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Economics of Wind Integration

An Acceptance Costs Approach

PhD Thesis

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Kgs. Lyngby, Denmark

9th December 2018

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Preface

This thesis has been submitted to the Department of Management Engineering at the Technical University of Denmark (DTU), in partial fulfilment of the requirements for a PhD degree. The work has been supervised by Professor MSO Henrik Klinge Jacobsen (DTU) and Professor Jacob Ladenburg (VIVE).

Funding was provided by the Danish Council for Strategic Research as part of the research project Wind2050.

The thesis consists of two major parts. The first part introduces the background and defines the scope of the study. It gives a brief overview of the methods applied and a summary and discussion of the results achieved. The second part consists of six scientific articles that form the major contribution of the study.

Kgs. Lyngby, March 2018

Pablo Hevia-Koch

English Summary

Concerns regarding anthropogenic climate change have been a driver for the de-fossilisation of energy systems worldwide. In the case of Denmark, wind energy has played a crucial role on minimising greenhouse gas emissions, and it is expected to continue to play a central role in the transition towards a green, sustainable society.

Despite the widespread support for green energy in Denmark at the national level, specific wind energy projects have experienced growing levels of public resistance, which translates into delays and possible cancellations. This situation not only increases the costs of expanding the energy system but reduces support and welfare of the general public.

This thesis, as part of the Wind2050 project, addresses the duality of global support and local resistance and the associated costs, by utilising a multidisciplinary approach. Thus, it aims at describing preference drivers for wind energy, providing quantitative measures of public resistance stemming from these preferences, and to create cost curves for the deployment of wind energy in Denmark that consider both technical and acceptance costs.

The nature of preferences for wind energy requires considering a wide range of fields, from social-geography and psychology to economic valuation and energy cost analyses. Therefore, this dissertation does not focus on developing a single method in depth, but instead on the integration of methods from several fields to provide an exploratory approach towards the creation of quantitative measures of acceptance costs.

This doctoral dissertation is composed of two parts: a background introduction of methods and theoretical framework, and six scientific papers. The scientific papers represent the incremental work towards identifying preference drivers for wind energy, creating quantitative measures of acceptance costs, analysing the possibilities of integrating acceptance costs with technical cost curves, and finally identifying policy-related challenges and solutions that would help in achieving a cost-effective wind deployment path for Denmark.

Altogether, the results of this thesis indicate that the cost-advantage of offshore versus onshore wind energy in Denmark is not clear-cut across the whole potential range of capacity expansion considered. More importantly, though, it shows that it is possible to incorporate both technical and acceptance costs with consistent results. While providing specific acceptance costs measures and levels, the emphasis of the results is towards the feasibility of such an analysis, and not towards providing accurate measures of acceptance costs for wind energy in Denmark.

Dansk Sammenfatning

Bekymringer vedrørende menneskeskabte klimaændringer har været en drivkraft for transition mod fossilfrie energisystemer verden over. For Danmarks vedkommende har vindenergi spillet en afgørende rolle i at minimere drivhusgasemissioner, og det forventes, at vindenergi fortsat vil spille en central rolle i overgangen til et grønt, bæredygtigt samfund.

På trods af omfattende støtte til grøn energi på nationalt plan i Danmark, har specifikke vindenergiprojekter oplevet voksende offentlig modstand, som har medført forsinkelser og opgivne projekter. Denne situation øger ikke blot omkostningerne ved at omstille energisystemet, men reducerer også offentlighedens opbakning, medvirken, og velfærd.

Via en tværfaglig tilgang adresserer denne afhandling, som en del af Wind2050-projektet, dualiteten mellem global støtte og lokal modstand og de dermed forbundne omkostninger. Den sigter således mod at beskrive præferencedrivere for vindenergi, kvantitative mål for offentlig modstand, som stammer fra disse præferencer, samt at udarbejde omkostningskurver, der overvejer både tekniske omkostninger og acceptomkostninger for udbygning med vindenergi i Danmark.

Karakteren af præferencer for vindenergi kræver, at man overvejer en bred vifte af faktorer fra socialgeografi og psykologi til økonomisk værdisætning og energiomkostningsanalyser. Derfor fokuserer denne afhandling ikke på at udvikle en enkelt metode i dybden, men i stedet på at integrere metoder fra flere felter og således anvende en eksplorativ tilgang mod at udvikle kvantitative mål for acceptomkostninger.

Denne afhandling består af to dele: en introduktion til metoder, oversigt over empiriske studier indenfor området, og teoretisk referenceramme samt seks videnskabelige artikler. De videnskabelige artikler repræsenterer det trinvise arbejde med at identificere præferencedrivere for vindenergi, skabe kvantitative mål for acceptomkostninger, analysere mulighederne for at integrere acceptomkostninger i tekniske omkostningskurver og endelig at tilvejebringe et bedre grundlag for den politiske beslutningsproces, der kan medvirke til at opnå en omkostningseffektiv løsning for udbredelse af vindenergi i Danmark.

Denne afhandling viser, at hverken onshore vind eller offshore vind er entydigt mest omkostningseffektivt ved alle udbygningsniveauer, når der tages hensyn til spændet af acceptomkostninger fra lokalt til nationalt niveau. Dog ses det, at det er muligt, med konsistente resultater, at inkorporere både tekniske omkostninger og acceptomkostninger i omkostningskurver. I afhandlingen afrapporteres specifikke mål for og niveauer af acceptomkostninger for vindenergi i Danmark, men det primære fokus er at beskrive gennemførligheden af en sådan analyse.

Resumen en Español

Las preocupaciones respecto al cambio climático antropogénico han sido una de las motivaciones principales para la des-fosilización de sistemas energéticos a nivel mundial. En el caso de Dinamarca, la energía eólica ha jugado un rol crucial en minimizar las emisiones de gases invernadero, y se espera que continúe ocupando un lugar central en la transición del país a una sociedad verde y sostenible.

A pesar de que la energía verde en Dinamarca cuenta con un apoyo extendido a nivel nacional, proyectos energía eólican en desarrollo han presentado niveles crecientes de resistencia por parte del público. Esto se traduce en posibles retrasos, o incluso la cancelación de estos proyectos. Como consecuencia, no solamente existe la posibilidad de que el costo de expandir el sistema energético aumente, pero también de la reducción del apoyo y bienestar del público general.

Esta tesis, como parte del proyecto de investigación Wind2050, intenta abordar la dualidad del apoyo global y resistencia local (y costos asociados) utilizando un enfoque multidisciplinario. De esta manera, intenta describir las motivaciones formadoras de preferencias del público respecto a energía eólica, producir medidas cuantitativas de los costos asociados a la resistencia del público formadas por estas preferencias, y crear curvas de costo para el despliegue de energía eólica en Dinamarca que consideren tanto costos técnicos como de aceptación social.

La naturaleza de las preferencias respecto a energía eólica requiere considerar un rango amplio de campos de estudio, desde geografía social y psicología, hasta métodos de evaluación económica y análisis de costos de energía. Por lo tanto, esta tesis no se enfoca en desarrollar un método específico en profundidad, sino en la integración de métodos de diversos campos, y así proveer una visión exploratoria de la creación de medidas cuantitativas de costos de aceptación social.

Esta disertación doctoral está compuesta por dos partes: una introducción de referencia al campo que incluye el marco teórico de estudio, y seis publicaciones científicas. Estas publicaciones representan el trabajo incremental hacia identificar las motivaciones formadoras de preferencias para energía eólica, la creación de medidas de costo de aceptación cuantitativas, el análisis respecto a la posibilidad de integrar estas medidas con curvas de costo técnico, y finalmente la identificación de desafíos técnicos y políticos (y posibles soluciones) respecto a la creación de un plan de despliegue de energía eólica en Dinamarca que sea económicamente eficiente.

Los resultados obtenidos en esta tesis indican que la ventaja económica de la energía eólica terrestre respecto a la marítima no es definitiva cuando se considera el potencial total de expansión. Sin embargo, el resultado central es el hecho de que es posible incorporar costos técnicos y de aceptación social con resultados consistentes. A pesar de que esta tesis

presenta resultados específicos respecto a niveles de costos para Dinamarca, el objetivo principal no es respecto al cálculo de costos de aceptación específicos, sino a demostrar la factibilidad de utilizar la metodología presentada para integrar estos costos en curvas de costo técnico.

Publications included in thesis

Journal articles

Hevia-Koch, P. & Jacobsen, H. K. (2018). Comparing offshore and onshore wind development considering acceptance costs. *Energy Policy (in Review)*.

Hevia-Koch, P. & Ladenburg, J. (2018a). Estimating preferences for wind turbine locations - A critical review of visualisation approaches. *The Energy Journal (in Review)*.

Hevia-Koch, P. & Ladenburg, J. (2018b). Size Matters? Does screen size affect the formation and validity of stated preferences for visualised amenities using web surveys. *Journal of Environmental Economics and Policy (in Review)*.

Hevia-Koch, P., Ladenburg, J. & Petrovic, S. (2018). The offshore-onshore conundrum: Preferences for wind energy considering spatial data in Denmark. *Energy Economics (in Review)*.

Katz, J., Balyk, O. & Hevia-Koch, P. (2018). The impact of residential demand response on the costs of a fossil-free system reserve. *IEEE Transactions on Sustainable Energy (Prepared for Submission)*.

Ladenburg, J., Hevia-Koch, P. & Andersen, H. L. (2018). The effect of prior experience in offshore wind turbine location – a natural experiment. *The Energy Journal (Prepared for Submission)*.

List of other publications

Hevia-Koch, P. (2015). The Visual Impact of Wind Turbines: Guidelines for Stated Preference Studies. *8th Annual Danish Environmental Economic Conference*.

Hevia-Koch, P., Jacobsen, H. K. & Ladenburg, J. (2016). Near-shore wind turbines: Does their cost advantage outweigh the preferences for visual disamenities reduction they elicit? *39th IAEE International Conference*.

Hevia-Koch, P. & Ladenburg, J. (2015). Is Willingness to Pay for Visualised Landscape Amenities Sensitive to Screen Size When Using Web Surveys? *33rd USAEE/IAEE North American Conference*.

Hevia-Koch, P. & Ladenburg, J. (2016). Estimating Preferences for Wind Turbine Locations - A Critical Review of Visualisation Approaches. *SSRN Electronic Journal*. doi:10.2139/ssrn.2848529

Hevia-Koch, P., Ladenburg, J. & Petrovic, S. (2018). Preferences for Offshore-Onshore Wind Power Development in Denmark– Accounting for Spatial Data. *SSRN Electronic Journal*. USAEE Working Paper Series.

Jacobsen, H. K., Hevia-Koch, P. & Wolter, C. (2016). Nearshore Versus Offshore: Comparative Cost and Competitive Advantages. *IAEE Energy Forum*, (Bergen Special 2016), 17–19.

Katz, J., Balyk, O. & Hevia-Koch, P. (2016). The impact of residential demand response on the costs of a fossil-free system reserve. *ENERDAY 2016 - 11th Conference on Energy Economics and Technology*.

List of abbreviations

AEP Annual Energy Production

CAPEX Capital Expenditure

DCE Discrete Choice Experiment

DEA Danish Energy Agency

EU European Union

GIS Geographic Information System

GW Gigawatt

GWh Gigawatt-hour

IEA International Energy Agency

IRR Internal Rate of Return

kW Kilowatt

kWh Kilowatt-hour

LCOE Levelised Cost of Energy

LL Log-Likelihood

MW Megawatt

MWh Megawatt-hour

NDC Nationally Determined Contributions

NIMBY Not-In-My-Backyard

NPV Net Present Value

NREAP National Renewable Energy Action Plan

OPEX Operational Expenditure

PAPC Post Announcement Pre Construction

PSO Public Service Obligations

RES Renewable Energy Sources

RES-E Electricity produced from Renewable Energy Sources

RP Revealed Preference

SP Stated Preference

UN United Nations

WACC Weighted Average Cost Of Capital

WTP Willingness to Pay

Contents

Chapter 1

Introduction

Concerns over climate change around the world in recent years have pushed countries to decarbonise their electricity generation systems, with many countries setting ambitious targets for renewable energy generation in the future. In Denmark, this process has been carried out by a significant expansion of wind energy in the electricity generation system, which is expected to continue in the future as a way to achieve the country's renewable energy goals.

While in Denmark there exists widespread public support for increased renewable energy, and particularly for wind energy, this support is not translated into support for specific projects. This phenomenon is not unique to Denmark, and it has been observed in many countries with increasing wind power development. As a consequence of public resistance, there is potential for new projects to be delayed or entirely cancelled, making the prospect of achieving the planned expansion of wind energy more costly and complicated. Despite initiatives aimed at increasing public participation and local acceptance, such as the providing shares of wind projects to neighbours or increased levels of public participation in decision making processes, the results have been unsatisfactory. Nowadays, both public and private bodies continue to experience a decrease in local acceptance of wind power projects despite the initiatives applied. This lack of support has been a frequent issue across Europe and America, with the factors driving and influencing acceptance seemingly differing depending on economic, political and cultural context.

Despite early public resistance being classified dismissively as not-in-my-backyard (NIMBY) behaviour, recent studies, such as Devine-Wright (2005) and Aitken (2010), have provided insights regarding this phenomenon as a result of the contrast between perceived lack of benefits for the local area where these projects are carried out, and perceived disamenities centred in the local area (such as visual impact, noise pollution, environmental effects on wildlife, and more). When understanding that the origin of public resistance is not whimsical, but driven by an imbalance between global benefits and local costs, the interest for further investigating the magnitude of these perceived disamenities is clear. Additionally, it would be of great use to policymakers if these disamenities could be translated into monetary terms, measured as acceptance costs. This kind of measurement could be used for comparing the costs associated to the produced disamenities, with the technical costs associated to siting wind turbines in areas where these disamenities are minimised (such as pushing wind farms further offshore or siting them in areas further away from the population).

This thesis is part of the Wind2050 project[1], which aims at understanding the dynamics behind preferences for wind energy in Denmark. As stated by Borch (2014), 'considering the expansion of wind power as a socio-technical system, we are going to generate new insights into how we can implement green energy solutions, not only in Denmark but also internationally. And better implementation, better decision-making and better anchoring of renewable energy projects in the local community is key to achieving independence from fossil fuels — technology alone is not enough'.

There is no canonic definition of acceptance costs and, as it will be discussed in chapter 5, there are strong arguments towards varying definitions, all of which are valid. In the broadest sense, they are an expression of the net sum of positive and negative externalities produced by all of the dimensions of wind turbines (further discussed in section 3.1), at an aggregated level which encompasses all relevant actors. This definition, while theoretically 'correct', suffers from being extremely broad and impracticable. As a consequence, for the purposes of this thesis, acceptance costs will be approximated by several more restricted definitions, such as the willingness to pay given by respondents of a stated preference study, or the property value loss experienced on properties after the construction of nearby wind turbines.

This dissertation aims to address the issue of public resistance and acceptance costs of wind energy by incorporating different economic methods while keeping technical engineering issues in mind. Rather than developing a single method in depth, the focus is to try to create a bridge between valuation methods for wind turbine disamenities and an expanded cost analysis for future expansion of wind energy. This is done by providing quantitative measures of acceptance costs and preference drivers, and analysing the feasibility and challenges of utilising the results obtained in such manner for policy recommendations.

1.1 Research interest and contributions

The objective of this thesis is to contribute to the understanding of acceptance costs for wind energy in Denmark and to utilise this knowledge to advance the generation of a cost-efficient country-wide development path for wind energy that includes both social acceptance costs as well as technical costs. This thesis presents a first approach towards the creation of a quantitative measure of acceptance costs associated with a potential expansion of wind energy in Denmark.

[1] http://www.wind2050.dk

The central research questions addressed are:

1. What methods can be used to estimate acceptance costs for the future expansion of wind energy and to provide an aggregated measure that can be integrated into cost curves?
2. Which drivers shape preferences for offshore and onshore wind energy in Denmark?
3. How can we create cost curves that incorporate both technical and acceptance costs?
4. How can a cost-efficient deployment path for wind energy be derived utilising the previously calculated wind acceptance externalities in conjunction with technical cost curves?

These research questions are approached by a series of six articles that form the main body of the research done, which will be referred from now on as Papers A-F. These papers address the previous research questions in the following way. Research question one is addressed by Papers A, B and C; research question two is addressed by Paper C; research question three is addressed by Paper D; and research question four is addressed by Papers E and F.

Paper A is a journal paper that carries out a literature review on stated preference studies regarding preferences for wind turbines. It focuses on the use of visualisations for assessing the visual impact of wind turbines in the scenario description. It presents a methodologic argument towards the need for visualisations in survey design when focusing on assessing the visual disamenities perceived due to wind turbines, and classifies the different visualisation approaches on an incremental scale. Examples of some of the reviewed visualisations and their classification can be seen in Fig. 1.

Paper B is a journal paper that studies the effect of the respondents' screen size on their preferences for wind turbines on web-based stated preference studies. By analysing differences in preferences of respondent groups with different screen sizes, we find that there are significant differences on the preferences for wind turbines regarding their visual attributes, as well as on the capability of respondents to see the visualisations provided. The study shows that preference estimates can be biased depending on the screen size of respondents and that if this phenomenon is not controlled for, distortions in estimated preferences are possible.

Together, these papers find existing limitations on studies that utilise stated preferences for estimating preferences and willingness to pay regarding wind turbines. While on the one hand, the presented shortcomings are a good source for future work and these papers provide suggestions on how to improve the quality of estimates produced by stated preference studies, they also serve to understand the limits of certainty associated to estimates produced by this kind of studies. By making some of these shortcomings

(a) Site-specific visualisation used in Knapp et al. (2013).

(b) Generic visualisation used in Ladenburg and Dubgaard (2007).

Figure 1.1: Example of visualisations reviewed in Paper A

explicit, it is possible to address the reliability and scope of the conclusions drawn from this type of data.

Paper C utilises data from a stated preference survey regarding preferences for onshore and offshore wind energy in Denmark, as well as spatial data based on a GIS analysis. Based on this data, we find significant drivers for preferences, both on wind turbine attributes, as well as on spatial data. Afterwards, we find significant preferences for several attributes of wind turbines, as estimates for willingness-to-pay, as well as preferences between siting further wind turbines offshore instead of onshore. These preference estimates provide estimates of the acceptance costs of different dimensions of wind turbines and siting options which can then be incorporated into technical cost curves for wind energy.

Paper D is a paper focusing on incorporating acceptance costs into technical cost curves for onshore wind energy in Denmark. In this paper, we consider three different measures for onshore acceptance costs, based on three different studies. The first one is based on Energinet.dk (2015), where they estimate additional costs for the expansion of onshore wind in Denmark based on compensation payments and property buy-outs required to further expand the installed capacity to a potential of 12 GW. The second measure is based on a revealed preference study (Jensen et al., 2014) whereby analysing house transaction prices in Denmark they find estimates for the property value loss produced by visual and noise impacts of wind turbines. The final measure is based on the willingness-to-pay estimates found in Paper C, which are aggregated at local and national levels. Finally, we integrate these three measures of acceptance costs into a basic cost curve that considers the technical costs for onshore wind expansion, and we compare this new onshore cost curve with an offshore cost curve. We find that it is possible to create consistent measures for acceptance cost with three different approaches and that when considering acceptance costs, the cost advantage of onshore wind versus offshore wind is not so clear-cut. Mainly, considering the possibility of extending acceptance costs beyond the local environment, as well as considering a more comprehensive measure of acceptance costs (such as the one considered on a stated preference study), the uncertainty associated to the estimates puts onshore and offshore costs on a very similar range.

Paper E utilises a natural experiment with two samples of Danish population to compare the effect of prior experience with offshore wind turbine farms on preferences. One of the samples consists of respondents living near the nearshore wind turbine farm of Nysted, which is visible from the coast, and the other consists of respondents living near the offshore wind turbine farm of Horns Rev, not visible from the coast. Based on parametric and non-parametric analyses, we find significant differences in preferences and certainty amongst the two samples, with the Nysted sample presenting significantly higher WTP for minimising visual impacts of wind turbines than the Horns Rev sample. This paper indicates that preferences for wind energy are dynamic, and that experience with wind turbines, such as living nearby a visible offshore wind turbine, affects the formation of preferences. When considering the deployment path for further wind energy in Denmark, this is a result of high relevance, since these dynamic effects have the potential to modify the acceptance costs of future wind farms significantly.

Paper F does not look at the social costs of further wind energy expansion but instead addresses one of the technical challenges associated with having a system with high shares of inflexible generation. This paper considers the possibility of utilising flexible demand as a provider of system reserves, both fast and slow, and therefore support the increased need of reserves as the amount wind energy on the system increases. We apply the BALMOREL model (Wiese et al., 2018), and further extend it with an add-on that allows to model flexible household demand in both the spot market and as a provider of reserves. We find that there exists a cost advantage on utilising flexible demand as reserves instead of having them participate the spot market. This cost advantage might be of relevance for facilitating the increased amount of wind energy on the Danish system.

The rest of this dissertation is organised as follows. Chapter 2 presents a background exposition of wind energy in Denmark. It shows the existing policy framework defining the Danish energy system, current and future development plans for onshore and offshore wind in the country, some insight on current cost levels, as well as a broad exploration of some of the current socio-technical challenges associated to expansion to high levels of wind energy in the system. Chapter 3 introduces theory and methods on which the work carried out in Papers A-F is framed. Mainly, it presents the theoretical framework existing in regard to the origin of wind energy preferences, an introduction to economic valuation, a derivation of the models utilised on the choice experiments carried out in this thesis, as well as a section on cost analysis and the use of levelised cost of energy (LCOE). Chapter 4 presents the primary results of the thesis on a per-paper basis and includes a discussion on the relation between the results of each paper and the overall objective of this dissertation. Finally, Chapter 5 presents the concluding remarks, conclusions of the whole thesis work, and some suggestions for further research in the area. In the final section of this document are the references, an appendix containing Papers A-F, and an appendix containing the survey utilised during the stated preference experiment that provided data for Papers A-C.

Chapter 2

Background

2.1 Policy Context

There are a number of policy goals and targets that shape the Danish energy system, both at a national level and as part of the European context. The overarching policy goal of the European Union in regard to energy is focused on three main aspects: competitiveness, sustainability, and energy security. The objective of competitiveness is to establish an international European market for energy that ensures access to energy at reasonable prices for all member states. Sustainability aims at addressing anthropogenic climate change, mostly by focusing on mitigation via consumption reduction and lowering CO_2 emissions through the use of renewable energy sources (RES). The third aspect, energy security, aims to lower the dependency of Europe on fuel imports from particular countries, via increasing technologies not dependent on fuels (such as wind, hydro, and solar energy), and having a varied technology portfolio. A more detailed view of the European Union policy goals and the three policy pillars can be seen in European Commission (2006) and European Parliament and Council (2006).

Based on this overarching policy goal perspective, the EU has established what is known as the 20/20/20 goals, which target a reduction of 20% of CO_2 emissions of 1990 by 2020, an increase of 20% of energy efficiency, and an increase of 20% of RES share across all sectors. These targets are to be materialised by specific targets for member states, defined through National Renewable Energy Actions Plans (NREAPs), where each member state presents their projected development and pathway towards the achievement of the EU targets. Furthermore, in 2014 the EU leaders adopted the 2030 Climate and Energy Framework (European Commission, 2014), which introduces binding targets for 2030. In particular, a 40% reduction in greenhouse gases (from 1990 levels), a 27% share of RES, and a 27% improvement in energy efficiency.

Beyond the European level, in 2015 the Paris Agreement by the United Nations member states presents a global understanding towards limiting the increase of global temperature to a maximum of 2 °C. The Agreement indicates that each party must communicate

Nationally Determined Contributions (NDCs), which present the domestic mitigation measures that are to be taken in order to achieve the 2 °C target. Successive NDCs should represent increases in the ambition of targets for the party, although these obligations are not binding. As of the end of 2017, Denmark is one of the 175 Parties that have ratified the convention.

In Denmark, several national policy agreements and targets mark the future development of the energy system. Two significant political agreements, at the time widely supported, are the Energy Agreement of 2012 (Danish Ministry of Energy- Utilities and Climate, 2012) and the Climate Change Act of 2014 (Danish Government, 2014). The 2012 Energy Agreement, signed the 22 of March 2012, covers the development of the energy system of Denmark between 2012 and 2020. The initiatives presented in the agreement were considered ambitious, aiming to push Denmark towards a 100% renewable energy supply, mainly through expanded offshore wind energy and biomass. Based on the initiatives of the agreement and current results, it is expected that Denmark will fulfil and surpass the EU 20/20/20 goals regarding energy efficiency, CO_2 emissions reduction, and RES development.

The second agreement, the Climate Change Act of 2014, is a law related to the long-term Danish positioning as a sustainable society. This law is based on the 2050 Energy Strategy (Danish Government, 2011). The 2050 Energy Strategy is introduced with the goal of transforming Denmark to a fossil-free energy society by 2050, and therefore remove reliance on coal, oil, and gas from the energy system. Beyond the relevant EU targets, the 2050 Energy Strategy aims for Denmark to be a green, sustainable society; to be amongst the top-three countries in the world with the highest increase in renewable energy since 2020; and amongst the top-three countries in the OECD in regard to energy efficiency. This energy strategy presents the further development of wind energy as central for achieving its targets, mainly offshore. The creation of Kriegers Flak, an offshore wind turbine farm of 600 MW that finished its auction process in 2017, is one of the measures proposed in the energy strategy document. Furthermore, it considers the creation of the previously mentioned nearshore wind farms, aiming to reduce the cost of offshore energy. Some of the areas considered for nearshore wind farms in Denmark are presented in fig. 2.1 below.

One final agreement worth mentioning is the political declaration done by the North Seas Countries[1] (North Seas Countries, 2016), which aims at a closer integration between the countries' energy grid, and presents as a primary objective 'To facilitate the further cost-effective deployment of offshore renewable energy, in particular wind, through voluntary cooperation, with the aim of ensuring a sustainable, secure and affordable energy supply in the North Seas countries'. As part of this cooperation agreement, the North Seas Countries plan on creating the North Sea Power Hub, a proposed offshore complex in the North Sea that will harbour significant amounts of wind turbines, with a

[1]The North Seas Countries are: Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the United Kingdom.

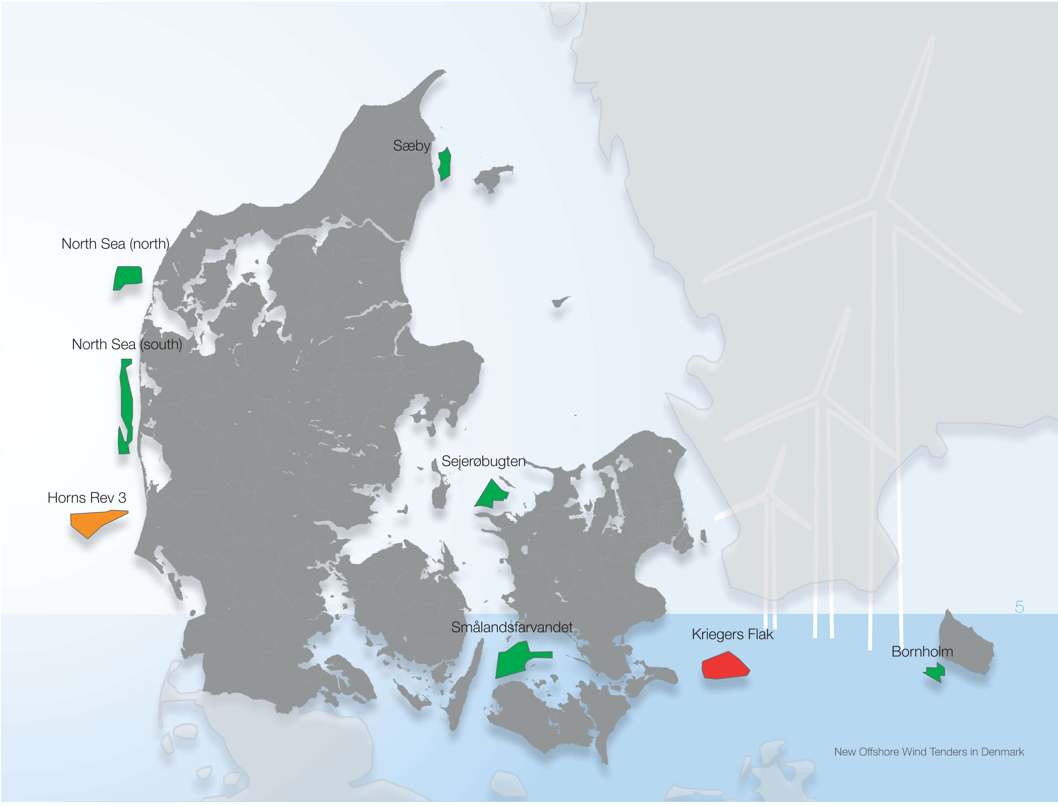

Figure 2.1: Nearshore sites for wind energy in Denmark in green - (Danish Energy Agency & Energinet.dk, 2013)

total installed capacity of several GW. A summary of the main policy targets and drivers, based on Danish Energy Agency (2018), is presented in table 2.1.

Table 2.1: Summary of the Danish climate policy framework - based on (Danish Energy Agency, 2018)

Framework	Area	Obligation/target
Government platform 2015	Phase-out of fossil fuels	Denmark is to be independent of fossil fuels by 2050
Danish climate law	Low emission society by 2050	Target is not specified
EU: 2020 targets	Greenhouse gas emissions from buildings, agriculture and transportation	- 20% reduction between 2005 and 2020
	Fraction of renewable energy in total energy consumption	- 30% reduction by 2020
	Fraction of renewable energy in the transport sector	- 10% reduction by 2020
EU: 2030-targets	The total emissions from the EU are to be reduced by 40 pct. between 1990 and 2030. This includes the following targets for the EU as a whole:	The emission reduction targets for the EU as a whole are to be implemented as national reduction obligations for buildings, agriculture and transportation.The Danish reduction obligations have not yet been negotiated.
	- 43 pct. reductions from large emitters such as power plants and the oil and gas sectors. - 30 pct. reductions of emissions from buildings, agriculture and transportation. - At least 27 pct. renewable energy in total energy consumption by 2030. - At least 27 pct. increase in energy efficiency by 2030.	The Danish reduction obligations have not yet been negotiated.

Table 2.2: Offshore wind farms in Denmark

Wind Farm	Lifetime Capacity Factor	Age (years)	Installed Capacity (MW)
Anholt 1	48.6%	4.4	399.6
Avedøre Holme	38.0%	7.2	10.8
Frederikshavn	30.5%	14.3	7.6
Horns Rev I	41.8%	14.8	160
Horns Rev II	47.7%	8	209.3
Middelgrunden	25.4%	16.7	40
Nysted (Rødsand) I	37.0%	14.2	165.6
Nysted (Rødsand) II	43.4%	7.2	207
Rønland I	44.5%	14.6	17.2
Samsø	39.1%	14.6	23
Sprogø	34.2%	7.8	21
Tunø Knob	30.2%	22.3	5
Vindeby (decomissioned)	21.6%	25.5	4.95
Total	41.4% (avg.)	13.2	1271

2.2 Wind Energy in Denmark

As of the end of 2017, Denmark has 5521 MW of installed wind capacity, which represents 41.9% of the total electricity production in the country. Out of the total installed wind capacity, 4229 MW correspond to onshore wind turbines distributed across the country, and 1292 MW correspond to offshore wind farms (Danish Energy Agency, 2017). A list of existing offshore wind energy farms and their characteristics is found in table 2.2

It is expected for offshore wind to keep expanding in future years, as part of the strategy regarding renewable energy goals. Currently, there are eight projects assigned for environmental impact assessment or development with a total nameplate capacity of up to 2.2 GW: Horns Rev 3, Kriegers Flak, Vesterhav Nord og Syd, Nissum Bredning, Omø Syd, Jammerland Bugt, Mejl Flak, and Lillebælt Syd. Furthermore, a number of tenders are being carried out for the development of new offshore wind energy farms. As shown in fig. 2.1, some of the tender areas are offshore locations close to the shore which aim to lower the costs for installing and operating the wind turbines, for example, Sejerøbugten, Smålandsfarvandet and Sæby (Danish Energy Agency & Energinet.dk, 2013). Many of the areas considered for further expansion have been defined based on the environmental impacts assessment carried out in the 2007 Environmental Assessment for Future Offshore Wind Turbines Placement, and the 2050 Energy Strategy (Danish Energy Agency, 2007; Danish Government, 2011).

Despite the political targets and planned projects, the actual level of realised future expansion for wind energy remains to be seen. Public resistance has managed to stop onshore developments in Denmark at the municipal level, despite the position of the national government, an imbalance in the decision making progress that has the potential

Table 2.3: Cost breakdown of onshore and offshore wind farms

	Onshore	Offshore
Capital investment costs (USD/kW)	1700 - 2450	3300 - 5000
Wind turbine cost share (%)	65 - 84	30 - 50
Grid connection cost share (%)	9 - 14	15 - 30
Construction cost share (%)	4 - 16	15 - 25
Other capital cost share (%)	4 - 10	8 - 30

to stall the progress towards the wind energy targets. On the other hand, offshore expansion has been losing political support due to the higher costs in comparison to onshore. This cost concern has further positioned nearshore wind farms as a possible solution, although their cost advantage comes at the cost of higher acceptance cost due to the proximity of the sites to population or recreational areas. The possibility of realising the proposed goals, therefore, hinges both on the feasibility of lowering costs for offshore and on correctly managing public resistance.

2.3 Cost levels

Compared to other types of generation, the cost of wind energy is dominated by the upfront capital expenses (CAPEX), (International Renewable Energy Agency, 2012). In the case of onshore turbines, close to 65% of the total CAPEX comes from the cost of the wind turbine itself (including blades, rotor, tower, and transformer), while the rest is divided chiefly amongst foundations, grid connection, and project engineering. When looking at the CAPEX for offshore wind turbines, the shares are different, with the cost for foundations and grid connection increasing significantly. Section 2.3 shows a comparison of cost breakdown between onshore and offshore turbines in developed countries.

Section 2.3 also highlights the current difference on average capital investment costs between onshore and offshore turbines. Nonetheless, offshore wind turbines present high variability on their costs, depending significantly on the depth of the water at the chosen site, the distance between the site to the coast and the nearest port, as well as seabed conditions. Nonetheless, onshore wind energy still presents a significant cost advantage in regard to investment costs.

Operational expenditures (OPEX) for wind energy are a significantly lower share of the total costs but account for 20% to 25% of the total LCOE of wind projects (European Wind Energy Association, 2009). There are both fixed OPEX that are measured per MW per year, and variable OPEX that are measured per MWh produced. For onshore wind turbines The Technology Data Catalogue from Danish Energy Agency (2016) assumes a share of 75% as fixed OPEX with a reference value for 2015 of 25,600 €/MW/year, and 25% as variable OPEX with a reference value of 2.8 €/MWh. For offshore wind turbines the split is the same, with a reference value of 57,300 €/MW/year for fixed OPEX and

4.3 €/MWh for variable OPEX. This significant difference between onshore and offshore further accentuates the technical LCOE advantage of the former.

2.4 Socio-technical challenges

According to Breukers and Wolsink (2007), even though the general public support for wind energy is high, wind projects are increasingly experiencing local opposition which delays or directly blocks further development. There is significant literature highlighting the resistance to several wind projects in England (Haggett, 2011), Wales (Devine-Wright & Howes, 2010; Haggett, 2008; Haggett & Smith, 2004), Scotland (Haggett, 2011), and Northern Ireland (Ellis et al., 2007), with consequences ranging from lack of generalised support to delays and losses.

The case for Denmark is no different: even while being one of the leading countries in developing and integrating wind energy in the national grid, the public's stance towards wind energy seems to be hardening (Cronin et al., 2015). Considering how reliant the future energy goals for Denmark are on further expanding wind energy capacity, public resistance, or just lack of support, can produce significant challenges in achieving the aforementioned targets.

Visual disamenities are one of the leading complaints that citizens present regarding wind turbines, both offshore and onshore, with noise and environmental concerns being other often named complaints as shown in Ladenburg (2009), Ladenburg and Dubgaard (2007), Meyerhoff et al. (2010) and Krueger et al. (2011), among others. In regard to noise and visual disamenities, there are direct possibilities for minimising these aspects of wind projects by siting new wind turbines further away from residences or further ashore in the case of offshore wind projects. The trade-off, though, is that it would limit the available onshore potential for further wind energy, and would increase the cost of new projects due to either the increased distance from the shore of offshore wind turbines or the need to compensate property owners of affected areas. Furthermore, this approach is incompatible with the possibility of further exploiting nearshore sites, an option that is considered in Denmark as a way to reduce the high investment costs necessary for offshore projects.

Another dimension of the public resistance stems from the perceived inequalities between local and global costs and benefits. For example, despite the growing wind energy industry in Denmark, the low electricity prices it produces, and its benefits in regard to de-fossilising the electricity grid, the costs are usually perceived to be borne by the population both due to the local disamenities produced, as well as the increased electricity bills due to Public Service Obligations (PSO). A possible approach to minimising public resistance relies on public participation, in a way that not only makes the public an active part of the project planning phase, but also that minimises this perceived inequalities. An example of this approach is the 20% share rule utilised in Denmark, where project developers have to make at least 20% of a wind turbine shares available to be bought by residents in the neighbourhood of the new project. This mechanism aims at redistributing a fraction of the benefits produced by the projects directly to the local community (Cronin et al., 2015; Devine-Wright, 2011). Another possible solution for increasing the onshore wind potential without significantly increasing acceptance costs is to renew old onshore wind turbines with newer and more efficient turbine models, although the additional potential exploited this way is limited Energinet.dk (2016).

From a technical perspective, challenges are varied. One of the significant drawbacks of wind energy is the lack of flexibility and variability of generation. The variability of wind generation and its lack of flexibility creates the need to have reserve generation to compensate the fluctuations of the electricity produced. As a consequence, there is an increased cost of wind energy associated to system regulation and grid integration.

In recent years, turbines have evolved towards larger rotor areas with lower specific power. This kind of design is more efficient at lower speeds and therefore not only allows the use of areas with lower wind potential but also minimises fluctuations in power generation, thus reducing the need for power regulation. It is expected for this trend to continue both offshore and onshore, and that future wind turbines will present even lower specific power (Danish Energy Agency, 2016). Nonetheless, there are different possible approaches for minimising the additional costs for regulation associated to wind energy, one of which is further explored in Paper F: the use of flexible demand as a way to provide system reserves.

Chapter 3

Theory and Methods

3.1 Preferences for Wind Energy

The initial discourse regarding preferences and opposition to wind energy has been centred on the concept of Not-In-My-Backyard (NIMBY), a term initially coined during the decade of the 80's to refer to opponents of nuclear energy (Haggett & Smith, 2004). Interestingly, NIMBY is just one many terms that have been used to describe opponents to specific projects, many of which seem to highlight aspects of irrationality: NIMTOOs (Not in My Term Of Office); CAVE people (Citizens Against Virtually Everything); BANANAs (Build Absolutely Nothing Anywhere Near Anyone); NIABY (Not in Anyone's backyard); and NOPEs (Not on Planet Earth) (Burningham et al., 2006). What all of these terms have in common is that there is not a single definition of what they actually represent, and in many cases, they are just used as a derogatory term to refer to all opponents of particular technologies or projects, while implying lack of rationality, and therefore as a way of discrediting them. (Burningham, 2000; Burningham et al., 2006; Dear, 1992). A more concise definition of the NIMBY concept, and without the pejorative charge sometimes attributed to the term, is given by (Wolsink, 2000), where he defines NIMBYs as 'people that combine a positive attitude and resistance motivated by calculated personal costs and benefits'.

Nonetheless, the use of NIMBYism as an explanation or description for preferences and resistance is considered by recent research as an over-simplification of actual preference formation dynamics and recommended to be used sparingly, if at all (Burningham, 2000; Devine-Wright, 2005; Wolsink, 2006).

Defining and measuring preferences for wind energy is a deceptively complex task, mainly due to the extensive amount of independent perspectives and attributes of wind farms over which preferences can exist. Wind farms and public preferences for them can be evaluated from physical, contextual, political, socio-economic, social, local, and personal perspectives. This multidimensional nature of wind turbines and wind energy becomes even more convoluted when one considers that preferences are seldom created

Table 3.1: Public perception factors - adapted from Devine-Wright (2005)

Category	Aspect
Physical	Turbine colour
	Turbine size
	Turbine acoustics
	Farm size and shape
Contextual	Proximity to turbines
	Landscape context
Political and institutional	Energy policy support
	Political self-efficacy
	Institutional capacity
	Public participation and consultation
Socio-economic	Shareholding
Social and communicative	Social influence processes
Symbolic and ideological	Representations of wind turbines
Local	Place and identity processes
	Local or community benefit and control
	NIMBYism
Personal	Previous experience and knowledge

by an isolated analysis of a particular perspective, but instead they tend to be formed through an interaction between many, or all, of these dimensions. A review of factors affecting public perception of wind turbines is carried out in (Devine-Wright, 2005) and summarised in table 3.1.

Based on this disaggregation of preference factors, it is necessary to understand that preferences for wind energy have to be understood as the result of interactions between preferences resulting from these diverse drivers and that explanations for resistance or support for wind energy have to account for this multidimensional preference-space. As presented on Burningham et al. (2006) earlier writings on resistance to nuclear energy, as for example DuPont (1981), tend to ignore this multidimensionality and to maintain a monolithic view of the public, defining opposition against projects as based on the 'irrational fears of the public' and that it should not sway project developers since 'the fear they feel is out of proportion to the actual risks [...] This is phobic thinking'. This vision of the irrationality of public resistance has not only been criticised by sociological studies, such as Irwin (1995), Wynne (1992, 1996) and Petts (1997), but also has failed to be confirmed by empirical studies, which show that active opponents to projects tend to be more knowledgeable than passive supporters (Barnett et al., 2008; Fischer, 2000; Heiman, 1990). Despite these criticisms, the same monolithic vision is often used when considering public resistance to renewable energy.

More recent research, mainly focused on preferences and resistance to renewable energy technologies and particularly wind energy, has attempted to provide a more nuanced understanding of public resistance. The literature reviews done by Devine-

Wright (2005) and Burningham et al. (2006) are an excellent source for a more in-depth view of recent research that studies preferences for wind energy beyond the NIMBYism explanation.

Some examples that highlight real concerns and that stand at odds with the NIMBY view are found in recent literature. In Kempton et al. (2005), they analyse opposition to an offshore wind project in Cape Cod, and find that concerns for opposition were beliefs regarding the uneconomic nature of the project, its associated environmental impacts, as well as 'the disparity between the global benefits of wind power being expounded by proponents of the scheme, and the immediate effect on the local area stressed by opponents'. A similar view is found in Haggett (2008), where in North Wales, local people believed that they were 'suffering disadvantages for the benefit of the distant English'. Ellis et al. (2007) study developments in Northern Ireland and find concerns regarding 'tangible local impacts [...] and local consequences'.

Under the understanding of the multidimensionality of wind energy preferences, this thesis does not aim at providing an all-encompassing measure of preferences for wind energy. Instead, following the recommendations presented by Devine-Wright (2005), it aims at providing a quantitative measure of preferences for wind energy in a narrowly defined context that might be used to operationalise this information via policy measures that incorporate an extended view of public preferences.

3.2 Economic Valuation

Whereas for goods traded on a market their price can be considered a measure of their value, it is not possible to measure the value of goods that are not traded on markets in the same way. This presents a problem when trying to measure the impact of changes in environmental quality, for example, or to internalise externalities. This section follows Bateman et al. (2002), Hanley et al. (1998) and Freeman et al. (2014) in presenting economic valuation as the process of eliciting values of non-marketed goods in terms of money, through different methods.

Based on Carson and Mitchell (1989), one can divide the methods for eliciting value on two classes: approaches based on observed market behaviour and approaches based on hypothetical markets. An observed market approach uses markets associated with the good one wants to measure and utilises them as a proxy for the good that is non-marketed. Consequently, by looking at the consumers' actual behaviour in these proxy markets, the value of the good in question is estimated. This kind of approaches is customarily called Revealed Preference (RP) methods.

There are several different revealed preference methods. in regard to environmental valuation, and in particular wind energy valuation, two are the most relevant. The first method is called hedonic pricing, and it is based on the idea that the value of the non-marketed good will be reflected in the price of a different marketed good. Often, hedonic pricing analysis is carried out at property prices, under the assumption that a non-marketed good (such as nearby wind turbines, or schools) will be reflected in the sale price of the property. The second method is travel cost analysis, which is based on utilising the cost of travelling to a location as a measure or bound of the value of the place being visited. This can be applied to visits to beaches, national parks, or recreation areas, and can also be used to compare similar locations with differing goods (national parks with or without rivers, for example).

Compared to observed market approaches, hypothetical approaches do not look at consumers' behaviour in analogous markets but instead directly asks for their behaviour for a given hypothetical situation. Methods following this approach are called Stated Preference (SP) methods. They rely on utilising surveys to elicit responses regarding the value of the good under study. These surveys can take place either in-person, via telephone, via mail (both postal and electronic), or through a website. There are different types of stated preference methods, defined by the structure of the survey, the formulation of questions contained within it, as well as the analysis of the data obtained. One of the earlier methods is called contingent valuation (CV), where respondents are directly asked to state the value they give to the good in question, sometimes expressed as a scenario. While simple to carry out, this kind of studies have been source of considerable controversy regarding the adequacy of the provided WTP estimates due to susceptibility to biases and design issues (such as embedding effect, anchoring effect, and others), as well as the cognitive load of asking respondents to put a money value on hard to define goods such as 'improved air quality'.

Choice modelling methods were developed to address many of these issues, and therefore to improve the reliability of the estimates provided. These methods do not present the respondent with an open-ended question, but instead present different scenarios, and ask the respondent to choose one of them (choice experiment), to rank the scenarios in order of preference (contingent ranking), to assign a scale value of preference to each scenario (contingent rating), or to state the level of preference of one scenario out of a pair (paired comparison). While more elaborate setups, such as contingent ranking, might offer more precise results, they are significantly harder to model and present an increased cognitive load on respondents compared to more straightforward approaches, such as choice experiments. These qualities of choice experiments have been instrumental in defining them as the method to be used for analysing stated preference data in this thesis.

There are significant differences between stated preference and revealed preference methods, both on the reliability of their results, as well as the applicability of the methods on different scenarios. The significant advantage of revealed preference methods is that it is based on actual economic transactions, and therefore is not subject to hypothetical bias. Consequently, when significant results are found, they have higher levels of reliability due to being based on actual behaviour. Stated preference methods, on the other hand, are not based on actual economic behaviour. As such, they are affected by hypothetical bias. The tendency of respondents to overstate the amount they are willing to pay for a good or service is well documented, with mechanisms created to minimise this bias, such as the use of a 'cheap talk' proposed by Cummings and Taylor (1999) and applied to wind turbine valuation in Ladenburg et al. (2011).

Another disadvantage of stated preference studies is their reliance on the survey design. Several factors affect the responses obtained, some of which are hard to control for. It has been shown that design elements such as the order in which the questions and alternatives are presented, the chosen value levels for the scenarios, the length of the survey, the use of images or other material as part of the scenario description, and the wording of the question have the possibility of affecting the responses obtained (Bateman et al., 2002). One particular example is whether the survey is formulated to elicit values of willingness-to-pay (WTP) or willingness-to-accept (WTA). While from a theoretical perspective these values should be similar, if not identical, to each other, studies have shown that elicited WTA values tend to be significantly higher than WTP values, either due to perceived injustice, budget constraints, or endowment effect.

The main disadvantage of revealed preference methods is that, unlike stated preference methods, they can only be applied a posteriori. That is, it is not possible to value goods or policy scenarios that have not yet been constructed or implemented since there is no associated real-world behaviour. Due to this, their usability is limited when dealing with recently developed goods, and practically inexistent when dealing with future scenarios. Considering that expansion of wind energy is a relatively new phenomenon, and limited to certain countries, it limits the possibilities of carrying out revealed preference studies on varied locations, technologies, and countries.

Despite their differences, both revealed preference and stated preference methods are tools with the same objective: to find monetary expressions of value for a given good or service. As such, they are of high relevance to the objectives stated in chapter 1.

3.2.1 Stated preference studies in wind energy

There are numerous studies in recent years utilising stated preference methods for valuating different aspects of wind energy that find significant effects on preferences based on various attributes of wind turbines. This section considers 26 different stated preference studies, and a résumé of the study details is presented in table 3.2. Most of these studies are based on choice experiments, although some of them (Boulatoff & Boyer, 2010; Georgiou & Areal, 2015; Knapp et al., 2013; Koundouri et al., 2009; Mirasgedis et al., 2014) utilise contingent valuation as the method to elicit value estimates. Some studies apply, in addition, other methodologies, for instance, Álvarez-Farizo and Hanley (2002) utilises contingent rating, but they are not used for estimating specific value measures, but instead to find relative importance of preference drivers or attitudes.

The focus of these studies is varied, but the visual impact produced by wind farms is a common recurrent attribute under study. This lies in line with the understanding that the visual impact is one of the main drivers of acceptance of wind turbines. The specificity of the measure of visual impact varies greatly among the studies considered. Some studies present site-specific visualisations of the impact produced by the defined wind turbine project (Álvarez-Farizo & Hanley, 2002; Knapp et al., 2013; Landry et al., 2012; Lutzeyer et al., 2016; Westerberg et al., 2013), other studies present generic visualisations of the appearance of generic turbines at certain locations or distances (Ackermann, 2014; Hosking et al., 2013; Krueger et al., 2011; Ladenburg & Dubgaard, 2007; Teklay Abay, 2014), some utilise explanatory drawings or graphs (Boatwright, 2013; Strazzera et al., 2012; Vecchiato, 2014) and finally some studies present no visualisations at all and just descriptive text (Dimitropoulos & Kontoleon, 2009; Georgiou & Areal, 2015; Koundouri et al., 2009; Meyerhoff et al., 2010; Mirasgedis et al., 2014; Reed & Scott, 2014). Tied to the visual impact, is the location decision of the wind turbines. This location can be presented as specific areas of the country (Teklay Abay, 2014) or as a generic decision between different geographical features such as mountains, forest, beach, or plains (Campbell et al., 2011; Ek & Persson, 2014; Vecchiato, 2014).

Compared to visual impact, the noise produced by wind turbines does not appear as often as the focus of the study. Only Boatwright (2013) and Ek (2006) present noise as an attribute with associated dB levels; other studies either ignore noise or assume it incorporated in the measure of location/distance of the wind turbines. In the case of Denmark, it is possible that due to the regulations governing the distance between wind turbines and residential buildings, noise is not experienced as often as the visual impact of the turbine.

Some studies focus more on acceptance of wind energy in general, particularly against other renewable and non-renewable technologies (Navrud & Bråten, 2007), or as proposed projects nearby respondents' locations (Boulatoff & Boyer, 2010; Georgiou & Areal, 2015; Knapp et al., 2013; Koundouri et al., 2009). While providing broader measures of acceptance of wind energy, they do not provide specific measures of acceptance for the particular attributes of the proposed wind turbine projects. This in contrast with other studies such as Hosking et al. (2013), Krueger et al. (2011), Ladenburg et al. (2011), Ladenburg and Dubgaard (2007), Meyerhoff et al. (2010) and Ek and Persson (2014), where they investigate specific attributes of wind turbines such as size, height, or number of turbines.

Concerns regarding the impact of wind turbines on the environment are reflected in the inclusion of this dimension on some of the reviewed studies (Álvarez-Farizo & Hanley, 2002; Börger et al., 2015; Campbell et al., 2011; Meyerhoff et al., 2010; Reed & Scott, 2014). These environmental impacts include the impact on flying species due to the spinning blades of the turbines, on marine species in the case of offshore wind turbines and their foundations and cabling, or general degradation of flora and fauna of the area due to human intervention. The difficulty of defining measurable levels of environmental impact, though, can be seen on the variety of levels and attribute definitions. Álvarez-Farizo and Hanley (2002), for instance, present a binary decision regarding 'protection of habitat and flora' or 'loss of habitat and flora'. Meyerhoff et al. (2010), on the other hand, utilise a specific percentage reduction of the red kite population. Evidently, defining quantitative measures of environmental protection that are at the same time easily understandable by respondents is not an easy task.

Other less common attributes considered in these studies are: the community benefit produced by the new wind projects, either in the form of job creation, or the creation of monetary funds to support the community (Ek, 2006; Hosking et al., 2013; Krueger et al., 2011; Reed & Scott, 2014); the ownership of the proposed projects (Ek, 2006; Strazzera et al., 2012); the inclusion of the community on the decision making process for the proposed projects (Dimitropoulos & Kontoleon, 2009; Ek, 2006; Reed & Scott, 2014); and possible changes in the utilisation of the beach by residents or tourists (Landry et al., 2012; Westerberg et al., 2013).

It is interesting to note that while most of these studies present value estimates for the attributes under study, normally measured as WTP or WTA; only the study by Landry et al. (2012) attempts to present an aggregated welfare measure based on the results obtained, where the estimated WTP values are utilised to give an aggregated measure of the total external costs at the level of Delaware state.

3.2.2 Revealed preference studies in wind energy

In comparison to stated preference studies, the quantity of revealed preference studies regarding wind turbines is smaller. More so, the quantity of studies that find significant effects regarding the value of wind turbines is even more reduced. This, though, is to be expected: revealed preference studies are restricted to considering real-world situations, and are not able to utilise hypothetical scenarios as stated preference studies do. As a consequence, data sets are limited by existing wind turbine installations. According to Hoen et al. (2013), to be able to find significant effects of wind turbine installations on house prices on a hedonic pricing study of the order of 3 to 4%, it is necessary to have a data set containing 350 to 700 property sale transactions within 1 mile of the turbines. This not only requires the turbines to be already built but also requires sufficient time in the area for enough transactions to occur.

Studies like Heintzelman and Tuttle (2012), Hoen et al. (2009, 2011) and Hoen et al. (2013), have all applied varied hedonic models utilising property transaction data in different areas of the United States and the United Kingdom, without finding significant effects on property prices posterior to the construction of the wind turbine. Particularly Hoen et al. (2013) utilise a dataset with a considerably high number of transactions within 1 mile of the turbines (1198 transactions, compared to less than 125 for the other named

Table 3.2: Stated preference studies on wind energy - adapted from Paper A

Study	Focus	Method	Country	Onshore or Offshore
Ackermann (2014)	Visual Impact	CE	DK	Onshore
Álvarez-Farizo and Hanley (2002)	Visual and Ecological Impact	CE/CR	Spain	Onshore
Boatwright (2013)	Visual Impact and Noise	CE	USA	Onshore
Börger et al. (2015)	Visual and Ecological Impact	CE	UK	Offshore
Boulatoff and Boyer (2010)	Interest in Wind Farms	CV	USA	Onshore
Campbell et al. (2011)	Location and Ecological Impact	CE	Chile	Onshore
Dimitropoulos and Kontoleon (2009)	Visual Impact, Location, Decision Making Process	CE	Greece	Onshore
Ek and Persson (2014)	Location, Ownership, Community Benefit, Decision Making Process	CE	Sweden	Both
Ek (2006)	Location, Visual Impact, Noise	CE	Sweden	Both
Georgiou and Areal (2015)	Attitudes and Interest in New Wind Farm	CV	Greece	Offshore
Hosking et al. (2013)	Visual Impact, Job Creation	CE	South Africa	Onshore
Knapp et al. (2013)	Interest in New Wind Farm	CV	USA	Offshore
Koundouri et al. (2009)	Interest in New Wind Farm	CV	Greece	Onshore
Krueger et al. (2011)	Visual Impact, Community Benefit	CE	USA	Offshore
Ladenburg and Dubgaard (2007)	Visual Impact	CE	Denmark	Offshore
Ladenburg et al. (2011)	Visual Impact	CE	Denmark	Offshore

Table 3.2 continued from previous page

Study	Focus	Method	Country	Onshore or Offshore
Landry et al. (2012)	Visual Impact, Utilisation of Beach	CE	USA	Offshore
Lutzeyer et al. (2016)	Visual Impact	CE	USA	Offshore
Meyerhoff et al. (2010)	Visual Impact, Impact on Birds	CE	Germany	Onshore
Mirasgedis et al. (2014)	Visual Impact	CV	Greece	Onshore
Navrud and Bråten (2007)	Wind Energy as Technology	CE	Norway	Undefined
Reed and Scott (2014)	Environmental Impact, Visual Impact, Decision Making Process, Community Benefit	CE	USA	Undefined
Strazzera et al. (2012)	Visual Impact, Location, Ownership	CE	Italy	Onshore
Teklay Abay (2014)	Visual Impact, Location	CE	Denmark	Both
Vecchiato (2014)	Visual Impact, Location	CE	Italy	Both
Westerberg et al. (2013)	Visual Impact, Tourism Impact	CE	France	Offshore

studies), without finding significant effects of wind turbines on house prices in the US [1]. It is interesting to note, though, that the result of this study seems to follow the behaviour shown in previous studies on the evolution of support for wind turbines (Devine-Wright, 2005; Wolsink, 2007), where risk-averse behaviour lowers support for projects when announced, but rises again after its construction.

On the other hand, some studies have found significant effects of wind turbines on property prices in the United Kingdom (Gibbons, 2015), Germany (Sunak & Madlener, 2012), and Denmark (Jensen et al., 2014). The study done by (Gibbons, 2015) finds an effect of 5-6% on properties within 2 km and a view of the wind turbines, which decays with distance. In Germany, Sunak and Madlener (2012) apply a hedonic pricing model on properties of Rheine and Neuenkirchen, finding significant effects of wind turbines on property price, with a reduction of the price of up to 11.95%. In Denmark, Jensen et al. (2014) manage to find significant effects of visibility and of noise, with a total reduction in property prices of up to 10% when considering both effects, out of which approximately 3% is produced by viewshed effects. A different approach is taken by Roe et al. (2001), where they apply a hedonic analysis of price premiums charged for green electricity, finding significant effects (and therefore a reflection of value) for green energy in general, with new wind energy having the highest associated premiums.

