173** (.087)	.045	–.160(.088)	.071	–.104 (.053)	.048
University	**.433** (.086)	.000	**.435** (.085)	.000	**.141** (.051)	.006
Age	–.050 (.089)	.577	–.036 (.090)	.687	–.064 (.054)	.232
Ocean meanings						
A beautiful place to look at	**.197** (.079)	.013	**.181** (.079)	.018	**.170** (.047)	.000
A place for recreation	.035 (.067)	.602	.524 (.068)	.524	–.023 (.040)	.571
A place for relaxation	–.058 (.060)	.335	–.056 (.061)	.541	**–.102** (.036)	.005
A place of inspiration	**–.132** (.057)	.055	–.109 (.058)	.128	–.054 (.035)	.118
A home for wild animals	.020 (.052)	1.000	.011 (.052)	.900	.017 (.031)	.577
A place for pristine nature	**–.267** (.047)	.000	**–.267** (.047)	.000	–.046 (.028)	.101
A place with intrinsic value	–.032 (.056)	.653	.015 (.056)	.724	–.001 (.034)	.971
Place attachment						
I miss the ocean when I am away			.041 (.054)	.557	–.001 (.032)	.974
The ocean is my favourite place			–.140 (.060)	.070	–.027 (.036)	.437
I feel happiest when I am at the coast			–.047(0.51)	.903	.052 (.030)	. .090
Technology benefits Floating wind technology is…						
Necessary					**.218** (.043)	.000
Beneficial					**.310** (.058)	.000
Good					**.274** (.051)	.000
Technology risks Floating wind technology is…						
Controversial					.008 (.028)	.916
Can affect the environment					**–.097** (.030)	.001
Risky					**–.123** (.032)	.000
R^2	0.076		0.083		0.686	
Adjusted R^2	0.099		0.101		0.684	
No. of respondents	794		794		794	

Note: All variables are measured on a 5-point Likert scale.

For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'.

For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'.

For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'.

Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis.

Table E: Linear regression models showing the effect of policy framings on attitudes towards floating offshore wind power.

	Electricity		Climate	
Independent variable	Coeff (s.e.)	P-value	Coeff (s.e.)	P-value
Socio-demographics				
Male	–.101 (.083)	.223	–.128 (.067)	.057
University	**. 147** (.079)	.066	**.143** (.067)	.033
Age	–.038 (.083)	.651	–.105 (.069)	.132
Ocean meanings				
A beautiful place to look at	**.185** (.074)	.015	**.130** (.059)	.028
A place for recreation	–.098 (.066)	.139	.042 (.049)	.391
A place for relaxation	–.033 (.061)	.592	**–.162** (.044)	.000
A place of inspiration	–.024 (.058)	.676	**–.060** (.042)	.000
A home for wild animals	.028 (.053)	.601	.020 (.037)	.939
A place for pristine nature	–.002 (.048)	.973	**–.289** (.034)	.022
A place with intrinsic value	–.043 (.054)	.435	.082 (.042)	.570
Place attachment				
I miss the ocean when I am away	.039 (.057)	.493	–.012 (.038)	.464
The ocean is my favourite place	–.070 (.060)	.246	–.022 (.044)	.965
I feel happiest when I am at the coast	.064 (.050)	.206	.045 (.036)	.079
Technology benefits				
Floating wind technology is…				
Necessary	**.371** (.066)	.000	.072 (.058)	.171
Beneficial	**.236** (.084)	.005	**.351** (**.**080)	.000
Good	**.173** (.076)	.023	**386** (.070)	.000
Technology risks				
Floating wind technology is…				
Controversial	.043 (.045)	.341	–.024 (.035)	.735
Can affect the environment	**–.132** (.046)	.004	**–.070** (.039)	.026
Risky	–.082 (.050)	.101	**–.153** (.041)	.002
Adjusted R^2	0.687		0.746	
No. of observations	379		415	

Note: All the variables are measured on a 5-point Likert scale.

For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'.

For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'.

For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'.

Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis (see the percentage of respondents for each of the variables in Table A).

Table F: Results for ordinal logistic regression for full data. The inverse Mills ratio is included to correct for bias due to missing data.

	Full	
Independent variable	Odds ratio (s.e.)	P-value
Inverse Mills Ratio	–.727(6.906)	.916
Socio-demographics		
Male	–.585(2.357)	.804
University	.182 (.142)	.199
Age	–.003 (.012)	.499
Ocean meanings		
A beautiful place to look at	**.589** (.149)	.000
A place for recreation	–.074 (.128)	.564
A place for relaxation	**–.281** (.114)	.013
A place of inspiration	–.199 (.112)	.076
A home for wild animals	– .029 (.100)	.771
A place for pristine nature	–.157 (.089)	.078
A place with intrinsic value	–.027 (.107)	.797
Place attachment		
I miss the ocean when I am away	–.008(.102)	.935
The ocean is my favourite place	–.092(.110)	.402
I feel happiest when I am at the coast	**.202** (.094)	.032
Technology benefits		
Floating wind technology is…		
Necessary	**.641** (.135)	.000
Beneficial	**.931** (.158)	.000
Good	**.806** (.096)	.000
Technology risks		
Floating wind technology is…		
Controversial	.001 (.096)	.992
Can affect the environment	**–.323**(.099)	.001
Risky	**–.364** (.102)	.460
Pseudo-R^2	0.392	
No of respondents	794	

Note: All the variables are measured on a 5-point Likert scale.

For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'.

For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'.

For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'.

Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis (see the percentage of respondents for each of the variables in Table A).

Table G: Results for ordinal logistic regression models showing determinants of attitudes for full sample and electricity and climate subsamples based on imputed data

	Full		Electricity		Climate	
Independent variable	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value	Odds ratio (s.e.)	P-value
Socio-demographics						
Male	**–.495** (.135)	.000	**.443** (.112)	.021	**.564** (.203)	.006
University	**.329** (.136)	.016	.316 (.197)	.107	**.419** (.203)	.038
Age	–.496 (.143)	.612	–.037 (.205)	.857	–.129 (.211)	.541
Ocean meanings						
A beautiful place to look at	**.478** (.131)	.000	**.392** (.188)	.038	**.549** (.186)	.003
A place for recreation	–.003 (.112)	.980	–.134 (.161)	.407	.117 (.162)	.472
A place for relaxation	**–.245** (.101)	.016	–.137 (.146)	.347	**–.355** (.145)	.015
A place of inspiration	**–.204** (.095)	.032	–.122 (.138)	.389	**–.272** (.135)	.044
A home for wild animals	.085 (.086)	.330	.120 (.132)	.360	–.041 (.120)	.739
A place for pristine nature	–.149 (.079)	.060	–.004 (.112)	.970	**–.274** (.112)	.014
A place with intrinsic value	–.017 (.092)	.856	–.087 (.138)	.529	.040 (.129)	.753
Place attachment						
I miss the ocean when I am away	–.066 (.088)	.454	.031 (.162)	.820	–.140 (.121)	.248
The ocean is my favourite place	.066 (.094)	.499	–.029 (.142)	.838	–.126 (132)	.342
I feel happiest when I am at the coast	.065 (.081)	.427	.071 (.124)	.566	.079 (.111)	.476
Technology benefits						
Floating wind technology is…						
Necessary	**.665** (.119)	.000	**.986** (.168)	.000	.311 (.17)	.083
Beneficial	**.858** (.146)	.000	**.657** (.194)	.001	**1.128** (.229)	.000
Good	**.885** (.135)	.000	**.661** (.174)	.000	**1.222** (.222)	.000
Technology risks						
Floating wind technology is…						
Controversial	–.085 (.082)	.303	–.006 (.111)	.957	–.157 (.123)	.198
Can affect the environment	**–.262** (.091)	.004	**–.322** (.122)	.008	–.213 (.134)	.113
Risky	**–.266** (.093)	.004	**–.**150 (.125)	.231	**–.354** (.135)	.009
Pseudo-R^2	.362		.357		.453	
No. of observations	1099		527		572	

Note: All the variables are measured on a 5-point Likert scale.

For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'.

For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'.

For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'.

Table H: Results for generalised ordinal logistic regression showing determinants of attitudes with socio-demographics as additional covariates.

	Model I	
Independent variable	Odds ratio (s.e.)	P-value
Socio-demographics		
Male	**–.382** (.165)	.020
University	**.473** (.164)	.004
Age*		
Panel 1 (1 vs 2,3,4,5)	–.721 (.396)	.068
Panel 2 (1,2 vs 3,4,5)	–.430 (.308)	.162
Panel 3 (1,2, 3 vs 4,5)	–.020 (.235)	.933
Panel 4 (1, 2, 3, 4 vs 5)	**–.627** (.249)	.012
Ocean meanings		
A beautiful place to look at	**.591** (.155)	.000
A place for recreation*	–.065 (.134)	.628
A place for relaxation	**–.997** (.273)	.000
A place of inspiration*	–.369 (.237)	.119
A home for wild animals	.019 (.101)	.847
A place for pristine nature	–.162 (.092)	.078
A place with intrinsic value	–.016 (.110)	.885
Place attachment		
I miss the ocean when I am away	–.013 (.102)	.898
The ocean is my favourite place	–.082 (.109)	.455
I feel happiest when I am at the coast	**.196** (.094)	.036
Technology benefits		
Floating wind technology is…		
Necessary*		
Panel 1 (1 vs 2, 3, 4, 5)	**1 .142** (.287)	.000
Panel 2 (1, 2 vs 3, 4, 5)	**.819** (.213)	.000
Panel 3 (1, 2, 3 vs 4, 5)	.281 (.182)	.123
Panel 4 (1, 2, 3, 4 vs 5)	**.933** (.249)	.000
Beneficial*		
Panel 1(1 vs 2, 3, 4, 5)	.121(.290)	.675
Panel 2(1, 2 vs 3, 4, 5)	**.621** (.235)	.008
Panel 3(1, 2, 3 vs 4, 5)	**1.247** (.230)	.000
Panel 4(1, 2, 3, 4 vs 5)	**1.174** (.307)	.000
Good	**.833** (.160)	.000
Technology risks		
Floating wind technology is…		
Controversial	.004 (.097)	.963
Can affect the environment	**–.368** (.102)	.000
Risky	**–.382** (.104)	.000
Pseudo-R^2	0.409	
No. of respondents	794	

*Note: Variables with * violate the proportional odds assumption. All the variables are measured on a 5-point Likert scale.*

For the attitudes towards floating offshore wind power, the score ranges from 1 'very negative' to 5 'very positive'.