Altogether, these mixed results highlight differences on the estimated levels of the effect produced by wind turbines, not only depending on the currentness of the study but also on the geographical area where it is carried out. On the one hand, differences in the number of existing projects nearby areas where transactions occur will affect the possibilities of seeing a reflection of wind turbines on house prices. On the other hand, it is important to understand that cultural differences between countries, or even regions of the same country, might affect both perceptions of wind energy as well as the extent of their effect on house prices. Different levels of place attachment, for instance, will affect the willingness to move from a region to another (Devine-Wright, 2009) and therefore it is possible that places with lower place attachment might experience something of a self-selection bias, where people that do not like wind turbines decide to move away from the area. This would also mean that the people buying houses in the vicinity of wind turbines will be people that do not have strong preferences against them, and therefore house prices might not be affected as much.

3.3 Choice experiments

Choice Experiments (CE), also called Discrete Choice Experiments (DCE), are a stated preference method that is based on observing peoples choices between different alternative scenarios. Every respondent is presented with a set of two or more alternatives, out of

[1] There are studies, like Hinman (2010) that find significant or close to significant effects on property prices on the post-announcement pre-construction (PAPC), these are more related with what is referred as 'anticipation stigma', and therefore not relevant for the current measure of value.

Alternative A

Number of turbines per farm: 49
Number of wind farms in Denmark: 14
Distance from the coast: 8 km
Yearly payment for renewable energy: 300 DKK

Alternative B

Number of turbines per farm: 144
Number of wind farms in Denmark: 5
Distance from the coast: 12 km
Yearly payment for renewable energy: 0 DKK
I prefer (mark with X) Alternative A [ ] Alternative B [ ]

Figure 3.1: Example of choice set - (Ladenburg, 2009)

which they must choose one. Each set is denominated a 'choice set'. It is possible that respondents are presented with several choice sets in succession, and they have to make one choice for every choice set. Each alternative of the choice set represents different scenarios, where the attributes of the good being valued present different levels. By designing the attributes and their levels properly, it is possible to estimate preferences of respondents for each attribute. In the case of wind energy, for example, these variations could be scenarios with different prices for electricity, a different number of wind turbines, or different locations for siting them. An example of a choice set can be seen in fig. 3.1.

3.3.1 Choice and utility

The background theory for the analysis of choice experiments lays on the theory of consumer choice proposed by Lancaster (1966). Lancaster proposes that instead of preferences for goods, consumers have preferences for the attributes or characteristics of goods and that those attributes or characteristics are what actually provide utility. Consequently, the decisions that consumers make in regard to their consumption are not made based on a consumers' subjective understanding of a good, but instead by their preferences for the good's characteristics. This utility definition can be expressed mathematically as

$$U_{jq} = U(X_j, S_q), \tag{3.1}$$

where U_{jq} is the utility provided by good j to consumer q, X_j is a vector of attributes of the good j, and S_q is a reflection of the preferences for attributes of consumer q.

Applied to the case of wind turbines, this theory would state that consumers do not have preferences for wind turbines as a good per se, but for the different attributes of wind turbines, which can impact different spheres of preference as shown in table 3.1. Wind turbines can be seen, for instance, as a physical building with aesthetic impacts on its surroundings depending on its size, shape, colour; but they also present attributes as an energy generating technology, with particular costs, technical qualities, and environmental impacts. It is on this disaggregated view of wind turbines as a good, that choice experiments are applied, measuring preferences for some of these attributes.

The derivation of choice models in this section will follow Train (2009) and McFadden (1973). If we consider C as the space of all possible alternatives, in a choice experiment, each respondent j is presented with a choice set of alternatives $Q \subseteq C$, and tasked with choosing one amongst several alternatives $q \in Q$, each with varied attributes. Following the random model of utility presented by McFadden (1973), one can write the utility U_jq that respondent j perceives from a scenario presented in alternative q as

$$U_{jq} = V_{jq}(\theta_{jq}, X_q) + \epsilon_{jq}, \tag{3.2}$$

where V_{jq} represents the systematic utility aspect of alternative q, X_q is a vector of attributes of the good in alternative q, θ_{jq} is a function of the respondents' preferences for different attributes of the good, and ϵ represents an error term.

Under the assumption of a rational agent with complete information, we can define that respondent q chooses alternative j over alternative i if and only if $U_{jq} > U_{iq}$. Therefore, estimating the probability of a respondent choosing alternative j is equivalent to estimating

$$P_{jq} = Prob(U_{jq} > U_{iq}) = Prob(\epsilon_{iq} < \epsilon_{jq} + V_{jq} - V_{iq}), \tag{3.3}$$

which can be rewritten as

$$P_{jq} = \int_{\epsilon} I(\epsilon_{iq} < \epsilon_{jq} + V_{jq} - V_{iq}) f(\epsilon_q)\, \mathrm{d}\epsilon_q, \tag{3.4}$$

where $I(\cdot)$ is the indicator function (which has value of zero if the argument is false, and one if true), and $f(\epsilon)$ is the density of the distribution of ϵ.

3.3.2 Logit model

The mathematical formulation of the model used to calculate the value V will depend on the distribution chosen for ϵ. For the particular case of logit models, the error terms are assumed to be iid. extreme value type 1 (EV1, also known as Gumbel distributed) across all alternatives j. The density of the EV1 distribution is defined as

$$f(\epsilon_{jq}) = e^{-\epsilon_{jq}} e^{-e^{-\epsilon_{jq}}} \tag{3.5}$$

and consequently, the cumulative distribution is

$$F(\epsilon_{jq}) = e^{-e^{-\epsilon_{jq}}}. \tag{3.6}$$

Based on eq. (3.3), we can generalise and say that the probability of respondent q choosing alternative j over all other alternatives is

$$P_{jq} = Prob(\epsilon_{iq} < \epsilon_{jq} + V_{jq} - V_{iq} \forall i \neq j). \tag{3.7}$$

Considering ϵ_{jq} as given, and considering that they are independently, identically distributed EV1, this probability is:

$$P_{jq}|\epsilon_{jq} = \prod_{j \neq i} e^{-e^{-(\epsilon_{jq} + V_{jq} - V_{iq})}}. \tag{3.8}$$

But since the error terms ϵ_{jq} are not known, the unconditional probability is obtained by integrating $P_{jq}|\epsilon_{jq}$ over all values of ϵ_{jq} weighted by its density defined in eq. (3.5):

$$P_{jq} = \int_{\epsilon} \left(\prod_{j \neq i} e^{-e^{-(\epsilon_{jq} + V_{jq} - V_{iq})}} \right) e^{-\epsilon_{jq}} e^{-e^{-\epsilon_{jq}}}, \tag{3.9}$$

which can be solved algebraically[2] to the following closed form expression:

[2] The algebraic procedure is detailed in Train (2009, Ch. 3)

$$P_{jq} = \frac{e^{V_{jq}}}{\sum_i e^{V_{iq}}}. \tag{3.10}$$

This form is the classical expression of the multinomial logit model probability expression, which represents the probability of choosing alternative j in a choice set with any number of alternatives. For the particular case of a choice set with only two alternatives j and i, the previous expression simplifies to the formulation denominated as binary logit model

$$P_{jq} = \frac{e^{V_{jq}}}{e^{V_{jq}} + e^{V_{iq}}}. \tag{3.11}$$

It is important to note that this expression satisfies the properties of a reasonable and well defined probability associated to utility. It is bound between zero and one, as required. Furthermore, as the utility V_{jq} rises, the probability approaches one. When the utility V_{jq} decreases, P_{jq} approaches zero. Finally, the probabilities for all alternatives sum to one.

In the case of a choice experiment, we can define the dependent variable D_{jq}, as a binary variable that represents whether respondent j chooses alternative q, and the independent variables (also called 'predictors') will be the attributes of the scenario presented. Therefore, the experimental value for P_{jq} is known, and equal to D_{jq}. What remains unknown is the systematic value of the different alternatives, V_{jq}, which according to McFadden (1973) should depend on both the preferences of the respondent and the attributes of the good. It is necessary to define the form of the systematic utility V_{jq} to make this dependance explicit. The utility form chosen is required to be both explicative and mathematically tractable. The most common formulation is the Linear-in-Parameters-Linear-in-Attributes (LPLA) utility function

$$V_{jq} = \theta \cdot X_{jq}, \tag{3.12}$$

where θ is a vector of parameters that represent the taste of respondents to each attribute, and X_{jq} is a vector of attributes of the scenario, either generic or specific for each alternative.

The values of θ will be estimated based on the choices made by the respondents, whereas X_{jq} represents the specific attributes of the scenario. Typical attributes used on surveys regarding wind energy are both specific attributes of the wind scenario used, such as the size of the wind turbine, its location, the distance to a specific point, etc.; as well as specific socioeconomic attributes of the respondent, like their gender, age, or income level. A simplified example of a systematic utility formulation for wind turbines can be

$$V_{jq} = \theta_0 \cdot \text{Cost} + \theta_1 \cdot \text{Size} + \theta_2 \cdot \text{Distance} + \theta_3 \cdot \text{Age}. \tag{3.13}$$

Having specified the utility function, it is possible to estimate both the parameters θ as well as the probabilities P_{jq} for each respondent and choice set by maximum likelihood estimation. The likelihood is defined as a measure of the number of correct predictions done by the model in regard to the choices done by respondents

$$L = \prod_{q \in Q} \prod_{j \in A(q)} P_{jq}^{D_{jq}}, D_{jq} = 1 \text{ if j chosen , 0 otherwise.} \tag{3.14}$$

With this formulation of likelihood, we can maximise L with respect to the parameters θ. Normally, the maximisation occurs over $\ln L$ due to favourable algebraic conditions. Since the $\ln$ function is monotonically increasing, and the formulation of L is strictly concave (if using the LPLA specification), maximising $\ln L$ and maximising L are equivalent.

The estimated maximum likelihood θ parameters are a measure of the relative importance of each predictor variable on the probability of choosing a specific alternative. They are consistent and normally distributed $\theta \sim N(\theta, S^2)$, where S^2 is the covariance matrix of the parameter. Knowing this, we can apply a t-test to check the significance of a parameter θ_k against a reference parameter, typically zero:

$$t = \frac{\theta_k^* - \theta_{\text{ref}}}{S_k} = N(0, 1). \tag{3.15}$$

Assuming a reference of zero:

$$t = \frac{\theta_k^*}{S_k}. \tag{3.16}$$

The value of t will be a measure of how significantly different the parameter is from the reference given. For a typical significance level of 95%, t has to be greater than 1.96.

3.3.3 Mixed logit model

While the previous formulation is convenient and straightforward, it has a number of shortcomings, many of which are of particular relevance for studies regarding preferences for wind energy. Amongst other restrictions, the multinomial logit model does not allow to account for correlation among observations (for example repeated choices made by the same respondent), as well as does not allow for random taste variations.

The mixed logit model is based on the multinomial logit model, and it maintains a simple mathematical form while allowing for preference heterogeneities, response heterogeneities, correlation among alternatives or parameters in the same alternative, as well as correlation of the same parameter over choice situations. The flexibility of the mixed logit model allows it to approximate any other choice model (McFadden & Train, 2000).

A mixed logit model can be defined by the form its choice probabilities take. In other words, one can say that a model is a mixed logit model if its choice probability can be expressed as

$$P_{jq} = \int L_{jq}(\theta) \cdot f(\theta)\, \mathrm{d}\theta, \tag{3.17}$$

where $L_{jq}(\theta)$ is the logit probability shown in eq. (3.10) with parameters θ.

$$L_{jq}(\theta) = \frac{e^{V_{jq}(\theta)}}{\sum_i e^{V_{iq}(\theta)}}. \tag{3.18}$$

If we utilise the LPLA utility definition shown in eq. (3.12), then the mixed logit probability in eq. (3.17) takes its standard form

$$P_{jq} = \int \left(\frac{e^{\theta X_{jq}}}{\sum_i e^{\theta X_{jq}}} \right) f(\theta)\, \mathrm{d}\theta. \tag{3.19}$$

This formulation indicates that the mixed logit is a weighted average of the logit formula, and the weights are defined by the density of the distribution $f(\theta)$. This mixing of different logits with varied θ's gives the name to the model.

Typically, though, a mixed logit model is derived from an interpretation of random parameters, or random error components. Under the random parameters derivation, we consider the fact that the respondents' preferences are represented by a number of vectors θ_q. These preference vectors are also assumed to be distributed across the population with a distribution density $f(\theta)$, which is defined by parameters ξ. In this way, we account for random variations of taste across different respondents or respondent groups. Therefore, our utility function will be

$$U_{jq} = \theta_q(\xi) \cdot X_{jq} + e_j q, \tag{3.20}$$

where ϵ_{jq} are error terms i.i.d. EV1, θ_q is a vector of parameters representing the preferences regarding attributes X_{jq} for respondent q, that varies across decision makers with density function $f(\theta)$. In general, this function is assumed to be normal or log-normal, although other distributions can be used. The previous formulation of utility derives directly into the probability function shown in eq. (3.17).

The derivation of the mixed logit via random error components, on the other hand, does not address the variation in taste via random parameters. Instead, it focuses on representing correlations across the utilities for different alternatives or respondents. Specifying the utility function as:

$$U_{jq} = \alpha_j X_{jq} + \mu_j Z_{jq} + \epsilon_{jq}, \tag{3.21}$$

where e_{jq} are error terms i.i.d. EV1, α_j is a vector of fixed parameters, x_{jq} and z_{jq} are vectors of observed variables for alternative j, and μ_j is a vector of random terms with zero mean. Under this formulation, the random part of the utility will be defined by $\eta_{jq} = \mu_j z_{jq} + \epsilon_{jq}$. Depending on the specification of z_{jq}, it is possible to create correlation among alternatives. As this formulation is equivalent to the random parameters and will yield a probability function as defined in eq. (3.17).

Since both of these formulations are equivalent, it is possible to easily derive a mixed logit model with a mix of both random parameters, and correlated alternatives through error components. It is possible to see that under particular specifications of the random components, the model is equivalent to the standard multinomial logit model.

The estimation of the mixed logit model is, unfortunately, more complicated than the estimation of a standard logit model. Assuming the model has the form defined in eq. (3.17), we can see that since the researcher does not know the parameters Ω of the distribution of θ, e.g. its mean and variance or other momenta, it is necessary to estimate them. This problem is well suited to estimation via simulation, where for any value Ω, we repeatedly draw a value θ^d from $f(\theta|\Omega)$ and calculate $L_{jq}(\theta^d)$. Averaging these calculated values of L_{jq} gives an unbiased estimator of P_{jq}, $\hat{P}_{jq}$:

$$\hat{P}_{jq} = \frac{1}{D} \sum_{d=1}^{D} L_{jq}(\theta^d). \tag{3.22}$$

As shown in Hole (2007), using these simulated probabilities, we can formulate a Simulated Log-Likelihood (SLL):

$$\text{SLL} = \sum_{j \in J} \sum_{q \in Q} D_{jq} \ln \hat{P}_{jq}, \tag{3.23}$$

with

$$D_{jq} = 1 \text{ if j chosen, 0 otherwise.}$$

Therefore, we can estimate the moments of the distribution Ω by maximising the SLL, which therefore provides estimates for the parameters of the mixed logit model.

3.3.4 Panel Data

The previously shown formulations have all assumed that each choice situation is independent. In the case of choice experiments, this tends not to be true. It is very common for a respondent to answer more than one choice set, and therefore we have a case of panel data. If we assume that the utility parameters are constant for a single respondent, but independent across different respondents, we can define the utility for respondent q, on choice situation t, for alternative j, as:

$$U_{jqt} = \theta_q \cdot X_{jqt} + \epsilon_{jqt}, \tag{3.24}$$

with e_{jqt} being i.i.d. EV1 across all indices.

If we consider the series of T choices made by a respondent q, the probability of this sequence of choices conditional to θ is the product of the logit formula

$$L_{qT}(\theta) = \prod_{t=1}^{T} \frac{e^{\theta_q \cdot X_{jqt}}}{\sum_i e^{\theta_q \cdot X_{iqt}}}. \tag{3.25}$$

Therefore, the unconditional probability is the integral over this product over all possible θ values:

$$P_{jq} = \int L_{jqT(\theta)} \cdot f(\theta)\, \mathrm{d}\theta. \tag{3.26}$$

As we can see, this formulation is remarkably similar to the mixed logit model, with the only difference being the use of a product of logit formulas as shown in eq. (3.25). The estimation process remains the same, by using random draws based on θ values to find an average estimator of P_{jq}, following eq. (3.22).

3.3.5 Willingness to Pay

The estimated value of a preference parameter θ is the logarithm of the odds ratio (OR) of that parameter on the probability the respondent of choosing alternative q (ceteris paribus). It can also be interpreted as the marginal utility for attribute k (Bateman et al., 2002). If the utility function is defined linear, as in eq. (3.12), then the ratio of two parameters θ_k/θ_l represents the rate of substitution at which the respondent maintains a constant level of utility. In the particular case when the denominator of the ratio is the parameter associated with the cost variable, this rate of substitution can be interpreted as the respondent's willingness to pay (WTP) for attribute k

$$\mathrm{WTP}_k = \frac{\theta_k}{\theta_{\mathrm{Cost}}}. \tag{3.27}$$

It is important to note that in the case of mixed logit models, the θ parameters are random variables, and as such, the WTP will be defined as a ratio between to random variables. The variance of WTP_k can then be calculated using the Delta-method, which Bateman et al. (2002) present as

$$\text{Var}\left(\frac{\beta_k}{\beta_{\text{Cost}}}\right) = \left(\frac{\beta_k}{\beta_{\text{Cost}}}\right)^2 \left(\frac{\text{Var}(\beta_k)}{\beta_k^2} + \frac{\text{Var}(\beta_{\text{Cost}})}{\beta_{\text{Cost}}^2} - \frac{2\text{Cov}(\beta_{\text{k}}, \beta_{\text{Cost}})}{\beta_k \cdot \beta_{\text{Cost}}}\right). \tag{3.28}$$

Depending on the characteristics of the distribution of both parameters, it is possible that the resulting distribution for WTP_k is heavily skewed, or has no defined moments. One simple solution is to consider the cost parameter β_{Cost} as a fixed value instead of a random variable, which produces a WTP_k distribution equal to the distribution of θ_k, scaled by the cost parameter. This solution, though, introduces the assumption of a constant marginal utility of income (or disutility of price) across all respondents (Meijer & Rouwendal, 2006) which may not hold true. Another solution, proposed by Train and Weeks (2005), is to reformulate the model to be estimated in WTP space. While more accurate, this solution is more cumbersome to implement. For a more detailed comparison between both solutions, refer to Hole and Kolstad (2011).

3.4 Cost analysis

Depending on the level of detail required, a cost analysis for wind energy can encompass a numerous amount of factors, and therefore sources of uncertainty. Furthermore, different cost measures will be of different use for different stakeholders: project developers might be more interested on cost measures that define profit margins, private citizens might prefer a cost analysis that highlights the effect on electricity prices, whereas policy makers might prefer measures of total system cost that balance the previous two perspectives.

When deciding how to analyse costs, not only the methodology is to be selected, but also the scope or limits of the system to be considered. Once again, this decision has to be made while balancing the objective of the study, the availability of data, and the effects on the uncertainty when making projections for the future. In the case of wind energy, the system scope can be defined as narrowly as the cost evolution of the physical wind turbine and its components, up to comprehensive views that consider job creation effects, technology development benefits, and possible early-adopter effects.

For the purpose of this thesis, there is a number of requirements that will determine the cost analysis method to be used. The first determinant, is the focus on a public assessment of wind energy costs. This is not a private-economic feasibility analysis, but a societal-perspective one, which does not require an in-depth analysis of the profitability of the projects, nor a detailed view on the effects of financing conditions. Another relevant aspect is the fact that our analysis will be limited to two technologies with extremely similar characteristics, onshore and offshore wind energy. As such, our cost measure is not required to be able to deal with technologies with significantly different production profiles, lifetimes, or cash flows over time.

in regard to the limits of the system, the cost analyses will be used in conjunction with other measures that incorporate significant levels of uncertainty. For this reason, defining an extremely detailed and wide scope of analysis, as for example ranging from a prime material cost evolution up to society wide learning effects or job creation possibilities, is not only unnecessary but might also communicate an unintended false level of certainty of the results and estimations carried out.

Considering the previous constraints, the availability of data, and the role of the cost analysis in the framework of the present dissertation, we decided to use the levelised-cost-of-energy (LCOE) as the prime cost measure.

3.4.1 Levelised cost of electricity

Based on International Renewable Energy Agency (2012), the LCOE is defined as the constant price of electricity such as a projects' revenues equal costs, including a return of investment defined by a discount rate. The general formula used in the previous study for calculating the LCOE for renewable generation technologies is

$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(I+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}, \tag{3.29}$$

where

LCOE: Levelised cost of energy

I_t**:** Investments in the year t

M_t**:** Operation and maintenance costs in year t

F_t**:** Fuel expenditures in year t

E_t**:** Electricity generation in year t

r**:** Discount rate

n**:** Economic lifetime of the system.

When calculating the LCOE for a specific project or technology, the first step is to define the limits of the analysis. The definition of which elements to consider as part of the costs of a project is an arbitrary one, and varies depending on the country. An example

Table 3.3: Comparison of LCOE evaluation methods in the UK and Denmark - adapted from Danish Energy Agency (2015), Visser and Held (2014)

Country	United Kingdom	Denmark
Equipment cost	Yes	Yes
Other investment & fixed planning cost	Yes	Yes
Capital cost (debt, equity)	No	No
O&M cost	Yes	Yes
Decommissioning cost	Yes	No
Cost assessment for grid connection	Yes	No
Network related cost/Balancing cost	Yes	Yes
Cost of market integration/Grid expansion cost	No	Yes

of the differences regarding which elements are considered when analysisng LCOE in different countries is shown in table 3.3.

For wind turbines, investment costs represent a big share of the project's total costs, moreso for offshore wind turbines. In comparison, operations and management are relatively low, and fuel costs are non-existent. Therefore, when considering a common discount rate, the main cost factors for the LCOE will be investment costs, and the energy production. The electricity generation of wind turbines is affected by several parameters, among them the wind speed at the proposed site, the technology of the wind turbine (hub height and rotor diameter), and wake losses specific to the project turbine distribution. While these elements can be accurately determined when analysing one specific proposed project, when analysing a large expansion of wind energy in yet-to-be-determined sites, this level of detail is unfeasible. For this reason, assumptions are made in regard to technologies, and an annual energy production is calculated based on expected capacity factors for the considered expansion sites and nominal nameplate capacities.

It is important to note that analysing LCOE from a public perspective will be different than calculating it from a private one. If one were to do an analysis of the private LCOE for a project, grater emphasis should be put on the financing structure of the project due to the heavy share of investment costs on total costs for wind energy. A common approach, shown for example in Fichtner/prognos (2013), would be to consider the return on equity and the cost of debt by utilising the Weighted-Average-Cost-of-Capital (WACC) as the discount rate. Since in this study we are analysing costs from a public perspective, differences in the discount rate or financing structure are not relevant. We will follow the methodology given in Danish Energy Agency (2015) regarding which elements are considered in LCOE calculations for Denmark, and utilise a common public discount rate of 4% (real), as suggested by Danish regulation (Danish Energy Agency, 2013).

For a private investor, while useful as an overview measure, the LCOE does not express the full profitability of a project, and that more nuanced project analyses are to be carried out, utilising indicators such as the Net Present Value (NPV) and the Internal Rate of Return (IRR).

While a convenient measure, and easy to calculate, the LCOE has several shortcomings that have to be considered carefully when deciding to use it as a comparation tool. One of the main issues, is that the LCOE does not consider the profile of generation, nor the variations in price. This means that it places the same value for every unit of electricity produced independent of the price at that particular point in time. As a consequence, it is not possible to appreciate advantages in regard to flexible production of energy, or generation profiles that match generation. This effect is significant in particular when comparing across technologies with different generation profiles, but not so relevant if the comparison is to be done among technologies of similar flexibility and generation profile. Another shortcoming, is that this formulation for the LCOE does not account for taxation, nor for different kinds of support schemes. Nonetheless, when considering only wind turbines for comparison and from a public perspective, the impact of these shortcomings is significantly minimised.

3.4.2 Integration costs

When comparing the costs of offshore and onshore wind energy, there are some important differences that are unfortunately not captured by the LCOE measure. In particular, the cost differences for integrating wind energy in the system between onshore and offshore are not captured by LCOE.

While some of the direct costs of grid integration are reflected, such as cabling investment costs, others are invisible in regard to LCOE. One of such is the difference in power generation profile and full-load hours between offshore and onshore turbines. Offshore wind turbines tend to have higher levels of full-load hours (Chabot, 2013), and while the effect on the annual energy production (AEP) is captured in the LCOE, the reduced need of reserve generators for regulation is not. By having a more stable generation profile, offshore wind turbines reduce the need for reserves activation in comparison to onshore wind. This effect is more pronounced when considering the possibility of overplanting wind farms, (Wolter, 2016), which further flattens the generation profile. The development towards wind turbines with lower specific power is a reflection of the benefit provided by this reduced generation variability.

On the other hand, there are significant differences in regard to the geographical distribution of wind turbines when considering onshore and offshore, and consequently, on the effects they have on the electricity grid. While onshore wind turbines tend to be distributed across Denmark in small clusters, offshore wind turbine farms tend to have higher capacities. As a consequence, offshore wind turbines will inject high amounts of power in the grid at specific locations, often far away from high demand centres, which has the potential to create congestion on transmission lines and higher losses.

Another significant cost dimension that is not considered by LCOE are the ultimate positive effects due to increased grid interconnection that some offshore wind farm projects might provide. One current example of this is the Kriegers Flak project, an offshore wind farm to be built in the sea between Denmark and Germany, which will be connected to both countries. The positive effects of such an interconnection are not reflected in the LCOE assessment, even though they might represent a significant cost saving versus having to build an independent cable connection between Denmark and Germany.

Incorporating the effects on the cost of the differences in reserve requirements and on grid effects is an arduous task. In particular, it would require a detailed geographical assessment of the locations of future wind turbine farms, both offshore and onshore, and their interaction with the system's power flow. While there is no doubt that such detailed analysis might provide significant and interesting results, it is a task that lies beyond the scope of this work.

Chapter 4

Main results and discussion

This section presents and summarises the main conclusions of this thesis' papers, and associates these results to the overall objective of the thesis, following what was presented in chapter 1.

4.1 Measurement of acceptance costs for wind energy

While without a doubt RP measures produce estimates with lower uncertainty, their main shortcoming is that they are restricted to post-factual assessments. In the case of new technologies being analysed by hedonic pricing models, many years are needed for the housing market to reflect changes, and as a consequence, few papers find significant effects. Recent studies have managed to find significant effects for onshore, and relevant information regarding effects of visual and noise impacts.

Despite their increased certainty, hedonic pricing studies produce an incomplete measure of acceptance costs, limited to only the people directly affected in the local area. Preferences of people not directly living in the area are not accounted for, despite them being affected either in regard to use-values not related to living in sight of the wind turbines (tourists, recreational users, among others) or for having non-use values for wind turbines.

The flexibility of SP studies is of great value for the case of wind energy, particularly for measuring hypothetical further expansions and preferences between offshore and onshore. Nonetheless, the method is quite susceptible to distortions from survey design issues and data interpretation. As observed on Paper A, despite the popularity of SP studies in the field of valuation of wind turbines, the quality level and formulation of the surveys on recent studies are extremely varied. A common shortcoming seen in numerous studies, is that they focus on studying the visual impact produced by wind turbines, but utilise surveys that do not ensure that respondents have a way to visualise this impact correctly. This could be done either by utilising pictures and video material, or by assessing the degree of familiarity that respondents have with the turbines considered for the study.

Another often-seen shortcoming is not correctly isolating the attributes under study. Very often, for example, the amount of total energy produced in the presented scenarios is not constant, and therefore there is a confounding factor that measures not only preferences for attributes, but for the energy produced by the wind turbine. While this kind of mistakes has been correctly identified in stated preference survey design literature for many years, they are still present in recent studies.

Utilising web-based surveys for SP studies has been preferred in recent years by researchers, mainly due to their lower cost compared to mail, phone, or in-person surveys. One of their drawbacks, is the lack of control researchers have on the conditions over which the survey is answered, both in the environment surrounding the respondent (such as noise levels, illumination) and the equipment utilised to respond to it (computer speed, screen size, colour fidelity). The sensitivity of estimates obtained in SP studies to the conditions of the study is observed in Paper B, where it can be seen that the size of the screen that respondents use for answering the survey has significant effects on the preferences of respondents.

In Paper C, we focus on measuring the acceptance costs for onshore and offshore wind energy in Denmark utilising a stated preference study. While previous stated preference studies in Denmark have addressed preferences over offshore and onshore wind energy, this is the first study to directly address onshore versus offshore preferences and to further include spatial data. We find strong preference drivers for offshore and onshore wind turbines in Denmark. When looking at the preferences obtained for the most significant attributes such as the distance between the shore and offshore wind turbines, size of the onshore wind turbines, and the density of the area chosen for siting the onshore wind turbines, we find that our results are in line with previous studies on the topic.

Regarding onshore preference drivers, we find that respondents present strong preferences towards siting wind turbines further away, as well as preferring fewer large turbines, over numerous smaller ones. When comparing onshore versus offshore wind turbines, we find extremely strong preferences for siting wind turbines offshore instead of onshore. Furthermore, respondents prefer to site wind turbines in areas with 100 residents or less.

Offshore preference drivers results also highlight the preference towards minimising visual disamenities, by siting wind turbine farms far away from offshore. Our results also suggest that at distances further than 18 km away from the coast, the visual impacts are already minimised. We did not find any significant preferences in regard to the specific location in Denmark for siting the offshore wind farm.

Our analysis of spatial data indicates that significant relations exist between the preferences and particular spatial variables. We find that the distance of the respondents' residences to the coast or to the nearest proposed wind site has significant effects on respondents' preferences. Other spatial attributes found significant, are the number of wind turbines that can be seen from the respondents' residence, and the number of wind turbines existing in the same postcode area as the respondent.

When comparing the obtained preferences for onshore and offshore wind turbines, it can be seen that we find strong preferences for offshore wind turbines compared to onshore ones. This preference when expressed as a WTP indicates a value of 612.5 DKK per household per year for siting wind turbines offshore instead of onshore. It is important to note that the magnitude of this WTP is higher than for most attributes considered in the study, indicating that respondents have high desire to avoid onshore wind turbines.

4.2 Inclusion of acceptance costs into cost curves

One of the objectives of the thesis was to study the possible integration of acceptance costs into cost curves for wind energy, and if possible, to determine which methods would allow to do this. In Paper D we include acceptance costs into cost curves for onshore wind, utilising three different methods for calculating acceptance costs. Method A is based on a study by Energinet.dk that considers compensation payments and purchase of properties where needed (Energinet.dk, 2015), method B is based on property price loss values obtained from an hedonic pricing study by Jensen et al. (2014), and method C is based on the stated preference study shown in Paper C, from which we extract a lower estimate that considers the same local population as in methods A and B, and a higher estimate that considers preferences of a nationally aggregated population.

We find that acceptance costs obtained by method A and method B, as well as the lower estimate of method C, are similar in level across most of the range of potential expansion considered (total capacity expansion of 12 GW). The differences become higher as we reach the upper limits of the considered expansion, point at which method A produces a much higher estimate, driven by the high cost of property purchases. When compared with a cost curve for offshore wind (with no acceptance costs), the level of these estimates indicates that for most of the potential expansion onshore wind has a clear cost advantage over offshore even while including acceptance costs. Only after a significant expansion of wind energy, more than 12 GW, does offshore become less expensive than onshore.

When looking at the high estimate of method C, though, the situation is quite different. The level of acceptance costs found is significantly higher than the estimates obtained by the other methods, as well as above the LCOE cost curve for offshore wind energy expansion. There are several explanations for this result. Firstly, it is expected for acceptance costs to be higher since we are considering a much larger share of the population. Secondly, there is a certain degree of overestimation due to the formulation of the survey questions that is not specifically formulated for considering impacts of an onshore wind turbine installed a long distance away from the respondent. Finally, the aggregation used also averages the acceptance costs in a flat manner, not considering the fact that acceptance cost per MW will change as the potential is further expanded. For these reasons, this curve should be interpreted not as a point estimate of expected acceptance costs, but as an upper boundary of their value.

Based on the work presented on Paper D, we can conclude that it is feasible to include acceptance costs in cost curves for wind energy, and that estimates for acceptance costs obtained through different methods, but equivalent assumptions, provide estimates that are consistent among them and lie on similar levels of cost. It is important to note that particularly when using stated preference studies as the source of acceptance cost estimates, the obtained levels will be very sensitive to the formulation of the study, and that special care has to be taken to ensure that the scenario formulation, as well as the population considered in the survey match the intended analysis scenarios for the formulation of cost curves. When integrating acceptance costs obtained via revealed preference methods, it is important to take into account the limits of value transfer. In particular, it is important to keep in mind that measures of acceptance cost obtained through a revealed preference study are constrained to the specific scenario in which the values were calculated, and that the certainty associated to the measure is tied to the extent over which one maintains that scenario in calculations. There exists the danger of applying acceptance costs measured by revealed preference studies to hypothetical expansion scenarios, and to falsely believe that the estimates obtained will maintain the level of certainty typically associated to revealed preference studies.

Finally, it is important to note that the cost curve obtained is based on the potential expansion of wind energy based on total installed capacity, but completely ignores the time dimension in regard to acceptance costs and considers them fixed.

4.3 Policy implications

Both Paper E and Paper F present results with interesting policy implications, although in different areas of interest. For this reason, they will be analysed separately. Paper E studies the effects of prior experience in regard to preferences for minimising the visual impact of offshore wind turbine farms. It uses a natural experiment comparing two population samples, one living near the Nysted nearshore wind farm and the other living near the Horns Rev offshore wind farm. The main difference between both groups is the fact that the Nysted wind farm is visible from land, whereas the Horns Rev wind farm is not.

Utilising parametric and non-parametric analyses of the preferences of both, we find significant differences between both samples. In particular, the Nysted sample has a significantly higher preference for choosing the high-value alternative when available and a significantly lower preference for choosing the zero value alternative when available. Besides, the Nysted sample presents in general higher WTP, although with low significance in regard to the differences of WTP between both samples. Finally, we observe significant differences in scale between both samples, with the sample living near Horns Rev presents significantly higher scales (i.e. lower variance). This increased certainty is further supported by an analysis done on the stated certainty of choice, where based on an ordinary least squares regression and a multinomial logit model, we find that respondents from Horns Rev present significantly higher levels of stating that their answers were 'Certain' and 'Very Certain'.

The most interesting result of this paper is not associated directly with the level of the differences between both samples. Instead, it is the fact that these differences imply a dynamic nature in regard to preference formation. The absence of significant differences in regard to the average mobility of respondents in both samples, as well as the sign of the differences in WTP, suggest that self-selection bias does not adequately explain these differences. We conclude that the prior experience with wind farms that respondents from Nysted had, has modified their preferences in time in regard to wind farms and their visual disamenities. This result is of high relevance for policymakers, as it indicates that future acceptance costs for wind energy will depend on the siting decisions taken before. In particular, based on the differences in WTP found, choosing to site offshore wind turbine farms in locations where they will be visible from land (such as some of the nearshore locations considered in Denmark) will increase acceptance costs for future wind turbine farms. Considering both technical costs and acceptance costs, this dynamic behaviour introduces the possibility of a 'cheap today/expensive tomorrow' situation, where policies that aim at minimising costs in the present have the potential of creating a much higher total cost over time.

Paper F focuses on one of the technical costs associated with energy systems with a high share of inflexible generation, such as wind energy. As discussed on section 2.4, high shares of inflexible generation increase the requirement of reserves on the system. The higher the share of flexible generation, the higher the amount of capacity that needs to be available but not running, which presents a problem not only in regard to the total system costs due to the high amount of redundant installed capacity but also in regard to making these standby power plants economically attractive to project developers.

To tackle this issue, the paper explores the possibility of utilising flexibility of household demand as a tool for providing system reserves, both fast and slow, in Denmark. Considering a future Danish system with a high share of wind energy, we compare the system costs between having flexible demand participate on the spot electricity market versus having it provide system reserves. We find that the value provided by demand flexibility as system reserves is much higher than when participating in the spot market. We also carry out a sensitivity analysis over the reserves requirement, as well as the household flexible demand potential, where we find that the cost savings potential is significantly affected by the flexible demand potential.

It is important to qualify these findings in regard to the limitations and simplifications made during the modelling and analysis of the system. in regard to modelling, there are several simplifications in regard to the assumed perfect foresight when flexible demand is participating in the spot market. Furthermore, we have excluded specific technologies (like heat pumps) as well as the possibility of cross-border provision of reserves based on Nordic cooperation. in regard to the realisability of the proposed system cost reductions, it is important to note the existence of technological barriers (such as those that would enable the centralised control of household devices) as well as sociological ones (consumers' resistance towards such automation equipment). Finally, there is the challenge for the system operator in regard to organising the recovery of the shifted demand, as well as the compensation or incentive method for consumers to provide flexibility.

Despite these qualifications, the results in regard to system cost advantages provide an interesting possibility for reserve provision, which in turn would facilitate and lower the integration costs of high shares of wind energy in the country. Policy measures that facilitate the participation of flexible demand in reserve provisioning might be an excellent complementary tool to promote the integration of high shares of wind energy.

Chapter 5

Concluding Remarks and Further Work

This thesis contributes to the field of wind energy from different perspectives. By utilising a multidisciplinary approach, it furthers the understanding of wind energy preferences and the effect they have when considering acceptance costs for the future development of the Danish energy system. This contribution is made through the suggestion of improvements in methods utilised for measuring preferences, the integration of aggregated acceptance costs measures into technical wind energy cost curves, and the exploration of some technical and preference-based phenomena that have the potential of affecting the future deployment of wind energy in Denmark.

The provided acceptance costs measures and integrated cost curves should not be used as the final quantitative measure for cost-benefit analysis based policies, or for specific system decisions such as determining the optimal balance between onshore and offshore wind energy. The objective of this thesis is to provide an initial exploration towards the quantitative integration of acceptance costs into cost curves and, based on this, to identify shortcomings of different methods, possible solutions, and challenges from a policy perspective. In that regard, the objectives have been fulfilled.

It is important to note that this thesis utilises a utilitarian approach that is better suited at describing preferences and their associated costs, than at explaining them. The current thesis is, of course, a reflection of fundamental assumptions based on a specific sociological and psychological understanding of the nature of preferences. Nonetheless, the analysis of this contextual framework beyond what has been presented in chapter 2 is not an objective. As a consequence, most of the conclusions of this thesis in regard to preferences should be understood as descriptive and not explanatory, even while some results, for example, those obtained on the prior experience experiment presented in Paper F, might tempt towards explanatory conclusions. In that regard, while this work manages to link social acceptance to the technical cost curves from a quantitative perspective, there still exists a gap to be bridged in regard to including a conceptual analysis based on social sciences.

Despite the previous disclaimer, the results obtained from this work are relevant and interesting. While not attempting to minimise in any way the uncertainties associated to the preference measures and the estimated acceptance costs, not only does it show that the inclusion of these costs into technical cost curves is possible, but that the cost measures obtained through different methods (namely hedonic pricing, compensation payment analysis, and choice experiments) provide comparable cost measures.

From a broader perspective, one should note that the uncertainty associated with the measure of acceptance costs does not reside solely on the choice of method used, but also on the definition and scope used. Once again, the determination of which precise definition of acceptance costs is the correct one is beyond the scope of this thesis. There exist technical, sociological, psychological, and political arguments towards utilising different definitions, and the choice taken will affect significantly the level of acceptance costs obtained. This issue is presented in the analysis done in Paper D, where we present two different acceptance costs curves based on the same willingness to pay estimation but differing in regard to the aggregation done. The decision of whether to include only the local population, the whole national (or even global) population, or any measure in between, is a decision that will have to be taken not only based on the understanding of preferences given by social sciences, but also while accounting for the practical context surrounding the intended use of the measure. In this sense, it is possible to argue that there is no single correct definition, but that it should be tailored to the specifics of the analysis being done.

The dependence of preferences on social, cultural, and geographical aspects, makes the transferability of the results of this thesis a tricky question. Throughout the development of this thesis, the scope has always been narrowed to the Danish context. As a consequence, while many of the results regarding wind energy preference drivers are in line with the ones obtained in different international studies on the topic, such as Krueger et al. (2011), Ladenburg et al. (2011), Ladenburg and Dubgaard (2007) and Meyerhoff et al. (2010) to name a few, there is no guarantee nor suggestion that it is reasonable to transfer the levels obtained on the analyses done in this thesis to other contexts. Nonetheless, the conclusions regarding the feasibility of quantitatively analysing and including acceptance costs into technical cost curves are applicable and transferable to a broad range of geographical and social contexts. Evidently, this requires that the definition of acceptance costs and the measurement method chosen reflect correctly the requirements applicable to the particular context over which the analysis is intended to be done. In this sense, any attempt to transfer the levels of the results obtained in the present work should be made with extreme care, and with similar recommendations like the ones existing when considering doing benefit transfer in a cost-benefit analysis.

For Denmark, the results obtained present interesting challenges for the future development of the energy system. While the increased clarity that this analysis provides in regard to the comparison of acceptance and technical costs gives more information to policymakers, it also suggests that when considering acceptance costs, the difference between onshore and offshore costs is not so clear-cut across the full potential considered. Given the national context and the existing proposals towards the development of nearshore, it highlights the need for further careful assessment of the topic, particularly when considering the results obtained in regard to the dynamic qualities of preferences. However, it should be stressed that the uncertainties regarding the cost-advantage of onshore wind are quite limited for the short-term levels of wind expansion.

There exist numerous avenues for further research and work, from methodological, experimental, and policy-making perspectives. In regard to the methods utilised, there is always space for improvements in regard to measuring preferences. The difficulty of transferring the levels of the results obtained in one study to other contexts creates a need for carrying out studies that measure preferences in the specific relevant places for the analysis. The choice of methods will be varied, depending on the budget, the objective of the study, as well as the availability of data. For this reason, developments in both revealed and stated preferences studies would be significant contributions towards the field.

In regard to stated preferences, there are numerous areas of development that might yield interesting results. While visual disamenities have been shown on numerous occasions to be one of the primary drivers for preferences regarding wind turbines, the accurate portrayal of the visual impact produced in turbines has not always been achieved. While several recent studies have opted for utilising visualisations as a tool to give respondents a representation of the visual impact produced by the turbines, there are many possibilities not exploited yet. The utilisation of video, or virtual reality, might provide information typically excluded from standard visualisations (such as flickering, night-time illumination, and weather interactions, to name a few) and provide a more accurate description of the effects produced by the turbines. While the inclusion of visual aids in scenario descriptions is still a contested topic, it is possible that when visual disamenities are the primary attribute of the good being studied, visualisations might produce an improvement in the measurement of preferences.

One of the shortcomings of the present dissertation, is the assumption of static preferences for wind energy when calculating aggregated measures of acceptance costs, even though Paper F indicates that preference formation is a dynamic process. This is compounded with the fact that we do not fully account for the time dimension when analysing the potential expansion of wind energy. Both of these issues present clear possibilities of further research.

As more countries expand the amount of wind energy in their systems, the possibility of analysing the effects of this expansion through a revealed preference study increase. It would be of interest to carry out revealed preference studies on areas previously analysed with other methods as a way to analyse the validity of previous studies. When comparing the results of revealed preference studies with the ones obtained via stated preference studies, though, it is of utmost importance to be aware of the differences in the types of value (and therefore preferences) being measured.

As previously stated, there is a significant breach between studies measuring acceptance costs, and the wealth of social science that deals with the origin of preferences for wind turbines. This is, without a doubt, one of the most interesting avenues for further research. The possibility of analysing the causes and functioning of preference-forming dynamics would allow for an analysis of acceptance costs that is not limited to the extrapolation of the preferences moulded by the status-quo. In this aspect, the present study only scratches the surface in regard to the possibilities of research that exist. Further research in regard to preferences when comparing the expansion of the energy system utilising wind turbines versus alternative forms of generation, or the effect of public participation in the decision process, and the incorporation of these preferences in quantitative measures would provide new and valuable knowledge.

While the work carried out in this dissertation is limited to wind energy, the methods utilised can be applied to different technologies. While wind energy is of high relevance for Denmark, it could be possible to adapt such a study to consider preferences for other technologies with potentials for public resistance.

The further research suggestions and conclusions presented in this dissertation define this thesis not as a final cost-benefit analysis, but as exploratory work towards creating an integrated vision of costs for wind turbines. While the information presented in this thesis is possibly of high relevance to policymakers, it should be taken with the understanding that this is but the first step towards providing quantitative measures of acceptance costs in an integrated manner, and that there are significant, and interesting, challenges yet to be solved.

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Papers and Appendices

Paper A

Estimating preferences for wind turbine locations - a critical review of visualisation approaches

Estimating preferences for wind turbine locations - a critical review of visualisation approaches

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Abstract

As the amount of wind energy installed capacity keeps growing, in Europe and the world in general, the siting of wind projects near population or recreational centres becomes a frequent possibility. Therefore, it is of high interest for policy makers and developers to be able to quantify the effect of wind projects on public acceptance.

Currently, one of the main drivers for acceptance of wind turbines by the public is their level of visual impacts. While recent studies have focused on estimating the welfare loss of visual impacts from wind turbines, a large share of the applied studies have used no or very simple visualisation of the actual visual impacts at stake. These studies thus rely on the cognitive skills of the respondents to imagine wind turbines of different sizes and locations; and on the prior experience people have had with wind turbines.

By extending the economic model of perceived quality developed by Blomquist and Whitehead (1998), this paper provides a theoretical argument for the need of visualisations when describing valuation scenarios for respondents, as well as the relevance to correctly define the amount of attributes of the good to be represented on the visualisation, and which visualisation techniques to utilise. Afterwards, we propose a framework for classifying different visualisation types and utilise it to classify recent studies regarding wind turbines acceptance, highlighting the lack of visualisations in recent studies, as well as the need to raise the bar on scenario descriptions for wind turbine visual impacts valuation.

Keywords: wind energy, stated preference studies, environmental valuation, landscape valuation, visualisations

1. Introduction

Fossil fuels have been the main energy generation source for many years, but concerns regarding CO2 emissions and climate change have motivated the search for alternative energy systems that can reduce the emission of greenhouse gasses. Energy goals across countries, as for example the Europe 2020 Climate and Energy Package, have been more and more focused on developing energy projects that do not depend on fossil fuels. In this context, wind energy has shown to be a clean technology with great potential for fulfilling these goals.

Originally, wind projects were few and had the possibility of being located on areas where the sites would not impact population centres and/or recreational areas. Currently, due to the significant growth that wind energy has experienced, some of the disamenities from wind turbine siting are being experienced more often by the population, namely visual impacts and noise disturbances (Gibbons, 2015; Jensen et al., 2014; Ladenburg and Lutzeyer, 2012; Sunak and Madlener, 2016). The perceived disamenities associated with wind power development have reached a level where some wind turbine projects have been terminated and scrapped due to resistance from the public arising from these disamenities.

This situation presents a tough decision making environment for the selection of wind turbine sites. While the public resistance due to disamenities is minimised when moving the wind turbines further away from population centres or even offshore, the costs of doing so increase considerably, especially when deciding to make the transition towards offshore wind turbine sites (EEA, 2009; Energistyrelsen, 2014). Accordingly, the choice of developing at different sites becomes an economic trade-off decision between costs of energy and external costs of the wind turbines projects.

As a consequence, the necessity for the measurement

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of external costs arising from the visual impact of new projects is evident. Quantification of the external costs can provide policy makers with important information when considering the trade-off between the technical advantages of the particular site, and the disamenities created.

Responding to this need, a large number of studies applying stated preference economic valuation methods have emerged the past 10-15 years. Most of these studies have estimated preferences for visual impact reduction either directly as a function of distance/number of turbines/formation of wind farms; or indirectly as a function of the location of the wind turbines. Interestingly, as we will discuss and argue in this paper, 31% of the 26 studies considered do not use visualisations at all, and 44% only use simple visualisations and thus depend on the cognitive ability of the respondent to create images showing the visual impact in their mind. Accordingly, it seems fair to question whether these economic valuation studies might fail to give reliable and objective information about the visual impacts attributes in focus, by the means of visualisations.

The aim of the present paper is to put economic valuation of visual impacts from wind turbines into an economic model framework, and based on this, to discuss and derive arguments for why rigorous visual aids are a necessary tool for eliciting valid and trustworthy answers from respondents in stated preference surveys. Accordingly, this paper also introduces a framework for classifying different existing visualisation approaches and applies it to give an overview of their use in recent studies. First, the importance of visualisations is derived from the economic model of perceived preferences presented by Blomquist and Whitehead (1998) considering the relevance of the visualisation presentation method itself, the attributes included in it, and the potential prior information people might have about the resource quality changes caused by wind power development. This is followed by a discussion of the possibility of respondents not having correctly updated priors, stressing out the use of visualisations. Afterwards, a framework for classifying visualisation approaches is presented, highlighting benefits and weaknesses of each method. Finally, a selection of recent studies regarding wind turbine valuation is classified utilising the presented framework and recommendations and conclusions are given.

2. An economic model for visual resource quality changes

2.1. Economic model of perceived quality

Following Blomquist and Whitehead (1998), for a representative agent, the perceived quality q of a good can be expressed in terms of the actual quality of the good θ, and the information received during the survey regarding the good's quality I:

$$q = \overbrace{\beta \cdot \theta}^{\text{Prior Info.}} + \overbrace{\delta \cdot I}^{\text{Add. Info.}} \tag{1}$$

Both the actual quality of the good and the information received during the survey are subject to individual learning parameters β and δ, respectively. These learning parameters do not refer to the amount of information provided, but to the capability of the respondent for absorbing this information, either due to personal characteristics (Cerda et al., 2014), motivation for processing the information (Meyers-Levy, 1986), the relevance of the information (Ertac, 2011), the availability of the information (Hoehn and Randall, 2002; Ladenburg et al., 2014), differences in prior information (Ladenburg et al., 2014; Tkac, 1998), or the type/quality of the information medium chosen (Bateman and Mawby, 2004; Blomquist and Whitehead, 1998; Cerda et al., 2014; Hoehn and Randall, 2002; Jacobsen and Boiesen, 2008; Hevia-Koch and Ladenburg, 2015). Therefore, the term $\beta \cdot \theta$ expresses the total amount of prior information on the resource quality that the respondent has regarding the good, while the term $\delta \cdot I$ represents the total effect on the perception of the resource quality from the information added to the respondent during the survey. [1]

Expanding this formulation from the standard CVM study framework used in Blomquist and Whitehead (1998) to the standard set-up of a Choice Experiment including n resource quality attributes of the good in focus, it is important to note that the quality changes under evaluation depend on the values of the n attributes and therefore the terms of eq. (1) can be expressed as vectors:

$$\begin{aligned} q &= \boldsymbol{\beta} \cdot \boldsymbol{\theta} + \boldsymbol{\delta} \cdot \boldsymbol{I} \\ &= [\beta_1, ..., \beta_n] \cdot [\theta_1, ..., \theta_n] + [\delta_1, ..., \delta_n] \cdot [I_1, ..., I_n] \end{aligned} \tag{2}$$

[1] It is important to note that this simple model does not exclude dynamic learning parameters allowing for value and institutional learning, as in Braga and Starmer (2005) or Bayesian preference updating processes as shown in Israel (2005). However, it is beyond the scope of the present article to expand the model while considering these dynamics.

Where every term of the vectors $\boldsymbol{\theta}$ and $\boldsymbol{I}$ represent the actual quality change produced by a specific attribute of the good, and the information given to the respondent regarding that particular attribute of the good during the survey, respectively. In the same way it is possible, if desired, to further expand the individual learning parameters for actual quality and given information, to a "per-attribute" basis, shown here as $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$. This can be used to express that some information is given in the survey using different mediums, such as text or images, which have different communication qualities and information absorption rates Bateman et al. (2002), shown in the per attribute values of $\boldsymbol{\delta}$. In the same way, while some attributes of a good might be well known by the general population, other attributes might be more ambiguous or subject higher levels of lack of knowledge or even misinformation, being reflected in the per attribute values of $\boldsymbol{\beta}$.

If we look at past wind power preference studies (Álvarez-Farizo and Hanley, 2002; Dimitropoulos and Kontoleon, 2009; Ek, 2006; Krueger et al., 2011; Ladenburg and Dubgaard, 2007; Landry et al., 2012; Meyerhoff et al., 2010; Navrud and Bråten, 2007; Westerberg et al., 2013), preferences regarding visual disamenities produced by wind turbines are driven by many different attributes of the wind turbine farm: number of turbines N, size of each individual turbine S, grouping of the turbines in the farm G, distance of the turbines from the viewpoint D, features of the particular landscape F, location of the turbines in the landscape L, just to mention some. Therefore, expanding eq. (2) for the particularities of wind turbine visual disamenities yields:

$$\begin{aligned} q =& [\beta_N, \beta_S, \beta_G, \beta_D, \beta_F, \beta_L] \\ & \cdot [\theta_N, \theta_S, \theta_G, \theta_D, \theta_F, \theta_L] \\ & + [\delta_N, \delta_S, \delta_G, \delta_D, \delta_F, \delta_L] \\ & \cdot [I_N, I_S, I_G, I_D, I_F, I_L] \end{aligned} \tag{3}$$

Based on this expansion it is possible to extract some meaningful observations regarding the importance of the survey design. As researchers, we are interested in obtaining preferences from respondents that are adequately informed about the consequences of the resource quality changes. As shown in eq. (3) this information has two sources: prior information possessed by the respondents, and the information given during the survey related to the specific attributes. Focusing on the latter, it must be the goal of the information given in the survey to update the prior information people have about the good in focus so they can state valid preferences for the resource quality changes. However, this might not be necessary if the respondents have sufficient levels of prior information. On the other hand, if we suspect that the respondents do not hold sufficient levels of prior information, we need to make sure to correctly update this prior information, and make a decision of what kind of visualisations to use. In the following section we will elaborate on the expected level of prior information among respondents in stated preference surveys eliciting preferences for wind power development. This is followed by and introduction to the different types of visualisations available and a review of how they have been used in academia.

2.2. Do we need to update preferences?

Looking at the complexity of eq. (3) naturally raises the question of whether we need to apply visualisations, and whether it is worth the effort to generate visualisations that objectively and accurately represent the changes in the visual landscape amenities. Two elements should influence this decision: do the respondents hold sufficiently high levels of prior information, and what is the impact of the visualisations on their expected stated preferences?

If we start with the former, we generally cannot expect all respondents in stated preference studies to have perfect knowledge about the good in focus. This is supported by studies that assess the level of prior information in respondents. Hoehn and Randall (2002) test different types of information on respondents of stated injury severity index related to a contingent valuation study, and find that heterogeneous effects from prior and new information exist. By assessing the level of prior information in a study focusing on preferences for wetlands, Czajkowski et al. (2014) find, based on nine questions related to the respondents prior information, that only 2.2% of the respondents can be characterized as having a high level of prior information and as many as 59.1% have a low level of information. In LaRiviere et al. (2014) the mean level of 8 questions probing for prior knowledge is 6 in a Choice Experiment on preferences for cold water coral reefs. In a third study examining preferences for river restoration (Kataria et al., 2012) it can be seen that approximately 34% of the respondents find that the river quality of the status-quo situation was different than the one presented in the scenario description.

If we move on and look into studies with a focus on wind power, the level of specific experiences with wind turbines has typically been assessed by asking respondents about the type and amount of experience they have with wind turbines. In Krueger et al. (2011) the share of respondents who have seen a wind turbine during their lifetime ranges between 54.3% to 72.9% across three samples. In two different Danish surveys (Ladenburg et al., 2013; Ladenburg, 2014) between 4.9% to as much as 64.4% of respondents have an onshore wind turbine in the viewshed from their permanent residence or summerhouse and 4.6% to 21.5% have an offshore wind turbine in the viewshed. Finally, while 23.6% report to see every day between 0 to 5 turbines, 27.2% see 6 or more turbines on a daily basis.

From the previous results, it can be seen that in the Danish case the existence of certain prior experience with wind turbines seems evident. However, even though respondents might be relatively well informed in regard to onshore wind turbines, the need for updating their knowledge through visualisations might still be relevant. For example, let us say that a study regarding wind turbine farms includes 3 dimensions: two types of grouping (groups of 10 and 20 turbines), two types of wind turbine sizes (1 [MW] and 2 [MW]) and two distances from the specific view point under study (0.5 [km] and 1 [km]). This is equal to $2 \cdot 2 \cdot 2 = 8$ different possible scenarios of quality changes in the landscape amenities. If the respondents only have experience with one or few of those visual dimensions, (groups of 10 turbines of 2 [MW] size each at a distance of 0.5 [km]), then if not presented with any visualisations, they have to create their own imagined impression of the quality changes in the landscape amenities in the 7 attribute combinations based on single experience combination. Another way to illustrate these properties is to use the offshore wind farm preferences data from Ladenburg and Dubgaard (2007) and Ladenburg et al. (2011). When the studies were carried out, several offshore wind farms were in operation with varying number of turbines in the wind farms θ_N [m], size of turbines, θ_S, and distances from the shore, θ_D [km]. Therefore, for this case previous information with the particular values existing at the time can be represented as:

$$\boldsymbol{\beta} \cdot \left[\theta_N \begin{pmatrix} 3 \\ 8 \\ 10 \\ 11 \\ 20 \\ 72 \\ 80 \end{pmatrix}, \theta_S \begin{pmatrix} 53.5 \\ 64.5 \\ 102 \\ 103.5 \\ 110 \\ 158 \\ 161.2 \\ 163.8 \\ 170 \end{pmatrix}, \theta_D \begin{pmatrix} 0 \\ 2 \\ 2.5 \\ 3 \\ 6 \\ 14 \end{pmatrix} \right]$$

However, the scenario description stipulated the use of 5 [MW] turbines in wind farm sizes of 49, 100 and either 144 turbines (Ladenburg and Dubgaard, 2007) or 100 turbines (Ladenburg et al., 2011); at 8, 12 18 and 50 [km] from the shore:

$$[\delta_N, \delta_S, \delta_D] \cdot \left[I_N \begin{pmatrix} 49 \\ 100 \\ 144 \end{pmatrix}, I_S(160), I_D \begin{pmatrix} 8 \\ 12 \\ 18 \\ 50 \end{pmatrix} \right]$$

Though there exists some overlap in the attribute levels, particularly regarding the size of the wind turbines, for both remaining attributes there is a non-trivial difference on the levels existing as part of prior information in comparison to the levels considered on the scenario description: The number of turbines in the existing wind farms is generally lower compared to the levels in the scenario description, and the distances considered are quite larger than most of the existing distances. We can see that in this case, even if the respondents did have previous information related to wind farm developments; this previous information was based on wind turbines with dissimilar characteristics to the ones considered in the scenario of the study. Because these differences reside on attributes that have a significant influence on the visual impact produced by the wind farms, they introduce a considerable distortion on the estimation of visual disamenities reduction preferences.

The case becomes even more evident if we look into some of the other offshore wind power studies. Several offshore wind power preferences studies have been carried out among population groups which we cannot expect respondents to have any specific prior information about the resource quality changes caused by the visual attributes of offshore wind power. Let us look at Koundouri et al. (2009); Krueger et al. (2011); Landry et al. (2012); Westerberg et al. (2013); Vecchiato (2014): To the authors best knowledge, when these studies were carried out no offshore wind farms were in operation neither in US, Greek, Italian nor French waters. In these studies, the primary offshore wind turbine attribute is the distance from the coast for fixed wind farm and turbine sizes within each study i.e. θ_D and I_D. Accordingly, the level of prior information related to the quality change of the landscape amenities from offshore wind farms was extremely low[2], i.e:

$$\boldsymbol{\beta} \cdot [\theta_N, \theta_S, \theta_D] \approx 0$$

[2]Naturally, the respondents might use prior knowledge related to other (non-wind power) coastal landscape features in the evaluation of the change in the seascape quality caused by wind farms at different distances. However, as a researcher/analyst we should have an idea of which elements might affect the respondents assessment and control for them if possible.

However, the scenario description stipulated the use of wind turbines of varying sizes θ_S [m], number of turbines in the wind farms, θ_N, and distances from the shore, θ_D [km]:

Vecchiato (2014):

$$[\delta_N, \delta_S, \delta_D] \cdot \left[I_N \begin{pmatrix} 4 \\ 15 \\ 50 \end{pmatrix}, I_S \begin{pmatrix} 450 \\ 120 \\ 200 \end{pmatrix}, I_D \begin{pmatrix} 0.1 \\ 0.25 \\ 1 \end{pmatrix} \right]$$

Krueger et al. (2011):

$$[\delta_N, \delta_S, \delta_D] \cdot \left[I_N(500), I_S(135), I_D \begin{pmatrix} 1.44 \\ 5.76 \\ 9.60 \\ 14.40 \\ \text{Not Visible} \end{pmatrix} \right]$$

Landry et al. (2012):

$$[\delta_N, \delta_S, \delta_D] \cdot \left[I_N(\text{N/A}), I_S(130), I_D \begin{pmatrix} 1.6 \\ 6.4 \end{pmatrix} \right]$$

Westerberg et al. (2013):

$$[\delta_N, \delta_S, \delta_D] \cdot \left[I_N(30), I_S(135.5), I_D \begin{pmatrix} 5 \\ 8 \\ 12 \end{pmatrix} \right]$$

If a respondent has limited availability of prior information, or even no prior information at all, to assist in the value formation for a resource quality degradation caused by offshore wind turbines, the stated level of preferences can be expected to be strongly dependent on what kind information that the respondents are presented with during the survey:

$$q \approx [\delta_N, \delta_S, \delta_D] \cdot [I_N, I_S, I_D]$$

Clearly the choice of visualisation, and the quality thereof, can be expected to influence the value formation and the subsequent levels of WTP. This exemplifies the need for correctly updating respondents' information even in cases where there exists some prior information on the topic, due to possible discrepancies on the number and levels of the goods' attributes. Therefore, the challenge is to create a study design that allows us to compensate for the imperfect prior information held by respondents and thus obtain preference estimates that are based on the best possible measures of the perceptions in the resource quality change.

The role of visualisations becomes even more evident if a SP study aims at estimating preferences for dynamic attributes of wind turbines, such as shadow effects/flickering and night time illumination.

Shadow effects refer to the visual impact produced by the shadows cast by the wind turbines depending on the time of the day. As the sun moves across the sky, the size and location of this shadow changes, sometimes shadowing areas of interest. Particularly important is how the wind turbines shadow is cast during sunrise and sunset, as it is during those points in time that the shadow cast is the longest and has a bigger chance of impacting its surroundings. The rotation of the blades is also an important element to consider, as the shadows cast are not static, but will move across the surface several times per minute as the blades rotate. The effect of the moving shadows produced by wind turbines has been studied in Pohl et al. (1999), concluding that it has a noticeably disturbing effect in most people, that in some cases might surpass the visual disamenities arising from the wind turbine itself.

Regarding night time illumination, wind turbines tend to be illuminated for security reasons after sunset, and as a consequence their visual impact varies drastically in comparison to daytime conditions as the lights contrasting the dark background can be more eye-catching than the wind turbines themselves during daytime. As shown in Lutzeyer (2013), the preferences of respondents that are presented with daytime and night time visualisations are significantly different than the ones of respondents presented with only the daytime visualisation. In particular, day time only visualisation respondents present a lower disutility from visual impact than the respondents that were presented with both kinds of visualisation.

So jointly, in order to capture the visual resource quality degradation caused by wind turbines, we need to make clever choices that give the respondents the best tools possible to state valid and trustworthy preferences, being in line with the recommendations presented by previous ground literature such as Bateman et al. (2002); Arrow and Solow (1993); Champ et al. (2012); Carson and Mitchell (1989), where it is asserted that to be able to accurately assess the perception of a good, it is necessary to describe the attributes of the good under investigation in a way that is meaningful and understandable to respondents. It is important to emphasise the need for the descriptions to be not only correct and complete, but in particular meaningful and understandable, therefore "descriptions may require a combination of textual information, photographs, drawings, maps, charts and graphs" Bateman et al. (2002). This is particularly important if the respondents are asked to make choices among complex choice sets. In the field of cognitive and educational psychology, Carlson et al. (2003) find that performance improved if information was conveyed with diagrams and not text alone. Interestingly, this effect was only present in tasks involving higher levels of complexity. In Hoehn et al. (2010) two scenario information formats are tested: text only, and text including tabular data. The results suggest that the tabular format reduced the variance of the estimated preferences parameters and induced a lesser use of choice heuristics. Furthermore, Hevia-Koch and Ladenburg (2015) find that the screen size in web surveys influences the visibility and the details in visualisations and stated preferences.

However, as addressed by Arrow and Solow (1993); Boyle (2003), using photographs and visualisations of other kinds (such as video material, maps or interactive features) should be done with care:

> "One effective mean for conveying information and holding interest in a CV interview has been the use of large and impressive photographs. However, this technique is a two-edged sword because the dramatic nature of a photograph may have much more emotional impact than the rest of the questionnaire. Thus it is important that photographs be subjected to even more careful assessment than verbal material if the goal is to avoid bias in presentation." - (Arrow and Solow, 1993, p55.)

Though the focus of the previous is on making sure that the respondents do not overestimate the value of the pictures shown as visualisations, the issue remains the same - visualisations of the changes in the resource quality can be powerful tools to increase the level of information among respondents, but due to the potential of generating distortion in the perceived values, it is paramount that their application is done in a rigorous manner.

3. The Visualisation Ladder and Review

In this section we will present and discuss the different existing visualisation approaches in an incremental way, hereafter named the visualisation ladder, and review the use of different visualisations in academic literature. Some studies have used a mix of different types of visualisations while other studies have used one type of visualisation only. Furthermore, when we move on to analysing the studies using some kind of visualisation, it is important to discuss whether or not the visualisations are scaled relative to the attribute and attribute level in focus. For example if the visual attributes are five 3 MW turbines (size) located 1 km from a view point (distance) the visualisations should represent both of those attributes in an accurate proportion. In the same line, if for example visualisations are used to give an impression of wind turbines in different landscapes, the wind turbines should be scaled identically, so that the distance to the turbines and number of size and the turbines are the same. If the visualisations are not scaled, the visualisations will give the respondents incoherent and potentially misleading information relative to the text description - being the point made by Arrow and Solow (1993).

3.1. No Visualisations

As a ground level, we have the no visualisation approach, where respondents are presented with textual information regarding the visual impact of the wind turbines but without any kind of visual aid. This approach has been widely used in previous studies, particularly because of its ease of implementation and evident inexpensiveness.

Among the 26 studies considered on the present paper, nine have decided not to present any visualisations to the respondents, and two have one or more visual attributes described by text only. Though these studies do not use visualisations, they still aim to estimate preferences for visual impacts attributes. Except for three (Navrud and Bråten, 2007; Börger et al., 2015; Georgiou and Areal, 2015), all of the studies include more than one visual attribute. Based on the model for preferences shown in eqs. (1) to (3), not giving any kind of visual aid stresses the dependence on the respondents prior experience with wind turbines/wind farms. In particular, when using only text for giving information on the scenario description, the learning factor δ will only relate to the changes described in words and it is up to the cognitive ability of the respondent to translate the written visual attribute changes into visual images based on his or her own skills, as well as the prior experience the respondent might have. This might be relatively easy when the study only includes one visual attribute, as done in Navrud and Bråten (2007); Börger et al. (2015); Georgiou and Areal (2015). However, when the studies include more than one visual attribute, the cognitive burden increases substantially, as the respondents are asked to trade-off visual impacts in multiple dimensions.

The best example thereof is the survey utilised in Meyerhoff et al. (2010). Without going into specific details, the respondents are asked to make choices between three onshore alternatives, that vary with the size of the wind farm (4-6 turbines, 10-12 turbine and 16-18 turbines), height of the turbines (110m, 150m and 200m) and distance from a residential area (750m, 1100m and 1500 m). Accordingly, the respondents state their preferences for wind power development including $3 \cdot 3 \cdot 3 = 27$ different visual outlays. Though the study is carried out in Germany, which has one of the highest wind power capacities in world, and the respondents might have some experience with onshore wind power, the task of accurately trading off the visual attributes without any visual reference for all of these dimensions in each scenario might be a serious cognitive challenge.

Another example can be seen in Campbell et al. (2011). This study estimates preferences for locating wind farms of three sizes (300, 500, and 800 football pitches), in different locations (offshore, onshore, on coast and in the mountains). The study was conducted in Chile, and at the time the study was carried out, there were no offshore wind farms in Chile, and a very limited amount of onshore wind farms. Accordingly, it can be expected that the respondents might have very weak prior information related to the visual attributes of an offshore wind farm and it might therefore be more difficult for the respondents to assess the type of visual impacts caused by offshore wind farms with the three different proposed sizes. In the same line, but considering only a single visual attribute dimension, Georgiou and Areal (2015) elicit preferences for an offshore wind farm located 2.75 km and 4.1 km away from two Greek islands. In the study, respondents are indirectly asked to trade-off renewable energy development and the impact associated with offshore wind farms. However, despite the potential visual impacts, the survey does not give any kind of visual aids (and does not mention the dimensions of the wind farms). Though several sites have been proposed for offshore wind power development (4COffshore, 2016), no offshore wind farms were in operation in Greek waters at the time the study was carried out. Accordingly, the respondents have little prior experience, which they can rely on.

The issue that we wish to raise is that the validity of the studies estimating the welfare cost of visual attribute disamenities from offshore wind farms without giving people visualisations could be questionable. That might be event if the respondents have some level of prior experience, This issue is acknowledged by Meyerhoff et al. (2010), that states on its conclusions section: "[...] as no visualisation was used interviewees could have misjudged the impact of high turbines on the landscape."

Due to these qualities, we would argue that the no visualisation approach should not be recommended for use in stated preference studies focusing on visual attributes of wind farms. An exception could be, if the respondents state preferences for removing the visual attribute impacts from a specific existing wind farms. In that case, we might expect that respondents have the visual impacts at first hand and therefore have good priors to state fair and just preferences. Due to the fact that visual impacts have been shown to be significant drivers for the preferences regarding wind turbines in both economic (Krueger et al., 2011; Ladenburg and Dubgaard, 2007; Landry et al., 2012); and non-economic studies (Betakova et al., 2015; Maehr et al., 2015; Palmer, 2015), it is important not to ignore the potential impact that these dimensions might produce when creating surveys that elicit preferences for wind energy.

3.2. Relative Wind Turbine Size Visualisation

This is the most basic approach to visualisations, where the respondent is shown only a diagram of the shape of the turbine, as well as the dimensions of it. It can also show some other form of reference, for example a human figure or a possible known building, next to the turbine. This type of visualisation has been utilised mainly due to its simplicity, as it does not require the creation of specific computer generated images or photographs, and represents an incremental step forward from the no visualisation approach.

From the studies reviewed, there are only two that decided to use relative visualisations. In Boatwright (2013), relative visualisations are utilised to present the size of two different types of wind turbines, an example of which is shown in fig. 1. The turbines are shown relative to a specific lighthouse, relating the scale of the turbines to a possibly known landmark. Importantly, the relative sizes shown have the same ratios as the numbers put forward in the relative visualisations, that is, the images of the wind turbines are scaled correctly according to their stated sizes. Thus, the respondent gets a true picture of the relative differences from the visualisations.

Another study (Vecchiato, 2014) utilises relative visualisations for representing three different dimensions: size of the wind turbines, distance from houses, and number of turbines in the farm. Unfortunately, the visualisations used suffer from scaling problems that hinder their quality and usability. Though there is some information about the differences in the visual attributes, much of it is left up for the respondents to cognitively process, and even worse, is distorted by images where their visual aspect does not match the stated distances, sizes and numbers.

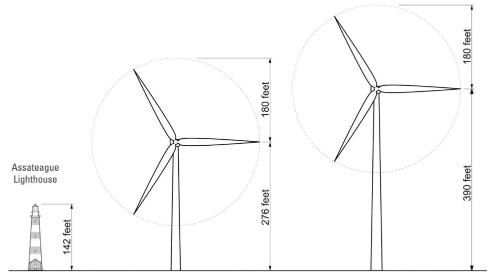

Figure 1: Relative visualisations from Boatwright (2013)

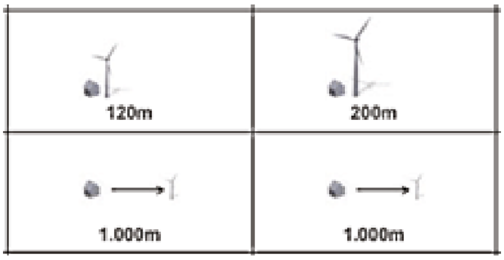

Figure 2: Relative visualisations from Vecchiato (2014)

If we go into more detail, it can be seen that the ratios of the wind turbine sizes are approximately 1:1.67:2.33 in the relative visualisations, but 1:2.4:4 in the text description of the scenario. The same problem seems to be the case with the wind farm sizes. In the relative visualisations, the wind farms size ratios are 3:7:11, which should be compared to 4:15:50 in the text. The relative visualisations related to the distance of the wind turbine to housing areas is also highly questionable, though verification requires access to a wind visualisation program. First, it can be seen that the distance itself between the house and the turbine is incorrectly scaled. Secondly, it can be seen that as the wind turbine is drawn further away from the house, its size is changed, perhaps to illustrate the changing effect on how visible it is from the house. It seems, that this scaling effect shown on the image is not based on the actual change of apparent size depending on distance, but merely introduced in an arbitrary amount. All of these effects can be seen on fig. 2.

Overall, the use of relative visualisations gives some information to the respondents, but still offloads the burden of determining the actual visual impact onto them. As such, we might expected that there will be distortions regarding preferences for the distance and/or height for the wind turbines, as the respondents answers will be mostly based on what they think the visual impact will be and not on the actual impact. Particularly evident in the case of the distance attribute, where the relative visualisation helps understand how far away from viewpoint the turbines will be located, but does not give information regarding the visual effect of that movement.

That said, these kinds of visualisations will be an improvement from no visualisation at all when respondents have never seen a wind turbine before and therefore have no reference point at all. If respondents have prior experience with wind turbines, the effectiveness of this visualisation approach is debatable. While this approach presents an improvement on the relevance of the *I* factor of the economic model, it is not enough to present a reasonable amount of information relevant for the decision making process of the respondents, particularly if the amount of experience they have with wind turbine is close to non-existent.

3.3. Generic Visualisation

In this kind of visualisation the wind turbines are shown in a generic environment, and scaled according to the turbine characteristics, and distance. This is normally done by utilising computer generated images that combine or generate a geographical location and insert the wind turbine in it, correctly scaled and illuminated.

This approach proves much better than the two previous ones as it does not require the respondent to imagine the effect of changing the turbine's height or distance, instead showing it explicitly. In this manner, the effects of the proposed alternatives are much clearer. This is the simplest approach that is capable of presenting actual visual impact changes to the respondents. As seen on the previous sections, it is possible to include various dimensions of attributes on the visualisation, as for example grouping, size, distance and number of turbines. Two important advantages are that its simplicity is reflected on ease of creation and lower cost; and the fact that by being generic it can be applied when referring to scenarios with indeterminate location or when doing cost-benefit analysis that has to be applied to a numerous amount of scenarios, making site-specificity infeasible.

Seven of the reviewed studies use generic visualisations to present all visual attributes and three studies to present at least one of the visual attributes, an example of which can be found in fig. 3. However, as we will come back to, the scale of the applied visualisations and the comparability across visualisations is questionable in some of the reviewed studies.

If we start with the former, Ek (2006); Vecchiato (2014); Hosking et al. (2013); Strazzera et al. (2012) all use generic visualisations that are out of scale. In Ek (2006), the wind turbines located onshore, offshore

Figure 3: Generic offshore visualisation from Ladenburg and Dubgaard (2007) (cropped)

Figure 4: Non-scientific visualisation from Strazzera et al. (2012)

and in the mountains seems to have different sizes and are visualized from different distances. The same issue is apparent in Vecchiato (2014) and as a consequence, the visualisations convey information that is not part of the visual attribute. In this study, for example, the wind turbines offshore can hardly be seen, which might make respondent prefer offshore locations to a higher extent, compared to had the turbines in the different landscape been equally scaled. In Hosking et al. (2013), the landscape type varies when presenting different wind farm sizes and the distance to the wind turbines from the nearest residential area. Accordingly, it is in principle impossible to decouple preferences for size and distance from the different landscapes that they are visualized in. Another study, by Strazzera et al. (2012), presents the same problem regarding strange scaling of wind turbine sizes on their provided visualisations. Unfortunately, as the study does not state which are the characteristics of the wind turbines used as a reference, it is not possible to accurately confirm if the apparent size of the wind turbines in the visualisations is correct.

Strazzera et al. (2012) also uses non-scientific generic visualisations to represent the potential visual impacts associated with locating wind turbines "close" and "far from" an unspecified archaeological site, with hand drawn images. Though the wind turbines differ in size at the two visualisations, much is left for the respondents to imagine - particularly as one visualisation shows four turbines and the other five turbines. Though it is not possible to determine with complete certainty, it raises the concern that the visualisations are not correctly scaled and located, and therefore do not give an objective impression of the visual impacts. The same situation can be seen in the site specific visualisations, in which the turbines seem oddly large in the landscape (see fig. 4) and with varying numbers of turbines depending on the distance.

That said, in the remaining studies using generic visualisation, the turbines are correctly scaled, with a minor issue present in the study done by Teklay Abay (2014) where there seems be some scale differences between the onshore visualisations (in which all visual attributes are in scale) and offshore visualisations. Interestingly, most studies using generalized visualisations elicit preferences for offshore wind farms - two exceptions being Ackermann (2014); Teklay Abay (2014).

The main shortcoming of the generic visualisation approach comes from the fact that it does not take into account the particularities of the environment where the turbine might be located, as well as the turbines' specific location, which can have a big impact on the perceived quality change. A wind turbine situated in a large plain with no other geographic features on sight will probably be more visible than a wind turbine located behind a forest or hidden by hills. As such, this kind of visualisation might over- or under-represent the visual impact of the wind turbine due to specific particularities of the selected wind turbine site.

Another disadvantage compared to the relative wind turbine size visualisation is that it is significantly more time consuming to be done, as it will be based on computer generated images that have to correctly account for wind turbine height and distance.

3.4. *Site-Specific Visualisation*

A site-specific visualisation not only accounts for the differences in distance and size of the wind turbines, as the generic visualisation does, but also shows the turbines immersed in the relevant geographical location. This allows the respondents to observe how the proposed project would look in the particular siting location, which can have a serious effect on the perception of the visual impact. Out of the reviewed studies, four utilise site-specific visualisations for presenting the vi-

Figure 5: Site-specific visualisation from Knapp et al. (2013)

sual attributes of the scenario. An example is shown in fig. 5

As wind turbine farms can be placed in locations of very different aspects and geographies, the visual impact associated to them can vary notably even when the turbine size and distance is the same. Turbines hidden by hills or a forest are evidently going to be less visible than if they were located on an open field. On the other hand, turbines that obstruct or distract from the view of an historical building, or a pleasant geographical landmark, will be considered having a bigger impact even if the size and distance do not change. This effect is more evident in places that have a value linked to its visual condition, as happens in areas where there are relevant tourism and recreational activities, or areas of particular historical or natural significance. Site-specific visualisations are able to show this effect, and therefore clarify any possible misunderstandings regarding the particular nature of the project on the respondents' part. For this reason, it further refines the amount of information given to and absorbed by the respondent, due to increasing the quality of both the learning coefficient $\boldsymbol{\delta}$ and the information given $\boldsymbol{I}$.

Evidently, this adds another level of complexity to the creation of these visualisations, as the conditions for the creation of generic visualisations are maintained, but now with the added requirement of using images specific to the proposed wind turbine locations. If the number of locations under study is big, then the cost and complexity for commissioning the creation of these visualisations increases significantly.

This visualisation approach has the potential to introduce important improvements over the generic visualisations. It is recommended to utilise this approach on projects where there exists reasons for believing that the geographical setting might impact the extent and acceptance of the visual impacts.

3.5. Dynamic Visualisation

One of the main characteristics of wind turbines is the movement of their blades. It has been shown that human vision responds more to moving objects (Franconeri and Simons, 2003), and therefore when looking at a wind farm this movement might make the wind turbines much more noticeable than if they were fully static. For this reason, visualisations that only include still images are unable to fully capture the visual impact arising from the movement of the wind turbines' blades.

A dynamic visualisation is a visualisation that changes its appearance over time, and as such it can illustrate the effect of movement whether by utilising a recorded video or a computer generated one. While the movement of the wind turbines' blades is an obvious candidate for being shown on a dynamic visualisation, it is not the only attribute that might benefit from it. Another attribute that can be represented utilising a dynamic visualisation is the interaction between the wind turbine and the sun, where the moving shadows can have an impact much higher than just a static shadow cast by the turbine when the sun rises or sets behind it, as explained on Section 3. While showing a picture of the shadow of a turbine falling in a house might illustrate some level of discomfort, utilising a dynamic visualisation that shows the shadow sweeping across the house several times per minute may paint a more appropriate picture. Other elements that might be possible to show are weather conditions, time of the day, obstructing car traffic, and more.

Because of the definition of dynamic visualisation, it is not completely a separate visualisation type per se, but it can be applied to any of the previously shown visualisation types. For the reasons outlined on the previous sections, it is evident that the biggest benefit and the most accurate visualisation would be generic and site-specific dynamic visualisation, as they will capture most of the elements that accurately represent the visual impact of wind turbine farms.

While video images are a standard approach for dynamic visualisations, they are not the only solution. More advanced techniques could include generating a full virtual environment where it is possible to see the proposed wind turbines in the selected environment from different points of view, with varying weather and time of the day conditions. One example of this is the work done in Zehner (2009), where he utilises a projected virtual reality environment to create a visualisation that allows respondents to experience the visual impact of the wind turbines in a way as close as possible to real life, as shown in fig. 6.

Figure 6: Site-specific visualisation from Zehner (2009)

The shortcomings of dynamic visualisations are related mainly to the cost and complexity. Generating these visualisations is definitely a more time consuming process, as it is necessary to generate a video or even a full virtual environment, not only a picture. Another restriction is that a dynamic visualisation limits the possibility of utilising mailed or printed surveys, and makes the logistics of applying the survey more complicated. In this aspect, internet based surveys seem to gain an advantage due to the relative simplicity of including video material on an internet site. For more elaborate set-ups, like the virtual reality based one done by Zehner (2009), the survey must be applied in person on a prepared location, making the study much more expensive and challenging.

Despite these challenges, this kind of visualisation is what future studies should aim towards, as it allows for the best representation of the scenarios under study and for representing relevant elements largely ignored in current visualisations (shadows, lighting, weather, night illumination and blade movement).

4. Assessment of Visualisation Methods on Literature

In the presentation of the visualisation ladder, it is clear that the studies have used difference approaches to give the respondents information on the visual dimensions of wind power development. In the following section, we apply the visualisation ladder actively, and subjectively rate the different studies in terms of the specific visual attributes in the studies, as well as the ability of the studies to convey objective visual impact information. For each study, we list the amount of attributes under study whose preferences are related to the visual impacts produced by the wind turbines; and the visualisation approach used. The possible visual attributes considered are: *Size* of the wind farm, *Height* of the wind turbine, *Location* of the wind farm regarding terrain or specific geographical area, *Distance* to residential areas/relevant sites, and *Visibility* of the wind farm from residential areas/relevant sites.

Based on this, we have tried to assign a level of visual adequacy to each study, that represents how effective are the visualisations chosen at correctly characterising the visual impact of the attributes that the study considers. The adequacy is graded on a relative scale that ranges from 0 to 4, with 0 being a very low level of visual adequacy, and 4 being the highest for the analysed studies. It is important to note that this assessment is only referred to visual aspect of the study, and is not an evaluation of the study quality as a whole.

From the results shown on Table 1 two issues can be observed. Firstly, there is a substantial number of studies that focus on visual attributes, while not providing any kind of visualisation that includes them. Secondly, many of these studies focus on several attributes that affect the visual impact at the same time while not providing an adequate representation of these attributes on the visualisation, nor choosing a relevant visualisation type. From our perspective, this can be seen in Hosking et al. (2013); Vecchiato (2014); Boatwright (2013); Meyerhoff et al. (2010). This is not to say that it is impossible to study several visual attributes at once: note that while Lutzeyer (2013) also considers many different attributes with relation to the visual impact, the visualisations chosen manage to give an objective representation of all of them, both due to the choice of creating site-specific visualisations, as well as the attributes included in them.

The relevance of any study that wants to address the economic significance of visual impacts, is directly associated to the scientific rigour with which the scenario description, and associated visualisations, are created. From this perspective, carrying out a study that focuses on an elevated number of visual attributes without the necessary quality of the scenario description, does not yield solid scientific conclusions and gives less grounds for application in policy decisions and economic analysis. Because of this, if researchers are faced with resource and/or time constraints that make it infeasible to create high quality visualisations for all visual attributes under study, limiting the amount of these attributes while making sure that the remaining ones are correctly represented in the scenario description, will allow them obtain conclusions of much higher scientific value.

5. Conclusions

While the topic of visual impacts for wind generation has been increasingly discussed on recent literature, the

Table 1: Literature Assessment

Study	Visualisation and Attributes	Adequacy	Journal
Ackermann (2014)	Height: Generic and Scaled Distance: Generic and Scaled Size: Generic and Scaled	1	Master Thesis
Álvarez-Farizo and Hanley (2002)	Location: Site-specific and Scaled	4	Energy Policy
Boatwright (2013)	Height: Relative and Scaled Size: Generic and Scaled Visibility: None	1	Master Thesis
Börger et al. (2015)	Height: None	1	Environmental Science & Policy
Campbell et al. (2011)	Size: None Location: None	0	Applied Economics Letters
Dimitropoulos and Kontoleon (2009)	Height: None Size: None	0	Energy Policy
Ek and Persson (2014)	Location: Generic (No Turbines)	2	Ecological Economics
Ek (2006)	Height: None Size:None Location: None	0	Book Chapter
Georgiou and Areal (2015)	Distance: None	0	Renewable and Sustainable Reviews
Hosking et al. (2013)	Clustering: Generic Not Scaled Distance: Generic not Scaled Size: Generic not Scaled	0	Master Thesis
Knapp et al. (2013)	Distance: Site-specific and Scaled	4	Master Thesis
Koundouri et al. (2009)	Size: None Visibility: None	0	Energy Policy
Krueger et al. (2011)	Distance: Generic and Scaled Location: Generic and Scaled	2	Land Economics
Ladenburg and Dubgaard (2007)	Distance: Generic and Scaled Size: Generic and Scaled	3	Energy Policy
Ladenburg et al. (2011)	Distance: Generic and Scaled	3	Danish Journal of Economics
Landry et al. (2012)	Distance: Site-specific and Scaled	4	Resource and Energy

Table 1: Literature Assessment (cont.)

Study	Visualisation and Attributes	Adequacy	Journal
Lutzeyer (2013)	Distance: Site-specific and Scaled Size: Site-specific and Scaled Visibility: Site-specific and Scaled	4	Ph.D. Thesis
Meyerhoff et al. (2010)	Height: None Distance: None Size: None	0	Energy Policy
Mirasgedis et al. (2014)	Visual Impact: None	0	Renewable and Sustainable Energy Reviews
Navrud and Bråten (2007)	Size: None	0	Revue d'conomie Politique
Reed and Scott (2014)	Distance: None Size: None	0	Journal of Environmental and Resource Economics
Strazzera et al. (2012)	Distance: Artistic Generic Not Scaled Location: Artistic Generic Not Scaled	1	Energy Policy
Teklay Abay (2014)	Height: Generic and Scaled Distance: Generic and Scaled Size: Generic and Scaled Location: Generic and Scaled within offshore/onshore	3	Master Thesis
Vecchiato (2014)	Height: Relative and Not Scaled Distance: Relative and Not Scaled Size: Relative and Not Scaled Location: Generic and Not Scaled	0	Aestimum
Westerberg et al. (2013)	Distance: Site-specific and Scaled	4	Tourism Management
Zehner (2009)	Height: Dynamic VR Distance: Dynamic VR Location: Dynamic VR	-*	Conference Paper

* Zehner (2009) is not a valuation study but a demonstration of how to utilise VR visualisations for wind turbines' visual impact valuation.

importance of including visualisations as a central part of the scenario description has not yet been discussed in depth. Considering the relevance of valuation in policy making, and the increasing deployment of wind energy on a global scale, it is necessary to make use of better methods and studies for estimating the value of visual disamenities produced by wind turbines.

By extending the theoretical model for perceived quality done by Blomquist and Whitehead (1998), this paper presents arguments towards the necessity of visualisations as part of the standard scenario description on any study whose conclusions might be influenced by the effects of visual impact of wind turbines. In particular, the importance of both the presentation of the visualisation, the scaling of the visual attributes, as well as the attributes of the wind turbine scenario represented on it, might influence the perceived quality of the good by respondents.

We develop and present the visualisation ladder, a framework for classifying different visualisations approaches, which allows us to have a starting point for comparing visualisation techniques in regard to the presentation method chosen, and to be able to discuss decisions made in recent studies in a comparative manner. The visualisation ladder also presents alternatives to current researchers regarding possibilities for visualisation of the visual impact for wind turbines, while highlighting their general benefits and shortcomings. It also makes it possible to comparatively review previous studies and discuss the quality of visualisations used in recent studies where visual impact of wind turbines has a high relevance.

We found that in recent literature, nine studies have not used any kind of visualisations, and two of these studies have only used text to describe one or more of the visual attributes in focus. Two studies opted for using relative visualisations to represent some of the visual attributes, and seven studies use generic visualisations to present all visual attributes, while three studies use them to present some of the visual attributes. Finally, four studies use site-specific visualisations for all visual attributes. Accordingly, even when looking at studies that are focused specifically on the acceptance of wind turbines, or the visual impact itself, the use of appropriate visualisations has not become standard practice.

The lesson to be learned is that the relevance and quality of any study that wants to address the economic significance of visual impacts, is directly associated to the scientific rigour with which the researchers create the scenario description and associated visualisations. From this perspective, carrying out a study that focuses on an elevated number of visual attributes without the necessary quality of the scenario description, might not yield solid scientific conclusions and gives less grounds for application in policy decisions and economic analysis. Because of this, if researchers are faced with resource and/or time constraints that make it infeasible to create high quality visualisations for all visual attributes under study, limiting the amount of these attributes while making sure that the remaining ones are correctly represented in the scenario description, will allow them obtain conclusions of much higher scientific value.

By arguing towards the relevance of visualisations on stated preference studies related to wind turbine visual disamenities from a theoretical standpoint, the need for rigorous and scientific formulation of them, and showing the relative lack of development in this area even on recent literature, this paper aims to raise the bar in regards to study design and to bring into discussion the relevance of visualisation for an accurate description of the scenarios considered.

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Paper B

Size matters: Effects of screen size on formation and validity of preferences when utilising web surveys

Size Matters: effects of screen size on formation and validity of preferences when utilising web surveys

Hevia-Koch, P., Ladenburg, J.

1 Abstract

Recently, stated preference studies have been increasingly carried out by utilising web surveys. Nonetheless, the validity of web surveys has been studied with mixed results: while flexible, a disadvantage of web surveys is the lack of control over the setting in which the respondent is presented with the questionnaire. This study focuses on analysing the effect of screen sizes on the stated value of respondents, based on a survey regarding visual disamenities produced by wind turbines with 1753 respondents. More specifically, the focus lies on how preferences (expressed as willingness-to-pay) and certainty in choice (both self-stated and analysed as variance of respondents' answers) are affected by the screen size utilised by respondents to answer the survey. Additionally, we explore the effect of screen size on the extent of protest choices.

Results show that there are significant effects in the elicited preferences, with screen size affecting willingness-to-pay for visual attributes. Furthermore, we find no effect on certainty in choice nor the extent of protest choices. Altogether, the results show that the size of the screen of the device utilised for answering a web survey has definite effects when the survey contains visual material. Therefore, it is necessary to consider and control for this effect, either in the modelling or directly in the development of the survey.

Keywords: wind energy; stated preference; environmental valuation; willingness to pay; web surveys; preference formation; landscape valuation

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2 Introduction

In recent years, the use of web surveys as a means to carry out stated preference studies has increased significantly. This can be attributed to an increase in the amount of internet users, as well as the advantages in terms of flexibility, cost, and time, that web surveys offer when compared to other survey methods (as for example telephone interviews, in person surveys, or other formats) some of which are explored in further detail by (Menegaki et al., 2016).

As warned by (Dillman & Bowker, 2001) it has not been survey methodologists advocating mainly for the use of web surveys due to superior quality, but a decision made by researchers looking for cheaper and easier deployment methods for surveys. The validity of web surveys has been studied with mixed results, focusing on the aspect of self-selection bias for respondents of these web surveys, as well as on the possible differences in preferences expressed in terms of Willingness-to-Pay (WTP). Some studies have found no differences in terms of the level of the answers regarding the expressed preferences (Lindhjem & Navrud, 2011; J. S. Nielsen, 2011) when comparing web-based surveys to face-to-face ones. On the other hand, some studies have found that web-based surveys produce overrepresentation of some sectors of the population (Kwak & Radler, 2002; Lindhjem & Navrud, 2011; Marta-Pedroso et al., 2007); and WTP estimates lower than those obtained with mail surveys (Morrison, 2013).

While flexible, a disadvantage of web surveys is the lack of control over the setting in which the respondent is presented with the questionnaire. In particular it is difficult, if not impossible, to control the environment conditions in which the respondent answers the questionnaire, or the specifications of the device utilised such as its screen size, sound system, and colour characteristics of the display. This lack of control means that the possibility exists for surveys that utilise visual aids as part of their scenario description, to present these visual elements in a different manner to different respondents. In particular, presenting the same image to respondents utilising different screen sizes might affect their perceived value of the good shown on the image, and therefore modify their stated preferences. Evidently, this phenomenon is highly relevant when considering studies that focus primarily on goods whose visual attribute is a main driver for preferences.

The mental perception of sizes is complex and involves many different cues, such as contrast, resolution, visual angle, depth information, foreground texture, and familiarity (Meehan & Triggs, 1992; Predebon, 1992; Roscoe, 1993). When the size of the picture changes, the relative meaning of these cues also change and thereby the perception of the content of the picture (Reeves et al., 1999). One such example put forward in the latter study, and of high relevance of our paper, is that five small trees might look like a small forest in a small picture, whereas the distance between them becomes more apparent in large pictures, making them appear as five distinct trees. Consequently, in the small picture the little forest represents only one object of attention whereas five distinct objects in the larger picture. Likewise, seeing a group of smaller turbines, being the subject of valuation in the present paper, on a small screen might only represent one object in the eye of the beholder, compared to several objects on a larger screen.

The first attempts to study the effect if screen size on viewers' quality perceptions were done in television studies. For example, (Hatada et al., 1980) find that increasing the visual angle (through large image sizes or nearer viewing distances) increased the feeling of realism. In another study, large television screens were associated with greater intensity relative to smaller television screens, though smaller screen had a better-stated picture quality (Grabe et al., 1999). Furthermore, (Reeves et al., 1999) find that participants pay more attention to the messages presented on large screens (55") than they do to messages presented on small (2") or medium-size (12"). According to the paper by (Detenber & Reeves, 1996), the best summary of past research is that "larger image sizes indeed can intensify viewers' evaluation of content" [pp. 70, line 5-6.]. Clearly, much has happened since the late 90's where the focus was on the size of televisions screens.[1]

However, besides the study by (Liebe et al., 2015), no other studies have looked into the effect of screen size on preferences nor focused on the effect on preferences of studies using visualisations. This is despite the range of stated preferences studies using web surveys with visualisations/detailed pictures such as (Ek & Persson, 2014; Ladenburg et al., 2011; Landry et al., 2012) in the case of wind power, (Jørgensen et al., 2013; Kataria et al., 2012) in case of fresh water quality, (Nielsen, Olsen, and Lundhede 2007) in the case of forest recreation attributes, (He & Gao, 2015) in the case for consumer choice, and (Hurtubia et al., 2015) studying preferences for public spaces, just to mention a few.

In this study, we look at the effect of differing screen sizes on the stated value of respondents regarding visual disamenities produced by wind turbines. Based on information of the respondents' screen sizes, we analyse the effect that this screen size has on respondents' preferences and certainty in choice. As screen sizes become bigger, the information related to the attributes represented on visual aids becomes better, as the images are clearer. We hypothesize that the screen size will affect the visibility of wind turbines in provided images and visual aids, and consequently affect preferences of respondents. We would expect that the different screen sizes have a significant effect on the preferences (as willingness-to-pay) for the attributes represented visually, in particular, for respondents with bigger screens to have higher willingness-to-pay due to the visual impacts being presented more clearly. On the other hand, we also hypothesize that bigger screens will reduce the error variance of the respondents and increase certainty in choice, as they provide higher quality information that helps respondents make more accurate decisions, while reducing heuristics and guessing. Finally, we do not expect that screen size affects the level of opt-in and opt-out protest choices, as attitude towards paying for environmental improvements and paying attention to the frame and definition of the scenario

[1] In addition, the academic literature has focused on functionality in relation to screen size and the potential effects in the areas of education (Furió et al., 2013), health technologies (Alghamdi et al., 2013, 2014), gaming experience (Hou et al., 2012), the ergonometric use of touch screen devices (Kietrys et al., 2015), and general use (Chae & Kim, 2004; Sweeney & Crestani, 2006).

description is expected to be independent on the size of the screen.

3 Survey and data

3.1 Survey development and data collection

The data utilised by the present study was obtained from a survey that contains both attitudinal questions and a choice experiment carried out in 2012 regarding preferences for wind turbines in Denmark. The questionnaire design is composed of three distinct sections. The first section covers the general perception and attitude of the respondents regarding green energy and wind energy. The second part contains the choice experiment following the designs presented in (Batsell & Louviere, 1991; Hensher, 1994), as well as some follow-up questions used to determine the extent of protest answers (Bonnichsen & Ladenburg, 2009; Meyerhoff et al., 2014; Meyerhoff & Liebe, 2010) and certainty in choice (Beck et al., 2016; Lundhede et al., 2009; Olsen et al., 2011; Uggeldahl et al., 2016). The third, and final, section collects information regarding the socio-economic characteristics of the respondents.

The survey considers a respondent sample drawn from an internet panel considering quota sampling based on the national Danish population according to geography, gender, and education level. In December 2011, a pre-test of the questionnaire was carried out and developed through the use of focus groups. The relevance of the questions, wording of them, as well as their ease of understanding, was discussed. In addition, the choice of payment vehicle, and the choice and level of attributes was tested with these groups. During this stage, participants expressed that the proposed questionnaire was demanding to complete, which may affect response rates. The survey was conducted between December 2011 and January 2012 as a web survey, where the respondents were e-mailed a link to the survey page where they were presented with the questions in order. The response rate was 8.57% for 1753 respondents. This low response rate can only be explained as a combination of the particularly high number of invitations sent by the survey company as part of their guarantee on number of responses, and the fact that it seems the energy topic was not attractive enough for respondents. The attractiveness is particularly relevant since almost half of the respondents stated that they had participated in 10 or more surveys in the past 6 month in the web panel, and approximately 25% had participated in 10 or more surveys in other panels. Likewise, 25% and 50% had completed a survey within the past one or two weeks respectively.

The creation of the choice sets was done by applying a D-efficient design with utility priors (Ferrini & Scarpa, 2007). After pruning for unreasonable and duplicate combinations (choice sets that yielded redundant measures of attributes or unfeasible combinations), 36 choice sets remained. These were subsequently assigned in a random manner to nine blocks with four different choice sets each. Each respondent was then presented with one of these blocks at random, facing four choice sets with two alternatives each.

3.2 Screen Size

Screen size was elicited from respondents during the last section of the survey. To make it relatively easy for the respondents to answer, they were provided with three screen size classifications, which they could choose between: larger than an A4 paper, same size as an A4 paper, and smaller than an A4 paper. In hindsight, it would also have had been relevant to ask about the type of device – computer vs mobile device. Again, comparing our data on screen sizes with (Liebe et al., 2015), it limits us in the sense that we cannot make continuous estimates of screen size effects, but allows us to study the effect of screen size based on this trinary classification.

3.3 Scenario, choice of attributes and attribute levels

The scenario considers a planned increased in onshore wind energy development of 450 [MW], across 150 different municipalities of Denmark, which according to the Danish Energy Authority (DEA) is representative of the actual development plans for wind energy in Denmark at the time.

The choice of attributes was based on results, conclusions and input from previous Danish and internal studies, such as (Ladenburg et al., 2011; Ladenburg & Dubgaard, 2007; Meyerhoff et al., 2010). For each scenario, the following attributes are presented: the distance of the wind farm to the nearest settlement, the size of the wind farm combining both the size of each turbine as well as the number of turbines in the farm, the cost, and the number of people living in the settlement nearest to the wind farm.

The level for the distance attribute was chosen to be either 500 [m] or 1000 [m]. This was based on the actual distances planned for future wind farms in Denmark, which account for the current legal regulations that define the minimum distance to residential settlements. As such, these levels are considered relevant and realistic given the national context.

The levels for the size attribute were chosen based on the generating capacities of current standard onshore wind turbines: 750 [kW], 1.5 [MW] and 3 [MW]. For each of these turbine sizes, the attribute levels were chosen by selecting the number of turbines that the wind farm requires to maintain the total generation capacities: 4 turbines of 750 [kW], 2 turbines of 1.5 [MW] or 1 turbine of 3 [MW], therefore defining the final three levels for the attribute. This was done to avoid respondents choosing one particular size of wind turbines just because they produce more, and therefore to isolate their preferences for wind turbines as an energy generation technology from their preferences regarding visual disamenities produced by the physical wind turbines themselves.

The attribute for number of people living in the nearest locality was included to analyse whether citizens prefer turbines sited in areas with a greater or lower density of inhabitants. The levels chosen, 1-10 residents, 11-100 residents, and >100 residents, were found to be relevant and relatable to the population densities of areas where wind turbine development is expected in Denmark.

In this survey, the cost attribute considers a payment vehicle of an annual payment on top of the normal household's electricity bill, with six different levels: 0, 50, 100, 300, 600, and 1200 DKK per household per year. The payment vehicle was chosen based on experience with focus groups during (Ladenburg & Dubgaard, 2007). In the general description, the respondents were urged to be sure that their household was actually willing to pay the amount specified in the chosen alternative. Additionally, both a short "cheap talk" (Cummings & Taylor, 1999; Ladenburg et al., 2011) and a budget reminder (Arrow & Solow, 1993) were given to the respondents, in an effort to make respondents aware of their budget constraints and minimise hypothetical bias.

For each alternative of the choice set, a consultancy company created computer-based visualisations that illustrate the visual impact of the particular combination of attributes. These visualisations were scaled appropriately and generic, as defined by the visualisation ladder classification framework (Hevia-Koch & Ladenburg, 2016). Clearly, it would have been better to have site-specific visualisations, however as the survey focused on development in all Danish municipalities, this would require 90+ different visualisation. Due to budget constraints, this was not possible. The visualisations do not account for weather or night-time illumination effects; see for example (Lutzeyer, 2013) in the case of the latter. The images containing the visualisations were embedded in the survey web page, and no mechanism existed to ensure their display maintained a specific size, although respondents were reminded to click on each image to display it in full screen. As the size of the full screen images depends on the size of the screen, this allows us to measure the effect of screen sizes on preferences.

A summary of the choice set attributes and their respective levels can be seen in Table 1, while an example of the choice set can be seen in Figure 1.

Table 1: Attributes and attribute levels.

Attribute	*Levels*
Size	4x750[kW], 2x1.5[MW] or 1x3[MW]
Distance	500, 1000 [meters]
Neighbours	1-10, 11-100, >100 [residents]
Cost	0, 50, 100, 300, 600, 1200 [DKK/household per year]

Figure 1: Example of Choice set

Alternative A	Alternative B
	
Turbine: 3MW	Turbine: 2x1.5 MW
Distance: 500 m	Distance: 500 m
Number of residents: >100	Number of residents: 11-100
Payment 0 DKK/year	Payment 1,200 DKK/year

Note: The present images are scaled down. The images in the survey are shown full-screen when selected

4 Econometric models

4.1 Econometric model of preferences

Based on the econometric model of preferences shown in (Blomquist & Whitehead, 1998), as well as the expansion presented in (Hevia-Koch & Ladenburg, 2016), the perceived quality q of a good can be expressed in vector form in terms of the actual quality of the good θ, the information received during the survey regarding the good's quality I, as well as the associated learning parameters β and δ:

$$q = \boldsymbol{\beta} \cdot \boldsymbol{\theta} + \boldsymbol{\delta} \cdot \boldsymbol{I} \tag{1}$$

When considering that in this survey, the scenario description contains attributes that are described either by text alone, or by a combination of text and images; it is possible to expand the learning parameter δ associated to the presented information into two coefficients, one representing the learning parameter of textual information δ_T, and one representing the learning parameter of information conveyed through visualisations δ_V:

$$\boldsymbol{\delta} = \boldsymbol{\delta_T} + \boldsymbol{\delta_V} \tag{2}$$

In particular, the learning parameter δ_T is dependent, among other factors, on the amount of text, the clarity of the written text, and the respondents' understanding of written Danish. Similarly, the learning parameter δ_V would depend on the quality of the visualisations, the apparent size of them, and how clear the attributes are shown.

By expanding Eq. 1 to include both the formulation shown in Eq. 2 as well as the particular attributes used in this survey, it can be seen which of the learning parameters affect each attribute of the scenario:

$$q = \boldsymbol{\beta} \cdot \boldsymbol{\theta} + \begin{pmatrix} \delta_T \\ \delta_T + \delta_V \\ \delta_T + \delta_V \\ \delta_T \end{pmatrix} \cdot \begin{pmatrix} I_C \\ I_D \\ I_S \\ I_P \end{pmatrix} \tag{3}$$

where I_C, I_D, I_S, and I_P represent the additional information given to respondents during the survey regarding the cost (C), distance (D), size (S) and population (P) attributes respectively. Therefore the perception of the quality changes in the wind power scenarios, and subsequently the stated preferences for the different attributes, is a function of the visual and textual attribute learning parameters. Evidently, the visual learning parameters will only affect the attributes that have visual information associated to them. In the case of this particular survey, only the distance and size attributes are represented on the visualisations. We therefore expect that only those attributes will be affected by the visual learning parameter δ_V. All things being equal, having a small screen would make it more difficult to see the wind turbines in the screen relative to seeing the turbines on a large screen and thereby the ability to acquire new information from the pictures.

4.2 Binary and Multinomial Logit Models

We model the respondents' choices between wind turbines scenarios in a random utility framework (Manski, 1977), where the utility associated with a particular alternative can be represented by a systematic component, and an error component that accounts for the unobserved utility of the particular alternative.

$$U_{ia} = V_{ia} + \epsilon_{ia} \qquad (4)$$

where U_{ia} is the total utility that the respondent i associates with alternative a, V_{ia} represents the systematic component of this utility, and ϵ_{ia} is the error term.

In a binary choice set, with alternatives a and b, respondent i will choose alternative a if and only if the respondents considers that the utility associated with this alternative is higher than the utility associated to alternative b, that is $U_{ia} > U_{ib}$. Based on this, we can express the probability of respondent i choosing alternative a over alternative b as:

$$P_{ia} = P(\epsilon_{ib} - \epsilon_{ia} < V_{ia} - V_{ib}) \qquad (5)$$

That is, the probability of choosing alternative a is the probability of the difference of the systematic utility between a and b being larger than the difference in the random utility between b and a.

By assuming that the error terms are i.i.d with a Gumbel distribution (also known as extreme value type I) the probability defined in Eq. 5 becomes:

$$P_{ia} = \frac{e^{\lambda V_{ia}}}{e^{\lambda V_{ia}} + e^{\lambda V_{ib}}} \qquad (6)$$

This probability defines the Binary Logit Model, based on respondents choosing between two different alternatives, where λ represents the scale parameter, inversely proportional to the variance of the model. In many cases, it is of interest to consider more than two alternatives. In such cases, it is possible to generalize Eq. 6 to consider n different alternatives. In this case, the probability of respondent i choosing alternative a is:

$$P_{ia} = \frac{e^{\lambda V_{ia}}}{\sum_{j=1}^{n} e^{\lambda V_{ij}}} \qquad (7)$$

which defines the Multinomial Logit Model (MNL). It is important to note that for both the Binary Logit Model, as well as for the MNL, the model is normalized so the scale parameter λ equals 1, without loss of information nor distorting the relation between the parameters (Ben-Akiva & Lerman, 1985).

Traditionally, for the Binomial Logit and the MNL, the systematic utility component V_{ia} has been defined as:

$$V_{ia} = \mathrm{B}_a \cdot z_i \qquad (8)$$

where a is an attribute dimension, B_a is the vector of parameters representing preferences for a particular alternative, and z_i is a vector of characteristics of individual i. This formulation assumes that the systematic utility of respondent i depends mostly on the characteristics of the respondent and not of the good (represented by the alternatives). In the present study, we are interested in exploring the respondents' preferences based on the characteristics of the alternatives. Due to this, we assume that:

$$V_{ia} = \mathrm{B} \cdot X_{ia} \qquad (9)$$

where B is a vector of parameters representing the preferences for each of the k attributes, and X_{ia} represents a vector of attributes of the alternative. This formulation is referred to as Conditional Logit Model and can be applied for both the Binomial Logit as well as the MNL. From here onwards, unless specifically referred to, all models will utilize the Conditional Logit formulation for systematic utility.

4.3 Mixed Logit

The formulation of the MNL shown before, while simple, assumes that the observed preferences do not vary across individuals; with all deviations and the influence of unobserved preferences being captured by the error term ϵ. By assuming that ϵ is i.i.d., we assume that the unobserved preferences are homogeneous across the population and that there is no taste variation between respondents.

When respondents of a survey are presented with consecutive choice sets, we have data that has a panel structure. This means that the error terms are not i.i.d., since there is a likely correlation on the error terms of all the choice sets answered by the same respondent (Hensher, 2001). The mixed logit model (MXL) is an expanded formulation that aims to overcome the deficiencies of the MNL model shown previously. The setup presented here follows (Hensher, 2001; Train, 2009). For the MXL, we define the utility of alternative a for respondent i as:

$$U_{ia} = \mathrm{B}_i X_{ia} + \epsilon_{ia} \tag{10}$$

where B_i is a vector of length k that contains the parameters related to preferences for each attribute of the choice alternatives associated to respondent i, and X_{ia} is a vector of length k representing the characteristics of alternative a. The MXL allows for taste variation across respondents by assuming that B_i is distributed $f(\mathrm{B}|\theta)$, with θ being parameters that characterise the distribution. The error term ϵ_{ij} is assumed i.i.d. with a Gumbel distribution, as in the MNL.

The terms B_i and ϵ_{ia} are known by respondent i but cannot be observed by the researcher. Therefore, the probability of respondent i choosing alternative a under the MXL now also depends on B_i and its distribution. Thus, we have to integrate the standard logit probability shown in Eq. 7 over the distribution of B_i:

$$P_{ia} = \int_{\mathrm{B}} \frac{e^{\mathrm{B_i} X_{ia}}}{\sum_j e^{\mathrm{B_i} X_{ij}}} \tag{11}$$

4.4 Heteroscedastic Logit

As presented before, the MNL assumes that the scale parameter is constant across individuals. In particular, the MNL assumes that λ is inversely proportional to the error variance σ_ϵ^2, leading to $\lambda = \pi/6\sigma_\epsilon^2$. The assumption of scale invariance across respondents might not always be fulfilled, and it is of interest to account for it. The logit scaling approach to test for scaling differences between samples takes its point of origin in the models introduced by (DeShazo & Fermo, 2002): the heteroscedastic logit model and the parametrized heteroscedastic multinomial logit as defined by (Hensher et al., 1998). This model is an alternative to the multinomial logit model, by allowing for unequal variances across individuals:

$$P_{ia} = \frac{e^{\lambda_i \mathrm{B_i} X_a}}{\sum_j e^{\lambda_i \mathrm{B_i} X_j}} \tag{12}$$

where λ is no longer assumed to be equally inversely related with the error variance σ_ϵ^2 for all respondents in the model, as in the MNL. Instead, it is assumed a function of individual characteristics. The relation between characteristics and the error variance is parametrized as $e^{Z_i\gamma}$ where Z_i is a vector of individual characteristics and γ is a vector of parameters reflecting the influence of those characteristics on the error variance.

5 Measurement of Screen Size Effects

5.1 Visibility of the wind turbines in the choice set visualisations depending on screen size

In the survey, the respondents were asked if the wind turbines always were visible. The respondents could state "Yes/No/Don't Know". The potential influence of screen size is tested using a MNL, where the answer to the visibility question is the dependent variable (Y_i), and the respondent's screen sizes MS_i (Medium Screen), SS_i (Small Screen) and a vector of control variables X_i are the independent variables in the model:

$$Y_i = \beta_1 \cdot SS_i + \beta_2 \cdot MS_i + \mathrm{B} \cdot X_i + \epsilon_i$$

where i denotes the individual respondent, and ϵ_i is an error term that has logistic distribution.

We expect that the screen size will influence the visibility of the wind turbines, with smaller screen sizes increase the probability of a respondent answering "No". This would be reflected in the model by having significantly different non-zero values for β_1 and β_2.

5.2 Protest preferences and screen size

Literature has numerous example and analyses of what influences protest answers or protest preferences in contingent valuation and choice experiment studies (Meyerhoff et al., 2014; Meyerhoff & Liebe, 2010). The reasons for most of protest answers are mainly related to actual willingness to pay (in many cases produced by perceptions regarding property rights), and actually doing trade-offs between different alternatives with varying prices. In this line of thinking, we expect the screen size not to influence protest preferences, as the objection to pay for an environmental good should not depend on the screen size. In this analysis, we will distinguish between respondents whose protest answers are always or never opt-out. Additionally, and with reference to Eq. 3, the cost attribute is verbal and not visual, which further supports the hypothesis of screen size not affecting protest answers. The potential influence of screen size is tested using a Binary Logit Model. In the model, the dependent variable Y_i is defined as equal to one if the respondent either has opt-in or opt-out protest preferences, or else equal to zero. In Table 2 the classifications for the opt-out and opt-in protest behaviour are presented.

Again, the respondent's screen sizes MS_i (Medium Screen), SS_i (Small Screen) and a vector of control variables X_i are the independent variables in the model:

$$Y_i = \beta_1 \cdot SS_i + \beta_2 \cdot MS_i + \mathrm{B} \cdot X_i + \epsilon_i$$

where i denotes the individual respondent, and ϵ_i is an error term that has logistic distribution.

5.3 *Preferences as WTP and screen size*

As presented during the previous sections, the choice experiment includes both visual (size/number of wind turbines, and the distance to the nearest residential area) and non-visual attributes (cost, and number of neighbours). In the analysis, we will focus on differences in the visual and non-visual attributes preferences.

For modelling the respondents' choices, we utilise a MXL. This is because the respondents in this survey are presented with four choice sets, and therefore the choice data has a panel structure. Accordingly, we know that we cannot assume that the error terms ϵ are i.i.d. The MXL allows us to introduce error terms that are correlated for the choices made by the same respondent.

For the MXL, we consider the dependent variable Y_i is either 0 or 1 depending on the which alternative the respondent selects for the presented choice set, and we consider the independent variables as a vector of control variables X_i:

$$Y_i = \mathrm{B} \cdot X_i$$

Besides comparing the general preferences among the three screen size samples, we also wish to compare the strength and direction of preferences in terms of Willingness-To-Pay (WTP). We assume that when a respondent chooses an alternative they are making a trade-off between the distance of the wind turbines to the nearest settlement and an annual fixed increase in the household electricity bill. In this way, the respondent's preferences are implicitly revealed. By including a monetary attribute, in this case the cost expressed as the annual increase in the electricity bill, it is possible to estimate WTP for the non-monetary attributes, i.e. the distance to the nearest residential area. This is done by scaling the coefficient of interest with the coefficient representing the marginal utility of price and multiplying with –1 (Louviere et al., 2000)

$$WTP_x = -\frac{\beta_x}{\beta_{cost}}$$

where WTP_x represents the willingness-to-pay for attribute x. The mixed logit model is estimated in STATA utilizing the coding provided by (Hole, 2007).