For ocean meanings and place attachment, the score ranges from 1 'strongly disagree' to 5 'strongly agree'.

For technology benefits and technology risks, the score ranges from 1 'to a very small extent' to 5 'to a very large extent'. Respondents who chose 'I don't know' or have a missing observation for any of the variables are excluded from the analysis (see the percentage of respondents for each of the variables in Table A)

Paper IV

Valuing externalities of offshore wind power: a review of discrete choice experiment studies

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Highlights

- A systematic review of offshore wind discrete choice experiments studies
- Thirteen studies across Europe, Asia, and the United States
- Varied design and presentation of attribute levels and payment across studies
- Preference for decreased visibility consistent across studies
- Impacts on the environment and competing offshore activities are increasingly valued

Abstract

The green energy transition entails a complete overhaul of energy systems by reducing reliance on fossil fuels and intensifying the use of renewable energy sources. Offshore wind plays a central role in this transition, and its deployment has been growing steadily worldwide. A growing number of studies use Discrete Choice Experiments (DCEs) to evaluate the project externalities that affect the mass deployment of offshore wind. This paper presents a systematic review of thirteen offshore wind power DCE studies with willingness to pay (WTP) estimates for visibility attributes such as distance from the shore, project size, and turbine height. It also covers attributes reflecting offshore wind's impact on the marine environment, offshore industries and activities, and other factors such as carbon emissions abatement, and project ownership, not examined by preceding review studies. Notably, preferences for installing offshore wind projects longer distances from the shore and preserving the marine environment prevail across studies. By contrast, offshore activities' impact on WTP for offshore wind varies significantly across studies and countries. Given the heightened importance of DCEs in informing policies, insights can be leveraged to improve future offshore wind DCE studies

through a conscious selection of attributes, their subsequent levels and presentation to reflect plausible characteristics of planned offshore wind power projects.

Keywords: offshore wind, discrete choice experiments, willingness to pay, systematic review.

1. Introduction

The Global Wind Energy Council forecasts that offshore wind will play a pivotal role in the transition to low-carbon energy systems (GWEC, 2023). However, developing offshore wind faces social acceptance issues which can hinder wide-scale deployment. Notable offshore project externalities are linked to visual effects and sound disturbances. While installing wind power projects far from the shore can minimize or even eliminate visual and sound disamenities (Ladenburg and Dugbaard, 2007; Krueger et al., 2011; Westerberg et al., 2013), the high cost of installation, operation, maintenance, and transmission remain a significant hurdle. Beyond the visual, sound and cost concerns, offshore wind power projects can potentially harm marine ecosystems and increase conflicts with fisheries, shipping and other traditional offshore industries.

While deploying offshore wind, energy planning authorities need to strike a balance between maximizing energy output and minimizing cost and negative project externalities. Discrete Choice Experiment (DCE) is the most prevalent stated preference method employed in the economic valuation of offshore wind externalities. In DCEs, hypothetical or real wind power project scenarios are presented, and individuals are asked to choose their preferred alternative. The alternatives are defined by a set of attributes, such as project size, where each attribute has varying levels. When individuals face numerous choice scenarios, their choices can reveal the relative importance they place on each attribute and attribute level. By including a cost attribute such as a change in electricity prices or taxes, we can calculate the willingness to pay (WTP) for variations in non-monetary attributes as the marginal rate of substitution between project attributes and costs. Thereafter, we can derive welfare estimates for different offshore wind power development scenarios by combining the various attribute changes.

This systematic review analyses the literature that uses DCEs to elicit WTP for offshore wind. Specifically, the review highlights and compares attributes reflecting positive and negative externalities of offshore wind with their subsequent values across studies. DCE studies have primarily featured attributes reflecting visual and sound externalities pertinent to near-shore wind power projects. This is plausible as near-shore wind power projects are commonplace due to their lower investment costs.

Owing to limited near-shore sites, and the prevalent social acceptance disincentives, wind power projects are increasingly inaugurated in open ocean spaces and deep waters (GWEC, 2023).

These ocean spaces are monopolized by conventional industries including shipping, tourism, fisheries, oil and gas. Consequently, new offshore wind power projects may encounter challenges linked to the use of ocean space, which can deter mass deployment. For instance, the presence of wind turbines elevates ship collision risks, prompting spikes in insurance premiums and fuel costs, as shipping vessels must navigate longer distances to bypass the turbines (Chaji and Werner, 2023).

Besides, environmental controversies exist regarding the potential undesirable effects of offshore wind on the marine environment. While a review of qualitative reports highlights the advantages of introducing wind turbines in marine environments, including the provision of new habitats for mussels and crabs and the creation of artificial reefs (Hal et al., 2017), several studies document that wind turbines can disturb marine mammals, fish, benthos, and birds, and engender the decline in habitat quality (e.g., Causon and Gill, 2018; Benhemma-Le, 2021). However, these studies also point out the uncertainty of offshore wind's impact on marine species. Affirming offshore wind's probable influence on offshore industries and the marine environment, several DCE studies are featuring both visibility aspects and other characteristics reflective of both near-shore and far-shore wind project externalities.

The most recent quantitative review of offshore wind studies was conducted by Wen et al. (2018), who utilize a calculus method to determine the marginal changes in WTP for visibility-related attributes. Wen et al. (2018) confirm the distance decay effect for the distance attribute but observe disparate preferences for the number of turbines and turbine height attributes. In contrast, the reviews by Ladenburg and Lutzeyer (2012) and Knapp and Ladenburg (2015) provide qualitative analysis, but like Wen et al. (2018), they also accentuate visual disamenities.

Wen et al. (2018) and Ladenburg and Lutzeyer (2012) included four and five offshore wind studies, respectively, while Knapp and Ladenburg (2015) included twelve studies, focusing on both onshore and offshore wind. Moreover, all the studies capture preferences for Western populations. The current literature has since progressed to cover more project externalities and other geographical regions i.e., Asia, most notably South Korea and Japan. We argue that this advancement necessitates an updated literature review. While visibility factors remain critical determinants of the social acceptance of offshore wind, other non-visual attributes may be integral.

Our review contributes to the existing literature by reviewing and comparing thirteen recent DCE articles that cover a wider geographical area and have a varied set of attributes compared to preceding reviews. The review addresses three research questions: (i) What attributes are valued in offshore wind DCE studies? (ii) How are the attributes designed regarding presentation and attribute levels? (iii) What are the WTP estimates for these attributes across various studies? Addressing these research questions can provide invaluable insights for future offshore wind power DCE studies.

The rest of this review article is organized as follows; Section 2 describes the literature search process and presents characteristics of available studies. Section 3 presents and discusses the results and draws comparisons across studies. Finally, section 4 presents the conclusions and implications for future DCEs for offshore wind.

2 Methods

2.1 Literature search process

This sub-section presents the steps used in assembling relevant literature for the systematic review. A systematic review is an iterative process where available scientific research articles are the data source. The objective of our systematic review is to identify attributes and their corresponding WTP estimates in the offshore wind literature. Accordingly, we followed a systematic process through a standardised review, selection and reading process (Şener et al., 2018). We identified the relevant articles by applying specific terms reflecting the energy source type, economic valuation method and the corresponding estimates. The decision to capture exclusively offshore wind DCE studies, rather than also onshore wind, is based on a predicted upsurge in offshore wind as an energy source in this decade (GWEC, 2023).

To compile the relevant articles, we used Web of Science and Scopus. First, we defined the search string using the keywords 'offshore wind' in tandem with; (i) choice experiment and (ii) willingness to pay. The three keywords are combined with 'AND' in the search syntax to ensure that we assemble only relevant articles that fit these search criteria. The literature search criteria are shown in Table 1.

Table 1 Literature search criteria

Database	Web of Science and Scopus
Search period	September 2023
Search string	'Offshore wind', and 'Choice experiment', and 'Willingness to Pay
Language	English
Documents	All

We apply the search strings in the two literature databases, which yield a total of 238 articles, after removing duplicates. Then, we perform a case-by-case selection by screening titles and abstracts. Articles featuring other renewable energy technologies, environmental issues, and other extraneous subjects are excluded. Thus, we remain with nineteen articles. Thereafter, we screened and read in full the nineteen articles.

To ensure the quality of the review, and answer our research questions, we applied the following exclusion criteria. First, our review highlights DCE studies, as this method provides WTP for specific attributes. Thus, we omit papers using other economic valuation methods such as Contingent Valuation (CV) or Hedonic Pricing (HP), as they do not measure WTP estimates for specific attributes, but rather a 'package of attributes' or indicators of a larger set of attributes, respectively (Nepal et al., 2018; Parsons and Yan, 2021; Lee et al., 2023). Second, since WTP for offshore wind is the main object under analysis, studies had to include WTP estimates for offshore wind power-related externalities or attribute levels. To that end, all articles that do not explicitly value offshore wind as the primary non-market good, but rather introduce offshore wind as an attribute level, are also excluded (e.g., Ek and Persson, 2014; Lamy et al., 2020; Linnerud et al., 2022). Third, as much as follow-up studies based on the same DCE data provide interesting insights, incorporating them in the review may be monotonous, hence they are excluded (This includes studies e.g., Ladenburg and Dubgaard, 2009; Ladenburg and Skotte, 2022). Applying these criteria, we identified twelve articles.

To ensure that we incorporate all relevant articles, we employ Google Scholar to perform backwards and forward reference chaining. This involves checking references of available studies, and who had cited the included article. By implementing these actions, we pinpoint two more studies by Iwata et al. (2023) and Kermagoret et al. (2016). The latter study is, however, excluded because it does not include a cost attribute.

2.2 Characteristics of the studies included in the systematic review

Our systematic review is based on thirteen articles, shown in Table 2. The earliest study found was conducted by Ladenburg and Dubgaard (2007) in Denmark. The thirteen studies were conducted across North America, Europe, and Asia. Specifically, five studies were implemented in the United States, while France, Denmark, and South Korea each have two publications, and the United Kingdom and Japan have one publication each. The sample sizes range from 375 to 2,436 respondents. Four of the DCE studies investigate public acceptance, accentuating large-scale wind power programs, while the remaining studies study local communities' acceptance of specific offshore wind power projects.

Table 2 Overview and description of DCE studies for offshore wind power

Study	Country	Sample	Sample size	Model	Cost attribute	Non-cost attributes
Ladenburg and Dubgaard, 2007)	Denmark	National	375	Fixed effect logit model	Electricity bill	Distance, number of turbines
Krueger et al. (2011)	United States	Delaware	949	Mixed logit	Electricity bill	Distance, location of wind farm, royalty fund, renewable payment
Landry et al. (2012)	United States	North Carolina	256	Mixed logit	Trip cost	Visibility, distance from the shore, distance from home, number of people on the beach
Westerberg et al. (2013)	France	Tourists	339	Latent class	Rental price	Distance, artificial reefs associated with recreational activities, sustainable tourism and coherent environmental policy
Börger et al. (2015)	United Kingdom	Local near the Irish Sea	519	Mixed logit	Tax	Turbine height, enhanced biodiversity, electromagnetic fields from cabling
Lutzeyer et al. (2018)	United States	North Carolina	484	Latent Class	Rental price	Distance from the shore, total number of turbines, number of turbines
Kim et al. (2019)	South Korea	National	1000	Multinomial logit	Tax	Distance, farm size, turbine height, decrease in marine life
Dalton et al. (2020)	United States	Recreational boaters in Rhode Island	684	Mixed logit	Trip cost	Distance, number of boats, main recreational activity, geographic location
Klain et al. (2020)	United States	Residents in New England	400	Mixed logit	Electricity bill	Distance, change in marine species biodiversity, ownership

Ladenburg et al. (2020)	Denmark	National	1754	Mixed logit	Electricity bill	Distance, location
Kim et al. (2021)	South Korea	National	1000	Mixed logit	Tax	Distance, number of turbines, height of turbines, reaction in marine life
Iwata et al. (2023)	Japan	National	900	Mixed logit	Levy on renewable energy	Distance, number of turbines, new jobs created, number of affected species, CO2 reduction
Joalland and Mahieu (2023)	France	National	2436	Mixed logit	Electricity bill	Project size, visibility from the coast, effects on jobs in the maritime economy, the origin of fresh seafood, permission for recreational boating

The cumulative number of times an attribute is examined by the different studies is shown in Figure 1. We observe that visibility attributes such as distance from shore, number of turbines, and turbine height are extensively valued across studies. By contrast, the effect on the marine environment and offshore activities attributes are featured in fewer and mostly recent studies. However, as illustrated by their steep curves in recent times, the frequency of valuation is gradually increasing. Project ownership and carbon emission attributes are valued once in the period 2007-2023 by Klain et al. (2020) and Iwata et al. (2023) and are therefore not depicted on the graph.

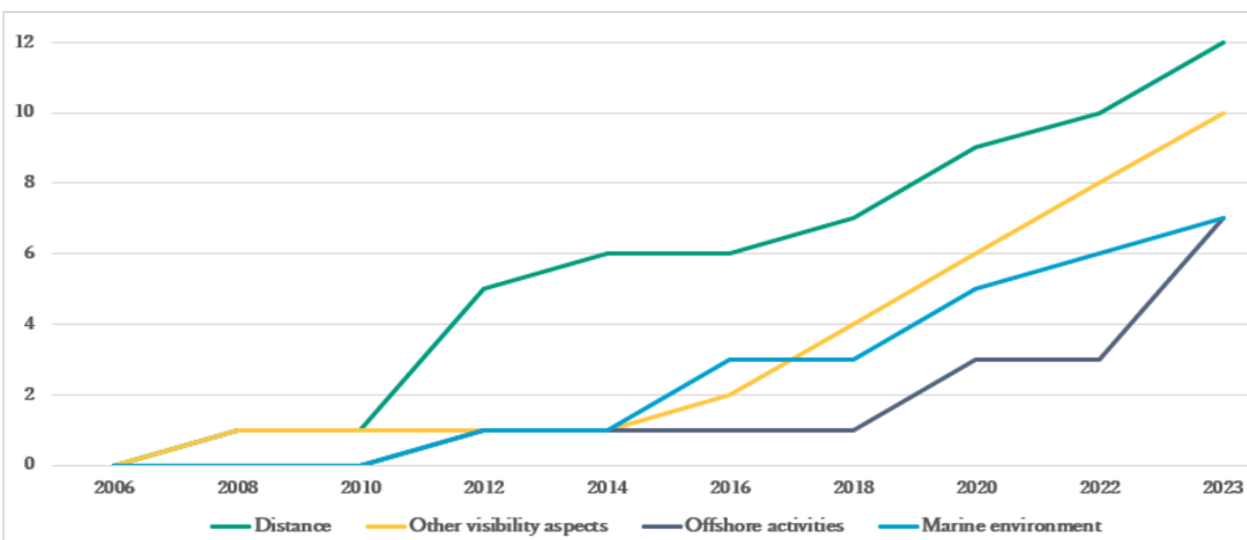

Figure 1 The cumulative number of times various attributes in DCEs of offshore wind power have been studied over time.

Note: A study is referenced for a certain attribute when it examines the WTP for that attribute. Thus, an article is counted several times if it evaluates several attributes. Other visual aspects include project size i.e., number of turbines, total installed capacity, and turbine height. Offshore activities include attributes related to tourism, recreation, job creation and fishing.

2.3 Retrieval and treatment of the willingness to pay estimates

The WTP estimates are based on either multinomial logit, mixed logit, or latent class models. Though both mixed logit and latent class models can account for heterogeneous preferences, they are different. While mixed logit computes WTP per attribute or attribute levels, latent class groups respondents into finite classes and estimates WTP per attribute for each class. As a result, we report WTP estimates per attribute or attribute level, for mixed logit models, and numerous WTP estimates for different groups of people for latent class models, including the weighted average WTP.

The highlighted WTP estimates are for visibility attributes including distance from the shoreline, project size, turbine height, effect on the marine environment, offshore activities, carbon emissions reduction, and project ownership attributes. For consistency, the WTP estimates are first transformed into annual payments, apart from estimates recorded on either a weekly (Westerberg et al., 2013) or per-trip basis (Dalton et al., 2020). The values are then converted to USD by purchasing power parity (PPP) corrected exchange rates (OECD, 2023) for the year the study was conducted; and if not reported, the publication year was used; only applicable to Kim et al. (2019). Thereafter, the WTP estimates in USD are adjusted for inflation using the CPI inflation calculator provided by the United States Bureau of Labour Statistics to reflect their real values in September 2023. Table A1 in the appendix presents more details on the conversion from the original values to WTP per household per year in 2023 USD PPP.

3 Results and Discussion

3.1 Visibility attributes

The visibility factors such as distance from the shore, turbine height, and project size are frequently valued in the literature, and they informed earlier discourses on whether to move wind power projects from onshore areas to remote offshore locations. In this subsection, we discuss the distance from the shore, turbine height, and project size attributes. We omit the location attribute because the attribute is designed and described in significantly different ways across studies (see Krueger et al. 2011, Ladenburg et al., 2020, Dalton et al., 2020, and Kim et al., 2021).

3.1.1 Distance from the shore

Distance from the shore is the prevalent attribute in the literature. Like onshore wind, proximity to residences or holiday homes seems imperative in determining social acceptance. This distance attribute is defined homogenously across studies, contingent on context, existing country conditions and sample used. The attribute is coded either continuously or dummy. Table 3 provides an overview of the studies that feature the distance attribute.

Ladenburg and Dubgaard (2007) is the first DCE study on offshore wind. They define four distance attribute levels: 8km, 12km, 18km, and 50km. The 8km level portrayed the minimum acceptable distance from the shoreline for utility-scale offshore wind in Denmark, at the time of the study. On the other hand, the 50km level is the technical distance whereby turbines with higher power ratings remain inconspicuous from the shoreline contingent on the horizon's curvature and weather conditions (Sullivan, 2013). Wind turbines are somewhat detectable at 12km and 18km, conditional on the turbine's rating and turbine height. Ladenburg and Dubgaard (2007) found that respondents were willing to pay USD 230 to move wind power projects from 8km to more than 50km from the shoreline.

More recently, Ladenburg et al. (2020) found substantially lower WTP among Danish respondents for installing the same wind farms far from the shore. Employing marginal WTP/distance calculations, (e.g., $^{\partial(WTP)}\big/_{\partial(Distance)}$), the change in WTP differs between the two Danish studies. While Ladenburg and Dubgaard (2007) document a 5 USD per km, for moving offshore wind from 8km to 50km, this value is only 1 USD per km in the study by Ladenburg et al. (2020). Nonetheless, both studies illustrate decreasing WTP with rising distance from the shore, as shown Table 3, also referred to as the distance decay effect.

The distance decay effect is also detected in other studies conducted in other regions. Studies administered in the United States by Krueger et al. (2011), Dalton et al. (2020) and Klain et al. (2011), although a decade apart, document analogous results to those found in Denmark. This is despite the United States studies using local samples, while Ladenburg and Dubgaard (2007) and Ladenburg et al. (2020), use national samples. Additionally, the 'distance to the shore' attribute levels employed are between 0.03 km to too far out to see, whereby the latter level exemplifies the 50 km level employed by Ladenburg and Dubgaard (2007) and Ladenburg et al. (2020).

A few studies included in this review analyse their distance attribute in the context of offshore wind effect on tourism (Landry et al., 2012; Westerberg et al., 2013; Dalton et al., 2020). These studies deduct tourists' welfare for visiting ocean areas, by examining whether the tourists are influenced by the presence of hypothetical wind turbines. Landry et al. (2012) define two attributes, (i) ocean view and (ii) sound view, with similar attribute levels, featuring unobstructed views and no sound, to turbines located a few miles from the shore. On the other hand, Dalton et al. (2020) define their attribute as distance to the wind farm during a fishing trip. Both studies reveal that the presence of offshore wind diminishes tourists' welfare, thus, tourists are willing to pay to avoid areas with offshore wind power.