5.4 *Stated certainty in choice, scale difference and screen size*

The differences in the screen size and the potential differences in the ability to see the wind turbines in the visualizations might not only influence preferences, but also the stated certainty in the choice that the respondents make and the associated variances for the estimated models. The potential influence of screen size on certainty in choice is tested using a Multinomial Logit Model as developed in (Maddala, 1986)

In this case, Y_i denotes the dependent variable, in this case the stated certainty of choice, and the respondent's screen sizes MS_i (Medium Screen), SS_i (Small Screen) and a vector of control variables X_i are the independent variables in the model:

$$Y_i = \beta_1 \cdot SS_i + \beta_2 \cdot MS_i + \beta_3 \cdot X_i + \epsilon_i$$

where i denotes the individual respondent, and ϵ_i is an error term that has a relevant distribution for each particular model.

Table 2: Classification of opt-in and opt-out protest preferences

Opt-out		Opt-in	
Statement	Protest	Statement	Protest
I cannot afford a higher payment	-	I did not consider the payment	P
I do not find the improvements by changing the location of the wind turbines worth the costs	-	I find the improvements by changing the location of the wind turbines worth the costs	-
I has a value for me to reduce the impacts from onshore wind turbines, but I do not want to pay more	P	I has a value for me to reduce the impacts from onshore wind turbines, but I do mind to pay more	-
I cannot relate to a higher payment	P	It is not real money, so I did not look at the payment	P
I did not know what to choose	-	I did not know what to choose	P

6 Results

We present the results for the estimation of different models exploring the possible effects of screen size on respondents' ability to see the turbines in the visualizations, protest behaviour, preferences, certainty in choice and error variance. The result tables shown for each subsection contain only the relevant coefficients being explored, but the full tables containing all the coefficients for the models can be found in the Appendix.

6.1 Sample characteristics

In order to control for the differences we have found in the sample distribution during the following analysis, we either use weights for data in our tests (in the MXL and Heteroscedastic Logit models) that eliminates the effect of this differences, or control for the differences directly in the regression model (Binary Logit and MNL models, Linear Regression models and Ordered Logit models). Unless explicitly mentioned otherwise, the results are based on models using weighted data. In this relation, it is important to stress out that we do not include the blocks of the choice sets in the weights, as it made it difficult to weight out the differences between the samples concerning the socio-demographics variables in the small screen sample. When estimating binary logit, MNL linear regression models and ordered logit models, dummy variables for the blocks are included. In the MXL and heteroscedastic models, we have tested whether weighting the block structure influences the estimated models. The results do not reject preference equality between block weighted and non-block weighted preferences. Consequently, we have strong confidence in only using the socio-demographic weights in the models.

The respondents' socio-demographic, knowledge of local wind turbine development and if the respondent have viewshed to onshore wind turbines are presented below in Table 3. The table is divided into the overall sample means and non-weighted and weighted means for each screen size sample. For each screen size sample, we also denote if the screen size sample mean (weighted or non-weighted) is significantly different from the overall sample mean. The differences in the samples presented in Table 3 are estimated using binary logit models taken the value 1 if the respondent is from one of the two samples in comparison or zero otherwise.

When comparing respondents' characteristics across screen size groups, we see significant difference between the samples with regard to the gender, age, and income level. These differences can potentially influence the preferences and thereby may blur our analysis for screen size effects. There are several examples in the stated preference wind power literature on how socio-demographics influence preferences and WTP, see for example the review by (Ladenburg & Lutzeyer, 2012) in the case of offshore preferences and the study by (Mariel et al., 2015) in the case of onshore wind power development. If we compare these differences with the findings in the type of device used to answer the questionnaire in (Liebe et al., 2015), there are both some similarities and differences. Naturally, we need to be aware of the fact that our data is somewhat older and that the use of mobile devices to answer surveys was less common in 2012, when our survey was carried out. (Liebe et al., 2015) find

Table 3: Socio-demographics.

	Sample		Large screen Non-weighted		Large screen Weighted		Medium screen Non-weighted		Medium screen Weighted		Small screen Non-weighted		Small screen Weighted	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Attitude regarding more wind power	3.67	[0.030]	3.65	[0.037]	3.67	[0.037]	3.70	[0.056]	3.66	[0.061]	3.79	[0.15]	3.71	[0.18]
Male	0.50	[0.013]	0.52	[0.015]	0.50	[0.015]	0.47	[0.025]	0.52	[0.026]	0.37^{*}	[0.059]	0.43	[0.064]
Age 20-39	0.37	[0.012]	0.32^{**}	[0.014]	0.37	[0.015]	0.48^{**}	[0.025]	0.37	[0.023]	0.49	[0.061]	0.37	[0.058]
Age 40-59	0.47	[0.013]	0.51	[0.015]	0.47	[0.015]	0.39	[0.024]	0.47	[0.026]	0.38	[0.059]	0.48	[0.064]
Vocational	0.17	[0.0095]	0.19	[0.012]	0.17	[0.011]	0.13	[0.017]	0.18	[0.022]	0.13	[0.041]	0.17	[0.052]
Short Secondary (Bachelor)	0.44	[0.013]	0.44	[0.015]	0.44	[0.015]	0.46	[0.025]	0.45	[0.025]	0.41	[0.060]	0.43	[0.063]
Masters or PhD	0.21	[0.010]	0.21	[0.012]	0.21	[0.013]	0.22	[0.020]	0.20	[0.020]	0.22	[0.051]	0.21	[0.050]
Income200k-399999	0.22	[0.011]	0.22^{+}	[0.013]	0.23	[0.013]	0.25	[0.021]	0.23	[0.021]	0.19	[0.048]	0.18	[0.047]
Income400k-599999	0.25	[0.011]	0.26^{**}	[0.013]	0.26	[0.013]	0.26^{**}	[0.022]	0.26	[0.022]	0.24	[0.052]	0.23	[0.053]
Income>600k	0.38	[0.012]	0.41	[0.015]	0.38	[0.015]	0.31	[0.023]	0.37	[0.026]	0.34	[0.058]	0.42	[0.064]
Future-ONFarm-Knowledge	0.15	[0.0091]	0.16	[0.011]	0.15	[0.011]	0.13	[0.017]	0.16	[0.021]	0.13	[0.041]	0.17	[0.051]
Number_view onshore_0	0.86	[0.0088]	0.84	[0.011]	0.85	[0.011]	0.91	[0.014]	0.90	[0.017]	0.87	[0.041]	0.85	[0.048]
N			1566					1086			412			68

Notes: Differences in the socio-demographics are estimated using logit models between the column sample and the two other samples for both the non-weighted and sample-weighted data.

Level of significance: + $p < 0.10$, * $p < 0.05$ and ** $p < 0.01$.

that the probability to use a mobile device relative to desktop/laptop is higher among younger respondents (fewer years of education), which matches the results in Table 2. However, they find higher income and lower education groups have a higher probability to use a mobile device, whereas we find a higher probability to use a larger screen. It is relevant to note that in our study, smaller screen sizes do not necessarily represent mobile devices exclusively, as they might include notebooks/laptops with screens smaller than an A4 page.

It is important to highlight that we do not find any differences in the attitude towards more onshore wind farms. Accordingly, the respondents in the three screen size samples are equally positive/negative towards more onshore wind power development. Table 3 also shows that the weighting of the data is an effective way to mitigate the significant differences found between the samples.

6.2 Wind turbine visibility and screen size

In the questionnaire, the respondents were asked if the turbines were easy to see in the visualisations on the screen. The respondents could answer "Yes", "No" and "Don't know". We estimate a MNL with the "Yes" category as the baseline and include controls in the model. In the model, we define the reference group as the respondents having a large screen. The results of the model estimation are presented in Table 4 and include respondents who have stated protest preferences. For the full model results, refer to the appendix.

Table 4: Screen size and wind turbine visibility in the choice sets

Screen Size	Answer	
	"No"	"Don't know"
Medium	0.217+	0.210
	[0.121]	[0.201]
Small	0.838**	-0.0132
	[0.272]	[0.563]
Controls	Yes	Yes

Notes: Standard errors in brackets
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We can see that having a small screen size significantly affects the probability of respondents answering "No" compared to having a medium or large screen size. In addition, having a medium screen size affects the clarity of wind turbines in the visualisation compared to the large screen size at a significance level of 90%. The screen size does not influence the propensity to provide "Don't know" as an answer. Interestingly, among the screen size variables and the controls, only the screen size variables are significant. Based on these results, it can be seen that there is a noticeable effect of screen size in regard to the clarity of the wind turbines in the supplied visualisations. The results show that the smaller the screen size the less visible the turbines are, which is consistent with naturally expected results, even after controlling for socio-demographics and which one of the nine blocks of choice sets the respondents have answered.

6.3 Protest preferences and screen size

In the questionnaire, the respondents who always chose the SQ-alternative (opt-out) or always chose the opt-in alternative answered a follow-up question to verify if the preferences behind the serial opt-out and opt-in choice behaviour were governed by protest behaviour.

Among the 1,753 respondents, 157 respondents (equal to 8.96% of the sample) have stated opt-out protest preferences and 30 respondents (1.71% of the sample) stated opt-in protest preferences.

In Table 5, we present the results from binary logit models testing the potential relation between screen size and protest behaviour. We run three models, one testing the effect of screen size on opt-out protest behaviour, one on opt-in protest behaviour, and one on the overall probability to have stated an opt-out or opt-in preference. In the models, we add sociodemographic and perception variables to control for the differences found among the three screen size samples. In each of the three models, the dependent variable has the value 1 if the respondent has stated a protest preference and zero otherwise.

Results indicate that respondents with small or medium screen sizes present neither a significantly higher nor lower probability to state a protest preference compared to respondents with large screens, which is consistent with our expected results. This is independent on the type of protest preferences type (opt-in or opt-out). Moving on to the control variables (see appendix); we find that older respondents and respondents with a positive attitude towards more offshore wind power have a higher probability to present an opt-in protest preference.

Table 5: Screen size and protest preferences (binary logit model)

	Opt-in protester	Opt-out protesters	Joined protesters
Medium Screen*	0.328	-0.0381	0.0149
	[0.428]	[0.203]	[0.186]
Small Screen*	-0.101	-0.0364	-0.0267
	[1.090]	[0.449]	[0.417]
Controls	Yes	Yes	Yes
N	1753	1753	1753
LL(0)	-151.8	-528.6	-595.2
LL(β)	-130.6	-503.1	-568.7
McFadden R2	0.140	0.048	0.044

Notes: *) Reference category is "Large Screen"
Standard errors in brackets

In contrast, some results suggest that the oldest respondents (more than 59 years) have a lower probability to present an opt-out protest preference. The same observation applies to respondents with a PhD, Master, or Bachelor relative to the respondents who only have 9th grade as the highest level of education. Finally, there are some indications that respondents from households with a yearly income level between 200,000 and 699.999 DKK have a higher probability to present opt-out protest preferences relative to respondents from households with low-income levels (less than 100,000 DKK). This reinforces the idea that the screen size affects only the visual attributes.

6.4 Differences in preferences, WTP and screen size

For estimating the differences in WTP across different screen size samples, we first estimate a random parameter MXL for each of the screen size subsamples, only considering respondents who have stated legitimate preferences (non-protest preferences). However, the models are restricted in the sense that only the alternative specific constant for the opt-out alternative is modelled as having a normal random distribution around the estimated mean. Though it was possible to estimate more advanced models for the Large Screen and Medium Screen samples, the relative small sample size of the Small Screen group made us decide for a simpler model formulation. For each screen size sample, as well as the full sample, we estimate both a main effect model (MEM) and a main effects model with an interaction between the distance and 2x1.5 MW turbines, which is found to be significant (MEM-I).

For each one of these models, we estimate the WTP associated to each attribute, and finally we calculate the differences in the estimated WTP for each pair of screen size groups. The results of the model estimations are shown on Table 6, and the results of the calculated WTPs are shown in Table 7.

The cost parameter was estimated as a fixed-point estimate. With a constant cost coefficient, the distribution of the WTP for the other attributes will be continuous and have the distribution of their respective coefficients. This is because the ratio of two normally distributed parameters has a discontinuous distribution with the denominator having singularity at zero (Hensher & Greene, 2002; Train, 2009). Therefore, keeping the cost coefficient constant ensures a continuous and normal distribution.

Overall, the respondents (independent on screen size) have negative preferences for increasing cost ($\beta_{Cost}<0$), prefer the wind turbines to be located at 1,000 m relative 500 m from residential areas, prefer fewer than 11 people in the residential areas ($\beta_{11\text{-}100}$ and $\beta_{>100}<0$), and have positive preferences for the status-quo alternative (which is defined as no additional costs, 1x3MW, 500 meter from residential areas with more than 100 residents). However, half of the previous attributes tend to be non-visual. When we move on to analyse the preferences for visual attributes (size, number of turbines, and the interaction between the distance

Table 6: Screen size and preferences

	Large Screen		Medium Screen		Small Screen	
	MEM	I-MEM	MEM	I-MEM	MEM	I-MEM
Mean						
Cost	-0.00180***	-0.00158***	-0.00181***	-0.00130***	-0.00266***	-0.00304***
	[0.000155]	[0.000166]	[0.000288]	[0.000289]	[0.000702]	[0.000898]
3 MW	0.685***	0.711***	0.607**	0.636**	-0.109	-0.189
	[0.122]	[0.122]	[0.204]	[0.202]	[0.457]	[0.473]
2xMW1,5	0.495***	0.0380	0.478^{+}	-0.656^{+}	1.123	1.722
	[0.148]	[0.213]	[0.247]	[0.350]	[0.777]	[1.155]
1000 m	0.518***	0.320**	0.397*	-0.0965	0.705^{+}	0.974^{+}
	[0.100]	[0.122]	[0.166]	[0.198]	[0.402]	[0.529]
Citizens>100	-0.475***	-0.514***	-0.160	-0.254	-1.033^{+}	-0.995^{+}
	[0.122]	[0.124]	[0.194]	[0.196]	[0.593]	[0.593]
Citizens11-100	-0.533***	-0.550***	-0.397^{+}	-0.452*	-0.191	-0.204
	[0.127]	[0.127]	[0.214]	[0.216]	[0.479]	[0.489]
SQ-Alternative	1.157***	1.114***	0.840**	0.763**	2.308**	2.400**
	[0.152]	[0.153]	[0.267]	[0.271]	[0.757]	[0.770]
2xMW1,5x1000m	-	0.716**	-	1.808***	-	-0.895
		[0.245]		[0.402]		[1.143]
Standard Deviation						
asc1	1.947***	1.931***	1.921***	1.920***	2.101***	2.160***
	[0.106]	[0.105]	[0.183]	[0.184]	[0.544]	[0.560]
No. choices	4,344		1,648		272	
LL(0)	-3011.0		-1142.3		-188.5	
LL(β)	-2149.9	-2145.5	-840.2	-829.4	-131.0	-130.7
chi2	439.9	440.8	127.1	133.7	29.26	29.58

Notes: Standard errors in brackets

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: WTP across samples

	Large Screen		Medium Screen		Small Screen		Δ WTP					
							Large Screen vs Medium Screen		Large Screen vs Small Screen		Medium Screen vs Small Screen	
	MEM	I-MEM	MEM	I-MEM	MEM	I-MEM	MEM	I-MEM	MEM	I-MEM	MEM	I-MEM
3 MW	381.1***	451.4***	336.2**	490.4**	-41.16	-62.18	76	-27	485	511**	377+	553*
	[75.24]	[92.18]	[112.7]	[165.3]	[171.3]	[153.3]	[145]	[191]	[249]	[178]	[205]	[225]
2 X MW1,5	275.4***	24.10	264.8*	-505.6	422.8	567.1+	46	569	-402	-553+	-158	-1,073*
	[80.12]	[134.4]	[129.5]	[329.4]	[271.0]	[300.1]	[172]	[368]	[523]	[324]	[300]	[446]
1000 m	288.2***	202.7**	219.8*	-74.33	265.3+	320.7*	51	275	-252	-115	-46	-395+
	[60.43]	[74.90]	[103.9]	[153.5]	[157.5]	[154.7]	[134]	[178]	[297]	[169]	[189]	[218]
Citizens>100	-264.4***	-326.3***	-88.56	-195.5	-388.7	-327.5	-234	-142	264	20	300	132
	[71.90]	[89.04]	[109.3]	[163.7]	[253.7]	[230.4]	[152]	[194]	[526]	[244]	[276]	[283]
Citizens11-100	-296.4***	-348.8***	-219.9+	-347.9+	-71.85	-67.10	-84	7	-204	-265	-148	-281
	[72.98]	[88.08]	[121.7]	[184.7]	[179.7]	[161.9]	[163]	[214]	[353]	[182]	[217]	[246]
SQ-Alternative	643.6***	706.8***	465.3*	587.7*	868.8*	790.3*	174	101	-714	-128	-404	-203
	[107.7]	[128.7]	[186.2]	[282.1]	[358.5]	[320.3]	[250]	[325]	[745]	[344]	[404]	[427]
2 X MW1,5 x 1000 m		454.2*		1393.3**		-294.7		-980+		722+		1,688**
		[179.8]		[498.4]		[333.3]		[544]		[380]		[600]

Notes: Standard errors in brackets

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

and wind turbines size and number) differences in the preferences seem to be present among the respondents in the three screen size samples.

Whereas the respondents in the large and medium screen size samples hold positive and significant preferences for 1x3MW turbine, the respondents in the small screen size sample hold negative, though not significant, preferences for a 1x3MW turbine. In the MEM models, preferences for 2x1.5 MW turbines are positive across all three screen-size samples. However, when including the interaction term between the 2x1.5 MW turbines and the distance attribute (1,000 meter), differences seem to appear. Whilst the inclusion of the interaction term seems to weaken the preferences for 2x1.5MW turbines in the large and medium screen size samples, the opposite seems to be the case for the preferences among the small screen size sample respondents. This is also illustrated by the estimated preference parameters for the 2x1.5MW and 1,000-meter interaction variable. More specifically, the interaction estimate is positive in the large and medium screen size samples, which points towards the fact that the respondents associate it with additional utility if 2x1.5 MW turbines are located at 1000 meters relative to 500 meters. Interestingly, in the small screen size sample, the respondents have stated negative, though not significant, preferences for the interaction term.

In Table 8, LR-test of preferences equality among the three samples are presented

The LR-tests for preferences equality cannot be rejected in any preference comparisons between any of the three screen size samples on a 95% level of confidence. However, given the rejection on a 90% level between respondents who have answered on a device with a medium or small screen, the results suggest weak preference equality between these two groups of respondents. However, though we cannot identify overall preferences inequalities, differences in preferences might appear on attribute level.

In Table 8, we also present the differences between WTP across screen size samples. Starting with the differences in WTP between the large and medium screen size samples, we can see that there are no significant differences in WTP based on the MEM models. However, in the MEM-I model, the respondents in the large screen size sample have a WTP for siting 2x1.5MW turbines at 1,000 meters that is 980 DKK lower relative to the respondents in the medium screen size sample, though the difference is only significant on a 90% level of confidence. In the same model, it is worth noticing that compared to the medium screen size sample, the respondents in the large screen size sample also have stated a WTP that is higher by 569 DKK for 2x1.5MW turbines, and by 275 DKK for locating wind turbines at 1000 m, though not significantly different.

Moving on to the comparison of WTP between the large and small screen size samples, significant differences are present in both the MEM and the MEM-I model, though only on a 90% level of confidence in the case of the former. More specifically, the results point towards that the respondents in the large screen size sample have a WTP that is 485 DKK higher for 1xMW3 turbine relative to 4x750 kW turbines, when compared to the WTP in the small screen size sample. This difference becomes even more significant (99 % level of confidence) in the MEM-I model, where the difference in WTP is 511 DKK. Furthermore, compared to the small screen sample, in the MEM-I model the WTP for 2x1.5 MW turbines is 553 DKK lower in the large screen sample (though only on a 90% level of confidence) and 722 higher in the LS sample for the interaction between 2x1.5MW and location of the wind turbine at 1,000 m at the same significance level.

Finally, in the comparison in WTP between the MS and LS respondents, significant differences are present in both models. In the MEM model, we can see that the WTP for 3 MW turbines is 377 DKK higher in the medium screen sample, at a 90% level of confidence. In the I-MEM model, the differences are more pronounced, with the medium screen sample having a WTP 553 DKK higher at a 95% confidence level. The preferences for 2 x 1.5 MW turbines are 1,073 DKK lower for the medium screen size sample, compared to the small screen size one, also at a 95% confidence level. We can also see a significant difference in the 1000 m distance variable, where the medium screen size sample presents a WTP that is 395 DKK lower, albeit only at the 90% confidence level. Finally, the interaction variable itself presents a large difference in WTP, with the medium screen size sample having a WTP that is 1,688 DKK higher than the small screen size

Table 8: Loglikelihood ratio test for equality of preferences among respondents with a large, medium or small screen size.

	Large screen vs. Medium screen		Large screen vs. Small screen		Medium screen vs. Small screen		Large screen + Medium screen vs. Small Screen	
	LS	MS	LS	SS	MS	SS	LS +MS	SS
LL(β)	-2149.9/2145.5	840.2/829.4	-2149.9/2145.5	131.0/130.7	840.2/829.4	131.0/130.7	-2990.0/-2974.9	131.0/130.73
$LL(\beta_a)+LL(\beta_b)$	-2990.0/-2974.9		-2280.9/-2276.2		-971.2/-960.1		-3122.5/-3110.0	
$LL(\beta_a+\beta_b)$	-2991.5/-2979.3		-2286.1/-2282.42		-976.2/-967.5		-3128.0/-3116.8	
ΔLL	1.48/4.43		5.28/6.22		4.99/7.43		5.48/6.79	
X^2(DF)	2.96 (8)/8.86(9)		10.57(8)/12.44(9)		9.98(8)/14.86(9)		10.95 (8)/13.58(9)	
LR-test	0.937/0.450		0.227/0.189		0.266/0.095		0.204/0.138	

one. This difference is also highly significant, at the 99% confidence level.

As a robustness check, we have run the same models on the non-weighted data. The results are available in the Appendix and strongly support our findings in the weighted models, being consistent with the expected results. Similarly, and as mentioned, weighting the blocks in the choice set does not change the conclusion. Jointly, these results support our expectations; the screen size only influences the preferences and WTP for visual attributes and not preferences and WTP for non-visual attributes.

6.5 Self-reported certainty in choice, error variance and screen size

After finishing answering the choice experiment, respondents were presented with a follow-up question that asks them to state how certain they felt about the choices made during the choice experiment. They were asked to rate their certainty using a 5-level Likert Scale.

Following (Olsen et al., 2011) we estimate models where the level of stated certainty is the dependent variable and the respondents' characteristics and the screen size are independent variables. To explore the potential effect of screen size on self-reported certainty, we estimated a MNL (using level 1 = "Very Certain" as the base line category). With references to the estimates, this means that negative estimates denote higher certainty and vice versa. Since we could not find any effect on the MNL, we also explored a formulation considering an OLS regression and an ordered logit model, with the same result. The results for the all model estimations are shown in Table 9.

Based on the estimation results, we see that none of the models shows any significant influence of screen size on the self-stated certainty of respondents. Accordingly, despite the fact that the respondents have stated differences in the visibility of the wind turbines in the visualisations, this has apparently not influenced their perception of their own certainty in choices. Moving on to the control variables in the models, the results show that males, respondents, younger respondents and respondents with a negative attitude towards more onshore wind turbines and respondents who see no turbines on a daily basis are more certain in their choice. The complete models are available in the Appendix.

Another possibility regarding the effect of screen size on the certainty of respondents' answers, is that independent of the self-stated certainty the screen size has an effect that is not consciously detected by respondents, but that can be appreciated by observing changes in the error variance, and therefore on the scale parameter, of the model. These error variance differences are estimated using three heteroscedastic conditional logit models, in which we test if screen size influences the error variance. We report the scale estimates for several models. In all models, we include a dummy variable for one of the screen sizes and three variables controlling for choice set number 1, 2 and 3, leaving the last choice set (4) as the reference level. We include control variables using the weighting matrix. Selected results are presented on Table 10 (see the Appendix for the full models):

As the heteroscedastic estimation models clearly illustrate, somewhat unexpectedly, the screen size does not seem to be associated with a higher or lower variance. We can see that none of the heteroscedastic variables associated to screen size are significant. As a validation of the models, heteroscedastic models for both large screen versus medium screen, and large screen versus small screen, suggest that variance is lower (they have a higher scale) in choice set 4, relative to choice set 1. This would indicate that scale has increased from choice set 1 to choice set 4, which corresponds to increasing learning effects (Carlsson et al., 2012; Czajkowski et al., 2014). Accordingly, the certainty in choice in error variance models point in the same direction.

As in the case with comparison of preferences and WTP, we have as a robustness check estimated the heteroscedastic model without weights. The results are in the Appendix and comply with the weighted models.

Table 9: Screen size and certainty in choice

Screen Size	OLS	Ordered Logit Model	MNL			
			2	3	4	5
Medium	0.0964	0.147	0.0565	0.128	0.453	0.252
	[0.0653]	[0.109]	[0.145]	[0.176]	[0.282]	[0.257]
Small	-0.0516	-0.148	-0.0097	-0.304	-0.423	0.0765
	[0.139]	[0.232]	[0.296]	[0.407]	[0.762]	[0.527]
Controls	Yes	Yes	Yes			

Notes: Standard errors in brackets

Table 10: Screen size and error variance (heteroscedastic variables only)

	Large vs Medium Screen		**Large vs Small Screen**		**Medium vs Small Screen**	
Large Screen	0.0698 [0.0688]	0.0621 [0.0677]	-0.0309 [0.139]	-0.0233 [0.146]	-	-
Choice-set2	-0.0640 [0.0997]	-0.0933 [0.0907]	-0.120 [0.112]	-0.132 [0.103]	-0.196 [0.193]	-0.234 [0.165]
Choice-set3	-0.0159 [0.101]	0.130 [0.101]	-0.0324 [0.112]	0.123 [0.114]	-0.234 [0.201]	-0.103 [0.187]
Choice-set4	-0.0338 [0.0919]	0.441*** [0.121]	0.0475 [0.0998]	0.491*** [0.136]	-0.239 [0.179]	0.288 [0.232]
Small Screen	-	-	-	-	0.104 [0.156]	0.0837 [0.161]
N	11984	11984	9232	9232	3840	3840
LL_0						
LL	-3324.0	-3293.1	-2537.4	-2517.4	-1079.3	-1066.5
chi2	1.829	25.58	3.098	26.18	2.940	6.921

7 Discussion

A clear limitation of our study is the rather crude and discrete measure of screen size. We did not have information on the actual screen size as in (Liebe et al., 2015). Further investigation should address these limitations and compare preferences for visual attribute as a function of a continuous measure of screen size.

However, the findings still suggest an effect from screen size on the tool to estimate preferences for visual attributes – the visualisations and the WTP for some of the visual attributes (Size/number of turbines and the distance to the nearest residential area). With this is mind, the results should cause some considerations in relation to the planning of future studies using visualisations to facilitate environmental quality degradations. One thing to take into account is whether it is possible only to allow people with a larger screen to answer the survey. Though not explicitly captured in the present paper, excluding the possibility to answer the survey on a smart phone or smaller mobile device could be a solution. However, a potential caveat of that approach could be selection bias into the survey as a function of the screen size. One potential solution could be to ask people to wait with completing the survey, until they have a laptop, tablet or similar at hand.

Another way around the problem could be to mail (postal) the visualisation to the respondents. A clear advantage of this approach is that we ensure that all respondent have the same type of visualisations. However, this would clearly make the survey more costly. However, seen in the light of the previously presented results, potentially worth the extra costs.

8 Conclusions

This study is the first one to consider the effect of screen sizes when dealing specifically with web-based surveys with a high content of visual aids and information.

As we expected, the effect on the visibility of the wind turbines in the provided visualizations is significant and clear. Respondents with smaller screen sizes find the wind turbines in the visualizations harder to see, when compared to respondents with medium and large screen sizes. Since the visual aspects of wind turbines are a significant driver for preferences, this finding is extremely relevant. In particular, the inclusion of visualizations and other visual aids in scenario descriptions is particularly relevant when valuing goods whose visual aspect is one of the main drivers in forming preferences for them (Hevia-Koch & Ladenburg, 2016). If these visual aids are presented without controlling for the screen sizes of the respondents, and therefore without achieving a standardized and uniform presentation across respondents; then we are presenting what, in practice, are different scenario descriptions to different respondent groups.

Despite differences in visibility of the wind turbines in the visualizations, respondents seem not to feel any less certain about their stated preferences. This might be either because they feel that the visibility of the wind turbines is not important enough to drive their choices, because they ignore the actual relevance of the visual information in their own decision making process, or because they consider that the textual description of the scenario is sufficient for making a decision in absence of clear visualizations.

When looking at the actual differences in preferences regarding willingness-to-pay across screen size groups, we find that smaller screen sizes present smaller WTP for 3 MW wind turbines compared to medium and large screen size groups. Accordingly, they present much higher WTP for 2 x 1.5 MW turbines. They also present a much lower WTP for the interaction term associated to 2x1.5 MW at 1,000 meters, compared to the other two screen size groups. Altogether, the results are consistent with our hypothesis: screen size affects majoritarily the visual attributes.

While the differences in WTP across screen size groups is clear, the interpretation on the causes for these differences is not evident. From the differences in WTP, it can be seen that respondents with small screen sizes have a higher WTP for 2x1.5MW turbines, while large and medium screen size groups have higher WTP for 3 MW turbines. A possible explanation is that the size of visualisations presented on small screen sizes does not allow to correctly identify the differences in visual impact between 3 MW turbines and 2 x 1.5 MW turbines, and that at small screen sizes, 2 x 1.5 MW might not be visible, in comparison to a single 3 MW turbine.

As consequence of these results, the researchers recommend that greater care be placed on the implementation of how to present visual aids to respondents. It is possible to show images while maintaining their apparent size consistent, independent of the screen size. This would ensure that the scenarios presented are more consistent across respondents. It should also be considered by researchers to forbid the usage of mobile devices, typically possessing small screens, if the survey contains visual material that is significant for the process of preference elicitation, as for example on the scenario description.

There certainly are possibilities for further research that could clarify more precisely the effect of screen size on preferences when using web surveys. A successive study could include precise measurement of screen size in inches or even testing in controlled conditions where the screens are set up by the researchers. This option could also be extended to study the time respondents spend looking at the visual aids (via eye tracking, for example) for different screen sizes.

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Appendix A: Full model screen size and wind turbine visibility in the choice sets

	Answer	
	"No"	"Don't know"
	Parameter estimate	Parameter estimate
Medium Screen[a]	0.217[+]	0.210
	[0.121]	[0.201]
Small Screen[a]	0.838[**]	-0.0132
	[0.272]	[0.563]
Male[b]	0.0464	0.0348
	[0.106]	[0.180]
Age:20_29[c]	0.00806	0.0963
	[0.229]	[0.381]
Age:30_39[c]	-0.0427	0.0516
	[0.170]	[0.298]
Age:40_49[c]	-0.169	0.00123
	[0.168]	[0.293]
Age:50_59[c]	-0.0652	0.178
	[0.171]	[0.292]
Master/PhD[d]	0.163	-0.605[+]
	[0.250]	[0.358]
Bachelor[d]	0.148	-0.744[*]
	[0.235]	[0.331]
Short Sec. Education[d]	0.0852	-0.206
	[0.272]	[0.373]
Highschool[d]	0.0675	-0.894[*]
	[0.273]	[0.416]
Vocational[d]	0.296	-0.426
	[0.249]	[0.349]
HHI100-199,999[e]	0.0554	0.321
	[0.296]	[0.492]
HHI200-299,999[e]	0.0728	0.136
	[0.299]	[0.507]
HHI300-399,999[e]	-0.00476	0.130
	[0.290]	[0.493]
HHI400-499,999[e]	0.140	0.170
	[0.296]	[0.506]
HHI500-599,999[e]	-0.0149	-0.422
	[0.292]	[0.525]
HHI600-699,999[e]	-0.0660	-0.143
	[0.296]	[0.513]
HHI_≥700,000[e]	-0.0831	0.0310
	[0.280]	[0.480]
Attitude towards more onshore wind farms (1-5)	0.0348	-0.0311
	[0.0430]	[0.0718]
Plans for onshore wind turbines in area[f]	0.0681	-0.460
	[0.146]	[0.284]
Sees no turbines daily[g]	0.107	0.0998
	[0.151]	[0.265]
Block1[h]	0.157	-0.108
	[0.213]	[0.429]
Block2[h]	0.974[***]	1.157[**]
	[0.228]	[0.391]
Block3[h]	0.520[*]	0.674[+]
	[0.220]	[0.396]
Block4[h]	0.426[*]	0.253
	[0.216]	[0.417]
Block5[h]	0.206	0.451
	[0.215]	[0.393]
Block6[h]	0.840[***]	0.974[*]
	[0.220]	[0.387]

Block7[h]	0.137	0.660[+]
	[0.220]	[0.380]
Block8[h]	0.126	0.538
	[0.221]	[0.390]
Constant	-0.642	-1.535[*]
	[0.430]	[0.703]
Number of respondents	1753	
LL(0)	-1646.0	
LL(β)	-1599.3	
McFadden R2	0.028	

Notes: Reference category [a)] Large Screen, [b)] Female, [c)] age> 59 years, [d)] elementary school (9th grade) [e)] Household income <100,000 DKK, [f)] No plans, [g)] One or more than one turbine seen daily and [h)] Block9, Standard errors in brackets. [+] $p < 0.10$, [*] $p < 0.05$, [**] $p < 0.01$, [***] $p < 0.001$

Appendix B: Full model screen size and protest preferences (binary logit model)	Opt-in protester Estimated parameters	Opt-out protesters Estimated parameters	Joined protesters Estimated parameters
Medium Screen[a]	0.328	-0.0381	0.0149
	[0.428]	[0.203]	[0.186]
Small Screen[a]	-0.101	-0.0364	-0.0267
	[1.090]	[0.449]	[0.417]
Male[b]	-0.611	0.245	0.107
	[0.401]	[0.177]	[0.163]
Age:20_29[c]	-2.147^{+}	0.583	0.132
	[1.200]	[0.394]	[0.363]
Age:30_39[c]	-1.133^{+}	0.445	0.105
	[0.628]	[0.301]	[0.264]
Age:40_49[c]	-1.134*	0.285	-0.0390
	[0.577]	[0.301]	[0.263]
Age:50_59[c]	-0.364	0.617*	0.382
	[0.487]	[0.295]	[0.254]
Master/PhD[d]	-0.612	-0.816*	-0.815*
	[0.719]	[0.373]	[0.339]
Bachelor[d]	-0.539	-0.610^{+}	-0.635*
	[0.633]	[0.331]	[0.301]
Short Sec. Education[d]	-0.509	-0.426	-0.471
	[0.761]	[0.390]	[0.355]
Highschool[d]	-1.383	-0.607	-0.746^{+}
	[1.191]	[0.424]	[0.398]
Vocational[d]	-1.244	-0.119	-0.270
	[0.805]	[0.335]	[0.310]
HHI100-199,999[e]	-0.589	-0.0754	-0.102
	[1.317]	[0.672]	[0.601]
HHI200-299,999[e]	-0.116	1.091^{+}	0.964^{+}
	[1.240]	[0.594]	[0.541]
HHI300-399,999[e]	-0.563	1.258*	1.044^{+}
	[1.250]	[0.586]	[0.535]
HHI400-499,999[e]	-0.0820	0.376	0.441
	[1.212]	[0.628]	[0.560]
HHI500-599,999[e]	-0.537	1.124^{+}	0.918^{+}
	[1.252]	[0.594]	[0.542]
HHI600-699,999[e]	-1.817	1.099^{+}	0.780
	[1.525]	[0.596]	[0.547]
HHI_≥700,000[e]	-0.469	0.758	0.607
	[1.199]	[0.588]	[0.534]
Attitude towards more onshore wind farms (1-5)	-0.442**	-0.0732	-0.157*
	[0.141]	[0.0698]	[0.0629]
Plans for onshore wind turbines in area[f]	-0.660	-0.223	-0.299
	[0.643]	[0.251]	[0.235]
Number of turbines seen daily[g]	0.300	0.00135	0.0580
	[0.640]	[0.252]	[0.237]
Block1[h]	-0.0118	-0.204	-0.203
	[0.847]	[0.367]	[0.341]
Block2[h]	-0.881	-0.821^{+}	-0.861*
	[1.178]	[0.428]	[0.404]
Block3[h]	-1.140	-0.288	-0.400
	[1.173]	[0.373]	[0.355]
Block4[h]	0.288	0.145	0.150
	[0.795]	[0.349]	[0.324]
Block5[h]	0.245	0.0151	0.0293
	[0.799]	[0.353]	[0.327]

Block6[h]	0.0292	-0.120	-0.102
	[0.799]	[0.356]	[0.329]
Block7[h]	0.756	-0.164	0.0378
	[0.723]	[0.368]	[0.329]
Block8[h]	0.0902	0.338	0.318
	[0.850]	[0.333]	[0.314]
Constant	-0.840	-2.846***	-1.846**
	[1.556]	[0.773]	[0.696]
N	1753	1753	1753
LL(0)	-151.8	-528.6	-595.2
LL(β)	-130.6	-503.1	-568.7
McFadden R2	0.140	0.048	0.044

Notes: Reference category [a)] Large Screen, [b)] Female, [c)] age> 59 years, [d)] elementary school (9th grade) [e)] Household income <100,000 DKK, [f)] No plans, [g)] One or more than one turbine seen daily and [h)] Block9, Standard errors in brackets. $^{+}\ p < 0.10$, $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Appendix C: Full model screen size and certainty in choice (binary logit model)	Linear regression	Ordered logit	Multinomial logit (2)	Multinomial logit (3)	Multinomial logit (4)	Multinomial logit (5)
Medium Screen[a]	0.0964	0.147	0.0565	0.128	0.453	0.252
	[0.0653]	[0.109]	[0.145]	[0.176]	[0.282]	[0.257]
Small Screen[a]	-0.0516	-0.148	-0.00969	-0.304	-0.423	0.0765
	[0.139]	[0.232]	[0.296]	[0.407]	[0.762]	[0.527]
Male[b]	-0.163**	-0.279**	-0.167	-0.384*	-0.199	-0.577*
	[0.0580]	[0.0970]	[0.127]	[0.157]	[0.267]	[0.237]
Age:20_29[c]	-0.239^{+}	-0.265	0.238	-0.141	-0.210	-1.059*
	[0.123]	[0.206]	[0.271]	[0.345]	[0.570]	[0.490]
Age:30_39[c]	-0.0845	-0.0868	-0.113	0.142	0.0180	-0.557
	[0.0929]	[0.156]	[0.206]	[0.251]	[0.419]	[0.340]
Age:40_49[c]	-0.257**	-0.345*	-0.138	-0.100	-0.604	-1.188**
	[0.0919]	[0.155]	[0.201]	[0.250]	[0.452]	[0.374]
Age:50_59[c]	-0.0916	-0.111	-0.00194	-0.00307	0.127	-0.511
	[0.0935]	[0.157]	[0.206]	[0.256]	[0.418]	[0.346]
Master/PhD[d]	0.107	0.210	0.538^{+}	-0.00742	0.890	0.468
	[0.136]	[0.227]	[0.299]	[0.353]	[0.806]	[0.571]
Bachelor[d]	0.0733	0.136	0.187	-0.0667	0.933	0.228
	[0.128]	[0.214]	[0.283]	[0.327]	[0.773]	[0.540]
Short Sec. Education[d]	-0.0144	-0.0519	-0.112	-0.201	0.506	0.0129
	[0.148]	[0.249]	[0.326]	[0.376]	[0.859]	[0.620]
Highschool[d]	0.107	0.101	0.0771	-0.369	1.246	0.435
	[0.148]	[0.246]	[0.325]	[0.398]	[0.822]	[0.606]
Vocational[d]	0.0643	0.0994	0.0493	0.0128	0.591	0.209
	[0.135]	[0.226]	[0.299]	[0.343]	[0.810]	[0.570]
HHI100-199,999[e]	-0.0426	-0.0364	-0.202	0.0241	0.454	-0.484
	[0.156]	[0.257]	[0.346]	[0.438]	[0.741]	[0.561]
HHI200-299,999[e]	-0.158	-0.268	-0.293	-0.361	0.274	-0.760
	[0.161]	[0.267]	[0.353]	[0.457]	[0.772]	[0.588]
HHI300-399,999[e]	-0.198	-0.270	-0.204	-0.182	0.00711	-1.010^{+}
	[0.156]	[0.257]	[0.342]	[0.437]	[0.779]	[0.593]
HHI400-499,999[e]	-0.223	-0.351	-0.340	-0.315	0.0296	-1.051^{+}
	[0.158]	[0.261]	[0.345]	[0.444]	[0.779]	[0.602]
HHI500-599,999[e]	-0.198	-0.317	-0.380	-0.288	0.196	-0.997^{+}
	[0.157]	[0.261]	[0.345]	[0.441]	[0.768]	[0.597]
HHI600-699,999[e]	-0.137	-0.156	0.0145	0.00757	0.196	-0.815
	[0.158]	[0.261]	[0.349]	[0.444]	[0.793]	[0.605]

HHI_≥700,000[e]	-0.205	-0.372	-0.408	-0.545	0.162	-0.804
	[0.149]	[0.248]	[0.328]	[0.427]	[0.733]	[0.547]
Attitude towards more onshore wind farms (1-5)	-0.110***	-0.205***	-0.128*	-0.304***	-0.266*	-0.260**
	[0.0235]	[0.0399]	[0.0531]	[0.0631]	[0.105]	[0.0923]
Plans for onshore wind turbines in area[f]	-0.108	-0.137	0.101	-0.172	-0.277	-0.395
	[0.0800]	[0.133]	[0.171]	[0.222]	[0.390]	[0.368]
Number of turbines seen daily[g]	0.191*	0.330*	0.198	0.456+	0.00495	0.919*
	[0.0827]	[0.139]	[0.175]	[0.237]	[0.362]	[0.421]
Block1[h]	-0.261*	-0.454*	-0.721**	-0.262	-0.644	-1.156*
	[0.119]	[0.199]	[0.258]	[0.323]	[0.555]	[0.518]
Block2[h]	0.128	0.283	0.113	0.691*	0.413	-0.0121
	[0.120]	[0.195]	[0.270]	[0.327]	[0.516]	[0.474]
Block3[h]	-0.119	-0.225	-0.695**	-0.0472	-0.297	-0.618
	[0.121]	[0.203]	[0.267]	[0.323]	[0.528]	[0.475]
Block4[h]	-0.316**	-0.582**	-0.614*	-0.752*	-0.656	-0.983*
	[0.121]	[0.203]	[0.257]	[0.354]	[0.554]	[0.499]
Block5[h]	-0.372**	-0.608**	-0.569*	-0.572+	-1.223+	-1.461*
	[0.120]	[0.201]	[0.253]	[0.342]	[0.645]	[0.570]
Block6[h]	0.0919	0.160	0.260	0.120	0.492	0.223
	[0.119]	[0.195]	[0.264]	[0.346]	[0.500]	[0.443]
Block7[h]	-0.0160	-0.0978	-0.571*	-0.0231	-0.348	-0.103
	[0.122]	[0.204]	[0.270]	[0.331]	[0.560]	[0.437]
Block8[h]	0.0138	0.0463	0.0702	0.229	-0.373	0.0752
	[0.124]	[0.203]	[0.272]	[0.345]	[0.612]	[0.466]
Constant	2.734***		0.785	0.610	-1.686	0.217
	[0.234]		[0.520]	[0.639]	[1.213]	[0.928]
cut1_cons		-1.675***				
		[0.392]				
cut2_cons		-0.102				
		[0.389]				
cut3_cons		1.122**				
		[0.392]				
cut4_cons		1.731***				
		[0.398]				
N	1566		1566		1566	
LL(0)	-2408.2		-2119.6		-2119.6	
LL(β)	-2361.4		-2069.0		-2028.6	
McFadden R2	0.019		0.024		0.043	

Appendix D:Full model screen size and error variance (Heteroscedastic Conditional Logit)	LS vs MS		LS vs SS		MS vs SS	
	choice	choice	choice	choice	choice	choice
Variables						
Cost	-0.00106***	-0.000559***	-0.00116***	-0.000634***	-0.00139***	-0.000681**
	[0.000140]	[0.000101]	[0.000222]	[0.000148]	[0.000321]	[0.000223]
3MW	0.455***	0.551***	0.544***	0.623***	0.506*	0.632**
	[0.109]	[0.0992]	[0.149]	[0.141]	[0.237]	[0.211]
S2 x MW1.5	0.127	-0.664***	0.201	-0.618***	0.185	-0.816**
	[0.0984]	[0.136]	[0.125]	[0.187]	[0.223]	[0.276]
1000 m	0.272***	-0.0925	0.321***	-0.0507	0.242^{+}	-0.215
	[0.0615]	[0.0680]	[0.0845]	[0.0832]	[0.128]	[0.145]
Citizens>100	-0.233**	-0.218**	-0.320**	-0.271**	-0.173	-0.219
	[0.0877]	[0.0775]	[0.116]	[0.103]	[0.185]	[0.159]
Citizens 11-100	-0.240**	-0.277***	-0.277**	-0.300***	-0.112	-0.247
	[0.0809]	[0.0696]	[0.103]	[0.0907]	[0.170]	[0.152]
asc1	0.612***	0.380***	0.721***	0.448***	0.625**	0.389*
	[0.0980]	[0.0963]	[0.151]	[0.134]	[0.196]	[0.195]
2xMW1.5x1000 m		1.339***		1.333***		1.741***
		[0.195]		[0.290]		[0.402]
Heteroscedastic variables						
Large Screen	0.0698	0.0621	-0.0309	-0.0233		
	[0.0688]	[0.0677]	[0.139]	[0.146]		
Choice-set2	-0.0640	-0.0933	-0.120	-0.132	-0.196	-0.234
	[0.0997]	[0.0907]	[0.112]	[0.103]	[0.193]	[0.165]
Choice-set3	-0.0159	0.130	-0.0324	0.123	-0.234	-0.103
	[0.101]	[0.101]	[0.112]	[0.114]	[0.201]	[0.187]
Choice-set4	-0.0338	0.441***	0.0475	0.491***	-0.239	0.288
	[0.0919]	[0.121]	[0.0998]	[0.136]	[0.179]	[0.232]
Small Screen					0.104	0.0837
					[0.156]	[0.161]
N	11984	11984	9232	9232	3840	3840
ll_0						
ll	-3324.0	-3293.1	-2537.4	-2517.4	-1079.3	-1066.5
chi2	1.829	25.58	3.098	26.18	2.940	6.921

Paper C

The offshore-onshore conundrum: preferences for wind energy considering spatial data in Denmark

The offshore-onshore conundrum: preferences for wind energy considering spatial data in Denmark.

Pablo Hevia-Koch*, Jacob Ladenburg, Stefan Petrovic

1 Abstract

Wind energy installed capacity has been increasing steadily all over the world and is expected to continue to do so in the future, following lowering costs of technology as well as increased renewable energy goals by governments. Nonetheless, public opposition has been increasing, and the discussion regarding siting wind turbines onshore or offshore is constantly present on public discourse. By combining a stated preference study with spatial data processed utilising GIS (Geographic Information System), we explore preferences for onshore and offshore wind turbines, considering their visual impact, costs, as well as socioeconomic and spatial attributes of the respondents. Results show that in general respondents show strong preferences towards offshore wind turbines as opposed to onshore. Furthermore, spatial data is found to be significant in regards to the preferences of the respondents, particularly the respondents' distance to the coast and the amount of wind turbines seen. In the same line, socioeconomic indicators such as age and income prove significant to respondents' preferences in line with previous research.

Keywords: wind energy, choice experiments, environmental valuation, landscape valuation, stated preference studies.

1. Introduction

The growth of wind energy on the last recent years has been constant, with the global installed capacity duplicating between 2012 and 2016. Concerns regarding climate change and pollution have further positioned wind energy as one of the main renewable technologies for electricity generation. Estimates of wind energy capacity for year 2030 (European Wind Energy Association, 2015) predict a significant increase in installed capacity for onshore and offshore wind turbines in Europe: It is expected that Germany increases its wind installed capacity to 80 GW, up from the 2016 capacity of 49.5 GW. Estimates for France show an increase to 32.5 GW installed capacity, most of it offshore, up from the 12 GW currently existing (all of which is onshore). Particularly in Denmark, it is expected that by 2050 close to 50% of the energy demand will be covered by wind, and that by 2030 the installed capacity will be close to 8 GW, compared to the current 5GW.

Outside of Europe, similar trends for the expansion of installed capacity of wind energy are seen: The U.S. Department of energy projects that by 2030 the installed capacity of wind energy will be approximately 400 GW considering onshore and offshore projects, up from the current 82 GW with no offshore farms (U.S. Department of Energy, 2015). China, following its pledge of increasing non-fossil primary energy generation to 20% of total consumption by 2030, expects installed wind power capacity to reach 495 GW in that year (Global Data, 2016).

Despite this global growth, or maybe actually because of it, approval and support for new wind projects is variable. Opposition by the public to new wind projects is always a concern, and policy makers and public planners are faced with the difficult task of balancing the preferences of the public, while expanding wind energy generation in a cost-effective manner.

An interesting element of this discussion is the decision of siting wind farms onshore versus siting them offshore. Though the one of the newest tender broke the record lowest offshore wind power development cost of 4.96 €cents/kwh (Danish Energy Agency, 2016) onshore wind farms are cheaper (Danish Energy Agency, 2014; Ea Energianalyse, 2014), but onshore wind farms they tend to produce higher resistance due to concern regarding visual disamenities and landscape. Offshore wind farms, on the other hand, present reduced visual disamenities but higher costs of installation and maintenance (European

Environmental Agency, 2009). Furthermore, the decision of how far away from the coastline or from residential areas will the wind farms be sited significantly affects both public preferences, as shown in (Krueger et al., 2011; Ladenburg et al., 2011; Ladenburg & Dubgaard, 2007; Landry et al., 2012; Lutzeyer et al., 2016; Westerberg et al., 2013), and project cost. The recent development of low-cost offshore wind turbines farms in Europe present wind energy as a highly competitive energy generation technology, particularly when discussing farms offshore. While typically considered extremely expensive, new projects have been accepted with extremely low subsidies (like Kriegers Flak with a subsidy bid of €49.9/MWh for a total capacity of approximately 600MW), or even without any subsidies at all, like the three projects awarded to Dong Energy in Germany (OWP West, Borkum Riffgrund West 2, and Gode Wind 3), with a ground-breaking zero euro bid (Jacobsen & Hevia-Koch, 2017).

The present paper aims to study public preferences regarding the siting of wind turbines, comparing preferences for offshore and onshore locations by means of a choice experiment. While previous research exists that considers a comparison of onshore and offshore location (Campbell et al., 2011; K Ek, 2006; Kristina Ek & Persson, 2014; Vecchiato, 2014), we present research that includes site-specific information regarding location of possible wind farms. Furthermore, we decide to explore the importance of spatial variables on the preferences for both offshore and onshore wind energy, which we do by utilising GIS to extract relevant spatial data for each respondent, such as distance to the beach, distance to the nearest potential offshore wind power development site and number of onshore wind turbines in the postal area. Finally, the study also includes scientific visualisations that represent accurately the main attributes driving preferences for wind turbine farms: size of the wind turbines, distance to shore, distance to viewpoint, and number of wind turbines in the farm. To the authors' best knowledge, the present is the only study that exhibits these characteristics.

In this study, we aim to identify the main attributes that driver preferences for onshore-offshore wind turbine farm comparisons including spatial and socioeconomic data. Furthermore, we try to measure relative willingness-to-pay (WTP) for some of these attributes across the comparison. Finally, we provide policy recommendations based on the obtained results.

2 The Survey

2.1 Survey setup

Data was acquired through a web survey, conducted between December 2011 and January 2012 in Denmark; and consisting of three parts: In the first section, the respondents are presented with diverse questions regarding their attitude towards green energy, global warming, and their prior experience with wind turbines. The second section contains a choice experiment considering both onshore and offshore scenarios, which will be further described later. The final section gathers socio-economic information of the respondents. To test the design of the survey, the attribute levels and formulation of the questions, a focus group interview and a pilot survey (without participation reminders) were carried out. Due to mistakes by the made by the survey company, we only have access to the response rate of this pilot survey, which was 8.57%. Considering that the actual survey did contain reminders, and based on experience with similar pilot surveys, we expect the actual response rate of the survey to lie in the 15%-30% range.

For the choice experiment scenario set up, we describe a planned development of 450 MW of wind energy in Denmark. These 450 MW can be constructed either by siting wind turbines in 150 different locations onshore, or in one of 5 defined offshore locations. While the onshore scenarios consider variable amount and turbine sizes for each one of the sites, but maintain a constant amount of installed capacity (3 MW per site). To try to minimise the NIMBY effect, as well as to compensate for respondents living in areas where there is no possibility of further onshore wind development, respondents were asked to assume that the onshore wind turbines would be sited either in their own or in a neighbouring municipality. The offshore scenario considers the development of a wind farm of 450 MW utilising 5 MW wind turbines. These numbers were consulted with the Danish Energy Agency (*Energistyrelsen*) and were found to be reasonable and representative of the plans for future wind energy expansion in the country at the time.

2.2 Attributes and attribute levels

In this section, we discuss the chosen attributes for both the onshore and offshore alternatives. All of the chosen attributes and their levels are summarised in Table 1 and Table 2.

Table 1: Attributes and attribute levels for the onshore alternative.

Attribute	*Levels*
Size	4x750[kW], 2x1.5[MW] or 1x3[MW]
Distance	500, 1000 [meters]
Neighbours	1-10, 11-100, >100 [residents]
Cost	0, 50, 100, 300, 600, 1200 [DKK/household per year]

Table 2: Attributes and attribute levels for the offshore alternative.

Attribute	*Levels*
Distance	8, 12, 18, 50 [km]
Location	Møn, Jammerbugt, Vesterhavet, Anholt, Bornholm
Cost	0, 50, 100, 300, 600, 1200 [DKK/household per year]

The cost of externality reduction is represented by the cost of each alternative scenario, which is the only common attribute across onshore and offshore alternatives. The chosen method was a uniform yearly lump sum payment added on top of the households' electricity bills. The costs range from 0 DKK to 1200 DKK per household per year. The chosen method and levels were defined based on the feedback given by focus groups during the development of the survey. To try to minimise hypothetical bias, the respondents were presented with a "cheap talk" (Bosworth & Taylor, 2012; Cummings & Taylor, 1999), which reminds them to consider their budget and really consider the alternatives' costs when answering, and that makes them aware of the tendency of people to overstate their willingness-to-pay.

2.2.1 Onshore scenario attributes

The attributes of the onshore alternatives are the distance of the wind turbine to the nearest settlement, the combined size and number of turbines, and the number of residents in the nearest settlement.

The number of residents in the nearest settlement aims to measure if there exist preferences regarding siting wind turbines in areas with higher or lower population densities. There are three possible levels: below 10 inhabitants, between 10 to 100 inhabitants, and more than 100 inhabitants. These levels are representative of the typical ranges of population density found in many areas with onshore wind turbines in Denmark.

In the present study instead of considering the size and the number of the wind turbines as separate attributes, we treat them together as a single one. This allows us to maintain the total generation of the wind turbines constant, independent of the size or number of wind turbines considered as done in (Ladenburg & Dubgaard, 2007) and (Lutzeyer et al., 2016). In this way, we isolate the preferences that people might have for wind energy generation as an energy generation technology. If we considered them separately, it is possible that people that hold positive views of wind energy would choose big wind turbines more often, not because of their visual preferences, but because they would generate more. For this reason, the levels chosen are 4 x 750 kW turbines, 2 x 1.5 MW turbines, and a single 3 MW turbine, all of which maintain the total generation constant.

The distance of the wind turbines can be either 500 meters or 1000 meters. Evidently, the distance is proportional to the visual impact generated. The distances chosen are reflective of Danish regulations regarding minimum distance of wind turbine sites to inhabited areas, considering the heights of the turbines included in this survey.

2.2.2 Offshore scenario attributes

For the offshore alternatives, the experiment setup defines the total generation as a constant 450 MW wind farm, and the size of the wind turbines as 5 MW. For this reason, the only attributes that vary are the distance and the location of the offshore wind turbine farm.

The distance represents how far away from shore the wind farm will be located, which varies from 8 km to 50 km. This distance has a direct effect on how visible the wind turbines are, and is therefore the main visual attribute for the offshore alternative. The distances chosen are considered realistic for Danish projects at the time, with 50 km being the limit, at which the wind turbine farm could be visible.

In regards to the location of the wind turbine farm, during the scenario description we defined five possible areas being considered for the development of wind turbine farms: Bornholm, Møn, Anholt, Vesterhavet, and Jammerbugt. We aim to identify if there exist preferences related to avoiding siting the wind turbine farm in certain areas compared to others.

2.3 Experimental design

During the choice experiment, each respondent was presented with four choice sets, each of them containing 2 alternatives: one offshore and one onshore. None of the alternatives represents the status-quo. Since the development of wind energy has already been decided by the Danish government, the question that we want to presents respondents with is not whether wind turbines should be placed or not, but instead how and where these new wind turbines should be placed to minimise their perceived disamenities. Following recommendations presented in literature (Alpizar et al., 2003; Kristina Ek & Persson, 2014; Hensher et al., 2005), it is preferable to create realistic alternatives, even though there will be no status-quo, than to include a status-quo even if it is unrealisable. Nonetheless, it is important to keep in mind that the lack of status quo has the potential to distort welfare measures calculated based on WTP (Alpizar et al., 2003).

Each one of the alternatives has a table, which presents all the attribute levels in text form. Additionally, each alternative is accompanied by a generic visualisation (Hevia-Koch & Ladenburg, 2016) that represents the visual attribute levels (distances for both offshore and onshore, as well as size and number for the onshore alternative) of the proposed alternative, in non-specific location and weather conditions. For the onshore alternatives, respondents were asked to imagine the wind turbines in their own, or an adjacent, neighbourhood, whereas for the offshore alternatives the location was defined. The respondents were instructed to open the provided visualisation images in full screen.