In France, Westerberg et al. (2013) undertook a survey sampling 389 tourists in the Languedoc Roussillon region of the French Mediterranean. They adopt a latent class model, with three segments: (i) Visitors most likely of French origin, (ii) Northern Europeans who are culturally motivated, and (iii) Retired French who are environmentalists. Their cost attribute is in the form of weekly accommodation prices. They select distance levels of 5 km, 8 km and 12 km, relative to 'no wind farms' as the base level. Observing the declining negative average weighted WTP estimates as the distance increased for the three groups, we assert that the distance decay effect holds. Notably, the retired French who are environmental enthusiasts had the highest negative WTP for all three distances. Westerberg et al. (2013) observe that the retired French segment considered the presence of wind turbines a nuisance, compared to the first two segments

Joalland and Mahieu (2023) incorporate visibility from the coast attribute, which implies, either distance from the shore, turbine height or project size attributes. They define this attribute with two levels, 'barely visible', and 'highly prominent' which mirror Klain et al. (2020) description of the distance attributes, 1 mile and more than 10 miles from the shore. Like preceding studies, Joalland and Mahieu (2020) find that people are willing to pay to move wind turbines to remote locations.

Focusing on WTP per kilometre increase in distance from the shore, we observe that the two studies implemented in South Korea (Kim et al., 2019, Kim et al., 2021) have below 1 USD in WTP for an increase in distance by 1 km, which is a significantly lower WTP than the US and European DCEs.

Table 3 Description and WTP for the distance attribute (WTP in 2023 PPP-USD)

Study	Attribute coding	Attribute, levels and subsamples	WTP for attribute/per attribute level	WTP per km
Ladenburg and Dubgaard (2007).	Dummy	**Distance from the shore**. Four levels: 8km, 12km, 18km, 50km	8km: base level 12km: 86.55, 18km: 180.48 50km: 230.18	Move from 8km to: 12km: 21.61/km 18km: 18.05/km 50km: 5.48/km

Krueger et al. (2011).	Dummy	**Distance from the shore.** Three levels: 0.9 miles(1.5km), 3.6 miles(5.8km), 6 miles (9.7km), 9 miles(14.5km), and Too far out to see. Subsamples: Inland, Bay area and Ocean	Too far out to see: base level WTP for 5km Inland: 29.23, Bay: 53.30 Ocean:124.05 *Weighted average WTP*: 52.56, WTP for 5.8km Inland: 13.55, Bay: 17.31, Ocean: 106.62 *Weighted average WTP*: 32.21 WTP for 9.7km Inland: 1.21, Bay: 9.04, Ocean: 54.41 *Weighted average WTP: 13.08* WTP for 14.5km Inland: 0, Bay: 3.193, Ocean: 41.31 *Weighted average WTP: 8.60*	
Landry et al. (2012)	Dummy	**Ocean view** Three levels: A clear view of the ocean, 1 mile (1.6km), 4 miles (6.4km) **Sound view** Three levels: A clear view of the sound, 1 mile (1.6km), 4 miles (6.4km)	A clear view of the ocean: base level 1.6km: 79.14 6.4km: −27.22 A clear view of the sound: base level 1.6km: 38.06 6.4km: −10.03	
Westerberg et al. (2013)	Dummy	**Distance from the shore.** Three levels: 5 km, 8km, 12 km, and no wind farm Latent segments; Visitors, Northern Europeans, and Retired French	No wind farm: base level: WTP for 5km Visitors: −59.52, northern Europeans: −79.02, Retired French: −537.73 *Weighted average WTP: −233.68* WTP for 8km Visitors: 48.96, northern Europeans: −41.24, retired French: −290.70 *Weighted average WTP: −107.68* WTP for 12km Visitors: 0, northern Europeans: 86.95 retired French: −79.43 *Weighted average WTP: 9.43*	
Kim et al. (2019)	Continuous	**Distance from the shore.** Three levels: 1.2km, 15km to 30km		0.23/km

Klain et al. (2020)	Dummy	**Distance from the nearest shore.** Four levels: 1 mile (1.6km), 4 miles (6.4km), 8 miles (12.9km), ≥ 10 miles from shore(16.1km)	1.6km: base level WTP for 6.4km: 7.02 12.9km: 8.19 16.1km: 10.53	
Dalton et al. (2020)	Dummy	**Distance to the wind farm during a fishing trip**. Three levels: nearby or about 100 feet, further away or about 1 mile, not visible or very far.	Not visible or very far: base level Nearby or about 100 feet: −2069; Further away or about 1 mile: 0	
Ladenburg et al. (2020)	Dummy	**Distance from the shore**. Four levels: 8km, 12km, 18km, 50km	8 km: base level WTP for 12km: 16.25, 18km: 67.72 50km: 60.40	Move from 8km to: 12km: 4.06/km 18m: 6.77/km 50km: 1.43/km
Kim et al. (2021)	Continuous	**Distance from the shore.** Three levels: 1km, 10km, 15km		0.78/km
Iwata et al. (2023)	Continuous	**Distance from the shore** Three levels: 10km,15km, 30km		0.10/kWh/km.
Joalland and Mahieu (2023)	Dummy	**Visibility from the coast** Two levels: Barely visible, Highly prominent.	Barely visible: base level WTP for Highly prominent: −50.87	

Note: The WTP estimates are first converted into annual payments for consistency, apart from those estimates recorded on a weekly (Westerberg et al., 2013) or per-trip basis (Dalton et al., 2020). The WTP estimates are then adjusted to USD using purchasing power parity (PPP) corrected exchange rates (OECD, 2023). Thereafter, WTP estimates in USD are adjusted for inflation up until September 2023 using the CPI inflation calculator provided by the United States Bureau of Labour Statistics to have all WTP estimates in 2023-USD. All WTP estimates are recorded per household apart from those reported by Westerberg et al. (2013) and Dalton et al. (2020) which are per person. We report several WTP estimates (for identified different groups of respondents) for studies using the Latent Class model (see Krueger et al., 2011 and Westerberg et al., 2013).

3.1.2 Turbine height

Research and development activities for wind power technology aim to boost turbine efficiency and promote a greater extraction of energy from wind resources. Thus, increasing the hub height and rotor diameter remains pertinent, as height is proportionate to higher energy production potential, partly due to increased capacity factors, and access to superior quality of wind resources. The majority of the studies use one turbine size. For instance, Ladenburg and Dubgaard (2007), and Ladenburg et al. (2020) utilize a 5MW turbine, 100m high and a wingspan of 120m. On the other hand, Krueger et al. (2011), specified a 79m (258 feet) high nacelle and extended blades to reach a total height of 134m

(440 feet). Westerberg et al. (2013) used 3.6MW turbines with a hub height of 75m and a rotor diameter of 104m in their illustrations. By contrast, Klain et al. (2020) inform their respondents that a typical turbine is around 360 feet (110m) above sea level.

Table 4 Description and WTP for the turbine height attribute (WTP in 2023 PPP-USD)

Study	Attribute coding	Attributes, levels and subsamples	WTP per attribute level
Börger et al. (2015)	Dummy	Height of the wind turbines in metres and visibility from coastal strips. Three levels. 180 m – visible from Anglesey and the Isle of Man. 240 m – visible from Anglesey, the Isle of Man and Cumbria, 300 m – visible from Anglesey, the Isle of Man, Cumbria and Liverpool.	80m: base level, 240m: −15.44 300m: −6.12 WTP per meter from 80m to: 240m: −0.10/m 300m:− 0.03/m
Kim et al. (2019)	Continuous	Three levels of turbine height. 60m, 100m, 150m	WTP per increase in meter − 0.07/m
Kim et al. (2021)	Continuous	Three levels of turbine height. 60m, 80m, 110m	WTP per increase in meter: −0.04/m

Only three out of the thirteen studies include turbine height as an attribute. The design of the turbine height attribute in the three studies is homogenous, both in terms of the unit of measurement (i.e., in metres) and description (i.e., turbine height). However, attribute coding varies across studies. Börger et al. (2015) employ dummy coding to calculate the WTP for three turbine height levels, 180m, 240m, or 300m, while Kim et al. (2019) and Kim et al. (2021) apply continuous coding. All three studies found a negative WTP for higher turbines. This substantiates people's preferences for minimal visual intrusion.

3.1.3 Project size

Offshore wind project size governs visibility issues, the effect on the marine environment, and expected total energy production. Four studies utilize the number of turbines to depict project size (Lutzeyer et al., 2018; Kim et al., 2019; Kim et al., 2021; Iwata et al., 2023), while Joalland and Mahieu (2023) adopt the number of households that can be supplied by the electricity produced, as a metric for project size.

Highlighting the studies by Kim et al. (2019) and Kim et al. (2021), we observe similar WTP for this attribute, as for the distance from the shore attribute. Respondents are willing to pay approximately a dollar or less per turbine to scale the number of turbines from twenty down to five in Korea.

Joalland and Mahieu (2023) represent project size in terms of the number of households supplied with electricity. They incorporate 3GW, 6GW, and 10GW project sizes, that supply electricity to 3, 6, and 10 million households, respectively. They find respondents to have a slightly positive WTP to increase the project size by one GW. The low WTP value may stem from a desire to avert visibility issues but can also signify the low priority placed on offshore wind as a new energy source.

Table 5 Description and WTP for the project size attribute (WTP in 2023 PPP-USD)

Study	Attribute coding	Attributes, levels and subsamples	WTP per attribute level
Lutzeyer et al. (2018)	Dummy	**Total number of turbines built** One level: 144 **Number of turbines visible from the shore** (Implied number built too far out to see, in parenthesis) Three levels: 64(80), 100(44), 144(0) Latent segments: All view, some view and never view	Weighted average Willingness to accept(WTA) estimates to move turbines from 30miles (48.24km) to 5 miles(8.08km) Ocean-front sample 64(80): 11,742, 100(44): 13348.77, 144(0): 14087.39
	Continuous	**Offshore wind farm size** Three levels. Farm size: 5, 10, 20	0.23/ turbine
Kim et al. (2021)	Continuous	**Number of turbines** Three levels 5, 10, 20	1.00/ turbine
Iwata et al. (2023)	Continuous	**Number of turbines** Three levels 20, 30, 40	0.04 per kWh/ turbine
Joalland and Mahieu (2023)	Continuous	**Millions of households supplied** Three levels of project size equivalent to the number of households: 3, 6, and 10 million	WTP per increase in 1GW/1 million households: 2.01

Note: Lutzeyer et al. (2018) provide willingness to accept estimates in rental discounts for moving wind power turbines different miles from the shore. They use the latent class model, with three segments, (i) All view, which captures 87% of the respondents who always chose a view with visible turbines, (ii) some view, majority of the respondents chose sometimes a view with turbines, and 13% always did, and (iii)never, view, respondents who always ranked the baseline view as their most preferred scenario. We include the estimates for moving wind turbines from 30 miles (barely visible) to 5 miles (more visible), For brevity in this review we only provide the weighted average willingness to accept estimates for the oceanfront sample.

Lutzeyer et al. (2018) define only one level of the number of turbines built (144 turbines), but the number of turbines visible from the shore varies across choices, with the number of turbines that are invisible from the shore stated in parentheses: 64(80), 100(44), 144(0). Lutzeyer et al. (2018) include both daytime and nighttime visualisation, and respondents are split into two groups, where the first group was shown only daytime images, while the other group received both daytime and nighttime images. The paper reports results for the latter group only. Overall, they find that the proximity of wind turbines to the shore resulted in negative utility, resulting in a higher willingness to pay estimates, regardless of how many turbines were visible.

3.2 Effect on the Marine Environment Attribute

Constructing and operating offshore wind can impact the marine environment, either positively or negatively. The contradicting effects are reflected by the attribute's description in the DCEs; in terms of using the percentage increase or decrease in marine life or the absolute number of affected species. Table 6 provides an overview of the marine environment attributes used in the DCEs.

Westerberg et al. (2013) defined the effect on the environment attribute as sustainable tourism and coherent environmental policy. They disclose to the respondents that the municipality would implement an environmental policy that promotes sustainable practices such as the use of public transport, renewable energy sources and organic products. They discovered that Northern Europeans had a substantially higher WTP, USD 322, for places that adopt sustainable practices, compared to the other two groups, visitors and retired French. Noteworthy, all three groups had a positive WTP for this attribute, showing tourists' preference for preserving the environment.

Börger et al. (2015) illustrate the effect on the environment by two attributes (i) enhanced biodiversity and (ii) electromagnetic fields from cabling. They find that people have a positive WTP, USD 14 and USD 28, for intensifying the number of marine species settling around offshore wind power farms by 10% and 30%, respectively, compared to the 'no change' base level. Alluding to their second environmental effect attribute, electromagnetic field from cabling, Börger et al. (2015) defined the attribute levels based on the existing guidelines. Standards stipulate that marine cables are buried at least 1m below the seabed for water levels of about 2000m, though some electromagnetic fields can still be felt at this depth by some benthic species (Gill et al., 2005). For this reason, it is recommended that sea cables be buried at least 2m below the seabed (Tricas and Gill, 2011). Accordingly, Börger et al. (2015) define two levels, (i) impact, cables buried 1 meter deep, and (ii) no impact, cables buried 2 meter deep. The respondents were willing to pay, USD 49, to forestall the undesirable effect from submarine cables.

While Kim et al. (2019) and Iwata et al. (2023) outline the probable afflicted species such as benthos, fish, mammals, and birds, Kim et al. (2021) do not specify. Besides, the direction of effect, either increase or decrease in marine life, is not clear in the Iwata et al. (2023) study. The two studies conducted in South Korea, (Kim et al., 2019; Kim et al., 2021) found negative WTP for a percentage reduction in marine life.

Distinct from other studies, Klain et al. (2020) feature the negative and positive ramifications of offshore wind on the marine environment., They illustrate their attribute levels as percentage loss and gain in marine life. When computing the WTP, they sort the respondents in terms of their attitudes towards environmental concerns measured by the New Ecological Paradigm (Dunlap et al., 2000). They find that respondents with a higher environmental concern have the highest positive WTP for safeguarding marine biodiversity.

Table 6 Description and WTP for the effect on marine environment attribute (WTP in 2023 PPP-USD)

Study	Attribute coding	Attribute, levels and sub-samples	WTP per attribute level
Westerberg et al. (2013)	Dummy	**Sustainable tourism and coherent environmental policy** Two levels: No, Yes. Latent segments named Visitors, Northern Europeans, and Retired French.	No: base level WTP Yes: Visitors: 79.63, North European: 322.39, Retired French: 149.52 *Weighted average* WTP: 246.36
Börger et al. (2015)	Dummy	**Electromagnetic fields** Impact: Cables buried at 1 m No impact: Cables buried at 2 m	No impact: base level: WTP: Impact:48.74
	Dummy	**Enhanced biodiversity** Levels: No change; 10% more species; 30% more species	No change: base level WTP 10%: 13.61 WTP 30%: 27.83
Kim et al. (2019)	Continuous	**Decrease in marine life** Four levels: 10%, 15%, 30%, 50%	WTP per percentage reduction in marine life: 0.23
Klain et al. (2020)	Dummy	**Change in marine species diversity and abundance** Four levels: 60% decline, 30% decline, 30% increase, 60% increase.	60% gain for high NEP scorers: 42
Kim et al. (2021)	Continuous	**Percentage reduction in marine life** Four levels: 10%, 15%, 30%, 50% decrease.	WTP per percentage reduction in marine life: 0.24.
Iwata et al. (2023)	Continuous	**Number of species that may be affected** Three levels 30, 60 to 90.	WTP /kWh per species affected: −0.01
Joalland and Mahieu (2023)	Dummy	**Impacts on marine biodiversity** Two levels: known, unknown	Known: base level WTP for unknown: −55.88

Lastly, Joalland and Mahieu (2023) capture the uncertainty in measuring the impact of offshore wind farms on marine life. They employ the impact on marine biodiversity attributes and specify two attribute levels, unknown or known. They find that French respondents have a negative WTP, USD 56 for imprecise project impacts, relative to the known, signifying aversion to obscure project impacts.

3.3 Tourism and Fishing Activities

The unease towards developing offshore wind power projects was informed by the projects' potential harm to tourism. Innumerable experts presupposed that wind turbines would visually deteriorate the seascape, erode the identity and culture of a place, and interfere with coastal recreation. However, the literature documents varying findings. Some studies document reduced tourist activities, while other studies report minimal to no impact (e.g., Trandafir et al., 2020), and even a surge in alternative tourism. Table 7 provides an overview of the effects on tourism and fisheries attributes used in the DCEs.

Westerberg et al. (2013) calculate the WTP estimates for offshore wind impact on tourism. They defined the attribute 'wind farms and artificial reef-associated recreational activities' with two levels, yes and no. The attribute captures the abundant reefs present around wind turbines which may increase anglers' catch rates and provide scuba diving opportunities. The three latent groups had significantly disparate WTP for this attribute. The Northern Europeans had a relatively higher positive WTP, USD 115, compared to the visitors who were mostly likely French, USD 44 and retired French, USD 65. Compared to the aversion to wind turbines observed in the distance from the shore attribute, the retired French are more willing to support wind turbines if they enhance the growth of artificial reefs.

In the United States, Landry et al. (2012) and Dalton et al. (2020) focus on the effect of offshore wind on the use of ocean space and recreational activities. Landry et al. (2012) use the number of people on the beach attribute, described by three levels: low, moderate and high. They found that people were willing to pay to avoid moderate levels of beach congestion. Similarly, Dalton et al. (2020) employ two attributes: (i) the number of other recreational boats and (ii) the main activity during a trip. They observed that respondents had a negative WTP for not taking boating trips and for taking trips to highly congested areas (too many boats). This implies that recreational boaters' welfare diminishes substantially in congested spaces or if prohibited from partaking in boating trips. Similar welfare effects are well documented for recreational activities for onshore wind (e.g., Kipperberg et al., 2019; Sæþórsdóttir and Ólafsdóttir, 2020).

Table 7 Description and WTP for effects on tourism and fishing activities attributes (WTP in 2023 PPP-USD)

Study	Attribute coding	Attribute, levels and sub-samples	WTP per attribute level
Landry et al. (2012)	Dummy	**People on the beach** Number of people per mile on the surrounding beach Three levels: Low (1-20 people per mile), moderate (20-80 people per mile) high (>80 people per mile)	Low: base level Moderate: 9.05 High: 46.97
Westerberg et al. (2013)	Dummy	**Wind farm and artificial reef-associated recreational activities** Two levels: binary response, either No or Yes Latent groups named Visitors, Northern Europeans and Retired French.	No: base level Yes: Visitors: 44.49, North Europeans: 114.78, Retired French: 64.80 *Weighted average WTP: 81.12*
Dalton et al. (2020)	Dummy	**Number of other nearby recreational boats** No trip: −2286.90 Few boats: 0 Many boats: −527.98	No trip: −2069.06 Few boats: 0 Many boats: −541.07
	Dummy	**The main activity during the trip** Three levels: Cruising or sailing, Fishing and catching non-target fish, Fishing and catching target fish	Cruising or sailing: base level Fishing and catching non-target fish: −4230.67 Fishing and catching target fish: −4407.51
Joalland and Mahieu (2023)	Dummy	**Main country of origin for fresh seafood** Three levels: France, UK, and Spain **Permission for recreational boating** Two levels: Forbidden, Allowed	Main country of origin for fresh seafood Base level: France UK: −128.96, Spain: −109.73 Allowed: base level: Forbidden: 30.05

Joalland and Mahieu (2023) estimate two offshore activity attributes. Specifically, the study defines the attributes as; (i) the main country of origin for fresh seafood, alluding to the decrease in domestic supply of French fish if more ocean areas are cleared for developing offshore wind power and (ii) permits for recreational boating. Joalland and Mahieu (2023) observe that French respondents have a negative WTP for fish that are sourced from Spain, USD 110, and England, USD 129. This implies a preference for preserving the local fishing industry and dissuading imports.

Like Dalton et al. (2020) above, Joalland and Mahieu (2023) found that French respondents were positive about restricting recreational boats from offshore wind sites. This implies a belief that boating activity could be conducted in alternative ocean space, or people are averse towards a probable collision between wind turbines and boating vessels and its subsequent consequences

3.4 Employment, ownership and reduction in carbon emissions

We review additional attributes highlighted in some of the articles. We highlight offshore wind effect on employment (Joalland and Mahieu, 2023; Iwata et al., 2023), reduction in CO2 emission (Iwata et al., 2023) and project ownership (Klain et al., 2020),

The impact of large offshore wind power projects on the local economy can be positive, negative or neutral (For a review, see Alem et al., 2020). Directly, new offshore wind results in new jobs by hiring local contractors. On the other hand, offshore wind can expedite green hydrogen, or stimulate the blue economy such as harbour operation, marine research, submarine cabling and aquaculture (Kahouli and Martin, 2018).