The creation of the choice sets was done by applying a D-efficient design with utility priors (Ferrini & Scarpa, 2007). After pruning for unreasonable and duplicate combinations (choice sets that yielded redundant measures of attributes or unfeasible combinations), 36 choice sets remained. These were subsequently assigned in a random manner to nine blocks with four different choice sets each. Each respondent was then presented with one of these blocks at random, facing four choice sets with two alternatives each.

After respondents answer all assigned choice sets, we identify respondents that always opted for the onshore or offshore alternative. These respondents are then presented with some follow-up questions that aim to identify protest answers. We considered as protest answers respondents who stated that "The cost attribute did not influence their choices at all", "It is not real money, so they did not pay attention to the payment" and respondents who "Did not know what to choose"[1].

3 Econometric Model for Preferences

3.1 Model of preferences

During the survey's choice experiment, respondents are asked to choose between two discrete options. In our analysis, we assume that if respondent i prefers alternative a to alternative b, it is because the utility U_{ia} they associated to alternative a is higher than the utility U_{ib} they associated to alternative b.

Furthermore, we will assume that the utility that individual i perceives from an alternative a can be expressed as a systematic utility V_{ia} dependant on the attributes of the alternative, and an error term ϵ_a.

We can further write the systematic utility V_{ia} as

$$V_{ia} = \beta X_{ia}$$

where β is a vector that represents the taste among the respondents, and is not observable; while X_{iq} is a vector that contains observable attributes of the good (in this case, the size of the wind turbines, the cost, the distance to shore, etc.). If we assume that the error terms are i.i.d. as a Gumbel distribution (extreme value type I), then we can write the

[1] A logit analysis of which respondents' characteristics and which spatial variables that influence the propensity to state a protest answer reveals that except for respondents with a bachelor degree relative to respondents with elementary school education, none of the other variables influence the propensity to state a protest answer significantly.

probability of respondent i choosing alternative a instead of b as:

$$P_{ia} = \frac{e^{\beta X_{ia}}}{e^{\beta X_{ia}} + e^{\beta X_{ib}}}$$

If we assume that β is constant across respondents, then we have the standard formulation for a Binary Logit Model. For our model, though, we want to allow for taste variations across respondents. This means that the taste vector will remain unobservable and unique for each respondent β_i. Furthermore, since each respondent is presented with four choice sets, we have panel date, and therefore we cannot correctly assume that the error terms are i.i.d., since we would expect them to be correlated for the choices made by the same respondent. Therefore, we have to consider the error terms as being dependant on the respondent ϵ_{ia}, and correlated correspondingly. With these restrictions, the formulation we utilise then is known as the Mixed Logit Model (MXL), where we define the utility of an alternative as:

$$U_{ia} = \beta_i X_{ia} + \epsilon_{ia}$$

and further assume that β_i is actually a random parameter distributed as $f(\beta|\theta)$, with θ being parameters that characterise the distribution.

Since we cannot observe the taste vector β_i, the probability of choosing an alternative a will now have to depend on the integral of the previous probability function, over the domain of the distribution of β_i:

$$P_{ia} = \int_{\beta} \frac{e^{\beta_a x_{ia}}}{e^{\beta_i x_{ia}} + e^{\beta_i x_{ib}}}$$

which defines the formulation of the binary MXL.

3.2 Willingness-to-Pay

The willingness to pay estimate is, as it will become apparent, a function of whether the attribute in focus is related to onshore or offshore attributes, as the sensitivity towards the parameter depends on the location. Accordingly, onshore and offshore WTPs will be estimated by the ratios

$$\overline{WTP}_{\text{Onshore attribute}} = -\frac{\hat{\beta}_{Onshore\ attribute}}{\hat{\beta}_{Cost}} * 50$$

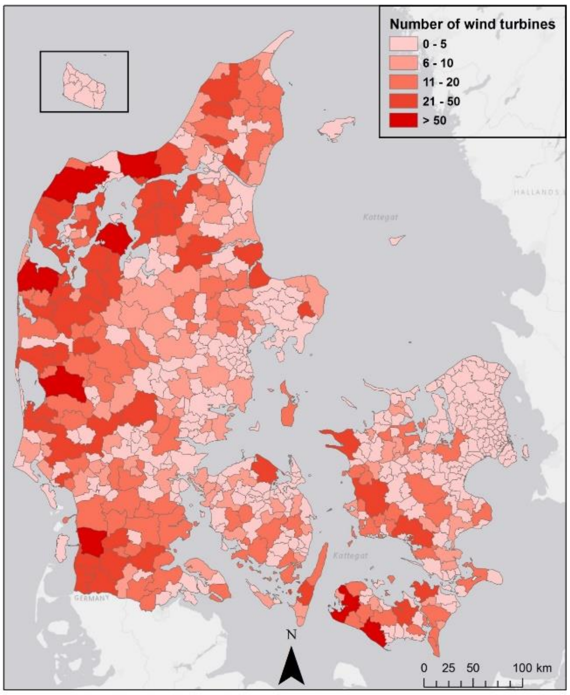
$$\overline{WTP}_{\text{Offshore attribute}} = -\frac{\hat{\beta}_{Offshore\ attribute}}{\hat{\beta}_{Cost} + \hat{\beta}_{Cost\_offshore}} * 50$$

Heterogeneity in preferences, and subsequently WTP, is estimated by adding the heterogeneous variable to the WTP function – that being in the denominator or numerator part.

3.3 Spatial analysis

We utilised GIS (Geographical Information System) in the present study to relate the responses from participants in the surveys with the spatial conditions that could affect their perception and/or exposure to the visual impact of wind turbines. The locations of existing and decommissioned wind turbines, along with their commission and decommission dates were obtained from the Master Data Register of Wind Turbines maintained by the Danish Energy Agency (Danish Energy Agency, 2015). Since the survey was done in 2012, it was necessary to represent only the wind turbines that existed in 2012. This was done by including all turbines commissioned before December 31st and excluding all turbines decommissioned before December 31st 2012. The distribution of the utilised turbines across Denmark is shown in Figure 1.

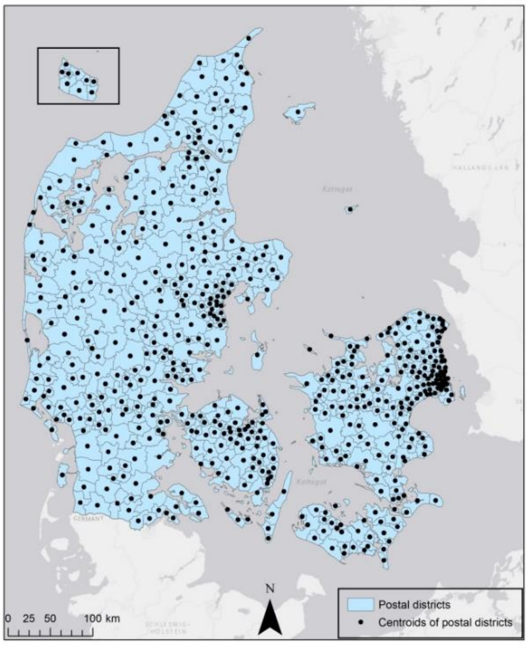
Figure 1. Number of wind turbines within postal districts in 2012



The location of every respondent is defined by their postal district, whose geographical location was obtained from (Danish Geodata Agency, 2015). The geographical representation with 593 postal districts is considered very detailed for a small country like Denmark (area of 43000 km^2 and 5.6 million inhabitants).

Since the specific location of respondents within their postal districts is not known, the centroids of postal districts is used as a representation of their specific geographical position, as presented in Figure 2.

Figure 2. Postal districts and their centroids



The locations of centroids are calculated by utilising the *Calculate Geometry* tool. The parameters used to approximate participants' visual exposure to wind turbines are:

- The density of wind turbines in postal code district, denoted Density.
- The distance to the nearest point at the coast, denoted Dist_Coast.
- The distance to the nearest of the five potential offshore wind farms, denoted Dist_Offshore_WF.

While simple, the applied method has some limitations. The participants' responses are linked to centroids of postal districts instead of exact locations of their residences. This approximation evidently produces errors, which are necessary since the exact locations of the respondents' residences is not available due to privacy issues. Finally, the distance/density from the residence is not the only measure of a visual exposure to onshore wind turbines. For example, wind turbines can frequently be seen if they are close to work, recreational or leisure facilities. It is important to note that the number of wind turbines seen from the residence or summerhouse is not calculated utilising GIS, but self-reported by the respondents. In the analysis of spatial preferences relations we focus on the cost attribute, the onshore/offshore attribute, and the interaction between the two attributes. Accordingly, though it might be interesting to explore how the spatial relations might be related to other attributes of the onshore and offshore alternatives, this is not done in the present paper.

4 Results

We present four different MXL models. The first model is a baseline model with attributes only (BASE). In the second model we incorporate interactions between the sociodemographic characteristics of the respondents and the different attributes (SEINT). In the third model, we include the significant spatial variables (SPINT). The results of these models is shown below in Table 3[2], where we show all significant parameters. As a spatial references model, we have also added a spatial model including all parameters (FSPINT). For reference, a full model with all spatial and sociodemographic interactions is included in Appendix A.

4.1 Analysis of the sample

The sample is intended to be representative of the Danish national population. In regards to gender, the sample is representative of the Danish population at the time. Respondents' ages range from 20 years to 67 years. When comparing this age range with the Danish population age in 2012, we can see that this range contains 65% of the Danish population, and therefore that around a third of all citizens are not represented by age. When looking at the distribution of age, we can see that there is an overrepresentation of middle-aged citizens (between 45 and 60 years old), and an under representation of people at the ends of the age limit (between 20 and 29 years old,

[2] Due to layout issues, tables 3, 4 and 5 are presented after the References section.

as well as between 60 and 69 years old). Consequently, the average age of the sample (45.1 years) is slightly higher than the Danish national one (43.8 years). The biggest difference in representation occurs in regards to education and income, where most of the respondents present both a higher education and a higher income level than the average Danish citizen. Nonetheless, this result was expected, as this is a common situation in surveys, particularly web-based ones.

Regarding the spatial variables, we can see that the vast majority of the respondents (86.5%) do not have view of a turbine from either their permanent or summer residence. This value is slightly higher than the estimated for the national population based on numbers of households with onshore wind turbines in the viewshed from the permanent or summer residence reported in (Ladenburg, 2014) and (Ladenburg et al., 2013), and based on Danish national survey data. It is tough to determine which numbers are actually correct. However, it is important to keep in mind that there might be a slight underrepresentation of households with a wind turbine in their viewshed in the present study. It is of interest to note that most of the respondents (56.8%) live in a postcode area where there are wind turbines, even if they do not have them in their viewshed.

When looking at the distance to the beach, we can see that on average the respondents' residences are located at 7.8 km, with a maximum distance of 52.3 km, and a minimum distance close to zero. On the other hand, the distance to the nearest potential offshore site presents a much higher variation, with an average distance of 40.6 km to the site, while the minimum being 7.7 km and the maximum being 206.3 km. This allows us to analyse any potential preferences relations due to the distance to the proposed sites. Finally, we can see that the average density of turbines in the postcode area of the respondent is highest for turbines with a 750 kW capacity or smaller (0.048 turbines per square kilometre) and lowest for turbines of 3 MW or larger (0.003 turbines per square kilometre).

A detailed comparison between the sample characteristics and the Danish population characteristics at the time can be seen in Table 4.

To ensure the validity of the information obtained from this spatial analysis, we also calculate the correlation across the spatial variables before mentioned. The calculated correlations are available in Table 5. We can observe that the spatial variables are in general weakly correlated, which makes the interpretation of the spatial preferences relation easier to interpret. As expected, and by construct, the categorical spatial variable of whether or not the respondent live in an postal area with at least one wind turbine is positively and relatively strongly correlated with the number of small, medium and large turbines in postal area.

4.2 Attributes only model (BASE)

This model only contains variables representing the attributes of the alternatives in the choice experiment, and does not contain any parameters related to characteristics of the respondents.

The cost attribute was modelled as a continuous variable, scaled down by a factor of 50 to improve convergence of the model. We can see that the estimated coefficient β_{cost50} is significant, and with the expected negative sign, indicating a preference for alternatives with lower costs.

For the offshore alternatives, the distance to shore is coded as three dummy variables (dist12, dist18, and dist50), utilising the distance of 8 km from shore as the baseline. It can be seen that all three parameters have positive sign, meaning that respondents prefer any of these distances compared to the baseline of 8 km for shore, but only the parameters for dist18 and dist50 are significantly different to zero. In terms of their relative magnitude, we can see that $\beta_{DIST18} > \beta_{DIST50} > \beta_{DIST12}$, indicating that respondents prefer siting wind turbines at 18 km as their first option, 50 km as the second, and with 12 km being preferred only in comparison to the baseline of 8 km. The preferences estimates for locating the wind farms at 18 km is though not significantly different from the preference estimates for locating the offshore wind farms at 50 km.

The onshore distance of 1000 m was coded as a dummy variable (dist1000) and the distance of 500 m was used as the baseline. We can see that the associated coefficient $\beta_{dist1000}$ is significant at the 0.001 level and with positive in sign, indicating that, as expected, respondents prefer siting onshore wind turbines at 1000 m compared to 500 m.

The attribute for turbine size and number for onshore sites was coded utilising two dummy variables (MW1_5 and MW3) representing 2 x 1.5 MW and 1 x 3 MW turbines, with the 4 x 750 kW arrangement used as reference. Both parameters are significant, and with a positive sign. We can see that $\beta_{MW3} < \beta_{MW1\_5}$ which seems to indicate that respondents prefer two 1.5 MW turbines, compared to a single 3MW, with four 750kW turbines being the least preferred. Nonetheless, while significantly different to zero, these parameters are not significantly different to each other, which means we cannot conclude that respondents prefer two 1.5 MW turbines over a single 3 MW turbine; we can only conclude that both alternatives are preferable to the four 750 kW turbines.

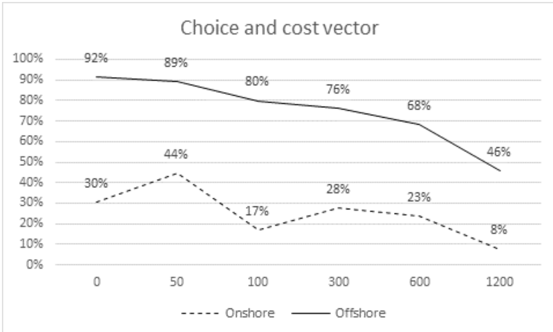
We also included interaction terms between distance and number/size of wind turbines. We can see that the associated coefficients $\beta_{dist1000xMW3}$ and $\beta_{dist1000xMW1\_5}$ are both significant and with a negative sign. In terms of magnitude, we see that $|\beta_{dist1000\_MW3}| > |\beta_{dist1000\_MW1\_5}|$, but very similar. Further interpretation of these results will be presented in the discussion section.

The amount of neighbours living nearby the proposed onshore wind turbine was modelled utilising two dummy variables, Residents11-100 and Residents100, representing a number of residents between 11 and 100 for the first variable, and more than 100 for the second. The reference level was less than 11 residents. We can see that $\beta_{Residents\ 100}$ is negative, indicating a preference for less populated areas, and significant to the 0.01 level. The coefficient $\beta_{Residents\ 11-100}$ is not significantly different from zero, so no conclusions can be drawn regarding preferences to that particular level.

Regarding the location chosen for the offshore wind turbine farm, it was modelled as a dummy variable for each location: Møn, Jammerbugt, Anholt, and Vesterhavet, with Bornholm being the reference. Only the coefficient associated to Jammerbugt was significant at the 0.01 level. With a negative sign, it indicates respondents are opposed to situating the new offshore wind turbine farm in that area, compared to the reference location of Bornholm. The coefficient associated to Vesterhavet is significant at the 0.05 level, and with a positive sign it indicates a slight preference for situating the proposed wind turbine farm in that area, compared to Bornholm. Respondents show no significant preferences for the remaining locations (Møn, Jammerbugt, and Anholt).

Finally, we can observe that the alternative specific constant associated to the offshore alternative (asc1), is highly significant, positive, and with a magnitude higher than any of the other dummy coefficients. We included an interaction term between the offshore alternative specific constant and the cost attribute, finding that the associated coefficient is significantly different to zero, and with positive sign. The differences in the cost sensitivity between onshore and offshore alternatives are illustrated in Figure 3 below, where the probability of choosing an alternative with a specific cost level is estimated for onshore and offshore alternatives. Accordingly, it can be seen that the respondents are clearly less sensitive to higher costs, if the alternative is one offshore wind farm relative to many onshore turbines sites.

Figure 3: Choice and cost vector



4.3 Socioeconomic Interactions Model (SEINT)

In this model, we maintain the attributes considered in the BASE model, but we add interactions accounting for particular demographic characteristics of the respondents. In the analysis of this model and the next, we will only focus on the results obtained for the newly added variables and interactions. Unless explicitly noted, the significance and sign of previously discussed coefficients is maintained, with only minor variations on the magnitude.

We can see that the cost attribute is affected by several characteristics. Older respondents present a lower sensibility to cost, as seen on the significant parameter $\beta_{age\ x\ cost}$, due to its positive sign. This results indicates that older respondents have a higher WTP to have their preferences fulfilled compared the younger respondents. We have tested if the age cost relation is dependent on onshore or offshore wind power development location, but the interaction variable is insignificant.

Another age relation can be observed on the alternative specific constant. We find that the coefficient interacting age with the alternative specific constant is positive and significant. This indicates that older respondents have stronger preferences for a single offshore wind farm relative to many onshore wind farms, when compared to the younger respondents.

After introducing these interactions, we can see that the coefficient β_{cost50} has a higher negative magnitude on the SEINT model compared to the BASE model, indicating a general increase in the disutility produced by higher costs for the general population, since we captured the age relation on the specific interaction term.

In regards to gender, we found the relation between gender and the specific site chosen for the offshore wind farm. While the BASE model indicated only one significant preference for the location of offshore wind farms, this changes when considering gender. In particular, we can see that male respondents have significantly different preferences for the locations of Jammerbugt, Anholt, and Møn. No significant relation was found for male respondents' preferences for Vesterhavet. Except for a location at Vesterhavet, this indicates that male respondents present higher preferences to these sites compared to female ones. It is important to note that due to the similar magnitude and opposite sign of the coefficients for Jammerbugt and the interaction between Jammerbugt and male respondent, the interpretation is that males seem to be indifferent to locating the offshore wind turbine farm Jammerbugt (in comparison to the baseline of Bornholm) while females are significantly opposed. Because of the introduction of gender interactions, we can see that the non-interacted coefficients for location increase in significance, with the coefficient associated to Anholt achieving significance at the 0.1 level, its negative sign indicating that female respondents prefer not to site the wind turbine farm in that location, compared to Bornholm.

The final socioeconomic variable consider is income, which enters the model as a linear function. We found that respondents belonging to the high-income group present higher preferences for siting offshore wind turbines at 50 km, compared to other respondents. This would mean that they have much stronger preferences for reducing the visual impact of wind turbines to the minimum.

4.4 Spatial Interactions Model (SPINT)

In this final model, we further extend the SEINT model by adding interactions that consider spatial information of the respondents based on the GIS analysis described on Section 3.3.

When looking at the distance of the respondents' house to the beach, we can see that it affects the sensitivity to the cost attribute, with respondents living further from the beach presenting a higher sensitivity to the cost attribute, although only significant at the 0.1 level. One obvious explanation is that respondents living closer to the sea, might use the beach more frequently and thereby have stronger preferences for the location of wind turbines, particularly offshore. This would be in line with Ladenburg and Dubgaard (2009), who find some indications of that frequent beach use increases WTP for location offshore wind farms at larger distances from the shore.

A similar and more significant relation can be seen when looking at the relation between the respondents' postal area and the distance to the nearest proposed offshore site, and the cost attribute. We can observe that the respondents are more sensitive to the cost attribute the higher the distance to the proposed site, this time significant at the 0.05 level ($\beta_{Cost\ x\ Distance\ potential\ offshore\ wind\ farm} > 0$). Though relations between existing onshore wind turbines and preferences for onshore wind power development (Meyerhoff, 2013) and spatial relations between existing and potential turbines have been reported in the wind power acceptance literature (Jørgensen et al., 2013; Ladenburg & Möller, 2011), except from (Ladenburg & Knapp, 2015), this is the first study to estimate significant distance dependency in offshore wind power literature. We have tested if the spatial relation is dependent on whether the cost vector relates to the offshore or onshore wind turbine development alternative ($\beta_{Offshore\ Cost\ x\ Distance\ potential\ offshore\ wind\ farm}$), but found to be non-significant.

Another spatial dimension considered was the number of turbines that could be seen from the residence or summerhouse of the respondent. When interacting this variable with the cost attribute we observe that the associated coefficient is significant at the 0.05 level, and of negative sign. This indicates that the more turbines are visible for the respondents, the more sensitive they are to the cost parameter. Nonetheless, when further interacting these two terms with the offshore alternative constant we see that it lessens the impact of the interaction between number of visible turbines and the cost variable, albeit significant only at the 0.1 level.

As we will come back to, these results thus point towards the WTP for onshore and offshore locations and wind farms attributes is decreasing with the number of turbines visible from the house ($\beta_{Cost\ x\ Number\ of\ turbines\ visible} < 0$), but that the decrease is smaller for offshore locations ($\beta_{Offshore\_Cost\ x\ Number\ of\ turbines\ visible} > 0$). A test reveal, that the combination of $\beta_{Cost\ x\ Number\ of\ turbines\ visible} + \beta_{Offshore\_Cost\ x\ Number\ of\ turbines\ visible}$ is not significantly different from 0. Accordingly, the spatial relation from the number of turbines seen only influence preferences and WTP significantly in relation to onshore wind power development.

The final spatial data considered in the SPINT model is whether respondents live in a postcode with no wind turbines at all. When interacted with the cost attribute the results show that respondents that live in postcodes with no wind turbines have a significant lower sensitivity to cost ($\beta_{Cost\ x\ No.\ turbine\ onshore} > 0$). This result, though, does not apply when considering offshore wind turbine alternatives ($\beta_{Offshore\_Cost\ x\ No.\ turbine\ onshore} < 0$). This goes in line with what was observed in the previous models: respondents are sensitive to the cost attribute differently when considering offshore alternatives, versus onshore ones. A test reveal, that the combination of $\beta_{Cost\ x\ No.\ turbine\ onshore} + \beta_{Offshore\ Costs\ x\ No.\ turbine\ onshore}$ is not significantly different from 0. Accordingly, the spatial relation from not having any onshore wind turbines postal area only influences preferences and WTP significantly in relation to onshore wind power development and *not* offshore development.

As we will come back to in the discussion, the results related to the spatial onshore dimensions (number of turbines visible from the residence and not having any onshore turbines in the postal area) suggest that onshore wind power development landscape apparently only influence preferences for further onshore wind power development and not offshore development.

4.5 Willingness-to-Pay

In this section, we analyse the resulting willingness-to-pay (WTP) of respondents regarding various attributes for both onshore and offshore alternatives, while considering the relations associated with the spatial and socioeconomic variables. Table 6 below shows the WTP values calculated for the main effects model.

<< Table 6 >>

The first interesting result observed in the model relates to preferences for offshore wind turbines versus onshore wind turbines. It can be seen that respondents have a WTP of 612.5 DKK/year/household for having new wind turbines sited in offshore locations versus onshore locations.

Regarding size and quantity of turbines, results for the attribute model denote that the respondents are willing to pay additional 327 and 331 DKK/year/household for using 3 MW or 2x1.5 MW relative to 4x750kW turbines, respectively. However, as we have included the two interaction variables for the 3 MW and 2x1.5 MW turbines located at 1000 m, the WTPs above only refer to the case where the 4x750 kW turbines are located at 500 m from the residential area. Likewise, the WTP estimate for locating wind turbines at 1000 m only represent the case of 4x750 kW turbines, which has a level of 307 DKK/year/household. The WTP for locating a 3 MW turbine or 2x1.5 turbines at 1000 m is a combination of the preference estimates for 3 MW + 1000m + 3 MWx1000 m (and likewise for the 2x1.5 MW turbines). Therefore, the estimated WTPs for 3 MW and 2x1.5 MW at 1000 m is -19 and 12 DKK/year/household, respectively.

The final onshore wind turbine development WTPs are related to the number of people living the residential area. On average, the respondents have stated a negative WTP of 186 DKK/year/household is the wind turbines are located near a residential area with more than 100 people living relative if there are living 10 or less people. The WTP for locating the wind turbines near residential areas with 11-100 residents are insignificant, though negative (-30 DKK/year/household).

If we move on to the distance from the shore parameters, the respondents state on average that they are willing to pay 89, 371 and 331 DKK/year/household for having the wind farms located at 12 km, 18 km and 50 km relative to 8 km from the coast, respectively. The differences between the 18 km and 50 km WTPs are not significantly different. These results are in line with the findings in other offshore studies, who find increasing WTP for increasing distance and decreasing marginal WTPs. The results suggest that the respondents have significant higher WTP (129 DKK/year/household) for locating the offshore wind farm at Vesterhavet relative to south west of the island Bornholm. On the other hand, they have a negative WTP (-295 DKK/year/household) for location the offshore wind farm in the Bay of Jammer relative to Bornholm.

4.5.1 Socioeconomic Variables and WTP

We will now analyse the relations associated with the different spatial and socioeconomic variables on the respondents' WTP for siting turbines. In the following figures, the lines represent the respondents' WTP for each of three different attributes: The continuous line represents the WTP for siting wind turbines offshore instead of onshore, the short-dashed line represents the WTP for siting onshore wind turbine farms at a distance of 1000m instead of 500m, and the long-dashed line represents the WTP to siting the offshore wind turbine farm at a distance of 50km from the shore, compared to the baseline distance of 8km. The significance of the estimated WTPs is denoted by the same significance symbols utilised in the tables showing model results: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Age

Age is a significant driver of preferences for onshore and offshore wind power development. In Figure 4 below, we report the sample average WTP for different ages for: an onshore wind farm location at 1000 m relative to 500 m, for an offshore location relative to onshore location and for locating the offshore wind farm a 50 km relative to 8 km from the coast. Recall from the model estimation that age has a significant influence on both the cost parameter and the parameter for onshore vs. offshore development. The results clearly demonstrate an increasing WTP for locating onshore wind farms at 1000 m relative 500 m from residential areas as age increases. The oldest respondents (70 years) are willing to pay almost twice as much (486 DKK vs 235 DKK) compared to the youngest respondents (20 years). The same goes for location the offshore wind farm at 50 km relative to 8 km from the shore (366 vs 213 DKK). Interestingly, the WTP for one offshore wind farm relative to many smaller onshore wind farms is almost three time higher for the oldest group of respondents (1.034 vs 313 DKK). This suggests that the older respondents have very strong preferences for offshore wind power development relative to onshore.

Gender

The models showed that there is a significant difference in preferences regarding the site for the offshore wind turbine farm among genders. The differences on WTP for this attribute across genders are shown in Figure 5 below. We can see that relative to location the offshore wind farm at Bornholm, the WTPs show that female respondents have significant negative WTP for location the wind farm at the Bay of Jammer and the island Anholt, the latter though only significant on 90% level of confidence. On the other hand, male respondents are indifferent in terms of WTP between the locating the offshore wind farm at these two locations. Both male and female have expressed non-significant WTPs for locating the offshore wind farm east of the island of Møn, though the point estimates are significantly different.

4.5.2 Spatial Variables and WTP

Distance of residence to the coast

The preferences model indicates that the distance of the house to the shore affected the respondents' sensitivity to the cost attribute, a relationship shown in Figure 6. This relation is observed when looking at the WTP for onshore wind turbines at 1000 m from the nearest residential area, which is 283 DKK/year/household for respondents living in a postal code area just next to the coast and decreases almost linearly to 213 DKK/year/household for respondents living in a postal code area 50 km from the nearest coastal point; which is equal to a decrease of approximately 31%. This decreasing trend is also observed when looking at WTP for one single offshore wind farm relative to many onshore wind farms, and WTP for locating the offshore wind farm at 50 km relative to 8 km from the coast, with the offshore vs onshore attribute presenting the highest WTP across all distances to the coast.

Distance to nearest proposed offshore wind farm

In the SPINT model the distance to the nearest proposed offshore wind farm correlates with cost sensitivity. This can be seen when observing the relation between this distance and the respondents' WTP. As shown in Figure 7, respondents that live in the same postal area as one of the proposed areas,

Figure 4: WTP depending on age

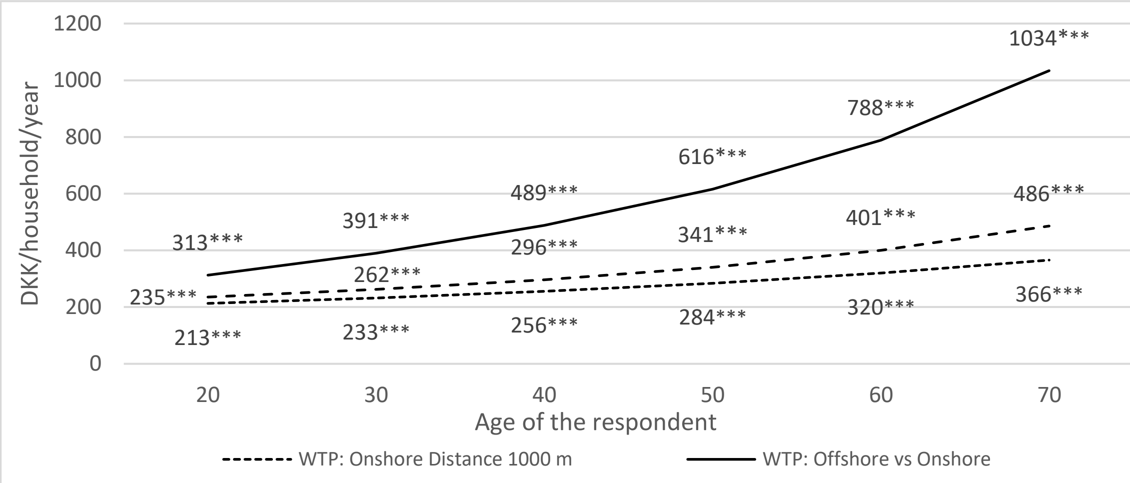


Figure 5: WTP for offshore location depending on gender

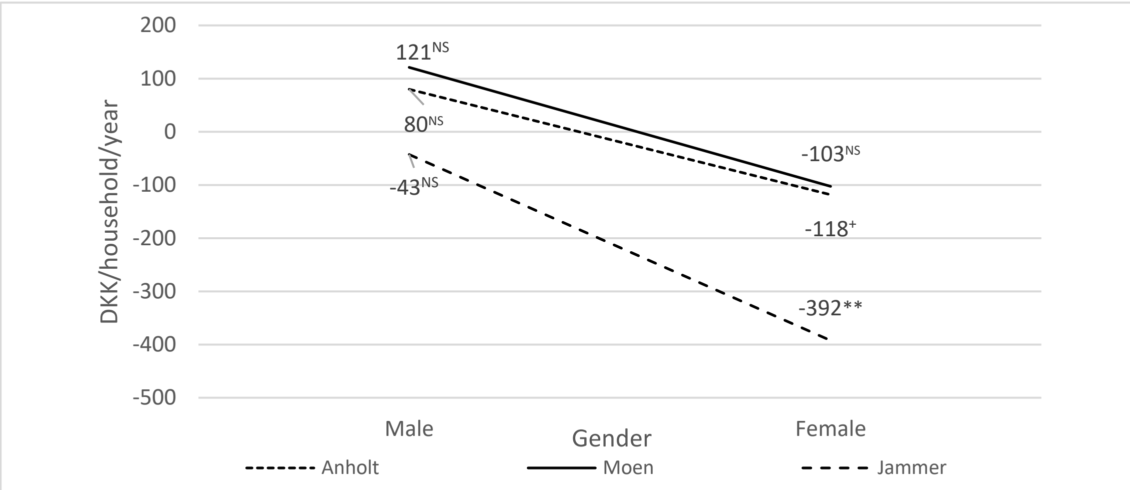


Figure 6: WTP and distance to the coast

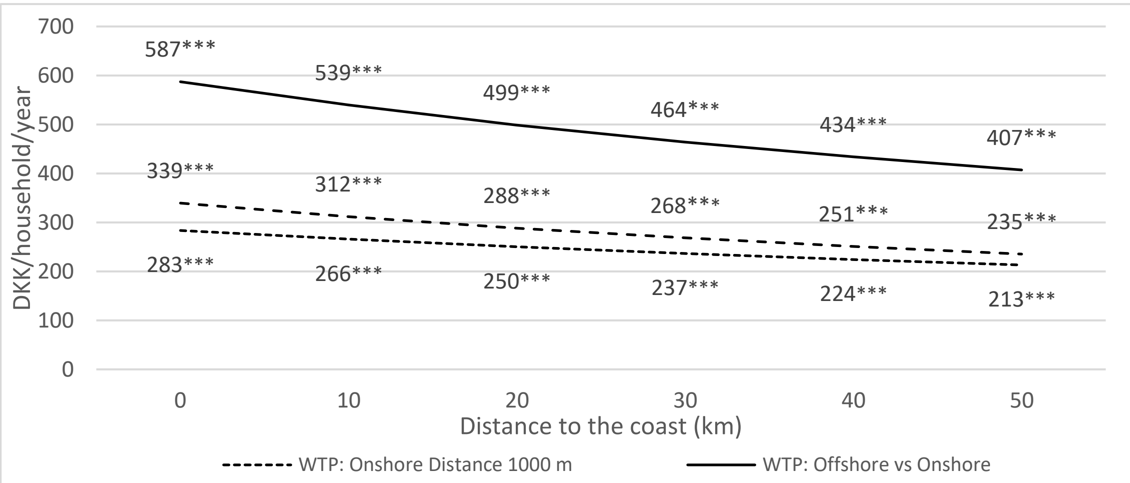
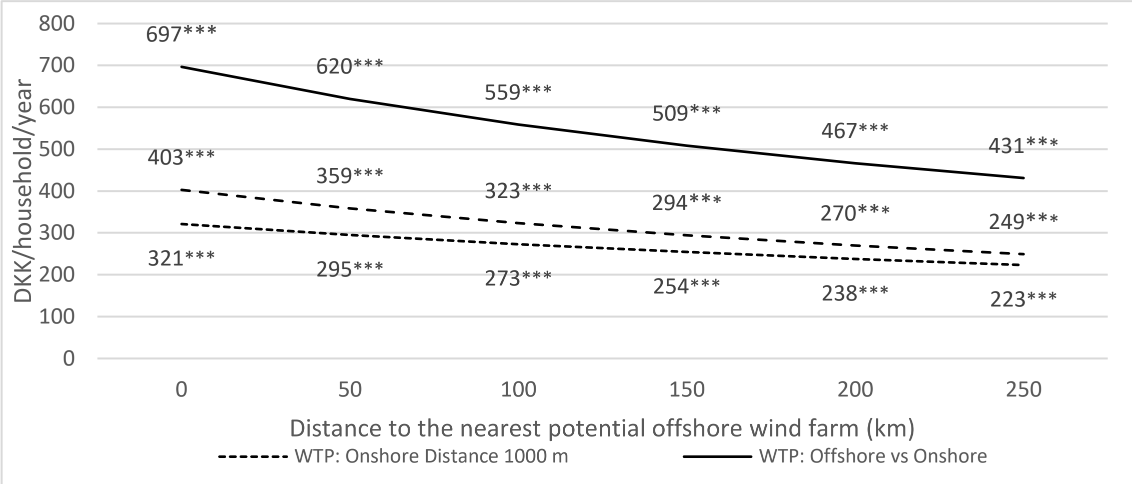


Figure 7: WTP depending on distance to nearest potential offshore wind farm



present higher WTP values than those living further away. The distance WTP relation is most obvious when looking at the WTP for siting offshore turbines instead of onshore ones, where respondents living in the same area as one of the proposed sites have a WTP of 697 DKK/year/household. As the distance to the proposed wind turbine farm site increases, so does the WTP, with a value of 431 DKK/year/household for respondents living at 250 km from the proposed sites. The same distance WTP relation can be seen for the WTP for siting offshore wind turbines farms at 50 km, and for siting onshore turbines at 1000 m; albeit with a smaller slope of decrease.

Existence of turbines in respondents' area

Based on the significance found in the preferences model, of the interaction between the attribute denoting respondents living in areas without any wind turbines and the cost attribute, we show the differences in WTP for both respondents living in areas without any turbines, versus those that live in areas where wind turbines exist. The results are shown in Figure 8. It can be seen that respondents that live in areas with no wind turbines present the highest WTP, particularly for siting new wind turbines offshore instead of onshore, with a value of 571 DKK/year/household; compared to 533 DKK/year/household of those respondents living in areas that have wind turbines, a decrease of 7%. A similar slope is seen on the decrease of WTP in regards to siting offshore wind turbines at 50km instead of 8km, from 330 DKK/year/household to 308 DKK/year/household. However, due to the difference in WTP value, significance is higher for the case of siting onshore wind turbines at a distance of 1000m, as opposed to 500m, where the decrease is approximately 14%.

Number of wind turbines seen from residence

The final spatial variable to be analysed in terms of WTP is the number of wind turbines seen from the residence, which has shown to affect the sensitivity to the cost attribute in the SPINT model. As shown in Figure 9, there is a clear decrease in WTP as the number of turbines seen from the respondents' residence increases. The highest WTP is seen in respondents with no view of wind turbines, for siting wind turbines offshore instead of onshore, at 558 DKK/year/household. This value decreases to 456 DKK/year/household for respondents with a view of 11 or more wind turbines. The same trend, although with different slopes can be seen also in the WTP for siting onshore wind turbines at 1000m instead of 500m, and for siting offshore wind turbine farms at 50km instead of 8km.

5 Discussion

5.1 Discussion of onshore results

Regarding the onshore alternative, results obtained regarding preferences are mostly as expected, with respondents preferring siting wind turbines further away, as well as preferring fewer large turbines over many smaller ones. While it is not possible to determine if respondents prefer single 3MW turbines over 2 turbines of 1.5MW, due to the values of the attributes not being significantly different, we can assert that both of these alternatives are preferred over 4 small turbines of 750kW. Since the amount of energy generated is constant across all possible sizes, these results would indicate that the perceived disamenities produced by smaller numbers of bigger turbines are smaller than the ones

Figure 8: WTP depending on existence of wind turbines in respondents' postcodes

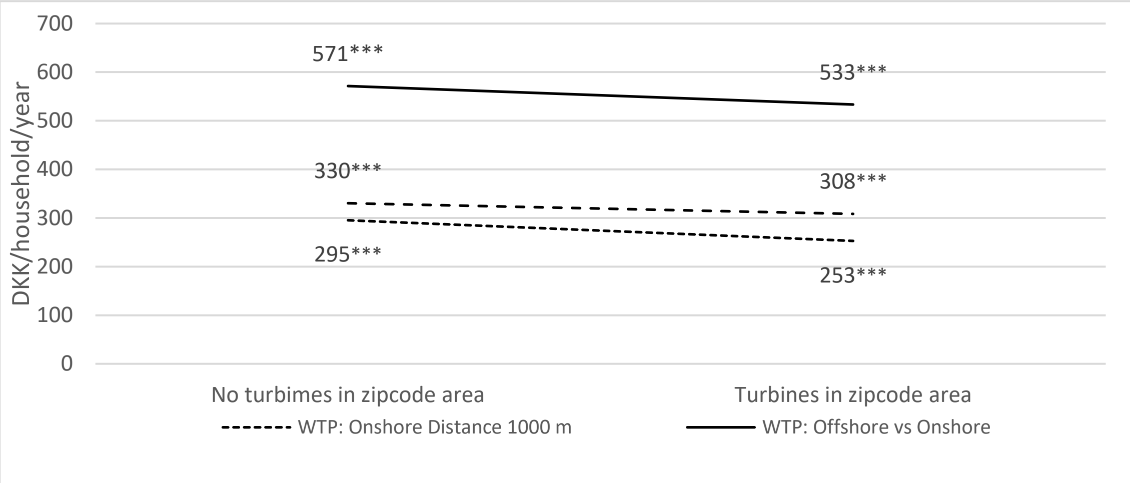
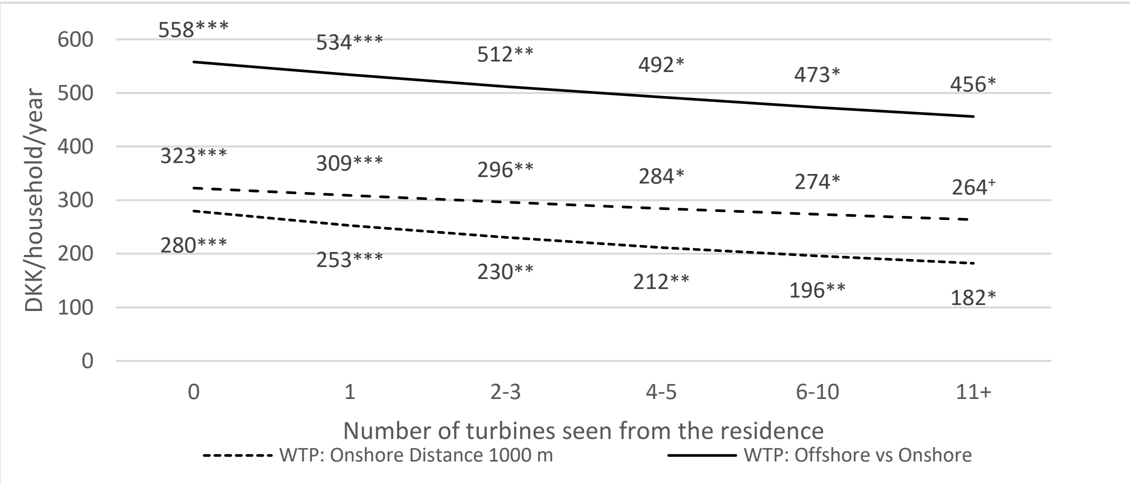


Figure 9: WTP depending on the number of wind turbines seen from residenc



produced by having a higher number of smaller turbines. Similar results have been observed in (Drechsler et al., 2011).

When considering the interaction between size and distance, we find that as the distance increases, the visual impact is lessened to a point where there is not clear difference between the visual disamenities produced by 3 MW turbines compared to 1.5 MW turbines. This indicates that when situating wind turbines at a distance of 1000 m, the impact of the wind turbine size and number is less important. Looking at the results obtained from estimating the WTP, we find a counterintuitive result: the WTPs estimated for the 3MW turbine and 2x1.5 turbines alternatives, situated at 1000m, indicate that respondents are indifferent between having 3MW turbines or 2x1.5 MW turbines at 1000m relative to 4x750kW ones at 500m from the residential area. This is counterintuitive because they also presented significant positive WTP for 3MW/2x1.5MW turbines relative to 4x750kW for the 500m case. One explanation for these results, could be the dominant preferences for offshores locations. Given the setup of the design, any choice of an offshore wind farm is also a signal about that the respondents dislike the onshore location and onshore attributes. If we restrict the models to consider only respondents that have strong preferences for onshore locations (defined as those respondents who choose the onshore alternative at least three times) these counterintuitive results are no longer present.

Looking at the preferences of the number of residents in the turbine area, the results show that respondents have significant preferences for locating the wind farms in areas with 100 residents or less. The respondents are thus willing to pay in order to reduce the impacts on households living the potential onshore wind power areas.

5.2 Discussion of offshore results

When focusing on the offshore alternative, the most relevant result is the fact that the alternative specific constant is highly significant and greater in magnitude than other dummy variables. This indicates that in general, there is a strong preference among respondents for offshore wind farms compared to onshore wind farms, independent of their particular attributes. While considering the interaction of the alternative specific constant with cost, we find that respondents are less sensitive to cost when considering the offshore alternative, compared to the alternative of onshore turbines.

Regarding the distance of the wind turbine farm to the shore, we find that the order of preferences is 18km > 50km > 12km > 8km. While we it could be expected that respondents preferred 50km to 18km, it is important to note that the WTPs for both of these distances are far from being significantly different from each other. A possible explanation is that at 18 km and beyond, the visual impact is extremely minimised and increasing the distance further does not present appreciable improvements on the amount of visual disamenities produced. Our results are thus in line with the general findings of preferences for far shore locations, as reported in the review by (Ladenburg & Lutzeyer, 2012) and we also find marginal decrease WTP as a function of the distance from the coast.

We find that the location of the proposed wind turbine farm is not highly significant, with respondents presenting preferences only against siting in Jammerbugt compared to Bornholm.

5.3 Discussion of socioeconomic relations

When including gender as an interaction, some clearer preferences appear, with female respondents having negative preferences for Jammerbugt and Anholt, and males being indifferent between the two. In addition, while WTPs regarding siting wind turbine farms west of Møn are not significantly different from zero for both genders, the point estimates are significantly different from each other.

For both onshore and offshore preferences, we find that age is a significant driver of preferences. In particular, older respondents are less sensitive to cost and present stronger preferences for siting wind turbines offshore instead of onshore. The age preferences relation can be seen clearly when looking at the WTP values for siting onshore turbines at 1000m vs 500m, where the WTP for the eldest respondents is almost twice as high compare to the youngest ones. Similarly, when deciding between a single offshore wind farm versus many small onshore turbines, eldest respondents have a WTP almost thrice as big as the youngest. This clearly demonstrate substantial differences in preferences and WTP between onshore and offshore wind power development between age groups. A possible explanation for the observed differences can be increased place attachment for older respondents, and therefore more resilient to accepting changes in their residence area. Other possibilities are differences in the acceptance of wind energy in general as a mean to reduce CO2 emissions, or additional leisure time typically associated to older respondents. The findings are in line with the other studies in the offshore preferences literature that test preferences heterogeneity in relation to the age of the respondents. (Krueger et al., 2011) find that older respondents have weaker preferences for wind power relative to coal/gas and conditional on an increase in the wind power capacity (Ladenburg & Dubgaard, 2007) and (Westerberg et al., 2013) find that older respondents have stronger preferences for far shore locations.

5.4 Discussion of spatial relations

The distance to the coast from the respondents' house has clear impact on the WTP for siting wind turbines through the cost attribute. The further the respondents live from the coast, the lower WTP do they have in general. In Figure 6, we exemplified it with locating the offshore wind farm at 50 km from the shore, an offshore wind farm relative to many onshore wind farms and the location of onshore wind turbines 1,000 meter from residential areas. As shortly mentioned, the distance to the coast relation might be produced by preferences of respondents living in areas closer to the coast might visit the beach more frequently and thereby have stronger preferences for particularly offshore locations, as found in (Ladenburg & Dubgaard, 2009).

A similar pattern, of a slightly higher

magnitude, can be observed on the WTP and distance relations of the respondents' residence to the nearest potential offshore wind turbine farm location, also referred to as distance dependency. These results are of particular interest, as they suggest that the external cost of for example location offshore wind farms close to the shore, will be higher in development area close to densely populated regions and vice versa.

It is interesting to see that there is a clear relation to WTP produced by the number of turbines respondents can see from their residence. The trend is clear: the more turbines they see, the lower the WTP, though only for onshore wind turbine attributes. One possible explanation is that respondents that see no turbines from the residence have an untouched landscape view that they would like to protect, whereas the more turbines you can see, the lower the impact of adding another one. Another possible explanation, compatible with the previous one, is that respondents that have visibility of turbines are more acquainted with their actual visual impact, and that either they do not overestimate the cost of the visual impact, or that they are used to wind turbines and bothered by them in smaller amounts. Finally, it is also quite possible that there is self-selection bias: respondents that live in residences where there is no visible wind turbines do so precisely because they want to live in areas without wind turbines, whereas respondents that can see wind turbines from their residence do not care as much for the visual impacts wind turbines produce. It is relevant to note that due to the sample and the siting of installed wind energy at the time, it is probable that most respondents that can see wind turbines from their residence, are observing onshore turbines and not offshore ones.

When we observe the results for WTP and density of turbines in the respondents' postcode, we find a similar relation: the WTP of respondents in areas with zero wind turbines is higher than the one of those living in areas where wind turbines exist, although the difference is only significant for onshore wind turbines attributes. The same possible explanations we presented for the relation between WTP and the number of visible turbines can be used to explain the relations associated with the amount of wind turbines in the area. These results are not only consistent with the phenomenological explanation of the differences in WTP, but also internally consistent in regards to the overlap between both respondent groups.

6 Conclusions

We manage to compare preferences between onshore and offshore for respondents in Denmark. We are able to find preference drivers for both onshore and offshore wind turbines, as well as specific drivers for preferences when choosing between onshore and offshore alternatives, while including site-specific information for offshore alternatives. Furthermore, we were able to find significant spatial preferences relations by utilising GIS, including the relation associated with the distance between respondents' residences and the coast, or the nearest proposed offshore wind farm site; and socioeconomic characteristics of the respondents.

The results found for respondents' preferences regarding offshore and onshore wind turbines are in line with previous research findings, in particular when discussing distance of the turbines to shore or residences, size of onshore wind turbines, as well as the siting of the turbines in areas with varying population densities. When comparing preferences between offshore and onshore alternatives, we find that respondents show strong preferences (and willingness-to-pay) for offshore alternatives, with a WTP value of 612.5 DKK/household/year that is higher than the WTP of most other attributes. This result has strong statistical significance and is of relevance for policy discussions regarding the siting of future wind turbines.

Utilising GIS data regarding spatial characteristics of the respondents shows that there are significant preference relations produced by spatial variables. In particular, we find that the distance to proposed offshore wind turbine sites, the number of wind turbines that can be seen from respondents' residences, and the number of wind turbines existing on the respondents' postcode area produce significant impact on preferences, specifically on cost sensitivity and preferences for offshore versus onshore alternatives. Regarding socioeconomics, we find that gender, income, as well as age are all significant drivers for preferences. It would be of interest to further explore the causes for certain preference relations, as for example the effect of seeing wind turbines from ones house, as it would provide important information of relevance for future siting decisions.

The obtained results shed light across many of the interactions that drive preferences for wind turbines, and might prove a valuable tool for future policy decisions regarding the siting of new projects and the expansion of onshore and/or offshore installed capacity. Given the projected growth of wind energy globally, as well as the increase public opposition that has been experienced on projects, these results are of interest for a wide range of institutions, both public and private, and present several avenues of further study regarding preferences for wind energy.

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8 TABLES

Table 3: Model estimation results

	BASE	SEINT	SPINT	FSPINT
Mean onshore attributes				
Cost	-0.302***	-0.432***	-0.399***	-0.438***
	[0.0306]	[0.0500]	[0.0532]	[0.0647]
1x3 MW turbine	1.974***	1.868***	1.813***	1.790***
	[0.315]	[0.317]	[0.313]	[0.311]
2x1.5 MW turbines	1.997***	1.955***	1.975***	2.015***
	[0.511]	[0.511]	[0.506]	[0.516]
Distance 1,000 m	1.850***	1.709***	1.660***	1.656***
	[0.382]	[0.384]	[0.379]	[0.380]
Residents 100+	-1.121**	-1.054*	-1.058*	-1.115**
	[0.415]	[0.420]	[0.423]	[0.432]
Residents 11-100	-0.181	-0.155	-0.171	-0.202
	[0.247]	[0.248]	[0.244]	[0.246]
1x3 MW turbine x Distance 1,000 m	-3.939***	-3.759***	-3.632***	-3.583***
	[0.638]	[0.636]	[0.625]	[0.623]
2x1.5 MW turbines x Distance 1,000 m	-3.775***	-3.695***	-3.688***	-3.726***
	[0.789]	[0.795]	[0.789]	[0.800]
Mean offshore attributes				
Offshore Cost	0.0831***	0.0721**	0.0801**	0.120**
	[0.0231]	[0.0232]	[0.0249]	[0.0464]
Distance 12 km	0.390	0.508*	0.524*	0.514*
	[0.249]	[0.255]	[0.251]	[0.250]
Distance 18 km	1.621***	1.605***	1.629***	1.629***
	[0.277]	[0.278]	[0.275]	[0.274]
Distance 50 km	1.447***	0.613	0.601	0.606
	[0.266]	[0.391]	[0.387]	[0.387]
Location Island Anholt	-0.185	-0.584+	-0.553+	-0.542+
	[0.263]	[0.298]	[0.293]	[0.293]
Location Vesterhavet	0.566*	0.474*	0.463*	0.468*
	[0.228]	[0.230]	[0.227]	[0.228]
Location Island Møn	0.0689	-0.393	-0.480	-0.508
	[0.359]	[0.388]	[0.374]	[0.370]
Location Bay of Jammer	-1.290**	-1.869***	-1.834***	-1.841***
	[0.451]	[0.508]	[0.504]	[0.507]
Offshore location	2.678***	1.456***	1.497***	0.870
	[0.324]	[0.435]	[0.430]	[0.604]
Socio-economic interactions				
Male x Location Island Anholt		0.928***	0.926***	0.922***
		[0.274]	[0.272]	[0.273]
Male x Location bay of Jammer		1.627***	1.634***	1.646***
		[0.428]	[0.429]	[0.434]
Male x Location Island Møn		1.092**	1.046**	1.054**
		[0.373]	[0.361]	[0.358]
Household Income x Distance 50 km		0.164**	0.166**	0.167**
		[0.0582]	[0.0579]	[0.0580]
Age x Cost		0.00282***	0.00325***	0.00328***
		[0.000674]	[0.000684]	[0.000688]
Age x Offshore location		0.0259***	0.0237**	0.0239**
		[0.00753]	[0.00748]	[0.00759]
Distance beach x Cost			-0.00193+	-0.00238
			[0.000988]	[0.00146

		]
Distance beach x Offshore location		-0.0000270
		[0.0133]
Distance beach x Offshore Cost		0.000706
		[0.00130]
Distance potential offshore wind farms x Cost	-0.000454*	-0.000426
	[0.000190]	[0.000267]
Distance potential offshore wind farms x Offshore location		0.00325
		[0.00273]
Distance potential offshore wind farms x Offshore Cost		-0.000113
		[0.000248]
Number of turbines visible x Cost	-0.0317*	-0.0340*
	[0.0142]	[0.0144]
Number of turbines visible x Offshore location		-0.0809
		[0.113]
Number of turbines visible x Offshore Cost	0.0215^{+}	0.0261*
	[0.0113]	[0.0130]
No Turbines Onshore x Cost	-0.0312^{+}	-0.0597*
	[0.0170]	[0.0275]
No Turbines Onshore x Offshore location		0.246
		[0.296]
No Turbines Onshore x Offshore Cost	0.0472*	0.0802**
	[0.0214]	[0.0303]
Distance existing offshore wind farm x Cost		0.000132
		[0.000119]
Distance existing offshore wind farm x Offshore location		0.00215
		[0.00175]
Distance existing offshore wind farm x Offshore Cost		-0.000200
		[0.000138]
Density <751 kW x Cost		0.359*
		[0.183]
Density <751 kW x Offshore location		2.060
		[1.967]
Density <751 kW x Offshore Cost		-0.308^{+}
		[0.172]
Density 751 kW -1,500 kW x Cost		0.508
		[0.660]
Density 751 kW -1,500 kW x Offshore location		-2.985
		[6.298]
Density 751 kW -1,500 kW x Offshore Cost		-0.201
		[0.573]
Density >1,500 x Cost		-1.860
		[1.241]
Density >1,500 kW x Offshore location		-2.693
		[6.656]
Density >1,500 x Offshore Cost		1.717
		[1.147]

SD				
Onshore attributes				
1x3 MW turbine	-1.146*	-1.206*	-1.092*	-1.020+
	[0.530]	[0.482]	[0.495]	[0.524]
Residents 100+	4.043***	4.033***	3.968***	4.028***
	[0.594]	[0.612]	[0.614]	[0.627]
Offshore attributes				
Offshore location	2.472***	2.419***	2.421***	2.434***
	[0.193]	[0.194]	[0.190]	[0.190]
Distance 12 km	-1.255**	-1.277**	-1.187**	-1.085*
	[0.408]	[0.424]	[0.422]	[0.461]
Location Island Møn	2.405***	2.410***	2.142***	2.086***
	[0.454]	[0.448]	[0.459]	[0.454]
Location Bay of Jammer	3.029***	3.261***	3.344***	3.444***
	[0.616]	[0.592]	[0.584]	[0.590]
$N_{Respondents}$				1,754
$N_{Choices}$				7,016
LL(0)				-4863.1
LL(β)	-2897.3	-2851.9	-2840.6	-2834.2
R^2	0.404	0.414	0.416	0.417

Standard errors in brackets

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Sample characteristics and national averages

Variable (N=1,754)	Mean/share	Standard Deviation.	Min	Max	Statistics Denmark [a, b]
Age	45.1	12.6	20	67	43.8
Male	49.6 %				
Education					
Primary school	5.4%				24.9%
High school	11.1%				9.0%
Vocational	18.4%				36.8%
Short Secondary	10.0%				4.5%
Bachelor	34.2%				17.1%
Master or PhD	20.2%				8.1%
Household income per year (€) (HHI)					
HHI<26,667	14.0%				22.6%
26,666>HHI<40,000	9.2%				19.8%
39,999>HHI<53,333	14.3%				14.3%
53,332>HHI<66,667	11.7%				9.5%
66,666>HHI<80,000	13.8%				7.5%
79,999>HHI<93,333	12.3%				7.2%
93,332>HHI	24.6%				19.2%
Knowledge of wind turbines development plans in municipality	14.8%				
Number of turbines visible from permanent or summer residence					
0 turbines	86.5%				74.8%/ 76.0%[d]
1 turbine	1.9%				
2-3 turbines	5.4%				
4-5 turbines	3.2%				
6-10 turbines	1.9%				
>10 turbines	1.0%				
Distance to the beach (km)	7.8	8.4	0.016	52.3	
Distance to nearest potential offshore wind farm (km)	108.8	40.6	7.7	206.3	
Density of onshore turbines in postal code area					
No turbines in postal code area	43.2%				
Density of small turbines in postal code area (Number/km2)	0.048	0.071	0	0.578	
Density of medium turbines in postal code area (Number/km2)	0.0063	0.017	0	0.2158	
Density of large turbines in postal code area (Number/km2)	0.0030	0.016	0	0.2346	

Notes: [a)] Statistics Denmark, age of population in age group 20-67 FOLK1A, [b)] Statistics Denmark highest completed education HFUDD10 age group 20-69, [c)] Statistics Denmark, family income level INDKF122[d)]Based on numbers of households with onshore wind turbines in the viewshed from the permanent or summer residence reported in Ladenburg (2014) and Ladenburg et al. (2013) based on Danish national survey data.