First, Joalland and Mahieu (2023) and Iwata et al., (2023) include offshore wind power's effect on employment attributes. Joalland and Mahieu (2023) find that French respondents have positive WTP, USD 67, for creating over five thousand jobs, and negative WTP, USD 83, for dwindling employment prospects in the blue economy relative to creating a thousand jobs. Consistent with loss aversion, a loss in maritime employment has a higher impact on WTP than a gain. In contrast, Japanese respondents are unwilling to pay more to generate jobs (Iwata et al., 2023). Unlike Joalland and Mahieu (2023), who compute the WTP for the impact of offshore wind on wider maritime employment, Iwata et al. (2023) focus on job creation per turbine. Hence the differing WTP estimates and the effects can be due to the distinct attribute framing.

Second, Klain et al. (2020) elicit WTP for ownership of offshore wind power projects. Their study defines four types of ownership: private, municipal, cooperative and state. Owing to the resulting WTP estimates, people preferred municipal, state or cooperative ownership, in that order, to private ownership. This may stem from the assertion that trust in project developers stimulates trust in energy technology. Accordingly, it is easier to trust municipal governments than private companies, and the former is also perceived as local whereas the latter, is international. Research documents that local ownership is prioritized over international companies (Leiren et al., 2020; Linnerud et al., 2022).

Table 8 Description and WTP for employment, ownership and CO2-reduction effects attributes (WTP in 2023 PPP-USD)

Study	Attribute coding	Attribute, levels, and subsamples	WTP per attribute level
Joalland and Mahieu (2023)	Dummy	**Effect on jobs in the maritime economy** Three levels: −2000, +1000, +5000	+1000: base level WTP for −2000: −82.51 WTP for +5000: 66.98
Iwata et al. (2023)	Continuous	**New jobs creation** (workers/turbine) Three levels: 20, 30, 50	WTP per job/turbine:−0.01 per job per turbine
Klain et al. (2020)	Dummy	**Ownership type.** Four levels: Private, State, Municipal, Cooperative	Private: base level State: 5.24, Municipal: 6.55 Cooperative: 3.93
Iwata et al. (2023)	Continuous	**CO2 reduction** Three levels: 5, 7, 10	0.07 per kW per ton CO2 per turbine

Lastly, the green energy transition is a twin challenge, intensifying energy production while abating carbon emissions. Although researchers have implied carbon emissions abatement, it is only Iwata et al. (2023) that explicitly define the carbon emission reduction attribute. Iwata et al. (2023) find that respondents are willing to pay for developing offshore wind to reduce carbon emissions. This may imply that the Japanese support the carbon emission reduction narrative, and they are unsure about the job creation potential. Their finding is in concert with existing studies that document preferences for energy projects to achieve climate objectives (Wüstenhagen et al., 2007; Petrova, 2013; Anshelm and Simon, 2016; Donald et al., 2023).

3.5 Cost attribute

The cost attribute is essential in calculating WTP estimates. The design of this attribute is contingent on the context and the good under analysis, which in turn impacts consequentiality and study validity (Johnston et al., 2017). Numerous studies document the influence of cost attribute levels and their range on the WTP (e.g., Glenk et al., 2019).

Electricity bill is the predominant cost attribute, and it is featured in seven studies. The remaining studies use taxes, trip costs and accommodation costs. The accommodation and trip costs are incurred per trip basis, the taxes per year, while the electricity bill surcharges are either annual, monthly or per kWh. The per kWh cost is employed solely by Iwata et al. (2023).

The studies differ in terms of payment duration. Krueger et al. (2011) use monthly payments for three years, Börger et al., 2015 specify annual payments for five years, Joalland and Mahieu

(2023) adopt monthly payments for ten years while Klain et al. (2020) use yearly payments for 25-year project lifespan. However, many studies do not specify the payment duration.

Table 9 Description of the cost attribute used in the DCE studies

Study	Cost	Description	Frequency	Duration	Levels
Ladenburg and Dubgaard (2007)	Electricity bill	Uniform surcharge to households' electricity bills.	Yearly	Do not specify	0, 12.5, 23, 40, 80, 175 Euro
Krueger et al. (2011)	Electricity bill	Renewable energy fees are added to households' electricity bills.	Monthly	Three years	0, 1, 5, 10, 20, 30 USD
Landry et al. (2012)	Parking fee	Amount paid to park a car	Per trip	Do not specify	0, 4, 8 USD
Klain et al. (2020)	Electricity bill	Addition to electricity utility bill	Monthly	Project lifetime, ~25 years	1, 5, 10, 20 USD
Ladenburg et al. (2020)	Electricity bill	Uniform surcharge to households' electricity bills.	Yearly	Do not specify	0, 50, 100, 300, 600, 1200 Danish kroner
Iwata et al. (2023)	Electricity bill	Levy on renewable energy (yen/kW)		Do not specify	1, 3, 5 yen/kW
Joalland and Mahieu (2023)	Electricity bill	Increase in the electricity bill	Monthly	Ten years	1.8, 2, 2.2, 4.5, 5, 5.5, 9, 10, 11, 18, 20, 22 Euro
Börger et al. (2015)	Tax	Addition to households' council tax	Yearly	Five years	£0, £5, £10, £25, £50 UK
Lutzeyer et al. (2018)	Rental price	Change in the rental price	Monthly	Do not specify	+5%, 0%, −5%, −10%, −15%, −20%, −25% USD
Kim et al. (2019)	Tax	Increase in yearly income tax per household	Yearly	Do not specify	0, 1000, 2000, 4000, 7000 Korean Won
Kim et al. (2021)	Tax	Increase in household income tax	Yearly	Do not specify	0, 1000, 2000, 4000, 7000 Korean Won
Westerberg et al. (2013)	Accommodation price	Change in the weekly accommodation price	Per visit	One week	-200, -50, -25, -10, +10, +25, +50, +200 Euro
Dalton et al. (2020)	Trip cost	Trip costs for necessities i.e fuel costs	Per trip	Do not specify	20, 50, 100, 250 USD

Noteworthy, the framing of the additional tax or cost on the electricity bill is distinct across studies. While some articles describe it as a renewable energy fee (e.g., Krueger et al., 2011) or a tax aimed at minimizing the environmental costs of developing offshore wind energy (e.g., Kim et al., 2019; Kim et al., 2021), others label it as a surcharge added to the electricity bill (e.g., Ladenburg and Dubgaard, 2007).

3.6 Opt-out options

An opt-out alternative represents a 'no contract' option and may capture realistic scenarios in a market. First, Ladenburg and Dubgaard (2007) and Ladenburg et al. (2020) did not include an opt-out alternative as they considered the decision to deploy offshore wind had been made already. In contrast, Kim et al. (2019) and Kim et al. (2021) used a baseline offshore wind project with less preferred environmental and visual aspects at zero cost as an opt-out alternative.

Table 10 Opt-out options used in the DCEs

Study	Opt-out option
Ladenburg and Dubgaard (2007)	No opt out option.
Krueger et al. (2011)	No wind power. Expansion of coal or natural gas power
Landry et al. (2012)	No opt-out
Westerberg et al. (2013)	No wind farm
Börger et al. (2015)	No change at zero cost.
Kim et al. (2019)	Baseline alternative at no cost with the attribute levels representing the worst visual and environmental effects
Lutzeyer et al. (2018)	Baseline image with no turbines in view
Klain et al. (2020)	New coal or gas plant
Ladenburg et al. (2020)	None
Dalton et al. (2020)	No trip
Kim et al. (2021)	Baseline alternative at no cost with the attribute levels presenting the worst visual and environmental effects
Iwata et al. (2023)	No windmills
Joalland and Mahieu (2023)	Three versions of alternative energy production

Second, Dalton et al. (2020) employed a 'no trip' alternative. In addition, Westerberg et al. (2013), Börger et al. (2015) and Iwata et al. (2023) chose 'no additional offshore wind, while Krueger et al. (2011) and Klain et al. (2020) specified that opposing offshore wind would increase oil and gas production. Lastly, Joalland and Mahieu (2023) adjust the opt-out alternative, whereby participants are first provided with information about France's existing energy. Later, they are enlightened about the consequences of opposing offshore wind: (i) extending the lifespan of nuclear power plants or, (ii) increasing onshore wind. Succinctly, the former opt-out alternative weakened the acceptance of offshore wind, compared to the latter.

4. Conclusion

This review analyses studies employing DCEs to value the external effects of offshore wind power projects. The offshore wind DCE studies feature attributes capturing both positive and negative externalities. These attributes include distance from the shore, turbine height, number of turbines, effect on marine biodiversity, impact on offshore activities, project ownership, job creation and projects' ability to mitigate climate change. The attributes are similar or can also vary in terms of design and description, with several attributes adapting country-specific and market conditions during the time of the survey. Moreover, the way the attributes are coded varies across studies thus challenging to compare WTP estimates. Furthermore, several studies apply the increase in electricity bills as their cost attribute. However, other studies use other payment vehicles including trip costs, rental discounts and accommodation costs, indicating that the choice is conditional on context.

The review finds that visibility attributes dominate the literature. Moreover, these attributes result in substantially higher WTP estimates. Noteworthy, people prefer offshore wind power projects with a low impact on the marine environment. Furthermore, aversion to loss of marine biodiversity intensifies with higher reported levels of environmental awareness. The effect on various offshore industries and activities on WTP is conditional on the type of offshore activity and where the study was conducted. Illustratively, people prefer developing offshore wind power that does not interfere with traditional offshore industries, and priority for exploiting ocean resources is given to the fishing industry. However, people think that offshore wind will not significantly hamper tourism, possibly because these activities can be moved to other ocean spaces. Succinctly, preferences for offshore wind are contextual and can be gauged by factors such as project ownership, and the possibility of mitigating climate change by deploying renewable energy projects.

This analysis presents considerable meaningful insights for future DCE studies. First, despite the new offshore wind projects being sited longer distances from the shore, visibility issues remain critical for assessing social acceptance. Planned offshore wind power projects will apply higher-rated turbines, over 18MW, visible at different observer angles and by different groups. This necessitates conscious sampling, comprising both local communities and users of the ocean space. Second, deploying assorted offshore wind power projects implies an imminently greater environmental footprint, heightening the importance of this attribute in economic valuation. Studies are tasked with documenting realistic impacts, reflecting the varied effects this attribute has on marine ecosystems. Third, conflicts about the exploitation of ocean resources will escalate, and like the effect on the environment attribute, the impact on other offshore activities will become pertinent for DCE studies. Lastly, social acceptance of new energy technologies is contingent on the context. Accordingly, researchers should feature context-specific attributes reflecting existing socio-political, market and energy landscapes as well as using a realistic payment vehicle (both in terms of direct relevance to the projects and payment duration) to ascertain policy and study consequentiality.