Table 5: Correlation of spatial variables

	Distance to the beach	Distance to nearest potential offshore wind farm	No turbines in postal code area	Density of small turbines in postal code area	Density of medium turbines in postal code area	Density of large turbines in postal code area	Number of turbines seen from the residence
Distance to the beach	1						
Distance to nearest potential offshore wind farm	-0.153	1					
No turbines in postal code area	-0.215	0.132	1				
Density of small turbines in postal code area	-0.0121	-0.134	-0.588	1			
Density of medium turbines in postal code area	0.173	-0.010	-0.309	0.052	1		
Density of large turbines in postal code area	-0.0048	-0.083	-0.161	0.137	0.066	1	
Number of turbines seen from the residence	0.0368	-0.055	-0.172	0.184	0.163	0.093	1

Standard errors in brackets

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Willingness-to-pay for the main effects model.

Attributes	Main effect model	Sample average model
1x3 MW turbine	327.0***	294.4***
	[50.22]	[49.00]
2x1.5 MW turbines	331.0***	320.7***
	[65.82]	[63.81]
Distance 1,000 m	306.6***	269.6***
	[53.61]	[53.27]
1x3 MW turbine x Distance 1,000 m	-652.7***	-589.8***
	[90.17]	[86.49]
2x1.5 MW turbines x Distance 1,000 m	-625.5***	-598.9***
	[88.22]	[88.09]
Distance 1,000 m +1x3 MW turbine + 1x3 MW turbine x Distance 1,000 m	-19.11	-25.78
	[53.76]	[50.97]
Distance 1,000 m +2x1.5 MW turbines + 2x1.5 MW turbines x Distance 1,000 m	12.09	-8.682
	[55.66]	[54.65]
Residents 100+	-185.7**	-171.9**
	[61.54]	[61.59]
Residents 11-100	-30.04	-27.72
	[39.79]	[38.72]
Offshore location	612.5***	549.2***
	[80.78]	[74.03]
Distance 12 km	89.13+	112.2*
	[53.76]	[49.78]
Distance 18 km	370.8***	348.5***
	[69.39]	[64.02]
Distance 50 km	331.0***	317.5***
	[61.05]	[57.15]
Location Island Møn	15.77	8.346
	[81.97]	[74.59]
Location Vesterhavet	129.4*	98.97*
	[54.38]	[50.27]
Location Island Anholt	-42.23	-20.03
	[60.03]	[56.08]
Location Bay of Jammer	-295.0**	-219.0*
	[111.0]	[102.7]

Standard errors in brackets

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

9 Appendix

Full model

	Mean	Gender	Age	Household Income per year	Knowledge of development plans onshore	Distance Coast	Distance potential offshore wind farms	Number of turbines visible	Density <751 kW	Density 751 kW -1,500 kW	Density >1,500 kW	Density = 0
Mean onshore attributes												
Cost	-0.459***	-0.00861	0.00319**	0.00224	0.0277	-0.00274+	-0.000483+	-0.0343*	0.339+	0.537	-2.262+	0.0847**
	[0.0730]	[0.0242]	[0.000985]	[0.00561]	[0.0381]	[0.00150]	[0.000272]	[0.0148]	[0.186]	[0.700]	[1.332]	[0.0306]
1x3 MW turbine	1.942**	-0.342	-0.00282	0.0380	0.358							
	[0.690]	[0.321]	[0.0129]	[0.0730]	[0.474]							
2x1.5 MW turbines	1.099	0.175	0.0298+	-0.0751	0.549							
	[0.998]	[0.432]	[0.0177]	[0.101]	[0.682]							
Distance 1,000 m	3.041***	-0.268	-0.0212	-0.0446	0.674							
	[0.803]	[0.352]	[0.0143]	[0.0830]	[0.519]							
Residents 100+	0.109	-0.343	-0.0338	0.0849	-1.111							
	[1.029]	[0.541]	[0.0216]	[0.123]	[0.796]							
Residents 11-100	0.860	0.333	-0.0147	-0.122	-0.791							
	[0.583]	[0.403]	[0.0139]	[0.0921]	[0.598]							
1x3 MW turbine x Distance 1,000 m	-3.925***											
	[0.683]											
2x1.5 MW turbines x Distance 1,000 m	-4.192***											
	[0.876]											
Mean offshore attributes												
Offshore Cost	0.134*	0.00386	0.000572	-0.00882	-0.0139	0.000859	-0.00000331	0.0268*	-0.249	-0.246	1.937	-0.0540+
	[0.0661]	[0.0301]	[0.00115]	[0.00697]	[0.0457]	[0.00133]	[0.000255]	[0.0135]	[0.174]	[0.600]	[1.245]	[0.0277]
Distance 12 km	0.0937	0.445	-0.00990	0.125	0.0992							
	[0.890]	[0.494]	[0.0189]	[0.113]	[0.722]							
Distance 18 km	2.357*	-0.286	0.00460	-0.144	-0.0566							
	[0.974]	[0.481]	[0.0197]	[0.114]	[0.763]							
Distance 50 km	-0.199	-0.405	0.0207	0.235*	-0.428							
	[0.794]	[0.435]	[0.0171]	[0.101]	[0.636]							
Location Island	-0.696	0.715+	-0.00278	0.0344	0.333							

Anholt	[0.735]	[0.387]	[0.0155]	[0.0901]	[0.584]							
Location	-1.325^{+}	0.745	0.0331^{+}	0.0256	0.0361							
Vesterhavet	[0.796]	[0.472]	[0.0183]	[0.108]	[0.675]							
Location Island	-1.302	1.165*	0.00306	0.144	-1.305							
Møn	[1.108]	[0.549]	[0.0219]	[0.128]	[0.799]							
Location Bay of	-3.115**	1.768*	-0.00432	0.199	0.878							
Jammer	[1.052]	[0.695]	[0.0234]	[0.153]	[1.042]							
Offshore location	2.463*	0.107	-0.00484	-0.0645	0.954	-0.00124	0.00293	-0.119	1.555	-2.198	-4.774	0.184
	[1.123]	[0.550]	[0.0214]	[0.126]	[0.803]	[0.0137]	[0.00280]	[0.117]	[1.991]	[6.522]	[6.978]	[0.300]
Standard deviation onshore attributes												
1x3 MW turbine	-0.992											
	[0.656]											
Residents 100+	4.399***											
	[0.709]											
Standard deviation offshore attributes												
Offshore location	2.509***											
	[0.203]											
Distance 12 km	1.201*											
	[0.484]											
Location Island	2.056***											
Møn	[0.478]											
Location Bay of	3.767***											
Jammer	[0.669]											
$N_{Respondents}$	1,754											
$N_{Choices}$	7,016											
LL(0)	-4863.1											
LL(β)	-2802.9											
McFadden R2	0.424											

Standard errors in brackets

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$S

Paper D

Comparing offshore and onshore wind development considering acceptance costs

Cost of onshore and offshore wind expansion in Denmark: LCOE estimates including acceptance costs

Henrik K. Jacobsen and Pablo Hevia-Koch

Abstract

Cost efficient deployment of wind energy is in focus for reaching ambitious targets for renewable energy and transforming the energy supply system to one based on renewables. However, as more wind is being deployed the available sites onshore become less attractive in terms of wind conditions and capacity factor and more resistance from population groups affected in the deployment areas results in a reduction of areas that can be developed. We consider three different methods for estimating acceptance costs, one based on compensation and property purchase costs, one based on property value loss due to wind turbines, and one based on willingness to pay calculated from a stated preference study. Utilising these methods, we provide an estimation of Levelised Cost of Energy (LCOE) for an expansion in Denmark of onshore and offshore wind capacity of 12 GW. We find that the three methods provide similar estimates for local acceptance, but that a high range of uncertainty exists in the upper bound of these acceptance costs. The main conclusion points towards the fact that onshore does not have a clear-cut cost advantage over offshore when considering substantial amounts of wind capacity expansion, and that further expansion of wind in Denmark has to be done with careful consideration of this fact. Otherwise, the risk is following a deployment path that does not minimise cost but instead transfers these costs from developers to the public.

1 Introduction

Cost efficient deployment of wind energy is in focus for reaching ambitious targets for renewable energy and transforming the energy supply system to one based on renewables. Wind energy is one of the most cost-efficient renewable technologies and increasing amounts of wind energy is being installed in Europe and worldwide. In many countries, the cheapest wind resources on-shore are now competitive with conventional generation. However, as more wind is being deployed the available sites onshore become less attractive in terms of wind conditions and capacity factor and more resistance from population groups affected in the deployment areas results in a reduction of areas that can be developed. That means further onshore potentials become scarce and development has been moving off-shore.

Even though recent years have shown a significant decrease in costs for offshore wind, and as a consequence a narrower differential between onshore and offshore wind costs, offshore wind remains more expensive than onshore wind. As a consequence of the shift from onshore to offshore projects and the higher costs associated to these, the expansion of wind contribution to electricity generation has become more expensive resulting in slower growth. Financing of the necessary support has become more of a public issue with electricity consumers, especially industry, increasingly pressuring to be exempted from contributing to financing via public service obligations.

One fundamental question is whether the onshore potentials could be made available with compensation to the population groups affected by the deployment onshore, or if the willingness-to-pay for moving wind offshore is more considerable than the additional costs of developing offshore. This question is relevant to address as far as possible if a cost-efficient deployment and a higher share of renewables are to be achieved. Here, the focus is on trying to determine the acceptance costs for Danish onshore development of wind, to add these costs to the primary development costs, and finally to compare this entire cost curve to the offshore wind costs.

2 Levelised cost of energy

When comparing costs of energy, the levelised cost of energy (LCOE) is a commonly used measure, which focuses on the cost of supplying energy (electricity) and do not include properties as the varying quality of supply and the fluctuating value of supply at different hours of the day and year. We are focusing on comparing onshore and offshore wind development including different sites that may imply a little variation as mentioned above, but not with significant issues as when comparing across more fundamentally different technologies.

There may be minor differences in the lifetime of turbines and the variability of the generation, but they are generally small within the wind technology, and therefore the LCOE is a reasonable measure for the comparison here.

2.1 LCOE assessment for power generators

Calculating the LCOE is a tool not only used for assessing the economic performance of offshore wind energy but is utilised throughout the industry to evaluate the cost-effectiveness of different forms of power generation technologies and to compare them with each other. In that way, a comparison also between conventional and renewable power generators can be made even though these technologies can differ significantly in their cost structure. While conventional generators usually face a high share of their total lifetime costs with variable costs such as expenses for fuel, for most renewable energy sources a significant part constitute the investment costs occurring at the beginning of the investment projects, particularly for those technologies where no cost for fuel accrues. The LCOE thus is, on the surface, a straightforward measure for the investigation scope of an energy market as a whole to examine the competitiveness of different energy technologies. The LCOE expresses the cost over the lifetime of an asset related to the expected energy production, which is usually based on average annual production, and it furthermore accounts for the time value of money by discounting the cost and energy over the lifetime. While it can be challenging to identify the correct discount factor to be used for calculating LCOE when comparing different technologies, in the case of comparing offshore with onshore wind, this is not a difficulty, and therefore LCOE is an excellent tool to use.

While comparing the LCOE for different power generation systems within a specific market is a simple indicator to identify which technology produces electricity at the lowest cost, it is not so simple to compare LCOE analyses of different markets or countries even for the same power generation technology. This is due to the fact that different countries have various regulations and guidelines of how to adapt the LCOE calculation with regard to its inputs and the regulatory considerations. A Danish partnership of different commercial and state entities has tried to propagate a standard approach to calculate the LCOE specifically for offshore wind energy (Forcherio, 2014) in order to facilitate a cost comparison of electricity production in a growing joined European energy system, but national regulations still have various methods for the LCOE assessment.

2.2 LCOE comparison of wind using national characteristics/differences

ECOFYS published a report about the different assessments of calculating the LCOE in different European countries (Visser & Held, 2014). It gives examples of the procedures of LCOE calculations used for subsidy tariff level setting processes employed in the Netherlands, Germany, United Kingdom and Spain. It indicates that the quality of LCOE estimates primarily is subject to the quality and the level of detail of the input data. Different countries use various assumptions of the scope of capital and operational cost components. In order to compare the approach of the United Kingdom , which is of interest for the present analysis, to the standard guideline for LCOE calculations in Denmark, a report of the Danish Energy Agency is used, which describes the financial and technical assumptions behind LCOE analyses in this country (Danish Energy Agency, 2015b). The comparison of the United Kingdom and Denmark regarding the relevant factors as presented by (Visser & Held, 2014) is shown in Table 2.1. The factors are indicated with yes or no depending on their inclusion in the respective LCOE analysis method.

Country	United Kingdom	Denmark
Equipment cost[1]	Yes	Yes
Other investment[2] & fixed planning cost	Yes	Yes
Capital cost (debt, equity)	No	No
O&M cost	Yes	Yes
Decommissioning cost	Yes	No
Cost assessment for grid connection	Yes	No
Network related cost/Balancing cost	Yes	Yes
Cost of market integration/Grid expansion cost	No	Yes

Table 2.1: Comparison of LCOE evaluation methods in the UK and Denmark

As seen in Table 2.1, whereas the general CAPEX and OPEX are included in the LCOE calculation in both countries, the inclusion of grid connection cost into the capital cost, in fact, differs due to different regulations in both countries. Also, the decommissioning costs are included in the British

[1] Technology cost, e.g. turbines, control systems

[2] Construction/installation cost, foundation cost

method and are taken into account as a "provisioning fund" as part of the total operational cost. By accumulating these payments over the lifetime, a fund is created that serves to pay the decommissioning expenditures at the end of the lifetime. The Danish approach, however, assumes that the decommissioning costs are offset by the residual asset value and thus are excluded from the assessment (Danish Energy Agency & Energinet.dk, 2014). The difference in both approaches may impact differently onshore and offshore projects, depending on the need to decommission foundations. The electrical balancing costs are included in both regimes, but a broader impact on investments concerning the electricity system is not considered in the British methodology. In Denmark, on the other hand, the costs for adjusting or expanding the electrical infrastructure, which is of particular importance for renewable energy sources, is included in the calculation.

The height of balancing costs differs in the countries due to the respective production portfolio and the flexibility of and the transmission with the surrounding electricity system. Despite a high share of energy production stemming from wind power, the average balancing costs for wind power producers in Denmark is estimated at 2 EUR/MWh, which is in the lower range of the wind energy balancing costs in Europe, due to the interconnection with other electricity markets and most notably the flexible hydropower plants in the Norwegian power system (Danish Energy Agency, 2015b). The balancing costs for wind power producers in the United Kingdom in contrast are estimated at 3 EUR/MWh at the upper range of average wind energy balancing costs in Europe, likely due to the poorer interconnection to the electricity grid of continental Europe (European Wind Energy Association, 2015), or differences in the design of the balancing market, in regards to regulating power and frequency restoration reserves.

As a consequence of the different approaches and values regarding the above-mentioned factors included in the LCOE analyses, a comparison of the LCOE of specific technologies assessments between different countries is somewhat biased. A general trend of cost development of specific technologies over different countries can therefore preferably be evaluated by relative cost reduction projections over time than by absolute values of specific years.

Another highly sensitive parameter for the LCOE calculation is the choice of the discount rate as stated in (Visser & Held, 2014), which usually varies throughout different countries. This procedure is due to a different perception of risk and various estimations of alternatives for public investments in specific national markets. If the risk for an investment is assumed to be high, an increased discount rate will reflect a higher needed return on the investment in order for the project to be regarded as profitable. The risk depends on the general market conditions such as the supply chain market or the dependency of imports and is estimated differently in different countries. Having many alternatives to the investment in a particular market furthermore generates opportunity costs for an investor that could be spent on other projects. The volume of alternative investment opportunities obviously also varies from country to country, thus also being reflected in different discount rates. The more alternative project possibilities there are investable, the more expected return is needed for the specific investment to be attractive enough.

The characteristic values of discount rates that are suggested by governmental bodies can differ significantly between countries and in particular between the United Kingdom and Denmark. While the British government suggests a discount rate of 10% (nominal) for all projects to be able to have a neutral national comparison of projects in terms of financing and risk assessment(DECC (Department of Energy & Climate Change), 2013), the Danish regulation suggests a discount rate of 4% (real)(Danish Energy Agency, 2013). Even though differing in nominal and real terms, inflation is not likely to compensate this gap if other factors such as market risks are not assessed in the difference between real and nominal discount rate. As a consequence, Danish LCOE assessments of offshore wind energy usually are characterised by a tendency of having lower levelised costs than British evaluations, due to the lower financing costs in Denmark. Therefore, the limited comparability between the absolute values of LCOE has to be kept in mind when comparing the economic performance of offshore wind energy between different countries.

From an investor's point of view, the LCOE assessment within a national market is also subject to other limitations. Since the projection of energy generation, especially for fluctuating renewable energy sources, is prone to uncertainty, an LCOE analysis does not always express the full profitability of a project for the investor, or it contrarily underestimates the LCOE by overestimating energy production. Moreover, monetary profits over the lifetime of the asset are not considered when looking exclusively at the LCOE, so that support schemes and electricity market prices are not integrated into the analysis. An attractive support scheme policy can, for instance, outweigh the accruing cost so as to promote a specific technology. Similarly, a particular market price structure can compensate for the occurring costs with the result that particular technologies can be more profitable although they are constituted by a higher LCOE. As (Joskow, 2011) argues, a comparison of LCOE for different technologies implies to treat the produced electricity as a uniform product which is always or in average priced equally. Yet due to market price fluctuations or different capacity factors and thus operating times the revenue stream can affect the actual profitability of the asset considerably.

A more detailed business case analysis which determines the project viability by other indications like the NPV or the internal rate of return (IRR) is more suitable for an investor, as they typically also underlie a more detailed cash flow analysis and provide a broader picture for investment decisions (Visser & Held, 2014). In fact, when conducting analyses of decisions with alternatives of investment, the scientific literature finds out the NPV to be the usual measure to determine the economic viability of a project (González et al., 2011). For the present analysis, though, these elements are not necessary, and we will only utilise the LCOE as the cost measure.

3 Onshore DK wind potentials and the cost curve

The wind capacity onshore in DK is 3954 MW at the end of 2016 (Danish Energy Agency, 2017). The additional potential estimated by (Naturstyrelsen, 2014) based on reporting from Danish municipalities are 2860 MW of which 1870 are in already designated planned areas. This adds up to approximately 6600 MW of long-term potential existing today.

This is a relatively conservative estimate and what is used in some of the modelling analysis of generation capacity options is a potential of around 6000 MW in 2012 rising to around 8000 MW for 2030, due to marginal expected additional planning and larger turbines (Balyk et al., n.d.). This is only a fraction of the possible technical potential of around 350 GW if all areas are used regardless of land use constraints and impacts on dwellings (Danish Ministry of Taxation, 2016).

In (Energinet.dk, 2015) an alternative method for calculating potentials reach a total economic attractive onshore potential in DK of around 12 GW for the year 2030. This is a long-term potential (and uncertain) since it requires that all the relevant buildings in the immediate vicinity of future development can actually be purchased. Up to 2030, there may be some difficulties in fully realising that. In our analysis, we base the cost curve on this onshore potential.

3.1 Investment cost for onshore DK development

Onshore investment costs have been declining globally and are now in the region 1000 EUR/kW to 1950 EUR/kW. For Denmark, it is assumed that investment costs will decline to around 1000 EUR/kW between 2020 and 2025. In comparison, the Technology Catalogue (Energinet.dk & Danish Energy Agency, 2017) assumes a reduction from 1070 EUR/kW to 910 EUR/kW for the period 2015 to 2030. Recent information from Vestas financial reports Q2017 suggests that average turbine prices have already dropped to just above 800 EUR/kW, although it is not clear whether it includes project management, grid connection, etc.

For the construction of Danish cost curves, a value of 1000 EUR/kW is used independently of the amount of wind installation. It may be argued that larger volume of installation may increase the restriction on the technology used, including size (hub height), and noise-reducing designs resulting in rising investment cost for larger volumes. We do not include this possible effect and also do not consider further benefits from increased turbine size from the present size of 3-4 MW.

3.2 Operation and maintenance costs

The operation and maintenance costs are assumed to be proportional to generation at around 8-10 EUR/MWh annually. In comparison (The Danish Wind Turbine Owners' Association, 2014) reports an estimate around 11 EUR/MWh for lifetime O&M cost for Danish onshore turbines. These costs may be influenced by longer lifetime for turbines in the future, due to slower technical progress (replacement with only slightly more efficient turbine) and a more substantial part of the remuneration from market income. Higher relative value of generation in later part of the lifetime may induce more maintenance effort than when all revenues from support are earned in the first 8-10 years of the lifetime. Due to this and a relatively stable turbine size, only minor reduction in maintenance cost must be expected. (Energinet.dk, 2016) estimates that present land wind requires a market price of around 13-16 EUR/MWh to maintain profitability after the subsidy is expired, which is consistent with the slightly higher O&M costs (more than 10-11 EUR/MWh) at the end of turbine lifetime.

3.3 Wind sites and the onshore Danish LCOE cost curve

Cost curves combine potentials (x-axis) with associated costs (y-axis). The potentials can be represented as the annual generation or as capacity. The cost concept can be defined in various ways of which the most commonly used are total investment cost per capacity unit or the LCOE per generated unit. For a discussion of LCOE construction see section 2. For a comparison of technology options with similar generation value (controllability), but different capacity factor (full load hours), and under similar economic constraints, the LCOE comparison is suitable and will generally be used here.

In Denmark, the lifetime assumptions were earlier for 20-22 years(Energinet.dk & Danish Energy Agency, 2017), but this is expected to increase to now around 25 years for presently installed turbines. Naturally, the technical lifetime is longer than the economic lifetime and as maintenance costs decrease this also leads to a longer economic lifetime of turbines. Uncertainty for this parameter may imply higher LCOE if only 20 years lifetime is achieved. Finally, the interest rate (discounting) used influences the LCOE with higher discounting of future electricity generation increasing the LCOE (see Figure 4). The low value of 4% used here (corresponding to social discount rate) reduce the LCOE relative to other studies using higher rates for example based on private financing cost calculations for business investing in wind development using WACC.

Apart from the cost side of the LCOE, the annual energy production (AEP) is the most critical parameter for the level of LCOE. Wind conditions and the power curve for individual turbines used will determine this. If we assume similar turbine designs (identical size, rotor diameter), the difference will be caused by the specific wind conditions (and topography) at the individual sites. In reality, there may also be variations in specific turbine designs for different wind conditions, but this is assumed to affect the cost characteristics relatively little. The following data for Denmark include this aspect, but not at the full microscale level. Figure 2 illustrates the actual capacity factor for onshore turbines in Denmark built recently and Figure 1 the calculated capacity factor for the wind potential identified in (Energinet.dk, 2015). Capacity factor is lowest for the turbines already in operation since 2010 (blue) compared to the larger and newer turbines in operation only from 2015 (red).

Based on the realised capacity factor for newer larger turbines in Denmark it is reasonable to assume that future large turbines (3.5 MW) will achieve approximately the same average capacity factor of around 35%.

In (Energinet.dk, 2015) the calculated potentials reach a total economic attractive onshore potential in DK of around 12 GW for the year 2030. This analysis is based on assessing the gross potential in areas where only a few dwellings will be affected and excluding areas with nature conservation constraints etc. This analysis assumes turbines of size 3.5 MW and only single 2600 m by 1200 m areas where either 3 or 5 turbines can be installed in a north-south direction requiring a maximum of 3 purchases of affected dwellings. These are dwellings in the near vicinity of the turbines (less than 600 m corresponding to 4 wind turbine heights). The method is thereby quite restrictive in not assessing options with less than three turbines or possible overlapping areas as well as cases with more than 3 low-value dwellings. Hereby the potential can be characterised as conservative without considering the restriction from local planning and neighbour compensation. However, the assumption on when it will actually be possible to purchase all the properties required is uncertain limiting the available short-term potential.

Comparing to international studies (Morthorst & Kitzing, 2016; Wiser et al., 2011, 2016) our Danish assumptions for onshore investment cost, O&M cost, lifetime and wind conditions (capacity factor) are in similar ranges, and therefore the resulting LCOE is at the low end of the range seen in Figure 3 and Figure 4.

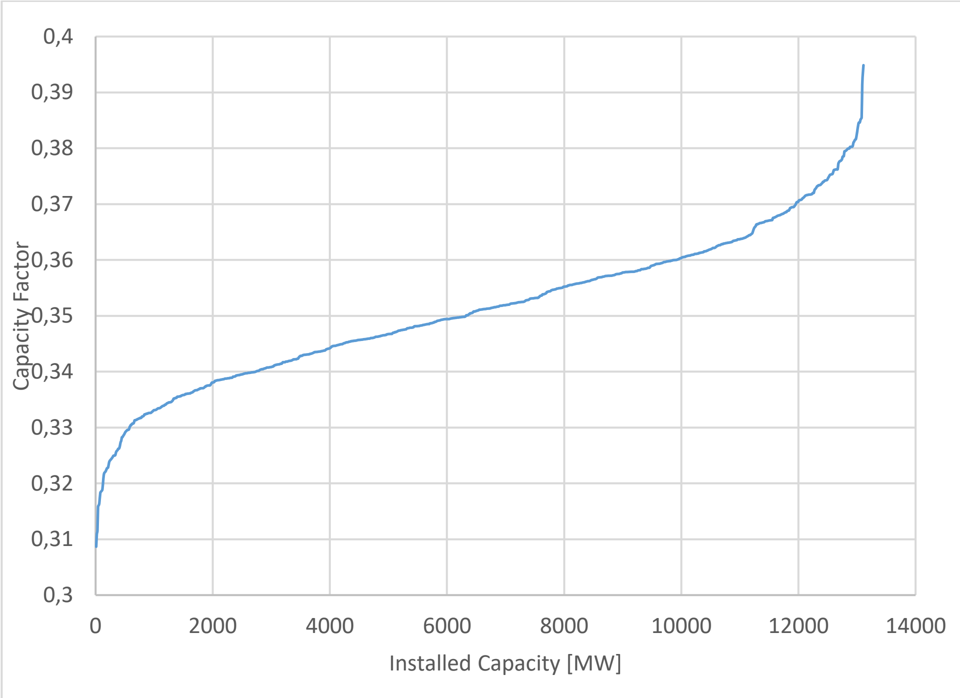

Figure 1: Capacity factor variation for future DK sites for onshore wind development with 3.5 MW (source:(Energinet.dk, 2015))

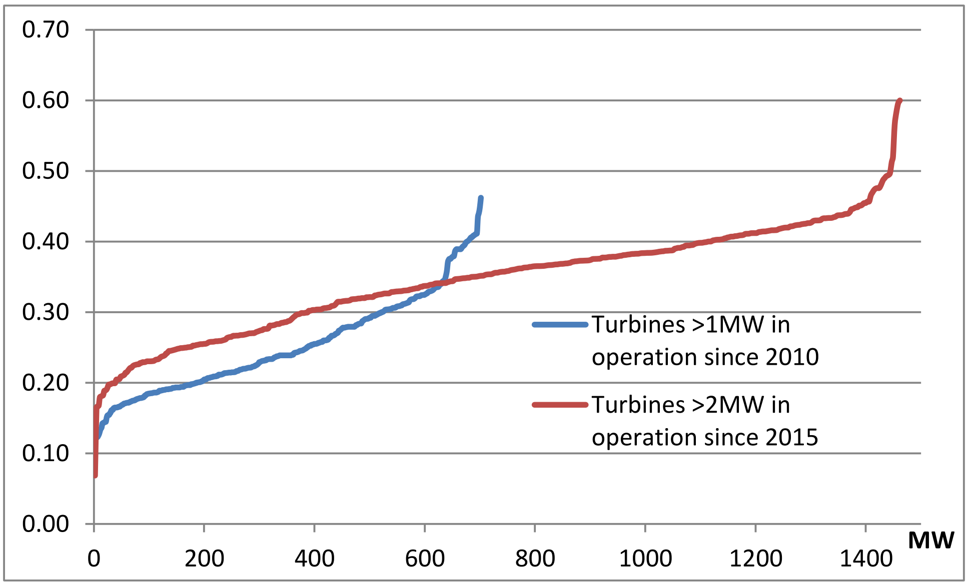

Figure 2: Realised capacity factor variation for larger DK onshore turbines in operation 2010-2016 (own calculation based on (Danish Energy Agency, n.d.))

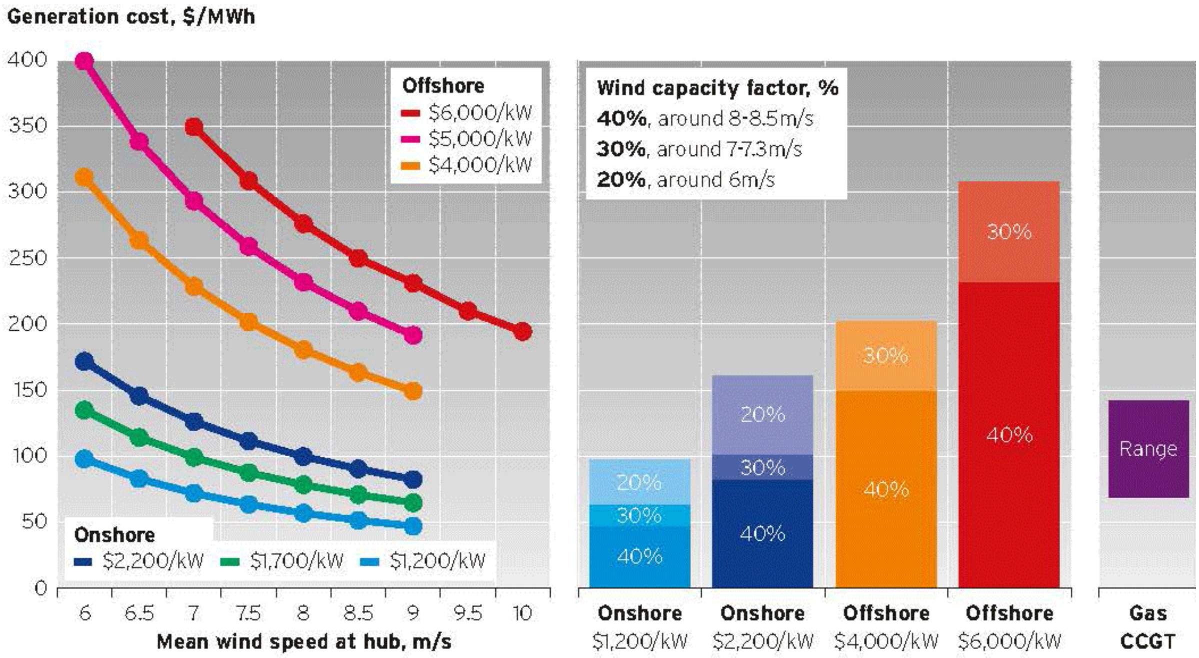

Figure 3: International comparison of LCOE for onshore and offshore wind depending on capacity factor and investment costs. Source: (Millborrow, 2016)

In Figure 3 the sensitivity of LCOE to investment cost and wind speed is given for both onshore and offshore wind. Only the lower cost level (1200 USD/kW) is similar to our assumption of 1000 EUR/kW. Furthermore, our capacity factor as shown in Figure 2 ranges from 30% to 40%, equivalent to the two lower light blue areas in the first column (4.5-6 USD cents/kWh), right panel of Figure 3.

Looking at estimates provided by (Wiser et al., 2011) shown in Figure 4, the left panel indicates an LCOE of 5 USD cents/kWh with low investment cost at a 35% capacity factor. The right panel indicates a reduction of LCOE by 1.5-2 USD cents/kWh by reducing the discount rate from 7% to 3%. Furthermore, (Wiser et al., 2011) illustrate the 2009 cost conditions and therefore the low-cost estimates may correspond with 2020-25 expectations for onshore. For offshore the general expectations for costs have been reduced following the recent price drops in auctions.

Thus for the low investment cost curve (1200 USD/kW) and a capacity factor around 35%, the LCOE lies around 5-6 USD cents/kWh in the two studies, which has to be reduced slightly due to our use of a discount rate of 4% compared to the 7% used in the curves shown in Figure 4, left panel. The comparable Danish LCOE based on these studies should thus be in the range 3.5-4.5 USD cents/kWh corresponding to 3-4 c€/kWh.

(Morthorst & Kitzing, 2016) state for offshore comparison that average onshore LCOE is around 5 USD cents/kWh for the low investment cost option (the same 1200 USD/kW) considering a capacity factor between 30% and 40%.

4 Offshore DK wind potentials and the cost curve

4.1 Current status of offshore wind energy in Denmark.

Offshore wind energy has been growing in Denmark in a sustained manner, since the first offshore wind turbine park, *Vindeby*, was erected in 1991. As of 2017, there are 12 offshore wind turbine farms in Denmark, since the decommissioning of the *Vindeby* park, with a total installed capacity of 1271 MW (Danish Energy Agency, 2015a).

It is expected for offshore wind to keep expanding in future years, as part of the strategy regarding renewable energy goals. Currently, there are eight projects assigned for environmental impact assessment or development with a total nameplate capacity of up to 2.2 GW: *Horns Rev 3, Kriegers Flak, Vesterhav Nord og Syd, Nissum Bredning, Omø Syd, Jammerland Bugt, Mejl Flak,* and *Lillebælt Syd.*

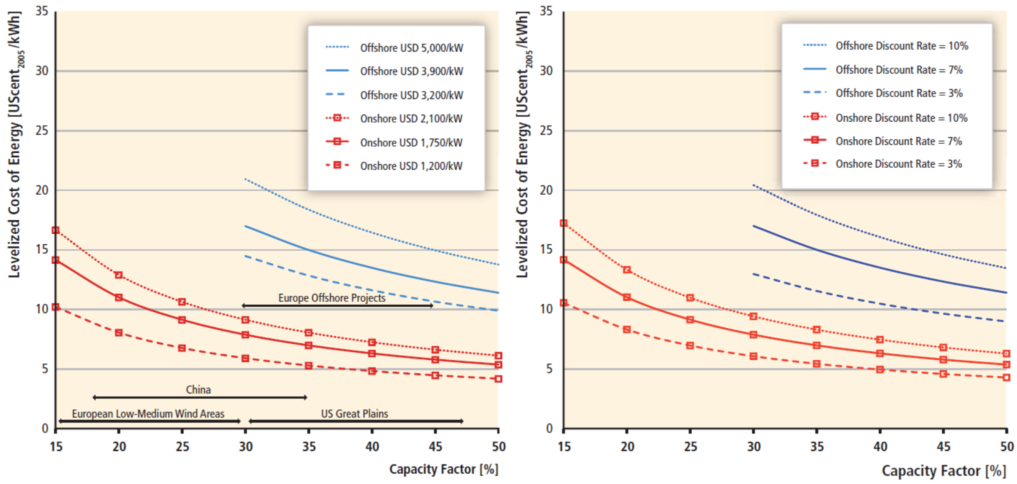

Figure 4: Estimated levelised cost of on- and offshore wind energy, 2009: as a function of capacity factor and investment cost* (left) and as a function of capacity factor and discount rate (right) (reproduced from ((Wiser et al., 2011, fig. 7.23))

Furthermore, a number of tenders are being carried out for the development of new offshore wind energy farms. Some of the tender areas are offshore locations close to the shore, which aim to lower the costs for installing and operating the wind turbines, as for example *Sejerøbugten, Smålandsfarvandet* and *Sæby* (Danish Energy Agency & Energinet.dk, 2013).

4.2 Costs for Offshore wind

In comparison with onshore wind farms, constructing offshore wind turbines is a more expensive undertaking, and significantly capital-intensive. Furthermore, costs will vary greatly depending on the location, due to water depth, distance to coast, sea conditions, and more (Kitzing & Morthorst, 2015).

4.2.1 Investment costs

Commonly the total investment costs are broken down into various cost components. By presenting different shares for the cost components, different projects can be compared with each other in more detail, since for instance the effects of the geographical characteristics of the offshore wind farms on the investment can be revealed. The comparison of different wind farms, however, in general, is more accurate for projects with similar commissioning time, similar geographical characteristics or comparable technical characteristics as for instance the type of turbines or the installed capacity.

Table 4.1 presents different cost breakdowns of offshore wind farms found in the literature for different publication years. The inclusion of components differs when looking at the different cost breakdowns, making it challenging to allocate different costs where they actually arise. Mainly, the installation cost is sometimes not reflected independently in presented cost breakdowns, leading to a distortion of the remaining cost component shares. Also, the cost for electrical components is sometimes not addressed in cost breakdowns, due to the fact that these components are not always included in the project scope of the wind farm investor, but are constructed and invested by other entities. The problem of different investment cost splits throughout the literature has been mentioned by (Voormolen et al., 2015).

4.2.2 Operation and maintenance costs

Operation and Maintenance costs (O&M) or OPEX are expressed within the annual costs after commissioning of the farm and tend to increase over the farm's lifetime. The O&M costs are either expressed as variable cost per MWh generated or as a fixed cost per MW installed capacity, also lacking a standard approach for their definition. This is due to the fact that different parts of OPEX are variable cost, such as repair costs and to a certain extent spare parts and maintenance (which are likely to be related to the production level) and other parts are fixed costs, such as insurance costs, administration and regular maintenance (which are likely to be related to the fixed installed capacity. According to (Energinet.dk & Danish Energy Agency, 2017), for 2015 fixed O&M costs are 57,300 EUR/MW/year, while the variable costs are 4.3 EUR/MWh.

One can combine the variable cost depending on the energy produced and the residual fixed cost to obtain

	EWEA (2009)	IRENA (2012)	Kitzing & Morthorst (2015)
Turbine	49%	44%	40%–60%
Foundation	21%	16%	20%
Electrical	21%	17%	
Installation		13%	25%
Other	9%	10%	

Table 4.1: Indicative cost breakdowns of offshore wind farms in the literature

the total OPEX cost. For offshore wind, the variable part of the OPEX is estimated to be half of the total OPEX (Voormolen et al., 2015). In general, information regarding OPEX is hard to obtain. In the literature it is estimated to be in a range of 15–49 EUR/MWh (Kitzing & Morthorst, 2015) in variable terms and 2.2%–4% in fixed terms as share of CAPEX (DECC (Department of Energy & Climate Change), 2013; Heptonstall et al., 2012; Prässler & Schaechtele, 2012). Over the total lifetime of the farm, the OPEX can encompass 25–30% of the total project cost (Kitzing & Morthorst, 2015).

Considering the aforementioned geographical cost drivers, mostly the distance to the nearest maintenance port directly affects the OPEX, due to the cost connected to the travel time of the maintenance vessel and potentially rougher weather conditions at sites further offshore, which constrain the operation time on site. After assessing the total cost of a wind farm project, the LCOE can be estimated when predicting the energy generation of the farm over the total lifetime.

4.3 The Danish offshore LCOE cost curve

As with the Danish onshore cost curve, we are interested in creating a cost curve that combines the potential exploited with the associated cost of doing so, for offshore wind energy. The factors that affect the costs for different potentials, we could consider three general categories: technical costs that will vary with water depth and distance to shore, costs associated to availability and profiles of wind in the area, and costs associated with the social impact produced by the wind farm.

From a technical perspective, as different wind sites are exploited, two main variables will affect these previous costs: distance to shore, and water depth. Technical costs will be affected by both variables: as water depth increases it becomes more expensive to install the wind turbines, and at specific water depths, more expensive foundation technologies have to be used. Similarly, as the distance to shore increases, O&M becomes more expensive and the costs for cabling during installation, as well as the costs related to port availability and installation time increase as well.

As with onshore wind energy, when looking at the prospect of future offshore wind energy expansion, we must account not only for the total existing potential in terms of areas with wind but also for the associated evolution of cost as this potential is exploited. As offshore wind energy grows, the first areas to be utilised will be those with lower costs, and therefore leaving for later exploitation high-cost areas. Even if we ignored the time dimension and associated technological changes, sites that are exploited earlier will still present lower costs, either due to being sites with better wind potential conditions, or with conditions that make investment costs lower (such as water depth).

Based on data obtained by the RESOLVE model, and presented in (Beurskens & Hekkenberg, 2011), we construct a cost curve for offshore wind potential in Denmark that considers a total offshore wind expansion potential of 10.7 GW. Based on the data and cost levels available at the time the LCOE levels range between 9 c€/kWh for small amounts of exploited potential, climbing steadily up to approximately 17 c€/kWh before spiking up to a final level of 19.9 c€/kWh for the full potential. This upwards sloping curve represents the increased costs of further exploiting wind sites, as discussed above. These estimates are consistent with several other studies finding prognosis of offshore wind LCOE (Fichtner/prognos, 2013; Fraunhofer ISE, 2013; International Renewable Energy Agency, 2012a; Mone et al., 2015; The Crown Estate, 2012; TKI Wind op Zee, 2015), a selection of which is shown in Figure 5. It is interesting to note the extensive range of uncertainty regarding the levels of LCOE prognosticated.

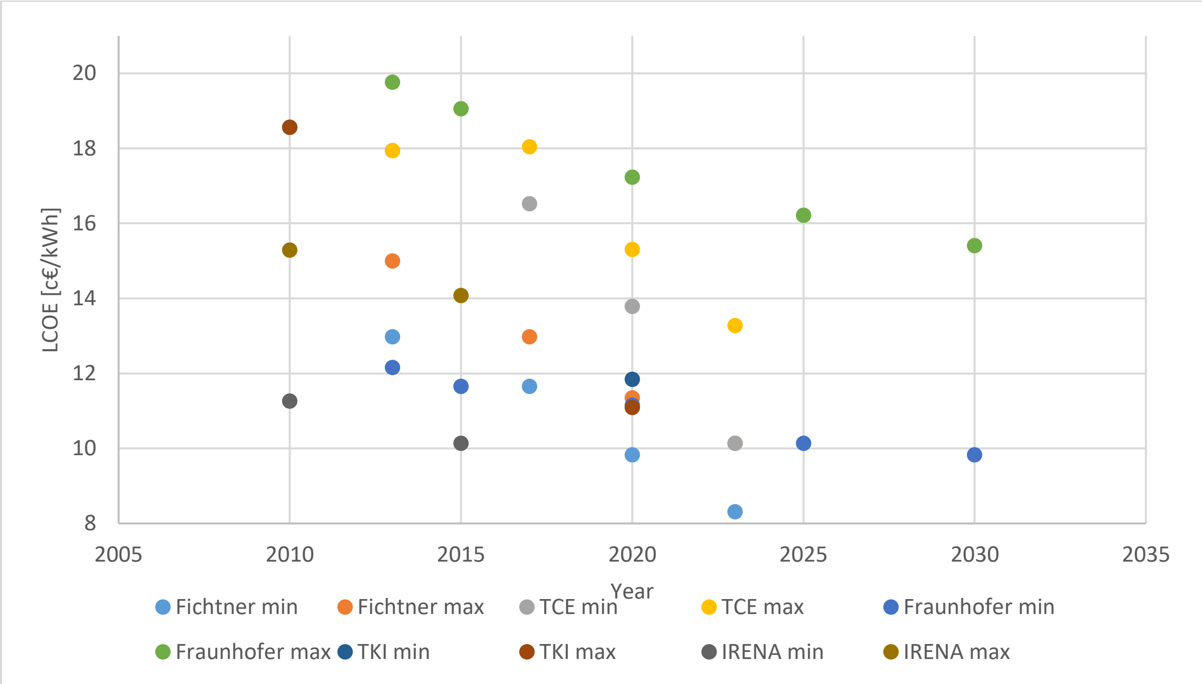

Figure 5: LCOE prognosis for offshore wind, own work based on (Fichtner/prognos, 2013; Fraunhofer ISE, 2013; International Renewable Energy Agency, 2012b; The Crown Estate, 2012; TKI Wind op Zee, 2015).

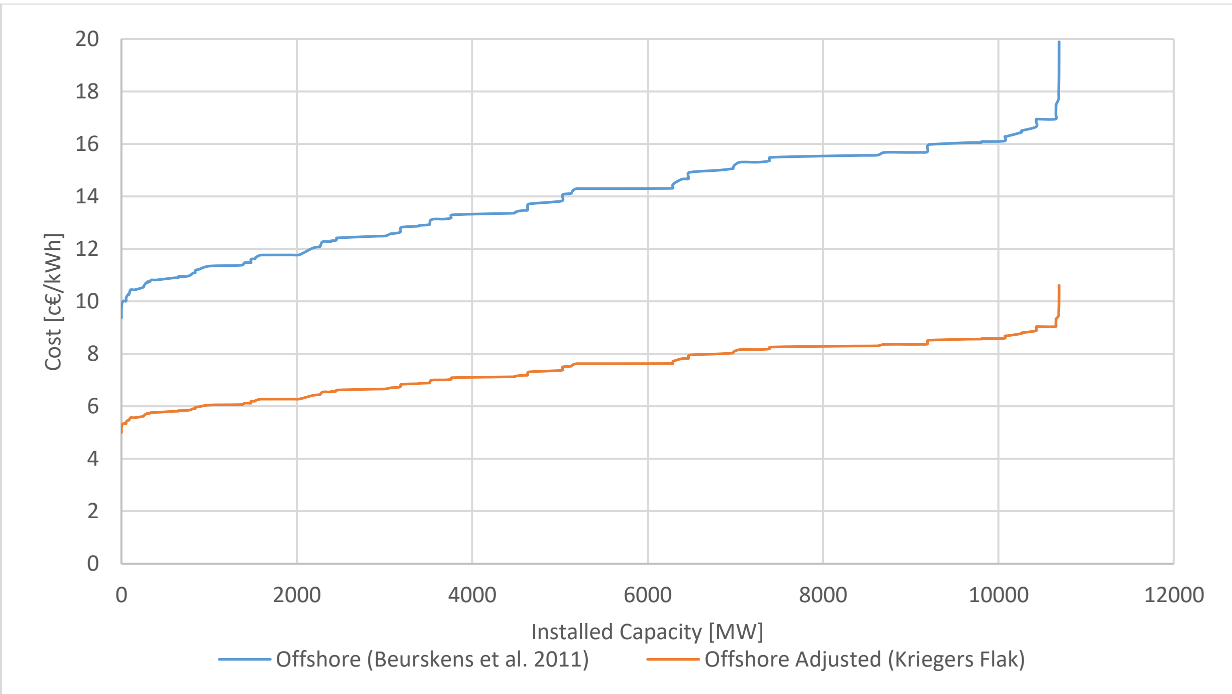

Figure 6: Original and scaled offshore LCOE curve

Recently, offshore cost estimates have dropped significantly for Denmark and neighbouring areas, as evidenced by the recent Kriegers Flak project with a winning bid of 4.9 c€/kWh. Interestingly, this development presents a level below any of the existing LCOE estimates. For this reason, we adjust the cost curve under the assumption that while the initial level of the costs (that is currently much lower due to technological and operational improvements) has changed significantly faster than expected, the drivers for the behaviour of the cost increase of exploiting larger amounts of potential have not, as for example the increased cost of exploiting areas with deeper waters, further from the shore, or with lower wind potential. Both curves, the original levels given by (Beurskens & Hekkenberg, 2011) and the adjusted ones, are presented in Figure 6.

Great care has to be taken when utilising LCOE measures for comparing different projects, mainly when the projects compared are sited in different countries. While the units for LCOE are the same, there is no standard definition regarding which costs are included in the calculation of this measure. (Visser & Held, 2014) studies different assessments of LCOE in the Netherlands, United Kingdom, Germany and Spain and finds out that besides from CAPEX and OPEX, which are considered in every analysis, residual costs such as decommissioning, grid balancing, and cost of market integration are not integrated into the LCOE analyses of every country. Furthermore, grid connection costs are frequently ignored, since very few countries (such as the UK) include these costs in the scope of the project and the LCOE assessment. These kinds of differences will, therefore, affect the LCOE estimates for different projects, and make comparison difficult. For the present study, all projects considered have been analysed under a similar regulatory framework, which makes comparison among them possible.

5 Calculating acceptance costs

Theoretically, acceptance costs for wind turbines should contain all externalities associated to the project being studied including use and non-use values. From a practical perspective, though, acceptance costs will be expressed via compensation payments, project development costs associated to local resistance, and similar additional costs. Evidently, these costs may be different for every person, and as such, the total acceptance costs should be aggregated based on these differences. Due to their extensive definition, the total acceptance costs are not directly measurable; nonetheless, in many cases, these costs can be approximated by looking either at legislation, standard practices, or various preference studies, either revealed or stated.

There are different extensions over which acceptance costs can be considered. In the present study, we consider two scopes: the localised acceptance costs, that encompass only the costs borne by the people living in the area directly affected by the proposed projects; and the nationally aggregated acceptance costs, that encompass the whole population of Denmark. While both scopes present generalisations, and therefore numerous sources of error, they provide us with a range of levels that will help define bounds.

We will utilise three different approaches for estimating acceptance costs of the expansion of onshore wind energy in Denmark:

A. Acceptance costs calculated using actual potential wind sites in Denmark, with compensation payments derived from the actually paid compensations, calculated payments to green funds, and calculated costs of offering shares in the project to local residents
B. Acceptance costs based on other researchers' revealed preference studies of average property value loss and information for the number of properties affected by the potential development at the same actual sites as in A.
C. Acceptance costs estimated based on a stated preference study, which considers different onshore and offshore scenarios, with varying, technologies, sites, and costs in Denmark. These values can then be aggregated to either a local acceptance scope, considering only the households defined in A, or to a national population level.

These acceptance costs are assigned to individual potential sites and can thereby later be added to the basic wind turbine development cost at these specific sites, process with which we can estimate a total LCOE cost curve for the expansion of wind energy in Denmark that accounts for acceptance costs.

5.1 Acceptance cost based on compensation schemes and property purchase (A)

The first method is using the data developed by (Energinet.dk, 2015) and made available for this analysis. The estimated compensation payments can be used as an approximation for the local acceptance costs interpreted as the minimum additional costs that are required to realise these projects.

The Energinet.dk analysis provides an onshore potential with the associated cost of adding sites including the marginal cost of purchasing specific dwellings around each site at 150% of the property tax value base and adding a few other compensating costs.

The marginal costs included in the assessment are:

1. Purchase of buildings within 600m
2. Compensation for impacts on buildings within the designated area but further away than 600m. (600m-1500m)
3. Cost of providing 20% asset share for locals
4. Green Fund contribution to municipality

The most substantial impacts are seen from the purchase of buildings (150% of property value reduced by land value), and it is also this cost element that contributes to the rising end of the total cost curve for LCOE seen in Figure 7. The cost includes EUR 13,400 (100000 DKK) per property for demolition cost.

Compensation calculation is based purely on the distance from the turbine to the house, the value of the house, and an estimated relationship between compensation approved and this distance. The data for the linear regression consists of the around 310 cases that have received compensation payment under this DK scheme (up to 2014). The total compensation approved has been 4.4 MEUR (33 MDKK), with a considerable variation in compensation ratio (ranging from 5% to 75% of the property value).

The last cost components correspond to the mandated offering of 20% of the ownership share of the project to locals at a direct cost price, and to the green fund contribution. This amounts to a rough estimate for each turbine of 0.3 MEUR (2.23 MDKK) for the ownership share and 0.05 MEUR (0.3 MDKK) per turbine for the green fund contribution.

The three cost components follow an entirely different path with increasing development of onshore wind. Examining the total LCOE costs per MW capacity added in Figure 7, the cost share of 20% asset ownership is a constant absolute addition corresponding to 5-10% of costs and the green fund cost share is a negligible share. The compensation payments are quite small, rising with the developed amount and varying a lot near the 12 GW of accumulated development, but with no significant accumulated cost contribution. The main contribution to the total cost is the purchase of property, which amounts to close to 30% of total cost for the last GW up to the economically attractive 12 GW.

The cost curve based on Energinet.dk data is the addition of primary cost and additional implementation cost as discussed above. Implementation costs are here interpreted as a proxy for externality costs and therefore similar to the costs derived from preference studies of attitudes (willingness to pay) towards moving turbines from onshore to offshore sites. The approach in (Energinet.dk, 2015) and the data used here is giving emphasis to the externalities of the few people most affected due to their residence being close to a wind farm. The number of households affected for a 12 GW expansion of wind corresponds to around 3400 dwellings. The average cost of purchasing these properties is around EUR 900,000. For the most expensive areas to reach 12 GW the total cost of purchasing the properties in the area matches the investment cost of the turbines.

When comparing these results to the externalities derived from stated preference studies, we can see that stated preference studies emphasise the lesser effects from visual impacts on a larger number of people living in the larger vicinity of more than 1500m from the wind turbines. On the other hand, the approach taken used in (Energinet.dk, 2015) is not affected by these extended effects.

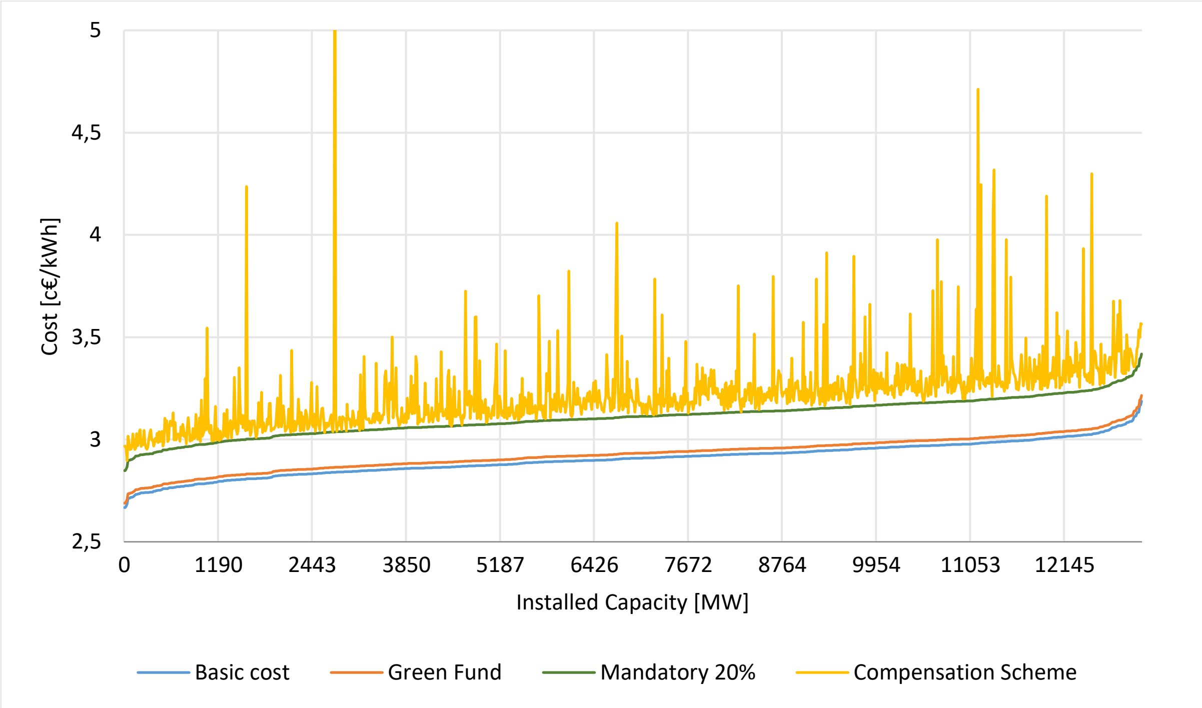

Figure 7: LCOE elements from the three compensation schemes in place in DK sorted by basic development cost

Figure 8: Components of cost in the total LCOE including property purchase sorted according to basic development cost

Comparing the LCOE from the Energinet.dk study with the global estimate of onshore wind LCOE provided by (Millborrow, 2016) for the low investment cost option (1200 USD/kW – and 40% capacity factor light blue in Figure 3) Energinet.dk is considerably lower for at least 6 GW of onshore capacity in DK. It is assumed that this is caused by assumptions on operation and maintenance cost, lifetime and discount rates.

The general conclusion from Figure 8 is that the variation of property purchase costs dominates the variation in all other costs. Therefore, this single cost element will dominate the ranking of possible future wind sites in DK. If the most economical sites to reach a total 12 GW were to be identified, all the sites in Figure 8 with costs above 5.05 c€/kWh should be excluded. The result of this sorting is illustrated in Figure 10 below. If the onshore potential is to be compared to offshore development as done below, this could be done based on the Energinet.dk assumption for offshore cost or other alternatives that, for example, project based on the recent offshore price reductions discussed above.

5.2 Acceptance cost based on property value loss data (B)

This approach compares the acceptance cost from the same potential sites as in A, but then the properties in the vicinity are assigned a property value loss based on an assumption using results from (Jensen et al., 2014). The number of properties affected is based on detailed information provided by Energinet.dk combined with an average property value for each site. This approach does not include the purchasing of any buildings, but the 4700 properties purchased in method (A) are added to the 129,000 properties receiving compensation in (A). All the properties within 1,500 m from a turbine are thus treated identically.

No additional cost of compensation, green fund etc. are added in this case since the full property value loss is interpreted as an alternative or just as the externality that the compensation payments etc. are intended to cover.

The central assumption for the calculation is an average value loss of 10% for all dwellings within 1,500 m of a turbine. This is within the hedonic price estimates (Jensen et al., 2014), for the dwellings where the turbines are visible within a distance of up to 1.6 km. They isolate visual and noise effects on the house prices and for the purpose here we treat their Table 5, "Distance as proxy" combined effect as the average effect for dwellings in the 1,082 potential wind development areas, further assuming that the average dwelling will be around 800 m from the turbines corresponding to a 10.1% value loss. We thus use an assumption of a 10% value loss for all the dwellings within 1,500 m of a turbine. This approach will overestimate the number of houses with the visual effect as the (Jensen et al., 2014) study notes that only around 33% of houses within the 1,600 m distance had a visual impact from the house. The average number of dwellings affected for the 1,082 sites is thus 123.

Using these assumptions we get a substantial variation in the calculated property value losses that are primarily a result of varying number of dwellings in the areas, and secondarily an effect of varying average value for the dwellings.

5.3 Acceptance costs based on stated preference data (C)

This third method is not based on data regarding existing economic transactions, like the two previously presented methods, but on responses to a survey detailing a hypothetical situation. While the previous two methods are able to give real measures of the actual costs experienced, they are not able to consider hypothetical future situations (and therefore possible scale effects) or to consider an extensive range of non-use values, such as those experienced by people living away from the local area affected by previous developments. For this reason, it is of interest to have a measure of acceptance costs that is able to account for these two elements.

In recent years, numerous studies have approached acceptance costs and environmental valuation of wind turbines by the utilisation of stated preference, and in particular choice experiments (Hevia-Koch & Ladenburg, 2016). In these experiments, by presenting respondents with choice sets where they have to repeatedly choose one hypothetical scenario among a number of other scenarios with different attributes, such as cost, number of turbines, the location of the turbines, or size of the turbines. Based on the responses given by respondents, it is possible to estimate the influence of each attribute on the preferences of the respondents. Furthermore, by comparing the ratio of the influence of a specific attribute with the cost attribute, one can calculate the willingness-to-pay (WTP), a monetary measure of the value respondents place on a specific attribute. If one were to utilise this WTP as a measure of acceptance costs, it would be necessary to aggregate it in regards to the relevant population.

While there exist numerous studies calculating WTP for wind turbines, few studies attempt to find an aggregate measure of cost based on their estimated WTP regarding different siting or technology options for wind turbines. One such study is the study done by (Krueger et al., 2011), where they calculate the total annual willingness to pay for 450 MW wind capacity shifted from 1.4 km to out of sight distance for the entire population (number of households) in the state of Delaware. The aggregated annual sum of 6.5 MEUR (7.6 MUSD) is then compared to US estimates of reducing costs by moving wind turbines closer to shore. These numbers are in the same range, 6.8-8.6 MEUR additional external costs per mile compared to 6-17 MEUR cost savings per mile. A very rough assumption would be that the annual acceptance costs of onshore wind turbines compared to far ashore turbines are 6.5 MEUR for the 450 MW of capacity. This is around 0.4 EUR cents in additional acceptance cost for onshore wind expansion. Comparing to our results for Denmark, this corresponds to the acceptance cost level associated to an onshore wind development of between 3 to 6 GW, depending on if method (A) or (B) is used (see Figure 7, Figure 8). Therefore, the level estimates obtained by the comparable Delaware study are contained in our estimates of the acceptance cost range obtained with method (A) and (B).

The precision of these cost estimates is a subject under discussion since there is evidence of the existence of several biases that affect the responses given by respondents. In addition, it has been seen that the results obtained regarding respondents' preferences on a choice experiment are sensitive to the formulation of the experiment, its questions, and the information presented in it (both quantity and the media used to display it). Therefore, it is paramount to rigorous in both in the study design, as well as the interpretation of the results obtained by it (Hanley et al., 1998; Hevia-Koch & Ladenburg, 2016). Nonetheless, stated preferences studies, and particularly choice experiments provide valuable information and valid measures of the respondents' preferences, and therefore in this case on the acceptance costs for wind turbines.

For calculating the acceptance costs, we utilise data from (Hevia-Koch et al., 2018), a choice experiment conducted in 2012 that examines preferences of Danish respondents regarding offshore and onshore wind turbines. In this experiment, respondents are presented with a hypothetical development of 450 MW of wind energy in Denmark, distributed either as a single offshore wind turbine farm or as small onshore wind farms of 1 to 4 turbines, distributed amongst different areas of Denmark. Each respondent is presented with eight choice sets of two different alternatives, one offshore and one onshore, with varying attributes. While the study calculates several preferences and their associated WTP, we are interested in a measure of the acceptance costs associated to onshore wind turbines. Therefore, the value we are interested in is the WTP associated with putting wind turbines offshore instead of onshore (presented as the WTP associated to the offshore alternative specific constant in the choice experiment). In effect, the amount respondents are willing to pay to remove onshore wind turbines and site them offshore is a measure of the acceptance cost of having onshore wind turbines.

The calculated WTP for siting wind turbines offshore is 612.5 DKK per household per year; nonetheless, this value is an average for the sample population of the study, which bears differences to the Danish national population, particularly in regards to age. For this reason, we re-estimate the WTP for siting wind turbines offshore as a function of age and create a weighted average that considers the age distribution of Denmark, resulting in a WTP of 541 DKK per household per year. It is important to note that the design of the survey presents the respondents with a situation where the proposed onshore turbine is either in their own municipality or a neighbouring one, and therefore respondents answer based on the possibility of having the onshore turbines nearby their homes.

When deciding which population group to be considered when aggregating acceptance costs, there is no simple answer. The precise identification of which citizens are affected by the proposed wind turbines is an arduous task, which requires a level of precision in data beyond the scope of this study. As an alternative, we define two bounds: a higher and a lower acceptance cost. We define the higher acceptance cost as the cost that considers every household in Denmark. This measure is extensive in terms of the amount of population considered. It is relevant to note that due to the design of the survey, we consider as if all of the population of Denmark was exposed to the possibility of having an onshore wind turbine near their home, which provides a measure of WTP that is higher than one considering realistic measures of who would be affected. On the other hand, we define the lower acceptance cost as the cost considering only the households that are considered to be compensated or bought due to the expansion of onshore wind turbines, as presented by the Energinet.dk analysis. This measure is restrictive, in the sense that it excludes any person not living in the immediate area of the proposed wind turbines, and ignores any costs not associated to the local environment. These two measures, then, define the region over which the acceptance cost lays. The calculation of the two measures is presented in Table 5.1:

	Number of households	Aggregated Avg. WTP/MW/year [DKK]	Aggregated Avg. WTP/MW/year [EUR]
Lower acceptance cost	133.764	160.929	21.747
Higher acceptance cost	2.670.059	3.212.300	434.095

Table 5.1: Lower and higher acceptance costs

These two measures are then transformed to c€/kWh by considering the relevant capacity factors for the possible onshore projects. Considering only the averages gives a flat cost curve, which is a reasonable measure when considering the High Acceptance Cost bound since it considers all of the Danish population at once. On the other hand when calculating the Lower Acceptance Cost, one should consider that future exploitation of the wind potential in Denmark will follow a similar pattern as the one assumed by Energinet.dk, where the cheapest sites are exploited first. Therefore, the lower acceptance cost curve is modified by creating a curve that maintains the total cost per kWh but follows the shape of the cost curve presented by (Energinet.dk, 2015) as a method for approximating this siting choice approach. On the other hand, since the high acceptance cost already considers all of the population in Denmark, and is defined as a high bound, we do not modify the shape of the curve. Figure 9 presents both the high and low acceptance cost curves, compared to the basic cost curve.

6 Comparing offshore and onshore development with acceptance costs: policy implications

6.1 Construction of onshore cost curve including acceptance costs

For the sum of basic onshore costs and acceptance costs, we use the primary cost curve for the 13 GW onshore capacity in 2030 sited in 1082 areas with specific wind conditions given by (Energinet.dk, 2015). We then independently add the acceptance costs obtained from method (A) and method (B). These two methods illustrate a possible span of total onshore wind development cost to be compared with the offshore development costs, based both compensation payments and purchase costs as well as calculated property loss.

Results of LCOE estimations obtained with method (A) results are illustrated in Figure 10. It can be seen that the estimates show rising total costs including the compensations and purchase costs. Therefore, the distance between the total LCOE and the basic cost illustrates a measure of acceptance costs. It is clear that acceptance costs are a major cost element for such an ambitious expansion of onshore wind capacity in Denmark, but also that a substantial expansion of wind can take place without exceeding the 4-5 EUR cents cost level. Again, it can be noted that the property purchase costs in method (A) are probably overstating the real costs as the properties after purchase in many cases may still possess value for alternative uses.

For comparison, method (B) results are shown in Figure 11. The importance of the property purchase cost, only included in method (A), is evident, as total cost rises only gradually in method (B) reaching only 4 c€/kWh around the 12 GW as compared to 5 c€/kWh in method (A). The cost of the approximately 3,400 dwellings purchased in method (A) is thus quite crucial for the resulting curve. In method (B) the basic value of the dwellings is the same, but the value loss is much lower as only 15% value loss is assumed for these according to the estimates in (Jensen et al., 2014) for distance to turbines of 200-600 m (maximum value in their Table 5). While this assumption may be too low, including full purchase costs and demolish costs for all these dwellings may also be seen as an upper bound for this cost component, since buildings may be resold and used for other purposes, such as farming, instead of being demolished.

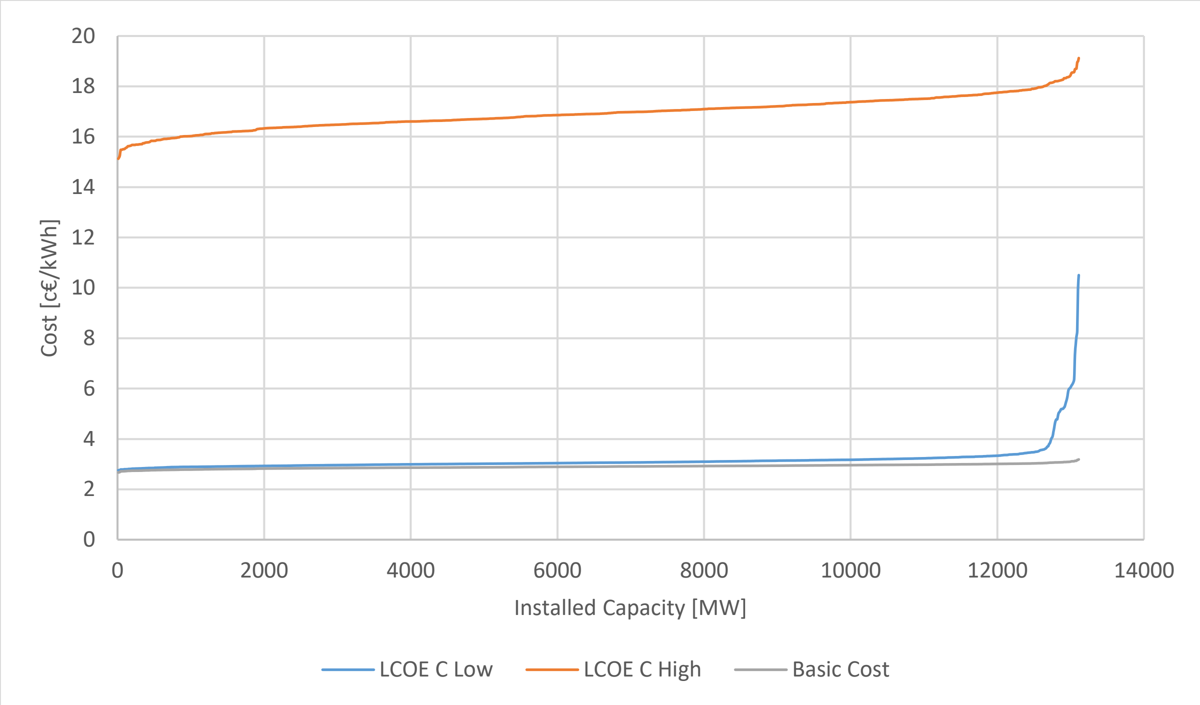

Figure 9: High and low acceptance cost curves

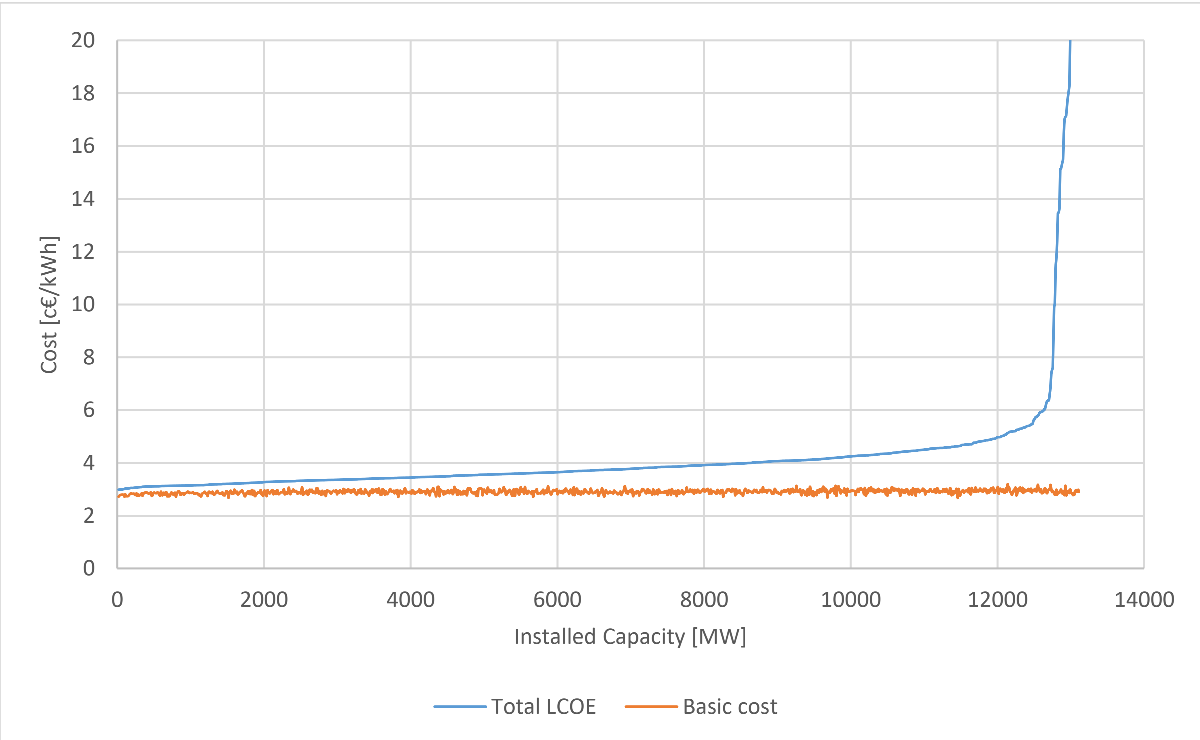

Figure 10: Onshore wind cost curve (LCOE) in Denmark including acceptance based on method A

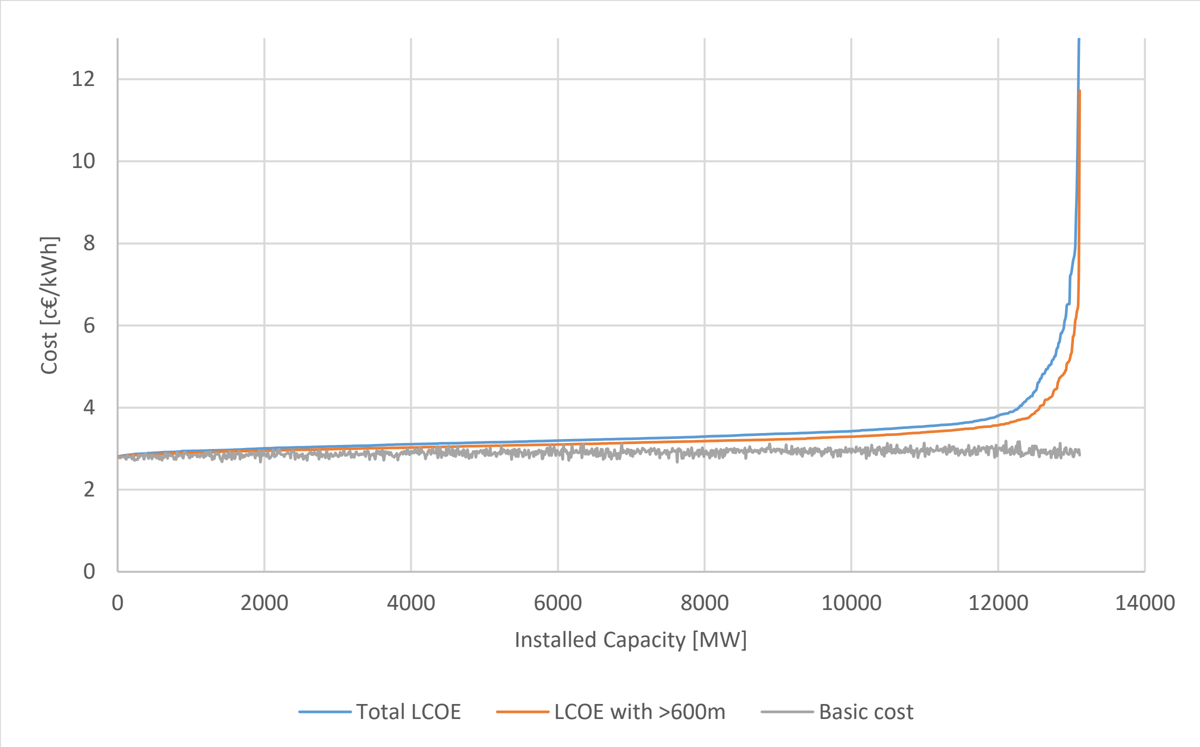

Figure 11: Onshore wind cost curve (LCOE) in Denmark including acceptance based on method B

Finally, for method (C) we create an LCOE cost curve for both high and low acceptance costs shown in Figure 12. We can see that the range of costs between the higher and lower estimate is quite extensive, mainly due to the high level of the upper estimate. This is expected, as the measure utilised for the high level of acceptance costs in method (C) is designed to be extensive and conservative, particularly in regards to considering every respondent in Denmark as being equally potential affected at every stage of development (due to the design of the survey, respondents are considering the expansion to affect them by siting wind turbines in their municipality or a neighbouring one). In regards to the lower LCOE curve, we can see that its levels are quite similar to the ones obtained with previous methods, with both curves from method (A) and method (B) laying above it. All three LCOE estimates are shown together in Figure 13, with a detail view in Figure 14.

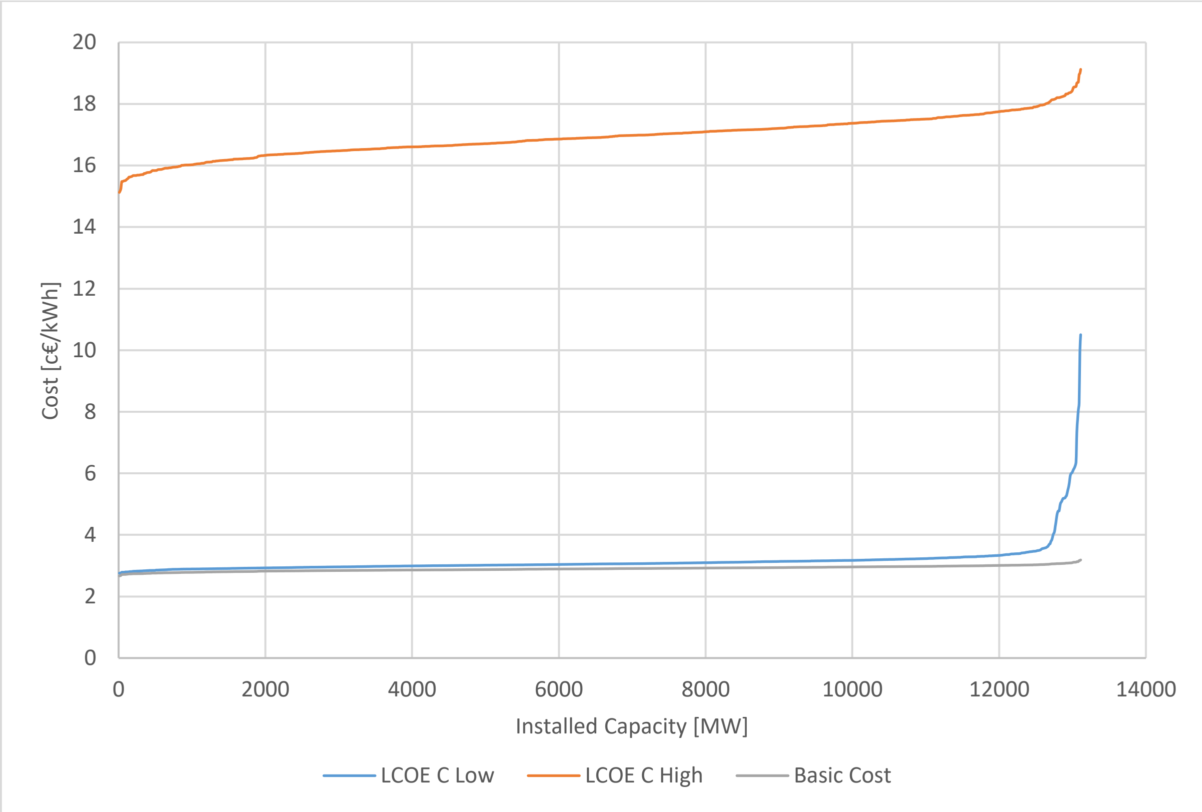

Figure 12: Onshore wind cost curve (LCOE) in Denmark including acceptance based on method (C)

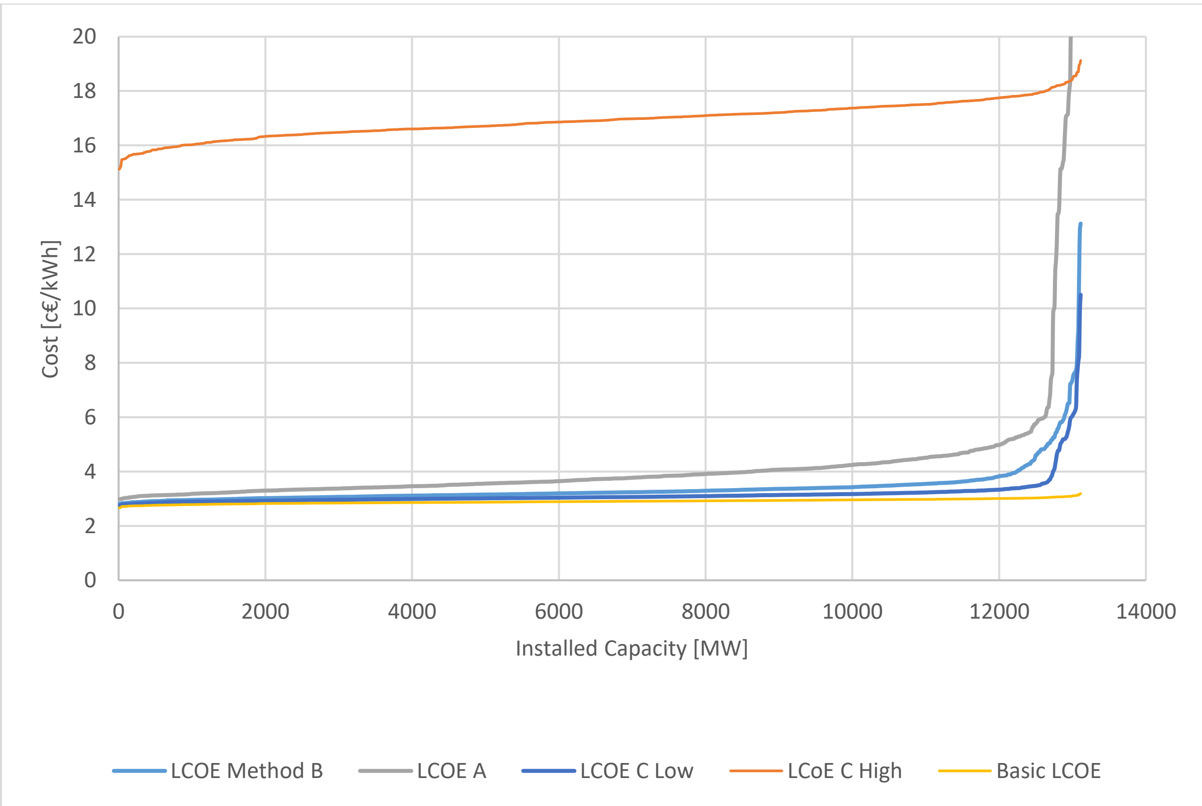

Figure 13: Onshore wind cost curves (LCOE) in Denmark including acceptance

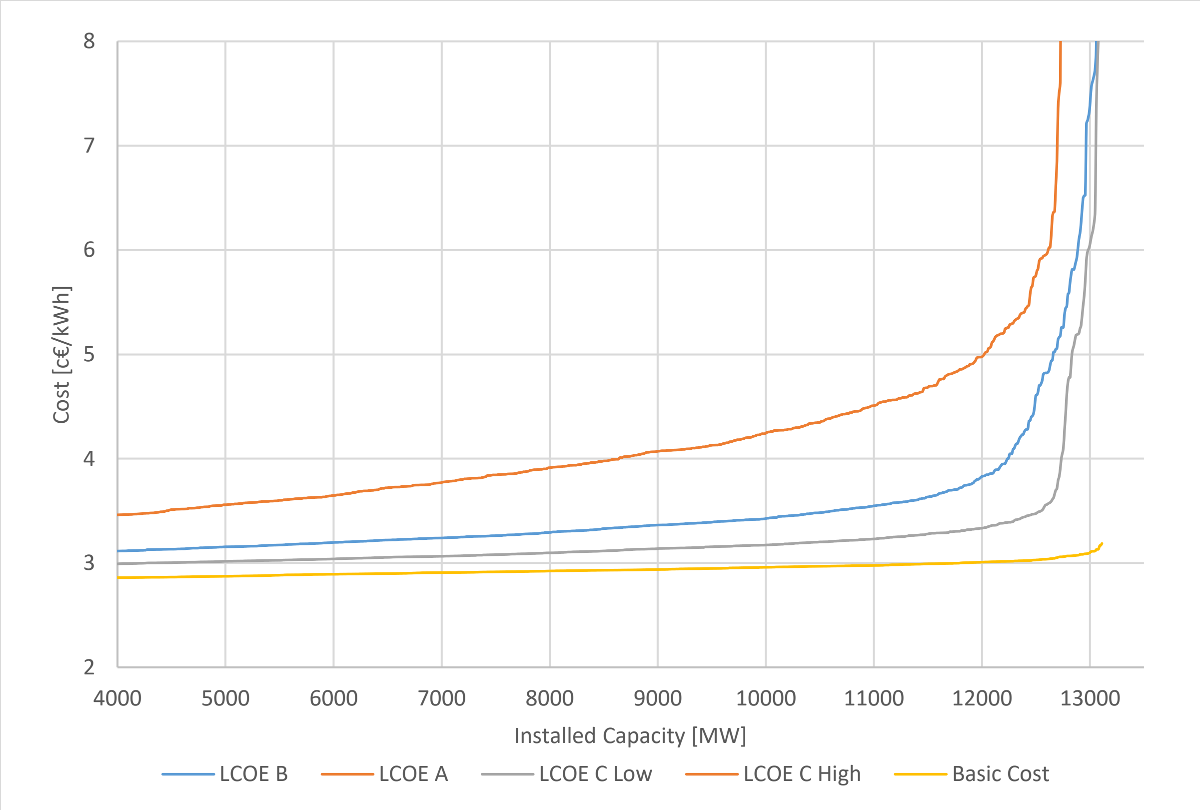

Figure 14: Onshore wind cost curves (LCOE) in Denmark including acceptance (Detail)

6.2 Comparing onshore and offshore cost curves

We have constructed cost curves onshore and offshore in Denmark with consistent assumptions on basic costs and added acceptance cost for the onshore part based on the previous three methods presented while assuming that there are no acceptance costs for the offshore wind potential. The assumption of no acceptance costs for offshore is based on the fact that the planned developments considered for the offshore cost curve are based on site beyond the limits of visibility from the shore, eliminating acceptance costs from visual and sound disamenities. It is possible that there are still minor acceptance costs, regarding offshore wind farms as a technology per se, but they are not included in the present analysis.

When looking at cost curves that include acceptance costs for both onshore and offshore levels, as shown in Figure 15, we can see that the curves obtained by methods (A), (B) and (C) low begin at very similar levels, and evolve with different slopes. Nonetheless, they are packed in a relatively tight range with differences being noticeable only from a capacity of 4000 MW and higher, point where the LCOE for method (A) increases faster than for method (B) and (C), due to the significant impact of increasing property purchase costs. We can see that the lower estimate obtained by method (C) provides an LCOE with lower levels of local acceptance costs than the other two methods, whereas method (A) produces the highest ones, with differences from 0.2 c€/kWh at low capacities, up to 1.4 c€/kWh at around 11 GW capacity, before the sharp increase on the latter stages of potential exploitation. On the other hand, the LCOE obtained by method (C) considering national level aggregation (that is, LCOE C High) has an extremely high level, comparable to the original offshore cost curve provided by (Beurskens & Hekkenberg, 2011). It is important to note that due to the nature of the aggregation and the design of the survey utilised, this acceptance cost level is expected to be high, and act as a measure of an upper bound, more than a precise cost level. Specifically, this method assumes a flat constant WTP based on the scenario shown on the survey (an expansion of 450 MW of installed wind capacity) and not precise steps for the total 12 GW potential considered here.

We can see that in general, the acceptance costs increase the total LCOE level for onshore wind energy. Nonetheless, both method (A) and (B) present cost estimates below the adjusted cost levels for offshore wind. Based on those figures we see that

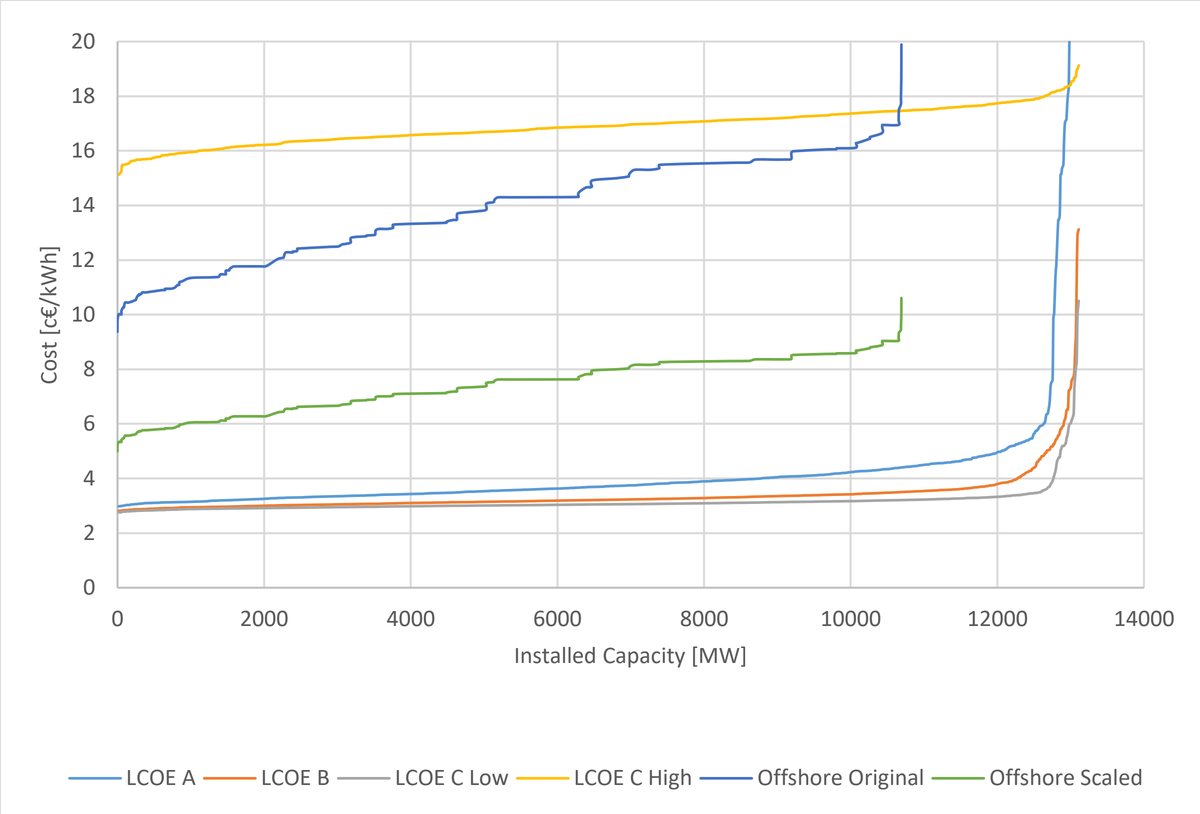

Figure 15: Onshore and offshore wind cost curves (LCOE) in Denmark including acceptance costs

up to 12 GW of wind capacity, onshore wind presents lower cost levels than offshore wind. When we look at method (C), though, we can see that while the lower bound cost curve is quite similar to the levels obtained by the previous two methods, the upper bound creates a wide range for increased costs. While part of this variation is intrinsic to the error associated with the methodology used, another part of it is dependent on the extent of the population considered. It is important to note that this method considers acceptance costs not included in the previous two methods. Based on both the broad range between upper and lower bounds, as well as the existence of sources of acceptance cost not considered by methods (A) or (B), it is entirely possible that the crossover point between offshore and onshore costs occurs at capacities lower than 12 GW.

Finally, LCOE levels for offshore wind are subject to high uncertainty, as evidenced by the significant differences between recent estimates and actual cost developments, as exemplified in Figure 6. As discussed previously, the LCOE of offshore wind energy has been reduced significantly in recent years, particularly compared to onshore, and if this trend were to continue the economic advantage of onshore versus offshore would be further reduced.

6.3 Policy implications

Danish energy policy has until today supported onshore and offshore wind development differently, with feed-in premiums onshore and tendered/auctioned offshore development with fixed amounts (TWh) supported by fixed feed-in tariffs (contract for differences). Apart from the support scheme differences also the resulting auction based level of support has been considerably higher for offshore wind development. Costs have come down considerably for offshore, but still, it is likely that considerable savings can be achieved by developing more onshore capacity compared to offshore. This is as illustrated above even the case with the inclusion of additional acceptance costs for onshore development. The exact share of onshore to offshore wind that should be installed is uncertain and will depend on further cost improvements of offshore development, as well as the definition of the population range to be considered as affected, and therefore included in the aggregation.

It is of relevance, then, to further study acceptance costs at a scope more inclusive than the local one, to determine precisely the optimal share of onshore to offshore wind expansion. This would, without doubt, require the design of stated preference studies that look at realistic nation-wide scenarios of wind expansion and that reflect so clearly on the survey design. Despite the approximations done in the present study, results indicate that there is still a significant advantage of onshore wind at lower expansion capacities, as well as the possibility of repowering existing wind farms with larger and more efficient wind turbines which, due to the reduced number, may lower acceptance costs. This presents an argument towards equivalence in support schemes for onshore and offshore wind development.

7 Conclusions

This paper shows three different approaches for calculating acceptance costs for onshore wind energy in Denmark and using these levels to create a cost curve for the expansion of wind energy capacity. Afterwards, we compare these cost curves for onshore wind energy to cost levels for offshore wind energy in Denmark.

We find that method (A), utilising data from the compensation scheme, green fund allocations, offering of 20% of the project locally, and required property purchases; provides an estimate that indicates that for most of the available expansion capacity, onshore wind is cheaper than offshore wind even when considering acceptance costs. With a sharp increase of onshore costs at high levels of capacity, associated with the necessity of buying more, and more expensive, properties. These acceptance costs are only local, thus largely restricted to the population living in the specific areas (less than 10 km^2) where wind turbines will be installed. When considering the large nation-wide expansion of onshore wind, there will be significant amounts of people affected, but only a few people for each turbine.

Also from a local acceptance costs perspective, method (B), based on a revealed preference study (Jensen et al., 2014), presents similar local acceptance cost estimates to method (A), when applied to an equivalent amount of households, although slightly lower. From this estimated curve, similar conclusions are drawn: onshore wind has an economic advantage over offshore wind for most of the wind capacity expansion range studied.

Utilising method (C), we obtain estimates for acceptance costs both at a local scope and a national scope, to be used as bounds for acceptance costs that will vary depending on the level of aggregation of the measure. The lower estimate (that is, considering only a local perspective as defined by method (A)), has cost estimates that are slightly lower, but similar to the costs obtained by methods (A) and (B); and with similar conclusions. The higher estimate, on the other hand, is a cost curve at an extremely high level, much higher than the adjusted offshore cost curve utilised in this study, which was expected due to the overestimating nature of the aggregation done. Based on the dimension of the range obtained, the fact that methods (A) and (B) are, while more accurate, ignoring the willingness to pay of the broader population to avoid turbines onshore; and the recent downwards development of offshore cost, it is much harder to conclude with certainty the absolute cost advantage of onshore wind versus offshore wind, as well as the specific crossover point. The main part of the onshore capacity available will be cheaper considering only the local acceptance costs but depending on how much of the estimated willingness to pay from the larger Danish population is included, larger parts of the onshore potential will be at cost levels that are matched by offshore potential.

The main conclusion points towards the fact that onshore does not have a clear-cut cost advantage over offshore when considering substantial amounts of wind capacity, and that further expansion of wind in Denmark has to be done with careful consideration of this fact. Otherwise, the risk is following a deployment path that does not minimise cost but instead transfers these costs from developers to the public.

8 Acknowledgements

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Paper E

The impact of residential demand response on the costs of a fossil-free electricity system reserve

The Impact of Residential Demand Response on the Costs of a Fossil-free System Reserve

Jonas Katz, Olexandr Balyk, and Pablo Hevia-Koch, *Member, IEEE*

***Abstract*—In order to achieve a better understanding of the system value of residential demand response, we study the potential impact of flexible demand on the costs of system reserves in a system with fossil-free electricity supply. Comparing these costs with traditional means of regulation, our analysis aims to contribute to the identification of the least-cost options for reserves in a fossil-free power system. To do so, we extend an existing energy system model with demand response and reserve modelling and analyse the impact for the case of Denmark in 2035 to reflect a system based on renewable resources for electricity and heating. The reserve requirement is determined subject to the installed wind power capacity. To reflect a realistic demand response potential, we base it on hourly load profiles of suitable household appliances. Our results show that residential demand flexibility could provide significant value if used for intra-hourly reserves. The reserve value of flexible demand might even be higher than the value attainable in the hourly spot market.**

***Index Terms*—Residential demand response, Load shifting, Operating reserves, Reserve requirement, Partial equilibrium model, Wind power**

I. Introduction

The flexibility potential of the demand side has received increased attention in recent years from policy makers in countries developing large shares of variable renewable electricity generation [2]. System operators and regulators frequently mention the potential contribution of demand response to reliability in a system with large shares of renewable energies [3]. Technically, load following production could provide a partial solution to the arising intermittency problem. Such potential contributions of demand response to the efficient operation of power systems have been studied extensively in many different settings [4] confirming that properly timed load adjustments generate benefits by avoiding or deferring investments in new generation or grid assets [5].

One limitation of many types of demand response is the restriction to a short duration [6]. Evaluation of contributions to system operation must, therefore, be sufficiently detailed on the time scale. Many analyses focus on the hourly scale, and often the economic potential found is limited [7], [8]. Demand side flexibility may, however, be better suited for short-term response. For instance, the [9] argues that new flexibility products are required to utilise demand-side resources; pure hourly spot price products would not suffice. In order to grasp the full potential one should include contributions within the hour [10]. Such flexibility could then be interpreted as a reserve to the power system.

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In the future, reserve markets will become increasingly important. As wind power production rises, its fluctuations add to the reserve requirement of the system, as has been analysed in previous studies (for a review see [11]). At the same time, the increased reserve demand has to be met by fewer dispatchable plants, because power from renewable sources displaces conventional generation. As a result, new providers of ancillary services will be needed [12]. Technically, demand response is capable of providing reserves if automation equipment is installed [13]. Such regulation is not just restricted to large industrial loads, but could also be provided by aggregation of many small residential loads [14], [15]. The available capacity could be used for reserves of different qualities [16]. It may even react faster than generation capacity, and some loads might be able to comply with the conditions for fast frequency control [17].

From a consumer's perspective, revenues in the reserve and balancing markets could significantly improve the business case of demand response [18]–[25]. The precondition to install automation equipment could pose a barrier; but at the same time, participation in demand response by automation may be the more comfortable and effective option as opposed to manual response. Pilots and field experiments have shown that the interest in manual activities may be rather low (for experiences in Denmark see [26], [27]), and that large groups of, in particular, residential consumers stay unresponsive to price signals [28]. This is even more pronounced for complex schemes based on real-time pricing [29]. Another positive side-effect of automation may be that it prevents *response fatigue*, that is, a declining willingness to react over longer times or upon many events within a short time frame [30]. Ultimately, to conclude on the attractiveness of demand response as a reserve, it is necessary to evaluate it from a system perspective. This has been done to some extent within different settings and by applying different modelling approaches in previous works. We briefly review these to point out the contribution of this paper.

In partial models of reserve markets, it has been concluded that demand response may reduce the cost of reserves and increase reliability [31], [32]. A linear model that explicitly includes the contribution of decentralised generation and demand in distribution grids to secondary reserves and reactive power has been presented by [33]. The authors demonstrate how the developed module can be directly applied within large energy system models. A stochastic unit-commitment model of the electricity system is used by [34] to evaluate operational benefits of demand-side resources, including the impact of providing system reserves. The study concludes that demand flexibility may significantly improve adequacy. It does not consider, though, how this would affect investments in new capacities. Another unit-commitment model is used by [35]; the authors include requirements for spinning and standing reserves to model the impact of different flexibility options (amongst them demand response) on system costs including investments in new capacities. Demand response is not allowed to provide reserves, though, as the capabilities of demand response regarding reserve provision are considered uncertain. A linear energy system model that explicitly models reserve provision of different qualities is presented by [36]. While the model is calibrated to German conditions, it does not include existing generation, interconnections to neighbouring countries or other energy sectors.

We want to contribute with a study of residential demand response in Denmark using *Balmorel*, a partial equilibrium model of the electricity and district heating systems formulated as a linear program (see [38], for detailed description and applications). In this paper, we (1) implement a residential demand response model in *Balmorel*; (2) implement a reserve requirement in the model based on statistical characteristics of forecasting errors and contingencies; (3) estimate the cost of reserves without demand response; (4) estimate the potential savings in costs of reserves with contributions from demand response. In comparison to most of the studies mentioned above, the model has a larger sectoral and geographical scope. Our focus, though, lies on Denmark and the cost of reserve provision in the electricity system. We use a strictly linear model resulting in formulations regarding the reserve provision that differs from previously published models. The flexibility potential we use is defined per hour and based on a bottom-up analysis of residential appliances. To determine the reserve requirement, we use a static probabilistic approach to construct a reserve demand curve dependent on the share of installed wind power. In order to achieve a more comprehensive grasp of the system value of demand flexibility, we study the potential impact of residential demand response on the costs of system reserves in a system with fossil-free electricity supply. Comparing these costs with traditional means of regulation our analysis might contribute to utilising the least-cost options for regulation in a fossil-free power system.

This paper is a continuation of the work presented previously as a conference paper [1]. While maintaining the use of Balmorel as the electricity system model, and the method for calculating reserves based on wind capacity; we have modified the modelling of flexible demand behaviour and reserves in the system, as well as further specified the profiles of the flexible demand potential based on the use profile of the appliances considered as possible flexible demand. We have included a linear approximation of ramping constraints and spinning reserves constraints, in favour of the previous capacity credits approach. The analysis of the system has been modified, changing the amount of cases run, as well as analysing further the behaviour of flexible demand across scenarios, and running a sensitivity analysis over the potential for flexible demand as well as the reserve requirement.

II. METHOD

A. Demand response modelling

As a first step, we extend the existing system model *Balmorel* by incorporating responsive electricity demand from households. Implementations of demand-side flexibility in *Balmorel* and similar models have been done in previous works. Some of these have focused on single applications like electric vehicles [40]–[42] or residential heat pumps [43], [44]. Early versions of the model already included the possibility of adding demand response in the form of elastic demand curves [45, see]. Certainly, good arguments exist to represent residential electricity consumers' ability to be flexible using price elasticities. On the other hand, due to the limited manual response under real-time pricing, automation of response could become a crucial factor. The automation algorithms may be better represented by generic storage-like models instead of elasticities (as implemented by e.g. [21], [46]–[48,]). Moreover, the technical potential can be more directly assessed looking at the usage of different appliances, as opposed to assessing the more abstract concept of price elasticity.

We implement a generic demand response model that is based on assumptions about the flexibility of different categories of household appliances.

We then use hourly consumption profiles per appliance category to define the distribution of the flexibility potential throughout the year. The consumption data set and its construction has been described by [49]. It builds on data from several sources. First, average daily load curves for individual appliances on working days and weekends have been adopted from a large European study [50]. These have been adjusted to Danish conditions using information about annual profiles of Danish household consumption [51] as well as ownership rates [52]. The daily profiles have been rolled out accounting for seasonality in appliance use (as observed by [53,]). Appliances covered make up around 25% of total Danish electricity demand.

The appliance profiles have been divided into four categories with different load-shifting capabilities. Time windows for load shifting have been assigned to each of the categories based on literature values as shown in Table I [54]–[56]. We restrict shifting to major appliances for cleaning, cooling and freezing. Appliances for cooking, lighting as well as smaller devices such as consumer electronics are not considered available for automated control. Figure 1 shows the hourly appliance profiles for one week coloured according to the assigned categories.

The consumption of the relevant appliances is included in the model as a flexibility potential. Our extensions to the model are described below with a list of symbols at the end of the paper.

Table I
LOAD-SHIFT POTENTIAL PER CATEGORY

Appliances	Time window
Cleaning	**24 hours**
Washing machine	
Dishwasher	
Tumble dryer	
Freezing	**4 hours**
Freezer	
Cooling	**2 hours**
Refrigerator	
Refrigerator with freezer	
Inflexible	**0 hours**
Lighting	
Cooker	
Microwave oven	
Electric kettle	
Vacuum cleaner	
Audio/Video	
Mobile phone charger	
Computer	

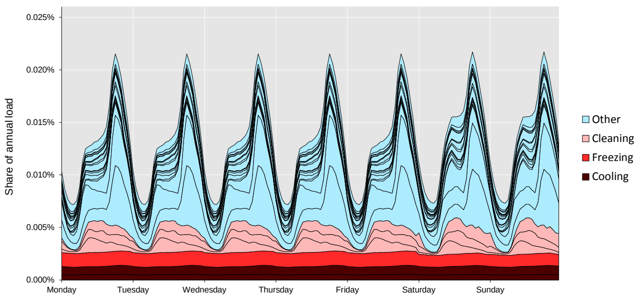


Figure 1. Hourly appliance load profiles for one week

For every hour h, geographic area a and appliance category j, we define a flexibility potential $D^{flex\text{-}pot}_{a,h,j}$ defined by the hourly end-use profiles per appliance.

The time windows defined in Table I are termed S_j. Within these windows the changes in demand due to load shifting $D^{flex}_{a,h,j}$ are determined such that:

$$\sum_{h}^{h+S_j} D^{flex}_{a,h,j} = 0 \quad \forall\, j, \{\, h \in T \mid (h-1) \bmod S_j = 0 \,\} \quad (1)$$

The sum of $D^{flex}_{a,h,j}$ over all categories j thus represents the hourly load-shift delta in MW relative to the baseline demand of the hour. It will also be used in the overall system balance equation to adjust the load to be served by the system. As the system model we use is defined with an hourly resolution, this representation reflects the participation of flexible demand in the hourly spot market. We could as well reserve the flexibility for activation within the hour reflecting the participation of demand flexibility in the system reserve. We will therefore include unused flexibility in our reserve modelling in section II-C, equations (10) and (11).

Equation (1) could have been applied to all hours $h \in T$, i.e. a rolling time window across all hours. Because we only consider demand flexibility actions that do not add or remove demand but just shift it across time, such a rolling constraint would create interdependencies, even for hours that lie far apart from one another. In order to avoid this, we use fixed time windows defined by the capabilities of relevant, flexible appliances. Therefore every window starts only in an hour h that is a multiple of the window length S_j determined by use of the mod-operator that provides us with the remainder of the division $(h-1)/S_j$.

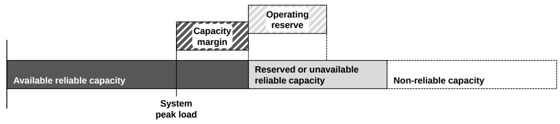


Figure 2. Division of installed capacity

To always cover inflexible conventional demand, flexibility is restricted in the following way:

$$D^{flex}_{a,h,j} \geq -D^{flex\text{-}pot}_{a,h,j} \quad \forall\, h, a, j \quad (2)$$

We allow $D^{flex}_{a,h,j}$ to reduce demand (i.e. the variable may become negative), but it is always limited by the potential. On the other hand, we do not include an upward limit so that the model is free to choose the optimal time of consumption within the time windows S_j.

B. *Reserve dimensioning*

A reliable system requires a certain reserve margin to ensure that sufficient capacity is available at any point in time to serve load. Figure 2 illustrates how installed capacity may contribute to the margin. The most simple approach to define an adequate capacity compares the system peak load with the available generation capacity. A distinction has to be made between reliable and non-reliable capacity. Plants with limitations in the fuel supply or their primary energy sources, such as wind and solar power, would traditionally not be counted as a reliable source [57]. In Europe at present, the whole definition of adequate capacity is subject to revisions that aim to include probabilistic analyses due to the development of renewable production [58]. As a result, certain shares of the variable production could be considered reliable in the future. Capacity from dispatchable plants counts as reliable unless it is out for maintenance, mothballed or reserved for system services. The remaining available reliable capacity should add up to exceed peak demand by a minimum spare capacity margin. Recommendations for such a margin range from defining it deterministically, i.e. as a percentage of total generation capacity, to using a probabilistic approach that ensures a shortage risk of, e.g., less than 1% accounting for the risk of outages.

In a linear programming model, like the one used for our analysis, a system balance equation warrants that production and load match in all time steps. Based on this constraint, costs would be minimised by investing in production capacity that is exactly able to cover demand up to the system peak load.

As illustrated by Figure 2, this would exclude the capacity margin. Accounting for a reserve margin thus requires the definition of additional constraints. Average availability factors may be used to implement the deterministic version of the above adequacy requirement. Plant availabilities between 90% and 95% depending on the technology have been suggested [40]. With such an approach alone, installed capacity would always have to be slightly higher than the load served, which would fulfil the adequacy requirement if the modelling period includes the system peak. Capacity defined as unavailable for adequacy, such as intermittent production, and non-domestic sources, i.e. imports, may have been included to cover for the required capacity, though.

There is no absolute set of rules for the calculation of the requirement for reserves, and different types of methodologies are available [61]. For continental Europe, rules are provided by [62]. Furthermore, a new grid code on load-frequency control and reserves is under development [63]. Nordic rules are defined by [64]. All of these arrangements, however, leave some degree of freedom to the individual system operators. Traditionally, deterministic methods have been used to determine reserves relying solely on variations in the system load. The ENTSO-E Operation Handbook still proposes a deterministic formula to size control reserves for predictable load and generation variations [65]. Methods that on the probabilistic characteristics of variability and contingencies, however, are becoming more common [66], [67].

For Denmark, criteria for measuring security of supply have been set forth [68]. The Danish Energy Agency uses a probabilistic model to determine the level of security of supply in Denmark [69]. A procedure to explicitly determine a reserve requirement, however, is not included. For the future Danish system the impact of fluctuations and forecast errors in relation to renewable energies on the demand for reserves will be a central issue. The influence of wind power on the reserve requirement is analysed in several studies (for reviews see [66], [70]–[73]). A general finding is that wind power only influences the operating reserve requirement and not the contingency reserves [70]. This would mostly affect slower types of reserves. With higher levels of penetration and the development of large offshore wind farms, however, fast frequency response may also be affected [74].

Our approach to determine the reserve margin is based on static probabilistic criteria. It combines the need for a capacity margin due to contingencies on plants and lines with deviations due to forecast errors. The requirement will not be dynamically updated and may, therefore, overestimate the actual costs of reserves slightly. Due to the focus of this paper on the change of costs from demand response contributions, we find this to be acceptable.

Following earlier findings , forecasting errors reflect the most important balancing issue introduced by wind power, which will make up a large share of the system we analyse [70], [75]. As an approximation, the standard deviation may be used to characterise the increase in operational reserve requirements from wind [76].

It has been found, however, that normal distributions are not good at approximating the distribution of wind forecast errors due to their narrow tails and a low peak [77]. Rather the use of the hyperbolic or the Cauchy distributions has been proposed instead [78]. Similar findings are presented by [79] proposing the beta distribution for a better fit, their main argument being pronounced kurtosis of the error distribution.

In a comparison of distributions of wind forecast errors across different countries [77], it has been found that, for Denmark, the distribution is fairly symmetric and its skewness not very distinct. We circumvent the question of the exact distribution of errors by using a probability density estimate based on the relative frequency count within 1 MW bins.

Danish day-ahead forecast errors on an hourly basis are available from for the years 2013 to 2015 from [80]. We use these data in combination with information on the installed wind capacities throughout the period [81] to determine a probability distribution of wind forecast errors relative to capacity. The day-ahead errors will to some extent be corrected in the intraday market by balance responsible traders. For the dimensioning of reserves capacities, a more critical dimension is the hour-ahead error [74]. Dragging on Danish experience, the normalised wind forecast error can be reduced from 5.2% at day-ahead to 3.0% at hour-ahead [82]. Even more optimistic figures are provided in a German study [83] that expects further improvements in the future. We, therefore, find it appropriate to use 50% of the observed day-ahead forecast errors as an approximation for the hour-ahead forecast (see the second panel in Figure 3 for the resulting distribution).

The role of the demand side as a driver for reserve capacity may be limited due to low forecasting errors of 1–5% [75]. In the future, therefore, operational reserve capacity may be dispatched mainly for reasons related to the supply side. Load forecasting errors will, however, still have a role to play in reserve dimensioning. We, therefore, construct a distribution of load forecast errors also using data from [80]. It is shown in the upper panel of Figure 3.

Besides operating reserves to cover forecast errors in load and wind, we take into account capacity to cover for contingencies, as critical outages may occur on power stations or transmission capacity. For the Danish system, we take into account capacities in Table II (data based on [84], [85]).

We only consider full outages and disregard the possibility of partial outages in this analysis. To calculate probability distributions for outages we use 4000 full load hours for power plant blocks, which corresponds to the number used by [86]. For transmission lines, we use 2500 full load hours corresponding to an average of data on imports over the different lines in 2015 (based on data retrieved from [87]). We use a common outage risk on all lines and plants of 1% in any given hour. This number is close to the outage risks considered in a comprehensive German study [88].

Figure 3 shows the resulting probability distribution for outages in the third panel, obtained by convolution of the indi-

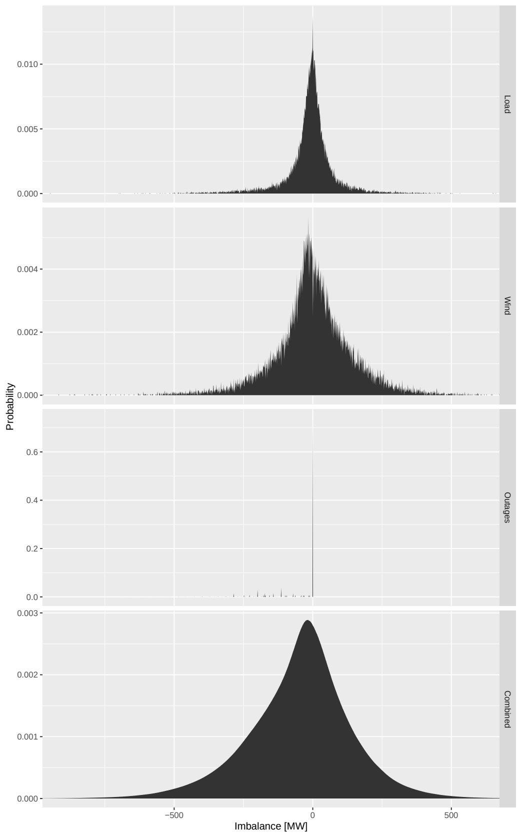


Figure 3. Distributions of load, wind, outages and combined distribution of imbalances

vidual outage risk probabilities. The probability of no failures occurring at all is thus around 70%.

With these 3 major sources of imbalance risk: wind forecast errors, load forecast errors and outages, we estimate a joint distribution of imbalances for the whole system by convolution (as commonly applied in, e.g. [67], [88]–[90]). In order to do so, we have to assume that the events are independent. For plant and line failures versus forecasting errors, this should be the case. A correlation of wind and load forecasting errors should not be ruled out in general. For the sake of this analysis, however, we ignore any potential correlations. As we have normalised the wind forecast errors to the installed capacity, we are able to scale them to the relevant capacity in future scenarios. Figure 3 shows the resulting distribution applying the currently installed capacity of around 5 GW.

In order to determine reserve capacity, we need to define the level of deviations required to be covered. The exact criteria used in practice is not publicly available. A security margin of 99.9% corresponding to a loss of load probability (LOLP) of 0.1% or 8.76 hours per year is sometimes used [65]. In the light of numbers for actual outages, this seems high in a Danish context. We calculate a reserve according to a requirement of a LOLP of 1 hour per year. We use the cumulative probabilities to find positive and negative reserve requirements.

Table II
CAPACITIES INCLUDED FOR CONTINGENCY ESTIMATION (ESTIMATIONS BASED ON [84], [85])

	Capacity [MW]
Power plants	
Fynsværket Block 7	380
Fynsværket Block 8	35
Nordjyllandsværket Block 3	380
Skærbækværket Block 3	390
Amagerværket Block 1	70
Amagerværket Block 3	250
Asnæsværket Block 2	140
Avedøreværket Block 1	250
Avedøreværket Block 2	545
HC Ørstedværket Block 7	75
HC Ørstedværket Block 8	25
Transmission lines	
Sweden - Eastern Denmark	800
	500
Germany - Eastern Denmark	600
	400
Norway - Western Denmark	250
	250
	500
	700
Sweden - Western Denmark	350
	330
Germany - Western Denmark	150
	550
	400
	400
	1000
	1000
UK - Western Denmark	700
	700
Netherlands - Western Denmark	700

For the reserve modelling, we only use the positive reserve assuming that negative capacity would always be available by means of reducing production. For different levels of installed wind capacity, the resulting reserve requirement is shown in Figure 4. We divide the reserve requirement into two qualities, fast and slow, representing two categories of response time largely corresponding to secondary and tertiary control. On the basis of the yearly maximum of the historically activated capacity of secondary and tertiary reserves (as of data retrieved from [87]) we use a division of 10% for fast and 90% for slow reserves.