With governments bracing themselves for investing in and deploying new offshore wind power projects, proper costing of project externalities can aid in optimal planning. Furthermore, properly executed DCEs can inform renewable energy policies, such as guidelines for auctioning. Ultimately, appropriate costing allows for more complete cost-benefit analyses of offshore wind power, which can guide decision-making towards optimal project deployment.

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Appendix

Table A1 Conversion of WTP estimates in the articles to 2023 USD PPP

Study	Survey year	Country and currency	PPP rate	Inflation adjustment factor
Ladenburg and Dubgaard (2007)[2]	2004	Denmark (DKK), but reported in Euro (€)	0.82	1.51
Krueger et al. (2011)	2006	US, Dollar ($)	1	1.55
Landry et al. (2012)	2009	US, Dollar ($)	1	1.45
Westerberg et al. (2013)	2010	France, Euro (€)	0.699	1.42
Börger et al. (2015)	2013-2014	UK, Pound (£)	0.698	1.32
Lutzeyer et al.(2018)	2012	US, Dollar ($)	1	1.38
Kim et al. (2019)	2018	Korea, Won (₩), but reported in USD	1	1.24
Dalton et al. (2020)	2018	US, Dollar ($)	1	1.24
Klain et al. (2020)	2015	US, Dollar ($)	1	1.31
Ladenburg et al. (2020)	2011-2012	Denmark, Krone (DKR)	7.564	1.38
Kim et al. (2021)	Not reported	Korea, Won (₩), but reported in USD ($)	1	1.16
Iwata et al. (2023)	2020	Japan, Yen (¥)	102.4	1.19
Joalland and Mahieu (2023)	2021	France, Euro (€)	0.719	1.16

Notes: All inflation adjustments made from the survey year to September 2023, except Kim et al (2021), where the publication year is used.

Ladenburg and Dubgaard (2007) wase conducted in Denmark but report numbers in Euros. We use the Euro values.

For surveys covering multiple years, we use the most recent year .

Kim et al (2019, 2021) are reported in USD. We use the USD values.

Iwata et al. (2023) had a payment vehicle in yen/kWh, but they do not refer to kWh when they present and discuss their WTP estimates in their paper. To get to the annual WTP per households the estimate has to be multiplied by the average annual electricity consumption of 5000 kWh. We were in contact with the authors on October 19, 2023, and they confirm that WTP estimates reported are per kWh of private electricity consumption and acknowledge a mistake in their Table 5 and the subsequent discussion of results. The WTP estimate of 98.20 yen in their Table 5 should be corrected to 0.9820 yen/kWh (as WTP was stated in sin, not yen). Similar adjustments should be made for all their other WTP estimates. The authors said they would contact the journal to correct the mistakes, but as the correction is not yet published, we do not report any annual WTP estimate from their study here.

Appendix

Original web survey questionnaire (in Norwegian) with Discrete Choice Experiment (DCE) used for Papers I, II and III

Velkommen til denne undersøkelsen om holdninger til vindkraftprosjekter i norske havområder.

Undersøkelsen inngår i forskningsprosjektet Enable (Enabling the green transition in Norway).
Prosjektet er finansiert av Norges forskningsråd, og har som mål å se på hvordan nye teknologier innenfor energi- og transportsektoren kan bidra til en grønnere omstilling i Norge.

Ditt bidrag vil gi oss kunnskap om nordmenns holdninger til mulige havvindprosjekter og kan påvirke norsk havvindspolitikk. Norges miljø – og biovitenskapelige universitet (NMBU) leder og er ansvarlig for denne delen av forskningsprosjektet.

NMBU vil motta anonymiserte data, og du kan som alltid lese mer om hvordan vi ivaretar personvernet ditt og dine rettigheter her: galluppanelet.no/Privacy. NSD – Norsk senter for forskningsdata AS har vurdert at behandlingen av personopplysninger i prosjektet er i samsvar med personvernregelverket.

Q02 - energi2: Energi, klima og det grønne skifte

Hvor positiv eller negativ er du til at norske myndigheter legger til rette for følgende utvikling?

	Svært negativ	Ganske negativ	Hverken negativ eller positiv	Ganske positiv	Svært positiv	Vet ikke
Utbygging av nye olje- og gassfelter	❍	❍	❍	❍	❍	❍
Oppgradering av eksisterende vannkraftverk	❍	❍	❍	❍	❍	❍
Utbygging av nye vannkraftverk	❍	❍	❍	❍	❍	❍
Utbygging av nye vindkraftverk på land	❍	❍	❍	❍	❍	❍
Utbygging av nye vindkraftverk til havs	❍	❍	❍	❍	❍	❍
Utbygging av nye bølgekraftverk	❍	❍	❍	❍	❍	❍

Vindkrafttekst1

Utvikling av flytende vindkraftprosjekter til havs for å møte etterspørsel etter strøm

Ifølge Norges vassdrags- og energidirektorat (NVE) forventes strømbehovet i Norge å øke med 15% innen 2040. Lignende økninger forventes i nabolandene.

I 2020 bestemte norske myndigheter at vi skal åpne havområdene Utsira Nord og Sørlige Nordsjø II for vindkraftprosjekter. For prosjektene som skal bygges der havet er dypt må det utvikles ny flytende havvindsteknologi. Norske myndigheter vil i en overgangsperiode gi økonomisk støtte til utvikling og bygging av disse prosjektene.

De flytende havvindsprosjektene vil hjelpe oss å møte økende etterspørsel etter strøm. Kritikere sier de kan påvirke kystlandskapet, andre næringer, fugler og marint liv.

Vindkrafttekst2

Utvikling av flytende vindkraftprosjekter til havs for å redusere utslippene av klimagasser
Norge har som et av 197 land signert Paris-avtalen om klimagassutslipp. Vi har forpliktet oss til kraftige kutt i utslippene i årene som kommer. For å nå målene i avtalen, må verdens land erstatte forurensende energikilder med fornybare energikilder.

I 2020 bestemte de norske myndighetene at vi skal åpne havområder i Utsira Nord og Sørlige Nordsjø II for vindkraftprosjekter. For prosjektene som skal bygges der havet er dypt, må det utvikles ny flytende havvindsteknologi. Norske myndigheter vil i en overgangsperiode gi økonomisk støtte til utvikling og bygging av disse prosjektene.

De flytende havvindsprosjektene vil hjelpe oss å redusere klimagassutslippene, men kritikere sier at de kan påvirke kystlandskapet, andre næringer, fugler og marint liv.

Eksempel på havvindprosjekter til havs og flytende havvind teknologi.

Valgeksperiment

Vi vil be deg velge mellom mulige flytende havvindprosjekter, som varierer i fem faktorer:

(1) Prosjektstørrelse
(2) Andel norsk teknologi
(3) Reduksjon i teknologikostnadene i 2030
(4) Bruk av strømmen
(5) Økning i husholdningens strømregning i tre år

Vi vil her kort forklare de fem faktorene. Vi ber deg lese beskrivelsene nøye.

1. Prosjektstørrelse
Den største foreslåtte utbyggingen har en installert kapasitet på 1500 Megawatt (MW), ca 150 vindmøller fordelt på tre områder, og vil innen 2030 kunne gi strøm til omtrent 400 000 husstander. Utbyggingen på 1000 MW vil ha ca 100 vindmøller fordelt på to områder. Utbyggingen på 500 MW vil ha ca 50 vindmøller på ett område.

2. Andel norsk teknologi
Norske bedrifter som opererer i olje- og gassektoren, har kunnskap og teknologi som kan tilpasses behovene til flytende havvindprosjekter. For å utvikle norsk havvindsektor, vil de foreslåtte prosjektene bruke teknologi fra norske selskaper. Den norske teknologiandelen vil være mellom 25% og 75% mens resten vil dekkes av internasjonale selskaper

3. Reduksjon i teknologikostnadene i 2030
Teknologiutviklingen i de foreslåtte prosjektene vil gi mellom 10% og 30% lavere installasjonskostnader for flytende vindkraftprosjekter planlagt etter 2030. Den samlede effekten av teknologiutviklingen i disse og tilsvarende prosjekter i andre land antas å redusere teknologikostnadene betydelig. Jo flere havvindprosjekter som bygges nå, jo fortere vil kostnadene reduseres.

4. Bruk av strømmen
Prosjektene er forskjellige med hensyn til hvem som skal bruke strømmen. De kan enten kobles til olje- og gassplattformer til havs, direkte til det norske kraftnettet, eller direkte til kraftnettet i andre land via internasjonale sjøkabler.

5. Økning i din husholdnings strømregning i tre år
Prosjektene har høye utviklingskostnader og trenger økonomisk støtte for å realiseres. Finansieringen av prosjektene vil føre til en økning i strømregningen for norske husholdninger i form av grønn avgift på mellom 10% og 35% i tre år.

Har du lest beskrivelsene av de fem faktorene nøye?

1	Ja, det har jeg gjort
2	Nei, det har jeg ikke gjort

Q03 - valgspørsmålene

Du vil bli presentert seks valgspørsmål. Hvert spørsmål har tre alternativer, to mulige flytende havvindkraftprosjekter og et «Ingen av disse». For hvert av de seks valgspørsmålene ber vi deg velge alternativet du foretrekker.
(I avhandlingen viser vi seks valgkort som ble presentert til respondentene i blokk 1, et av tre blokker)

Valgkort1

	Havvindprosjekt 1	Havvindprosjekt 2	Ingene av prosjektene
Prosjektstørrelse	1000 MW	500 MW	
Andel norsk teknologi	75%	25%	
Reduksjon i 2030 teknologikostnader	10%	20%	
Bruk av strøm	Norsk olje- og gassektor	Overført til det norske fastlandet	
Økning i husholdnings strømregning	10%	35%	
Hvilket prosjekt foretrekker du?			

Valgkort2

	Havvindprosjekt 1	Havvindprosjekt 2	Ingene av prosjektene
Prosjektstørrelse	500 MW	1500 MW	
Andel norsk teknologi	75%	25%	
Reduksjon i 2030 teknologikostnader	30%	30%	
Bruk av strøm	Overført direkte til andre land	Overført til det norske fastlandet	
Økning i husholdnings strømregning	10%	20%	
Hvilket prosjekt foretrekker du?			

Valgkort3

	Havvindprosjekt 1	Havvindprosjekt 2	Ingene av prosjektene
Prosjektstørrelse	1000 MW	500 MW	
Andel norsk teknologi	25%	75%	
Reduksjon i 2030 teknologikostnader	10%	30%	
Bruk av strøm	Overført til det norske fastlandet	Overført direkte til andre land	
Økning i husholdnings strømregning	15%	35%	
Hvilket prosjekt foretrekker du?			

Valgkort4

	Havvindprosjekt 1	Havvindprosjekt 2	Ingene av prosjektene
Prosjektstørrelse	1500 MW	1000 MW	
Andel norsk teknologi	25%	75%	
Reduksjon i 2030 teknologikostnader	30%	30%	
Bruk av strøm	Norsk olje- og gassektor	Overført til det norske fastlandet	
Økning i husholdnings strømregning	20%	15%	
Hvilket prosjekt foretrekker du?			

Valgkort5

	Havvindprosjekt 1	Havvindprosjekt 2	Ingen av prosjektene
Prosjektstørrelse	1000 MW	1000 MW	
Andel norsk teknologi	25%	75%	
Reduksjon i 2030 teknologikostnader	20%	10%	
Bruk av strøm	Norsk olje- og gassektor	Overført direkte til andre land	
Økning i strømprisen i tre årene	35%	10%	
Hvilket prosjekt foretrekker du?			

Valgkort6

	Havvindprosjekt 1	Havvindprosjekt 2	Ingene av prosjektene
Prosjektstørrelse	1500 MW	1500 MW	
Andel norsk teknologi	50%	50%	
Reduksjon i 2030 teknologikostnader	20%	30%	
Bruk av strøm	Overført direkte til andre land	Norsk olje- og gassektor	
Økning i husholdnings strømregning	30%	35%	
Hvilket prosjekt foretrekker du?			

Q04 – oppfolging1: oppfølgingsspørsmål til valgspørsmålene

Hvor viktig eller ikke viktig var følgende egenskaper da du gjorde dine valg?

	Ikke viktig i det hele tatt	Litt viktig	Ganske viktig	Viktig	Svært viktig	Vet ikke
Prosjektstørrelse	❍	❍	❍	❍	❍	❍
Andel norsk teknologi	❍	❍	❍	❍	❍	❍
Reduksjon i teknologikostnadene i 2030	❍	❍	❍	❍	❍	❍
Bruk av strømmen	❍	❍	❍	❍	❍	❍
Økning i din husholdnings strømregning i tre år	❍	❍	❍	❍	❍	❍

Q05 - oppfolging2: Oppfølgingsspørsmål til valgspørsmålene

Hva er grunnen(e) til at du valgte 'Ingen av disse' i alle valgoppgavene?

Du kan velge en eller flere grunner.

1	Utbyggerne bør selv dekke alle kostnadene ved vindkraftprosjekter til havs
2	Havvindkraftprosjekter vil ødelegge for fugler og marint liv
3	Jeg har ikke råd til å betale mer for strøm
4	Norske husholdninger bør ikke dekke kostnadene til utbygging av havvindprosjekter
996	Annet, vennligst spesifiser: **Open *Fixed*
999	Jeg vet ikke **Fixed *Exclusive*

Q06 - oppfolging3: Oppfølgingsspørsmål til valgspørsmålene

Hva er gjennomsnittlig strømregning per måned for husstanden din hittil i 2021?

Vennligst velg det du tror passer best.

1	Mindre enn 300 kroner
2	300 – 599 kroner
3	600 – 1199 kroner
4	1200 – 1799 kroner
5	1800 – 2399 kroner
6	2400 - 3000 kroner
7	Mer enn 3000, angi omtrent hvor mye …… **Open*
999	Vet ikke **Fixed *Exclusive*

Tilknytning til norske havområder

Q07 - tilknytning1: Tilknytning til norske havområder

Bor du ved den norske kysten?

1	Ja
2	Nei
3	Vet ikke

Q08- tilknytning2: Tilknytning til norske havområder

Har du en fritidseiendom ved den norske kysten?

1	Ja
2	Nei
3	Vet ikke

Q09 - tilknytning3: Tilknytning til norske havområder

Hvor ofte tilbringer du tid ved kysten eller på sjøen / havet?

1	Daglig
2	4 til 6 ganger i uken
3	1 til 3 ganger i uken
4	1 til 3 ganger i måneden
5	Mindre enn 1 gang per måned
6	Vet ikke

Q010 - tilknytning4: Tilknytning til norske havområder

I de neste spørsmålene ber vi deg tenke på havet som omgir Norge.
Hvor enig eller uenig er du i følgende utsagn?

Jeg tenker på havet som...

	Helt uenig	Delvis uenig	Hverken uenig eller enig	Delvis enig	Helt enig	Vet ikke
.. vakkert å se på	❍	❍	❍	❍	❍	❍
.. et sted for friluftsliv	❍	❍	❍	❍	❍	❍
.. et sted for å slappe av	❍	❍	❍	❍	❍	❍
.. et sted for å få inspirasjon	❍	❍	❍	❍	❍	❍
.. et hjem for ville dyr	❍	❍	❍	❍	❍	❍
.. et sted for urørt natur	❍	❍	❍	❍	❍	❍
.. et sted for egenverdi, uavhengig av oss mennesker	❍	❍	❍	❍	❍	❍

Tilknytning til norske havområder

Q011 - VBB:

Hvor enig eller uenig er du i følgende påstander om din tilknytting til havet som omgir Norge?

	Helt uenig	Delvis uenig	Hverken enig eller uenig	Delvis enig	Helt enig	Vet ikke
Jeg lengter ofte til havet	❍	❍	❍	❍	❍	❍
Havet er mitt favorittsted	❍	❍	❍	❍	❍	❍
Jeg liker godt å være på havet	❍	❍	❍	❍	❍	❍

Utvikling til havs

Q012 - energi1: Energi, klima og det grønne skifte

Hvor enig eller uenig er du i følgende påstander?

	Helt uenig	Delvis uenig	Hverken uenig eller enig	Delvis enig	Helt enig	Vet ikke
Klimaendringer er et av de største problemene menneskeheten står overfor	❍	❍	❍	❍	❍	❍
Menneskelige aktiviteter er den viktigste bidragsyteren til klimaendringene	❍	❍	❍	❍	❍	❍
Klimaendringene fører til betydelige negative konsekvenser	❍	❍	❍	❍	❍	❍
Klimaendringer er et mindre problem enn det miljøorganisasjonene påstår	❍	❍	❍	❍	❍	❍
Klimaendringer er et naturlig fenomen som hovedsakelig drives av andre faktorer enn menneskelig aktivitet	❍	❍	❍	❍	❍	❍
Klimaendringer har ingen negative konsekvenser	❍	❍	❍	❍	❍	❍

Q013 - utvikling_havs1: Utvikling til havs

Hvor positiv eller negativ er du til utbygging av flytende vindkraftprosjekter til havs?

1	Svært negativ
2	Ganske negativ
3	Hverken negativ eller positiv
4	Ganske positiv
5	Svært positiv
6	Vet ikke

Q014 - UTVIKL:

Mange næringer ønsker å benytte norske havområder. Hvor positiv eller negativ er du til videre vekst i følgende næringer i norske havområder?

	Svært negativ	Ganske negativ	Hverken negativ eller positiv	Ganske negativ	Svært negativ	Vet ikke
Olje og gass	❍	❍	❍	❍	❍	❍
Skipsfart	❍	❍	❍	❍	❍	❍
Flytende vindkraftprosjekter til havs	❍	❍	❍	❍	❍	❍
Turisme	❍	❍	❍	❍	❍	❍
Fiskeoppdrett	❍	❍	❍	❍	❍	❍
Karbonfangst og lagring under den norske havbunnen	❍	❍	❍	❍	❍	❍

Q015 - utvikling_havs2: Utvikling til havs

Hvor enig eller uenig er du i følgende påstander?

	Helt uenig	Delvis uenig	Hverken uenig eller enig	Delvis enig	Helt enig	Vet ikke
Kystsamfunnene bør til enhver tid motta oppdatert og detaljert informasjon om nye nærliggende vindkraftprosjekter til havs	❍	❍	❍	❍	❍	❍
Kystsamfunnene bør bli grundig konsultert i alle prosjektfaser for nye nærliggende vindkraftprosjekter til havs	❍	❍	❍	❍	❍	❍
Kystsamfunnenes synspunkter bør i stor grad påvirke avgjørelsene om nærliggende vindkraftprosjekter til havs	❍	❍	❍	❍	❍	❍

Utvikling til havs

Q016 - hovedpovirkning1:

I hvilken grad tror du at utbygging av flytende havvind teknologi ..

	I svært liten grad	I ganske liten grad	Hverken eller	I ganske stor grad	I svært stor grad	Vet ikke
.. er nødvendig	❍	❍	❍	❍	❍	❍
.. er fordelaktig	❍	❍	❍	❍	❍	❍
.. er bra	❍	❍	❍	❍	❍	❍
.. er kontroversielt	❍	❍	❍	❍	❍	❍
.. kan påvirke miljøet	❍	❍	❍	❍	❍	❍
.. er risikabelt	❍	❍	❍	❍	❍	❍

Q017 - hovedpovirkning2:

I hvilken grad tror du at resultatene fra denne og tilsvarende spørreundersøkelser påvirker politiske beslutninger om utforming av havvind i Norge?

1	I svært liten grad
2	I ganske liten grad
3	Hverken eller
4	I ganske stor grad
5	I svært stor grad
6	Vet ikke

Q018 - hovedpovirkning3:

I hvilken grad tror du at resultatene fra denne og tilsvarende spørreundersøkelser påvirker hvor mye du kommer til å betale for strøm i framtiden?

1	I svært liten grad
2	I ganske liten grad
3	Hverken eller
4	I ganske stor grad
5	I svært stor grad
6	Vet ikke