C. Reserve modelling

In order to determine the cost of a reserve capacity margin in a fossil-free scenario for Denmark in 2035, besides the reserve requirement of the system, we need to define the

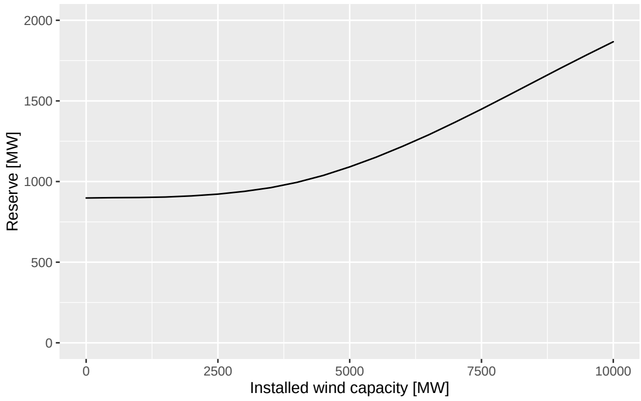


Figure 4. Reserve requirement dependent on the installed wind capacity assuming a LOLP of 1 h/a

capacity available to cover for the reserves. We require the total capacity to be able to fulfil demand in any given hour. The hourly flexible demand variable as introduced in equations (1) and (2) enables peak shaving in order to save costs of installing peak capacity.

Moreover, we want to ensure that in any given hour we are able to cover for an additional reserve requirement as determined in the previous section II-B. In order to take into account the capability of different types of generation technologies in regard to ramping, we define subsets of technologies that are able to provide the system with fast (FR) and with slow reserves (SR). Fast reserves include capacities for regulating and ramping reserves corresponding to secondary reserve in ENTSO-E terms that are immediately activated [72]. Slow reserves include capacities for load-following reserve and supplemental reserves corresponding to tertiary reserves. Depending on the technology used, a share of capacity may be required to be spinning. This way we make sure that technologies with long start-up times or slow ramping capability are actually available in the required hour. Technology types used for reserves are shown in Table III.

Table III
GENERATION TECHNOLOGIES PROVIDING RESERVE

	Slow	**Fast**
spinning required	Steam turbines CCGT	Steam turbines CCGT Gas turbines
no spinning required	Gas turbines Combustion engines	

Technologies capable of providing fast reserve capacity should reserve a share of capacity in any given hour such that, after planned generation, the sum of available capacity covers the reserve requirement. We define a variable for such reserved capacity per technology g, area a and time step h for both slow and fast reserves respectively ($K_{a,g,h}^{FR/SR}$). To fulfil the reserve requirement in every country c we define:

$$\sum_{a \in A_c} \sum_{g \in FR} K_{a,g,h}^{FR} \geq R_c^{FR} \quad \forall\, h, c \tag{3}$$

Similarly for the slow reserve capacity:

$$\sum_{a \in A_c} \sum_{g \in SR} K_{a,g,h}^{SR} \geq R_c^{SR} \quad \forall\, h, c \tag{4}$$

The installed capacity of any individual technology capable of providing reserves constrains hourly reserve provision such that:

$$K_{a,g} - G_{a,g,h} \geq K_{a,g,h}^{FR} + K_{a,g,h}^{SR} \quad \forall\, h, a, g \tag{5}$$

For the technologies providing fast reserve capacity we also want to ensure that sufficient capacity is spinning:

$$G_{a,g,h} \geq k^{spin} \cdot K_{a,g,h}^{FR} \quad \forall\, h, a, g \tag{6}$$

where k^{spin} defines the proportion of capacity available for reserves. A similar constraint is added for the slow reserve technologies required to be spinning.

This ensures that no reserves may be provided if a technology is not running. At the same time the constraint forces capacities to be running at higher levels to be able to provide sufficient capacity.

This formulation is only an approximation in order to avoid unit commitment. We do ensure on a technology basis that capacity will be spinning. We do not, however, exactly ensure in this way that a particular unit considered for up-regulation will be spinning. What we do know is that some capacity of a technology that would be capable of fast up-regulation is spinning. As usually several units of the same technology type would be present in the system, we may risk that all spinning units are fully utilised, and that we are relying on a different non-spinning unit for the fast reserve. We do consider this inaccuracy to be acceptable in the context of our analysis.

The constraint we use to force spinning capacities in equation (6) allows for increasing levels of reserve provision per technology, as the generation of that technology increases. To reflect the ramping capability of generation technologies more realistically we introduce an additional constraint to limit the reserve provision of each technology to a certain percentage of installed capacity.

$$K_{a,g} \cdot k^{ramp} \geq K_{a,g,h}^{FR} \quad \forall\, h, a, g \tag{7}$$

We use approximate ramp rates; moreover, we define the spinning factor k^{spin} such that it stays active only until a minimum load level of 20% is reached.[1] Therefore, as far as reserve provision is concerned, the full ramping capability is only utilised at levels above the minimum load. Again we avoid unit commitment modelling and do not model minimum load requirements explicitly. We do, however, substantially restrict reserve provision at generation levels below the technical minimum using this kind of non-integer linear approximation. Table IV shows the technology characteristics used (based on [91]). The potential for reserve provision subject to the level

[1]This will be the case for $k^{spin} = \frac{load^{min}}{k^{ramp}}$

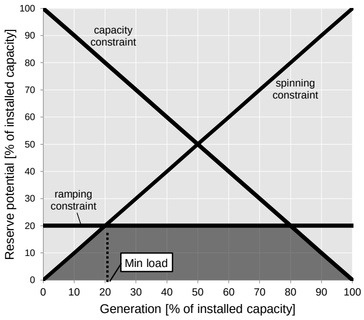


Figure 5. Potential reserve provision from steam turbines and CCGT

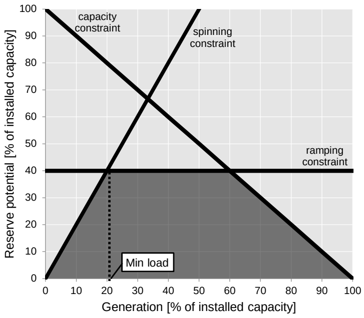


Figure 6. Potential reserve provision from gas turbines

of generation of the different technologies is indicated by the dark grey areas in Figures 5–7.

Table IV
TECHNOLOGY CHARACTERISTICS USED IN RESERVE CONSTRAINTS

Technology	**Min. load** [%]	**Ramp rate** [%/5 min.]	k_{spin} [-]
Steam turbines	20%	20%	1
CCGT	20%	20%	1
Gas turbines	20%	40%	0.5
Combustion engines	0%	100%	-

To determine the overall required capacity we apply an approach incorporating demand flexibility in a way similar to that of [43].

We have defined an operating reserve requirement by equations (3) and (4). This far, demand flexibility only explicitly affects the hourly energy balance of the system, and demand flexibility is able to reduce required peak capacity to serve hourly load. We would like to extend this approach, though, to also allow for the provision of reserves from demand flexibility. To analyse this case we extend the reserve capacity equations (3) and (4) with variables reflecting reserve contribution from demand response $R_j^{Dflex,SR/FR}$:

$$\sum_{a \in A_c} \sum_{g \in FR} K_{a,g,h}^{FR} \geq R_c^{FR} - \sum_j \sum_{a \in A_c} R_{a,h,j}^{Dflex,FR} \quad \forall\, h, c \tag{8}$$

$$\sum_{a \in A_c} \sum_{g \in SR} K_{a,g,h}^{SR} \geq R_c^{SR} - \sum_j \sum_{a \in A_c} R_{a,h,j}^{Dflex,SR} \quad \forall\, h, c \tag{9}$$

The flexibility potential of the demand side may only contribute to reserves if it is not utilised in the spot market. As we only consider positive reserves, we have to be able to reduce consumption in order to contribute:

$$D_{a,h,j}^{flex\text{-}pot} + D_{a,h,j}^{flex} \geq R_{a,h,j}^{Dflex,FR} + R_{a,h,j}^{Dflex,SR} \quad \forall\, h, a, j \tag{10}$$

We want to avoid, however, that a planned increase in consumption due to postponed demand in earlier hours will be postponed even further as this would violate the assumptions used in the demand response modelling of a limited time window for any response. Therefore additional demand due to activated flexibility is not allowed to be curtailed and used for reserves. Consequently, any contribution of demand flexibility to reserves is restricted to the original flexibility potential:

$$D_{a,h,j}^{flex\text{-}pot} \geq R_{a,h,j}^{Dflex,FR} + R_{a,h,j}^{Dflex,SR} \quad \forall\, h, a, j \tag{11}$$

$$\cdots + D_{a,h,j}^{flex} + \alpha \sum_j \left(\sum_{t=h-S_j}^{h} \frac{R_{a,j}^{Dflex,FR}(t) + R_{a,j}^{Dflex,SR}(t)}{S_j} - R_{a,j}^{Dflex,FR} \right. \tag{12}$$

The factor α represents the fraction of reserve capacity expected to be activated. Based on historical observations [87] we use a factor of $\alpha = 0.15$.

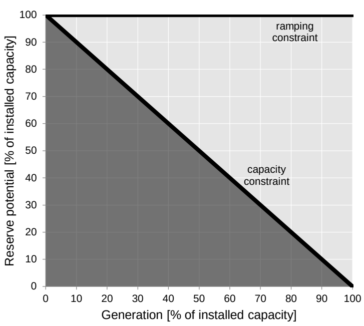


Figure 7. Potential reserve provision from combustion engines

D. Scenario set-up

Denmark pursues a strategy of decarbonising its energy system. Although not undisputed, the long-term target of a fossil-free energy system in 2050 is widely supported. An important contribution is supposed to come from the electricity and heating sectors, both of which should become fully renewable by 2035 according to a strategy set forth by the Danish Government [92]. We reflect this strategy in our model using framework conditions in line with the Danish Energy Agency's "wind scenario" [93] (for further details regarding the scenario implementation see [94]). Although the model formulations in sections II-A and II-C are applicable to cover any country that is part of the model, we focus on Denmark only for this case study. Both the reserve requirements and the demand response model are therefore only applied in the two Danish regions East and West in order to isolate the effects.

We set up the following model runs for the year 2035 in order to evaluate the system contribution of demand response with high shares of renewable energies:

1) Reference case: including neither reserve requirement nor flexible demand;
2) Reference with flexibility: including flexible demand, but no reserve requirement;
3) Reserves with hourly flexibility: including reserve requirement, and flexible demand in the hourly energy balance equation;
4) Reserves with demand flexibility reserve: including reserve requirement, with flexible demand included in the energy and reserve balance equations.

The difference in costs between the reference and the base case reflects the costs of the reserve requirement if no flexible demand is available. We want to determine the potential contribution of flexible demand to a reduction of these costs. Therefore we need to isolate the effect on reserves from general savings in the spot market. We can calculate the benefit that demand flexibility generates in the hourly spot market as the difference between the total system costs of cases 1 and 2, the reference cases without and with demand flexibility. To determine the net effect of a direct contribution of demand flexibility to reserves, we first find the reference costs of reserve without demand flexibility (case 2 minus case 3) and compare it to the new reduced costs (case 2 minus case 4).

E. Sensitivity analysis

We are interested in further analysing the effect on the cost associated to providing adequate reserves by two specific variables of interest: the amount of flexible demand capacity available, and the amount of required reserves (both fast and slow).

For this, we conduct a three-level sensitivity analysis, where we calculate the cost reduction achieved by providing reserves from flexible demand. The sensitivity analysis is done for each variable independently, running the model for two scenarios: *Reserves with hourly flexibility*, and *reserves with demand flexibility reserve*; from which we calculate the net contribution to costs of demand flexibility reserves as the difference of the objective function value in each scenario.

For each variable, we defined two additional levels, one 10% above the original, and the other one 10% below. In the case of the requirement of reserves, the changes were done to both fast and slow reserves simultaneously.

III. Results

The reference case results provide us with a benchmark to compare results of the remaining cases. We derive total costs of maintaining a certain capacity in excess of demand to provide balancing services covering the imbalances introduced by wind power and load forecasting errors as well as potential plant and line outages as shown in Figure 8. We derive annual benchmark costs of €104 million to provide sufficient reserve capacity to the Danish system in the year 2035. We use the full flexibility of the supply side of the power system, including flexibility in the district heating sector for as far as it may affect the electricity balance.

It should be mentioned that this cost only covers the availability of capacity and not the potential activations due to actual deviations.

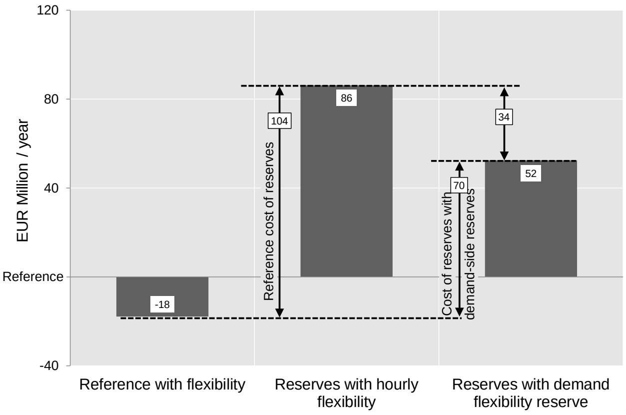


Figure 8. Reserve costs derived from case results 2–4 relative to the reference case 1

Including demand response as a resource that may be used just as any supply-side resource to provide flexibility in order to minimise total system costs, will in the first instance be equivalent to optimising available capacity in the hourly spot market. As we run the model on an hourly basis, any contribution can only be on an hourly level. Moreover, the deterministic nature of the model within a year means that we do not deal with uncertainties in the first place. The participation in the spot market yields a positive effect on the total system of €18 million. As should be expected from the formulation of the demand response model, within the given assumptions on the flexibility of consumers, load may be served in a cheaper way. The resulting demand profile for one of the modelled weeks is shown in comparison to the original profile in the top panel of Figure 9.

Another effect we observe is whether and to what extent the optimisation in the spot market relieves capacity and makes it available for use as system reserve capacity. In particular, if investments in new capacity that should stay available as peak and reserve capacity could be avoided or reduced, this could be expected to generate significant benefits attributable to the utilisation of demand response – although only participating in the spot market. We do observe a change in the demand response pattern (see mid panel of Figure 9), however, the cost of reserves is hardly affected by the hourly demand flexibility.

We assume idle demand response capacity to be available as

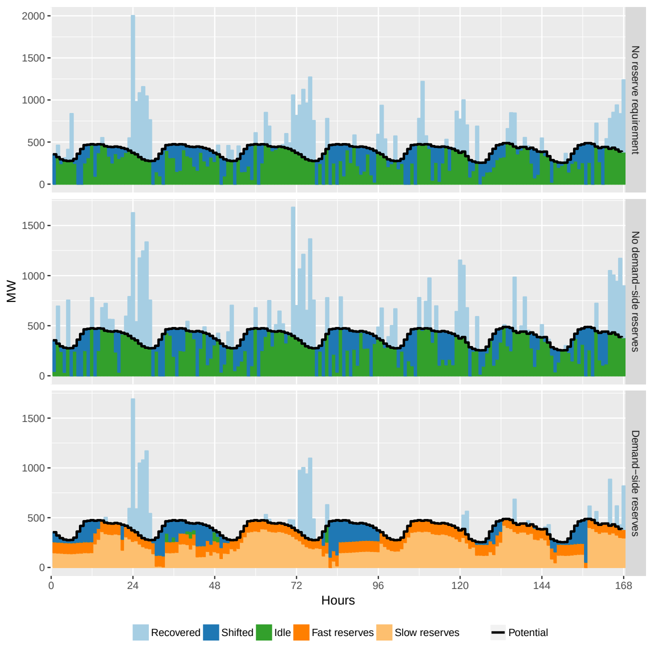


Figure 9. Utilisation of flexible demand during one week by case

reserves, as it implicitly contains a potential for curtailment or load increase.

The ability of the demand side to leave idle capacity for system reserves results in a reduction of costs for providing reserves. Comparing the reference cost with the demand response case (right bar in Figure 8) we find that contributions from the demand side could reduce the costs of reserves provided by generating units by €34 million. The resulting costs lie at €70 million corresponding to a reduction of approximately 33%. One has to mention here that this result does not take into account other costs than the opportunity costs of withholding capacity from the hourly market and the cost of recovering activated reserve at later points in time.

A notable result is that the types of demand flexibility that we included in our calculations are more valuable as a system reserve than in the hourly spot market. Based on our assumption the savings of €34 million generated in reserves are almost double the savings of €18 million generated in the hourly market. Accordingly, idle flexible demand is utilised as reserves to a large extent when allowed to, as it can be seen in the lower panel of Figure 9. At the same time, hourly benefits may be maintained at the same level as in the case without demand-side reserve provision.

The composition of capacities available for reserves changes slightly under the different scenarios. In Figure 10 we show the composition in cases with and without demand participation in reserves.

We can see that demand is mostly substituting reserves provided by large-scale biomass plants based on wood chips, that originally provide a big share of the slow reserves. In the case of fast reserves, the demand side reduces the relative high share of biogas, while small effects on the reserves based wood generation.

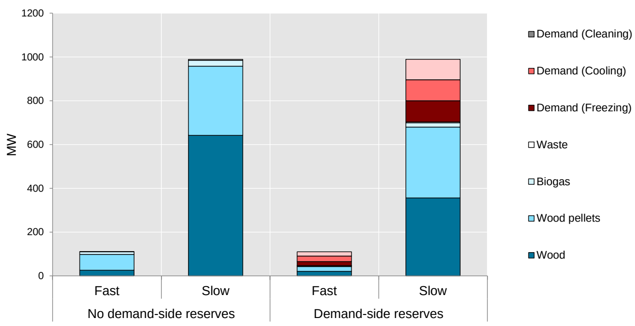


Figure 10. Annual average reserve provision by technology

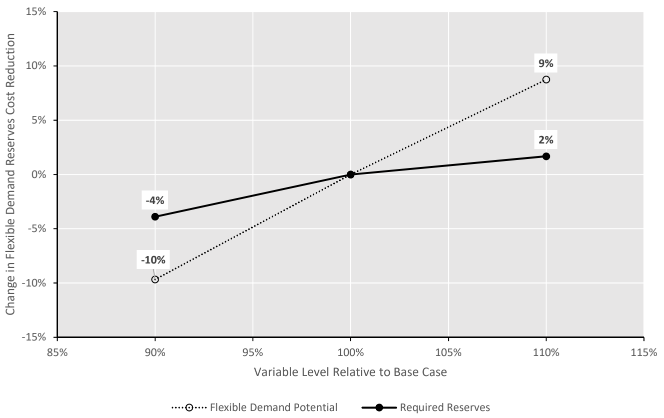
Looking at the sensitivity analysis regarding the cost reduction produced by including reserves from flexible demand shown on Figure 11a, we can see, as expected, that increasing the flexible demand potential increases the cost reduction. The relation between the change in flexible demand and the reduction of cost is quasi-linear, with a slope close to 1.

On the other hand, the effect of changing the required reserves does not have as big of an impact but maintains the same direction of change. Furthermore, the effect of reducing reserves has a higher impact than increasing them, providing a non-linear relation. It is interesting to note that increasing the required reserves, also increases the cost reduction produced by including reserves provided by flexible demand. This is because increasing the reserve requirement implies that the cost of reserves represents a higher share of the system cost, and therefore providing cheaper reserves through flexible demand has a bigger effect on the total system cost.

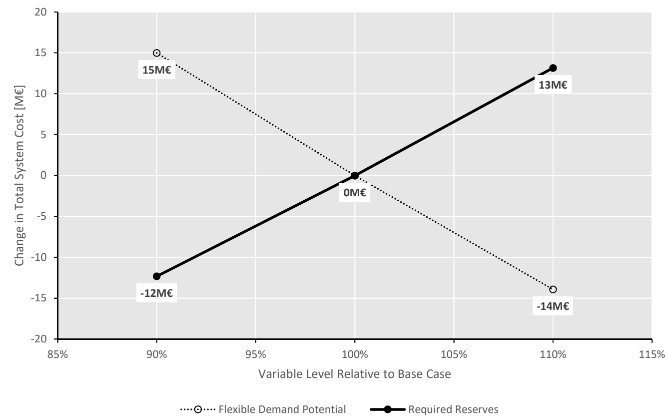
When we look at the effect of these variables on the total system cost as shown on Figure 11b, we can see that both variables have a quasi-linear relation with the system cost, although opposite. Increasing the required reserves produces an increase of similar magnitude in the total system cost, by incrementing the amount of generation capacity that needs to be reserved or installed to provide these reserves. On the other hand, increasing the potential for flexible demand produces a percentual decrease in total system cost of similar magnitude, due to the increased possibility of replacing expensive reserve generation with reserves provided by flexible demand.

IV. Discussion

Our case study results show that intra-hourly flexibility holds a significant value potential for demand response. To the extent that the control of residential appliances, e.g. cooling, freezing or cleaning, may be automated, even household customers could be able to capture some of this value. The benefits of providing reserves clearly exceed those of hourly load shifting. In our calculations demand response reduces system costs by around three times as much when providing reserves as compared to when it is utilised only in the hourly market.



(a) Changes in cost reduction produced by flexible demand provided reserves



(b) Changes in total system cost

Figure 11. Sensitivity analysis results

Thus, the value of participating in reserve markets could potentially contribute to two-thirds of the total value. The provision of reserves could also be attractive for another reason: in the spot market revenues may only be generated when load is actively shifted, whereas in reserve markets only parts of the offers will be activated and result in actual load shifts. Therefore it may be an option for the demand side to participate primarily in the reserve markets, despite the trade-off present in the model results between utilising response potential in the spot market and leaving it to stay available for intra-hour demand response.

It should be noted, though, that the absolute level of the reserve costs and the corresponding savings are somewhat uncertain. A crucial model input is the reserve requirement and its forward projection based on installed wind power. Although the resulting curve of the reserve requirement resembles findings of similar analyses [95], it cannot be fully verified. We are able, however, to validate the order of magnitude of the resulting reserve costs on the basis of costs published by the Danish system operator. In 2015 the costs for reserves was stated to be close to €79 million [96], but costs have been as high as €142 million, as of 2008 [97]. Our estimations are slightly higher than the 2015 values, which should be expected as we scale wind forecast errors with the expected capacity in 2035 and, accordingly, assume a higher reserve requirement. A couple of conditions make it difficult to compare the model results with actual costs directly, though. Nonetheless, our estimation lies in the range of previously published values. The modelled costs reflect the need for building additional capacity, while it is unclear in how far plant operators actually rely on reserve markets to drive investments. Moreover, we do not reflect, in our reserve dimensioning and modelling, the Nordic cooperation that enables cross-border provision of reserves subject to available transmission capacities. We also exclude some potential providers of reserves, like heat pumps, from the market. A slight overestimation of costs, thus, seems to be inherent in our assumptions. Considering the substantial simplifications in the dimensioning and modelling of reserves, however, we regard our cost estimates as rather close to actual costs.

In relation to the demand-side contributions to reserves, we need to add some qualifications. An important precondition for using demand response as reserve capacity, in general, would be automatic control. Devices could be controlled in a centralised way or even in a more autonomous decentralised manner. It is unlikely, however, that a system operator would rely on price-based manual control to ensure system reliability. Our analysis relies on studies that identified certain potentials, some of which may not be fully automated. Moreover, automation will come at a cost that has not been considered in our model runs. Additional uncertainty is added by the adoption behaviour of households and a limited willingness to accept automation equipment [98], [99]. The total cost savings should therefore be considered as an upper bound. Household consumers with a high flexibility potential and the willingness to accept automated control would still be able to benefit considerably. It should also be noted that other appliances, like heat pumps and electric vehicles with a possibly even higher potential in the future, would be able to contribute in a similar way and compensate for the lack of potential in the appliances used for this analysis.

A general challenge for load-shifting demand is that a response will have to be made up at a different point in time such that the overall consumption does not change. In an hourly market this could be planned ahead of time, although one may have to rely on price-independent bidding. In a regulation market, if capacity is provided as reserves within an hour and then activated, activation will only occur in one direction. The recovery will require changing consumption in the opposite direction. At present this could not occur within the regulating market, as it would not be possible to place a bid for the recovery beforehand. Compensation has to occur at a later point in time, potentially through intra-day activities or through the placement of adjusted bids in the following periods for regulation. Alternatively it might be helpful to integrate load recovery directly into the bidding mechanism [100]. The challenge could also be decreased if settlement periods were shortened and the regulating market would be re-organised around such periods. With any bid placed in this market, one would only commit capacities during a comparatively shorter time frame, and recovery could happen through short-term market transactions in subsequent periods. If none such options are established, recovery would have to be settled through the imbalance mechanism, potentially recreating the problem it was meant to solve in the first place. Demand participation as reserves in the form of load shifting may therefore be limited until products are re-designed.

Another issue that may have an influence on the value of demand flexibility is the timing of its introduction. Early availability of demand flexibility will reduce or delay the investment needs in new flexible capacities. We have in our analysis restricted demand response to the Danish market. The potential value that could be achieved in the ordinary spot market, thus, reflects either early adoption in Denmark, or delayed adoption in surrounding countries. With neighbouring regions pursuing similar plans for demand-side flexibility, the value in the internationally coupled hourly markets would become lower than estimated. The value of reserve provision should not be affected in the same way, as the reserve requirement will be provided by domestic resources to a larger extent. Efforts towards an improved international integration of reserve and balancing markets, however, could have an impact on the intra-hourly value in the future as well.

Finally, as the sensitivity analysis shows the biggest effect on both total system costs, and potential savings obtained by introducing demand flexibility reserves, is the amount of available flexible demand. As expressed by our previous comments, there is a high degree of uncertainty on the expected amount of flexible demand that could be available for use as reserves, both from a technical and a regulatory perspective. This uncertainty is therefore extended to the levels of cost savings obtained.

V. Conclusion

Keeping in mind the limitations discussed above, we were able to determine a first estimate of the system value that demand flexibility could contribute with by participating in hourly spot and reserve markets. While attractiveness of the price differences in hourly spot markets may also be limited in future systems with large shares of variable renewable production, participation in reserve markets could provide an interesting additional source of income to providers of flexibility on the demand side. We focussed on the Danish case, but analysed the feasibility taking an energy system approach. In this way, we were able to reflect the dynamic interactions with neighbouring systems and the heating sector as well as, to a certain extent, competition with other sources of flexibility.

An important conclusion is that the value of shifting load intra-hourly may exceed the value of doing so on an hourly basis. Thus, it might be an attractive market segment for the demand side to participate in, and our results suggest that the short-term value of demand response should be analysed in greater detail. The addressed short-term flexibility, however, is complex to handle and its utilisation is subject to several preconditions. It seems recommendable to further explore the value potential through system studies based on refined modelling of reserves and demand flexibility. A more detailed assessment of the input parameters regarding the reserve requirement and specific load characteristics may be required in order to draw more robust conclusions. Also, the potential of increased competition from other flexibility measures both domestic and in neighbouring regions should be considered.

From a more practical point of view, technical and regulatory limitations need to be addressed. First of all, the processes of bidding and activation need to be largely automated. But besides such technical constraints, the large-scale participation of demand-side units requires some of the market mechanisms to be adjusted accounting for the specific characteristics of load shifting.

If no measures are taken, demand-side reserve provision will stay restricted to mere load curtailment or load shifts with a longer time horizon; these conditions would probably exclude many residential loads. To utilise the full value potential that lies within the intra-hourly time frame, therefore, the reserve market design should provide for better integration of residential demand flexibility.

APPENDIX A
NOMENCLATURE

h: index for hours
c: index for countries
g: index for generation technology
j: index for consumer appliance
a: index for areas
A_c: set of areas belonging to country c
FR: set of generation technologies capable of providing fast reserves
SR: set of generation technologies capable of providing slow reserves
$D_{a,h,j}^{flex\text{-}pot}$: hourly demand flexibility potential of appliances j in area a [MWh]
$D_{a,h,j}^{flex}$: shift from flexible demand in area a [MWh]
S_j: load shift horizon of appliances j [h]
$K_{a,g,h}^{FR}$: hourly capacity of technology g in area a reserved for fast reserves [MW]
$K_{a,g,h}^{SR}$: hourly capacity of technology g in area a reserved for slow reserves [MW]
$G_{a,g,h}$: hourly generation by technology g in area a [MWh]
R_c^{FR}: fast reserve requirement in country c [MW]
R_c^{SR}: slow reserve requirement in country c [MW]
$R_{a,h,j}^{Dflex,FR}$: hourly demand flexibility from appliances j reserved for fast reserves in area a [MW]
$R_{a,h,j}^{Dflex,SR}$: hourly demand flexibility from appliances j reserved for slow reserves in area a [MW]
$K_{a,g}$: installed capacities of generation technology g in area a [MW]
k^{spin}: factor for spinning requirement [-]
k^{ramp}: factor for ramping limitation [-]
α: average share of activated reserve capacity [-]

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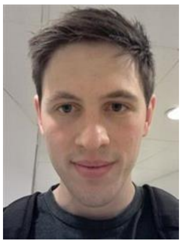

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Paper F

Dynamic sea scape amenity costs from offshore wind farms: Causal effects of prior experience from a natural experiment

(Draft)

Dynamic sea scape amenity costs from offshore wind farms: Causal effects of prior experience from a natural experiment.

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Abstract

Offshore wind power is one of the major drivers in the change to a fossil free energy production. Compared to onshore wind farms, offshore is expected to on one side leviate some of the external cost of wind energy but on the other hand increase production costs. This makes is highly attractive to locate offshore wind farms close to shore as the cost thereby is minimised. Using a natural experiment with two samples of respondents with near shore and far shore wind farms, the present paper test if near shore locations relative to far shore location influence the preferences for mitigating sea scape amenity costs caused by offshore wind farms. Based on a choice experiment, the results of the analysis clearly demonstrate that the respondents living in an area with a nearshore wind farm are less sensitive towards costs and choose the 0 price alternatives and 173€ alternatives, significantly fewer and more times, respectively. In terms of preferences and WTP this translates into significantly different preferences and higher levels of WTP for locating the offshore wind farms further from the shore. The results also point towards that the preferences and WTP differences specifically is related to choice sets with a 0 or/and 173 € price alternative. When confronted with choice sets with prices in the intermediate range (0<price<173), neither preferences nor WTP differences can be found. Interestingly, the difference in prior experience also influences the error variance of the model. Respondents from the nearshore area, has substantially lower McFadden R^2 compared to the respondents in the sample with a far shore wind farm. Again these differences can solely be found in the choice sets with 0 and 163 € alternatives and not in the intermediate priced choice sets. Jointly, the results point towards that location of offshore wind farms close to shore can form the perception of the sea scape quality degradation caused by offshore wind farms and subsequently introduce dynamics in the preferences formation and external cost of wind power.

Introduction

From the yearly stated preferences studies significant resources have been invested in the designing surveys and analysing preferences to get valuable insight into how information influences demand relations and acceptance of the hypothetical market put forward. Following Mitchell and Carson (1989) information is "among the most important and most problematic sources of error". One part of the literature have focus on how variation in the information about the quality of the good in focus influences subsequently stated preferences (Munro and Hanley 2001; Bergstrom, Stoll, and Randall 1989, 685-691; Blomquist and Whitehead 1998, 179-196; Boyle 1989, 57-63; Samples, Dixon, and Gowen 1986, 306-312). Other studies have tested information in other dimensions such as order effects (Day et al. 2011, 73-79; Carlsson, Mørkbak, and Olsen 2012, 19-37; Van der Waerden et al. 2006, 12-18) and mitagating biases through information prior to the preferences elicitation. More specifically, entreaties/scripts have tested to reduce hypothetical bias on the internal and external margins of preferences (Cummings and Taylor 1999; Bosworth and Taylor 2012;

Ladenburg and Olsen 2014), protest behaviour (Atkinson, Morse-Jones et al. 2012), use of learning choice sets (Ladenburg, Olsen 2008, Meyerhoff, Glenk 2015) and detailed presentation of the choice tasks (Advanced disclosure/visible choice set) (Bateman, Cole et al. 2004, Day, Bateman et al. 2011).

Far fewer studies have looked into how preferences and prior information / knowledge / experience interact. This is despite the inherent valuable information the prior preferences relation might entail. If exogenous differences in prior information significantly influence preferences, this will give more valid welfare estimates of different policy outcomes. Furthermore, understanding differences in the demand relation as a function of prior experiences gives value information in when designing of stated preferences studies.

In the earlier studies addressing the relation between experience and preferences Cameron and Englin (1997) find that experience (number of years fishing) increases the WTP for doubling trout population and decrease conditional variance. Loomis and Ekstrand (1998) find that better knowledge about the Northern and Mexican Spotted Owls as well as endangered fish in the Colorado River increases WTP. Tkac (1998) tests how differences in preferences for environmental protection schemes differ between two distinct samples; biologist students and economics students. She finds WTP significantly correlates with the level of prior knowledge[1]., but also that prior knowledge made new information inert. These studies suffer from potential endogeneity. Or as stated by Cameron and Engling (1997) "The modeling exercise is further complicated by the fact that experience or familiarity with environmental goods may be obtained in two ways. A respondent may have experience that is exogenously provided by a survey instrument or endogenously determined by the respondent's past behaviour. Several studies have tried to use the exogenous survey instrument approach.

In another study Hoehn and Randall (2002) test how resource injury information affected preferences and how the information effect correlated with prior knowledge. Their results showed that the perceived injury change changed with different treatment of information and that perceived changed related to the valuation of the good in focus. However, their results also showed that the perceived injury change was not unidirectional. Given that prior knowledge was heterogeneous, some respondents reduced the perceived injury change as a function of the new information[2]. Furthermore, the result also indicated that the differences in prior knowledge (with the sample mean as an benchmark) had an effect on WTP, i.e. the higher level of prior knowledge compare to the sample mean the higher WTP and vice versa. Lariviere er al. (2014) test for differences in correct objective knowledge about cold water corrals and relate the level of knowledge with stated preferences for the protection of cold water corrals and preference scale in an experiment, where a random sample of the respondents are informed about their level of knowledge. The results before the information experiment show positive relations between the

[1] In her study, prior information is represented by the number of correct answers in a small quiz on a preservation experiment for the Harlequin Duck.

[2] In their paper, prior knowledge was represented by the assessment of the perceived injury change of the good in question based on a description which did not include specific injury information.

correct level of objective knowledge and WTP. Likewise, the higher knowledge the higher scale (lower variance). The results from the information treatment, showed no effect scale (the respondents with the highest objective level of knowledge still had higher scale independent on being informed about the level of knowledge). However being provided with information about the level of knowledge, particularly influenced the respondent with a higher level of knowledge. Tu and Abildtrup (2016) apply the number of visits and number of different forest visits as experience variables and find experience to increase scale (lower variance). Recently Lariviere er al. (2016) screen respondents level of knowledge about the flooding, flood protection and wetland. Respondent were afterwards given three, six or nine pieces of information about flood attributes, corresponding to the initial nine knowledge questions. The number of information pieces were conditional were randomised, so that on the number of correct answered questions varied among the respondents. After being presented with the valuation scenario, the respondents were given the initial quiz again. The study find evidence of incomplete learning and fatigue. As the respondents are given more information about the resources in focus, their marginal learning rates decrease, but also that there is no marginal impact of knowledge on the mean nor the variance of WTP. However, as found in many of the other studies ex ante knowledge affects WTP.

However, though it is attempted to induce exogenous variation in the level of information across the respondents before preference elicitation, no studies have to the authors knowledge estimated causal effects of prior experience on preferences and willingness to pay

Building on the above mentioned literature, we take advantage of a natural experiment and explores the demand relation space. Specifically, we explore these properties by estimating the preferences of visual disamenity reductions among respondents with two sets of different levels of prior experience (near shore wind farm and far shore wind farm) with offshore wind farms. We test if differences in prior experience influence preferences, model scale and stated preference certainty. Our results strongly suggest experience effects the location and shape of the demand curve, preferences for wind farm location and configuration but also scale and stated preferences certainty. In addition to adding to the prior experience literature our results also brings forth significant results to the stated preference wind power literature and policy setting (Krueger, Parsons et al. 2011, Ladenburg, Bonnichsen et al. 2011, Ladenburg, Dubgaard 2007, Landry, Allen et al. 2011, Westerberg, Jacobsen et al. 2013, Lutzeyer, Phaneuf et al. 2016). If preferences are sensitive to variation in experience with the good, path dependency in the assessment of the welfare cost of energy might emerge and biased policy recommendation might be a consequence. This might be of particular interest in areas with steep coastal water, such as the US, large parts of the European coastal areas pointed out for future wind power development. As our results strongly suggest that near shore wind farm experience might induce stronger preference for location wind farms further from the coast and thereby increasing the welfare benefits of doing so.

The article is structured as follows. First the economic model of prior experience and choice is presented, which is follower up by a presentation of the data and the natural experiment, econometric model, results and conclusion.

Economic model of information and prior experience

Following Blomquist and Whitehead (1998), the perceived quality of a good can be expressed in terms of the actual quality of the good θ, and the information received during the survey regarding the good's quality I:

$$q_i = \beta\theta \ + \delta I \ [1]$$

Both the objective quality of the good and the information received during the survey are subject to individual learning parameters β and δ, respectively. These learning parameters do not refer to the amount of information provided alone, but also to the capability of the respondent for absorbing this information, either due to personal capabilities, motivation for processing the information, the availability of the information, or the quality of the information medium chosen. Therefore, the term $\beta\theta$ expresses the total amount of previous information on the resource quality that the respondent has regarding the good, while the term δI represents the total effect on the perception of the resource quality from the information added to the respondent during the survey.

Expanding this formulation to the standard setup of a Choice Experiment including *n* resource quality attributes of the good in focus, the quality changes under evaluation depend on the values of the *n* attributes and therefore the terms of the equation [1] can be expressed as vectors:

$$q_i = \hat{\beta} \cdot \hat{\theta} + \hat{\delta} \cdot \hat{I} = [\beta_1, \dots, \beta_n] \cdot [\theta_1, \dots, \theta_n] + [\delta_1, \dots, \delta_n] \cdot [I_1, \dots, I_n] \quad [2]$$

Where every term of the vectors $\hat{\theta}$ and $\hat{I}$ represent the actual quality change produced by a specific attribute of the good, and the information given to the respondent regarding that particular attribute of the good during the survey, respectively. In the same way it is possible, if desired, to further expand the individual learning parameters for actual quality and given information, to a "per-attribute" basis, shown here as $\hat{\beta}$ and $\hat{\delta}$[3].. The past studies have focused on the relation between exogenous variation in information (ΔI), the learning ability δ and the level of prior information β*θ (Tkac 1998, Hoehn, Randall 2002, Lariviere, Czajkowski et al. 2016). In the same way and being the focus of our paper, while some attributes of a good might be well known by the general population, other attributes might be more ambiguous or subject to higher levels of lack of knowledge or even misinformation, being reflected in the per attribute values of $\hat{\beta}$.

Following Koch and Ladenburg (2015), we extrapolate [2] to the specific case of preferences for visual disamenity reductions. Studies show that preferences regarding visual disamenities produced by wind turbines are driven by many different attributes of the wind turbine farm: Number of turbines NT, size of each individual turbine S, grouping of the turbines in the farm G, distance of the turbines from the viewpoint D, features of the particular landscape F, location of the turbines in the landscape L, and number of wind farms NF (Meyerhoff, Ohl et al. 2010, Dimitropoulos, Kontoleon 2009, Ladenburg, Dubgaard 2007, Landry, Allen et al. 2011, Westerberg, Jacobsen et al. 2013, Álvarez-Farizo, Hanley 2002). Therefore, expanding equation [3]

[3] This can be used to express that some information is given in the survey using different mediums, such as text or images , which have different communication qualities and information absorption rates, shown in the per attribute values of $\hat{\delta}$

for the particularities of wind turbine visual disamenities yields:

$$q_i = [\beta_{NT}, \beta_{,S}, \beta_G, \beta_D, \beta_F, \beta_L, \beta_{NF}] \cdot [\theta_{NT}, \theta_S, \theta_G, \theta_D, \theta_F, \theta_L, \theta_{NF}]'$$

$$+[\delta_{NT}, \delta_{,S}, \delta_G, \delta_D, \delta_F, \delta_L, \delta_{NF}] \cdot [I_{NT}, I_S, I_G, I_D, I_F, I_L, I_{NF}]'$$

Applying this framework to our data, the respondents are asked to state their preference for 3500 MW offshore wind farms located 8, 12, 18 or 50 km from the coast, with 160 m high 5 MW turbines with 49, 100 or 144 turbines per wind farm and a total of 5. 7 or 15 wind farms (depending on the number of turbines per wind farm)

$$[\delta_{NT}, \delta_{,S}, \delta_D, \delta_{NF}] \cdot [I_{NT}\begin{bmatrix}49\\100\\144\end{bmatrix}, I_S[160], I_D\begin{bmatrix}8\\12\\18\\50\end{bmatrix}, I_{NF}\begin{bmatrix}15\\7\\5\end{bmatrix}$$

This setup is the same for the two samples. Moving on to the prior experiences with offshore wind farms, the respondents in Nysted have experiences with a wind farm with 72 110 m high turbines located app. From app 6 km from the coast. In the Horns Rev sample the local wind farm consist of 80 110 m high turbines located from 14 km from the coast i.e.

$$[\beta_{NT_{NY}}, \beta_{S_{NY}}, \beta_{D_{NY}}, \beta_{NF_{NY}}] \cdot [\theta_{NT_{NY}}[72], \theta_{S_{NY}}[110], \theta_{D_{NY}}[6], \theta_{NF_{NY}}[1]$$

$$\left[\beta_{NT_{HR}}, \beta_{S_{HR}}, \beta_{D_{HR}}, \beta_{NF_{HR}}\right] \cdot [\theta_{NT_{HR}}[80], \theta_{S_{HR}}[110], \theta_{D_{HR}}[14], \theta_{NF_{HR}}[1]\Big]'$$

Comparing the prior experience elements between the two samples, clearly suggest, that the main difference seems to be the distance from the shore that the Nysted and Horn Rev wind farms are located at i.e. the visual disamenities from the local offshore wind farm. If this difference influences either the value formation through the $\beta\theta$ element or the δI element, we would expect preferences for visual disamenity reductions of offshore wind farms to be different between the two sample all things else equal. Unfortunately, we do not have randomized choice sets order within each choice set block. Accordingly, we cannot estimate directly the effect of institutional and value learning (Carlsson, Mørkbak et al. 2012, Czajkowski, Giergiczny et al. 2014) or apply more advanced Bayesian information updating models over choices sets (Lariviere, Czajkowski et al. 2014).

Case Study

As a part of a large offshore impact study (Dong Energy, Vattenfall, et al. 2006) related to the establishment of the two offshore wind farms Horns Rev an Nysted in 2002-3, we carried out a stated preference study among a sample of respondents living in the areas close to the two offshore wind farms[4]. Each sample consisted of 350 randomly selected individuals between the age of 20 and 65 drawn from the Danish Civil Registration System's (DCRS) database[5] from the coastal areas close to Nysted and Horns Rev

[4] We also carried out a national survey. The results have been reported in Ladenburg and Dubgaard (2007, 2009).
[5] The DCRS was established in 1968, where all persons alive and living in Denmark were registered. Among many other variables, it includes individual information on personal identification number, gender, date of birth, place of birth, place of residence, citizenship, continuously updated information on vital status, and the identity of parents and spouses, see [37]

offshore wind farms. Information on the preferences for the visual disamenities and thereby the ground for testing the effect from differences in prior experience was collected by mail-delivered questionnaires in yearly summer 2004. The survey was launched only app. 1 1½ year after the wind farms were put up, but also sufficient long time for the preference and perceptions of the wind farms to mature from potential during projects reactions (u-shaped acceptance curve, Wolsink (2007)).

The questionnaire was tested in both focus groups and a pre-test and is available upon request from the authors. The questionnaire was directly addressed to the individual in the household drawn from the Danish Civil Register System database. Up to two reminders, which did not include a new questionnaire, were sent to the respondents, who had failed to return their questionnaire. In total 132 and 168 usable questionnaires were returned from the Horns Rev and Nysted samples, respectively. This equal to effective response rates of 37.7 % and 47.1 %.

The questionnaire consisted of number of background questions about perceptions and attitudes toward wind energy. After the general attitude questions, the respondents were presented with a scenario description of policy change under evaluation, which was followed up by the traditional questions about socio-demographics. The scenario setting up the valuation experiments was based on an offshore wind power development plan from 1996. The plan stipulated that 35% of Danish electricity consumption should come from wind power by 2030 (Danish Energy Authority, 1996). It was expected that 4000 MW was to be developed offshore. Given the offshore capacity was about 400MW at the time the survey was carried out, the scenario depicted an offshore expansion of 3600MW. 5MW turbines (100m high and with a 120m wing span) were used in the valuation scenario to give a realistic description of future development. Consequently, the scenario entails the establishment of app. 720 (720x5=3600MW) turbines offshore. To minimize potential value biases in the survey it was emphasised that the location of future offshore wind farms would be chosen in such a way that the impact on biodiversity and landscape would be minimised. The CE experiment included the following attributes and levels

The distances in Table 1 were set to illustrate possible future locations of wind farms relative to the shore. In Denmark, 8 km was the minimum accepted distance at that time from the shore for future large-scale wind farms (Environmental Steering Group, 2004). Accordingly, 8 km from the shore was used as the benchmark distance in the survey. In other countries the minimum acceptable distance might be smaller. Distances of 12 and 18 km from the shore were considered as being realistic whilst 50 km is the technical distance from which a wind farm consisting of turbines as large as 5MW cannot be seen from the shore due to the curvature of the earth (Nielsen, 2003). Siting wind turbines at a distance of 50km from the shore is technically feasible in the relatively shallow waters around Denmark, which have been designated for future wind power development. In practice, however, the distance at which 5MW turbines become indiscernible from the shore may be closer or further away than 50 km, as the exact distance is project specific and depends on factors such as weather conditions and landscape elevation.

The number of turbines (49, 100 and 144) represents possible wind farm sizes. 49 turbines per farm is less than the number of turbines

Table 1: List of attributes defining the visual externalities of offshore wind farms

C	Description/levels	Variable definition
Distance from the shore	8 km, 12 km, 18 km and 50 km	Dummy coded with 8 km as a reference DIST12= if is distance from the shore = 12 km, else =0 DIST18= if is distance from the shore = 18 km, else =0 DIST50= if is distance from the shore = 50 km, else =0
Number of turbines per wind farm	49, 100 and 144	Dummy coded with 49 turbines as a reference 100 TURBINES =1 if number of turbines = 100, else = 0 144 TURBINES =1 if number of turbines = 144, else = 0
Number of offshore wind farms in Denmark[a]	5, 7 and 14	
Annual cost (Euro)/household/year	0, 12.5, 23, 40, 80 and 175	COST: Continuous variable

[a] The number of wind farms is almost perfectly correlated with the number of turbines per wind farm. More specifically, people were offered three configurations of wind farm sizes and wind turbine numbers i.e. 14 wind farms with 49 turbines (14*49), 7 wind farms with 100 turbines (7*100) and 5 wind farms with 144 turbines (5*144). Consequently, this variable was not included as an attribute in the design of the survey.

present at the existing offshore wind farms at Horns Rev (80 turbines) and Nysted (72 turbines). Constructions comprising 100 or 144 turbines must therefore be considered as being relatively large, but they are still within the expected range of future wind farm development (Madsen, 2005). The turbines in existing offshore wind farms in Denmark are typically arranged either in a trapezium layout or in one or two rows. From a research and policy perspective, it would have been interesting to include the particular layout as one of the wind farm attributes. However, in order to minimize the number of attributes and thereby to keep the choice task simple, the layout of the wind farms was kept as a fixed attribute. Having consulted with the wind farm developers, a quadratic layout was chosen as being the most appropriate to use in the survey. The number of turbines per wind farm is therefore 7^2, 10^2 and 12^2. The total number of turbines in the scenario must sum to approximately 720 turbines. Accordingly, the number of turbines per wind farm and the total number of farms are almost perfectly (negatively) correlated (14*49 = 686, 7*100 = 700 and 5*144 = 720).

The cost/price was set between 0 and 175 Euros/household/year, the assumption being that it would be a lump sum to be paid on top of the electricity bill. The plausibility of the price levels and payment mode was tested during the focus group interview.

The number of possible combinations given the attributes and the attribute levels is 3x4x6 = 72. It was decided to implement a fractional design of 36 alternatives. Whereas it would have been possible to do a smaller main effect design, which would have increased the representation of each alternative in the data, it was believed that the visual impacts associated with the size of the wind farm/number of wind farms and distance attributes could be causally correlated. Therefore, it was important to control for the possible interaction effects, between size of the wind farms/number of wind farms and the distance to the shore, in the elicited choice model. The alternatives were generated in the SAS system using the macros and the design efficiency recommendations found in Kuhfeld (2004). The initially generated alternatives were blocked in choice sets of two and combined in groups of three choice sets. To minimise both the number of dominating alternatives and non-causal alternatives, the swapping procedure presented in Huber and Zwerina (1996) was used to construct the final choice sets.

A status quo option was not included. The main motive for not giving respondents an opt-out possibility was that the decision to develop offshore wind power has already been taken by politicians. Consequently, including an optout was unrealistic from a policy point of view. According to Hensher et al. (2005), the choice to not include a status quo option is valid in such circumstances.

The visual impacts of the generated alternatives were illustrated by a computer-based visualisation, which was prepared by a specialist consultancy company. It should be emphasised that the generated visualisations represent a view of the wind farms under nearly perfect visibility conditions. However, on many days during the year, the visibility of offshore wind farms will be reduced, relative to the generated images, due to inclement weather conditions. Consequently, the chosen visualisations may have resulted in a tendency for respondents to overrate the actual disamenities from offshore wind farms. In Fig. 1 an example of a choice set is presented.

The natural experiment

In in 1999 the Danish Energy authority gave green light to initiate the preliminary analysis of the of erecting two large scale offshore wind farms at Nysted in the south of Denmark on the Island Lolland and Horn Rev on the west coast of Jutland (see Figure 1) close to the large harbour city Esbjerg Horns Rev and Nysted site, followed by an environmental impact assessment of both sites in 2000 and approval of both projects in 2001.

The two chosen locations were, The wind farm in Nysted was constructed in the period 2002-2003 and the wind farm at Horns Rev at 2002 the end in 2002. The wind farm at Nysted is located app xx-10 km from the coast where as the wind farm at Horns Rev is located app. 14-20 km. The timing of the wind farm construction and the differences in the visual experience with the wind farms due to the location of the two offshore wind farm gives grounds for a natural experiment. As we have preferences collected in the two areas, the natural experiments can be used to identify the potential effects differences in the experience with visual impacts from offshore wind farms on the preferences for the location and configuration of future wind farm development.

Figure 1: Example of choice sets with visualisations

Alternative A

Number of turbines per farm: 49
Number of wind farms in Denmark: 14
Distance from the coast: 8 km
Yearly payment for renewable energy: 300 DKK

Alternative B

Number of turbines per farm: 144
Number of wind farms in Denmark: 5
Distance from the coast: 12 km
Yearly payment for renewable energy: 0 DKK
I prefer (mark with X) Alternative A [ ] Alternative B [ ]

Figure 2: Location of the Horns Rev and Nysted offshore wind farms in Denmark (from Dong Energy et al. (2006))

Data from the two samples represent as natural experiment in relation to the experience with visual disamenities from offshore wind farms. However, the causal interpretation of potential difference in the effect from difference in prior experience on preferences for offshore wind power development rests on the assumption, that the people living in the sampled areas do not react on the presences of the two offshore wind farms at Nysted and Horns Rev and move out. We therefore investigate the trends in inhabitant composition using five key variables obtained from a 10 pct. random sample of the working age population of the annual population in the respective areas. The data are based on a national administrative register at the individual level, where the individual is uniquely identified. For each person we have annual information on gender, age, income, education, the postal address and the date for latest move of address for each of the years 2001-2006 (both inclusive). Each sample area consists of 10 (Horns Rev) and 12 (Nysted) postal codes. For each postal code in the case areas, we selected the geographically closest neighbour, which did not belong to any of the two sample areas. These two groups are used as the control areas in the analysis of changes on moving patterns in the case areas close to the wind farms. If we detect at significant changes in moving patterns in the case areas relative to the control area, before the time when the survey was collected, this could indicate a reaction to the presence of the wind farms in Nysted and Horns Rev. For each area we calculate the mean for each year for the following; share who has moved in the current year, age, share of men, income, years of completed education and the share who has moved in the current year.

The descriptive statistics of the trends in the development of the average mobility and demographics are in Figure 3-7. We have added a linear trend line to the case and control areas, respectively. In only one case is the trend significantly different at the 5 percent level - namely the share of men in Nysted. In all other cases the trends in the respective areas and variables are not significantly different. This reassures us that our identifying argument is valid.

Figure 3: Comparison of trend in average mobility in Nysted and Horns Rev sample compared to control areas.

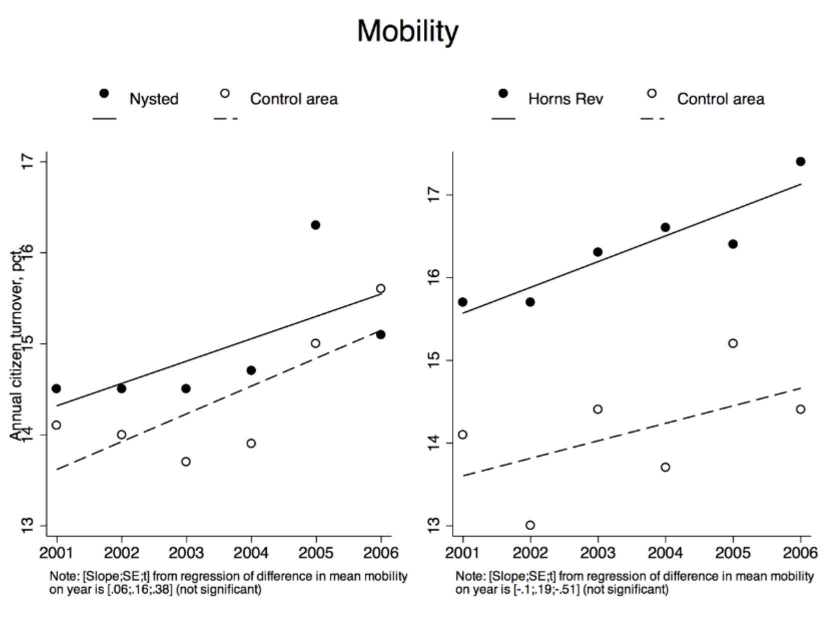


Figure 4: Comparison of trend in average age in Nysted and Horns Rev sample compared to control areas.

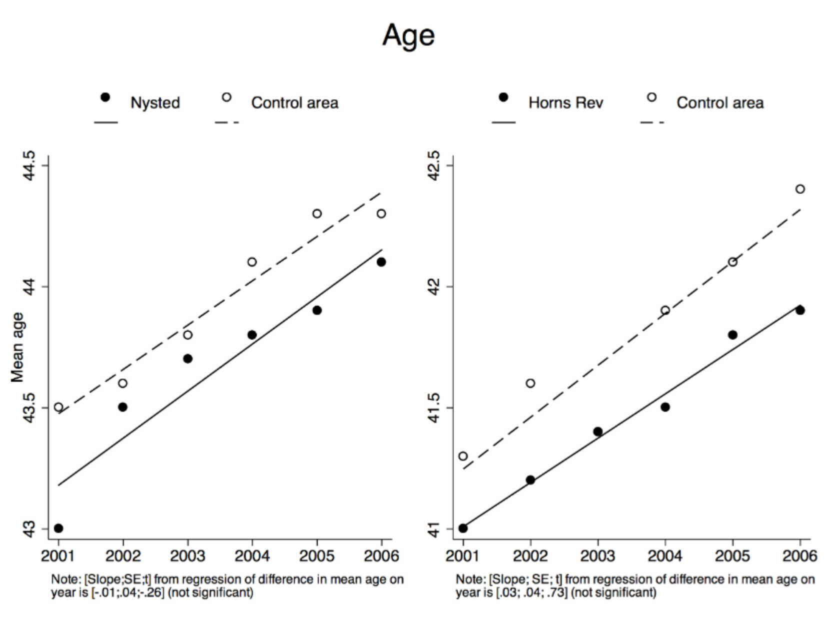


Figure 5: Comparison of trend in average years of education in Nysted and Horns Rev sample compared to control areas.

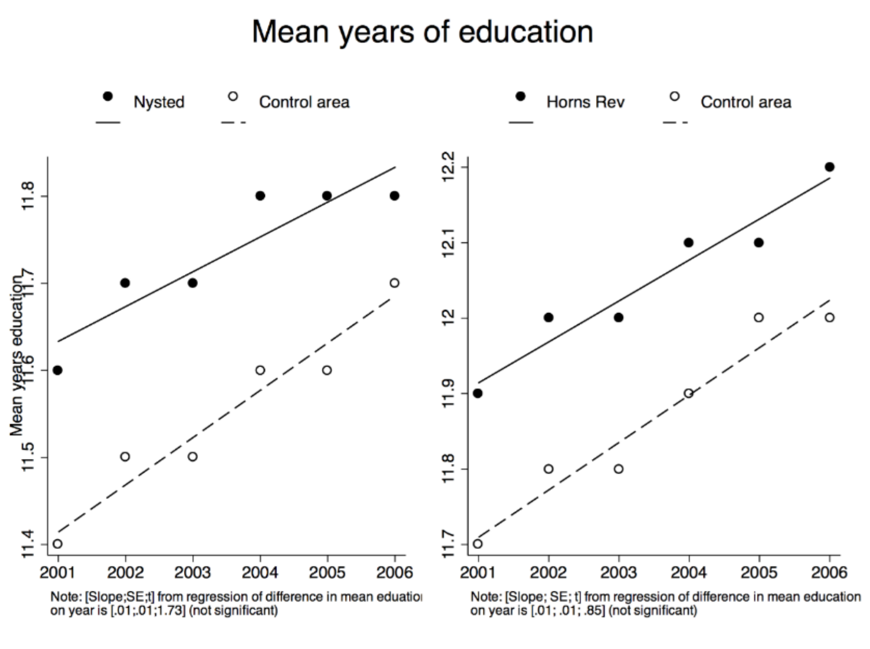


Figure 6: Comparison of trend in average share in men Nysted and Horns Rev sample compared to control areas.

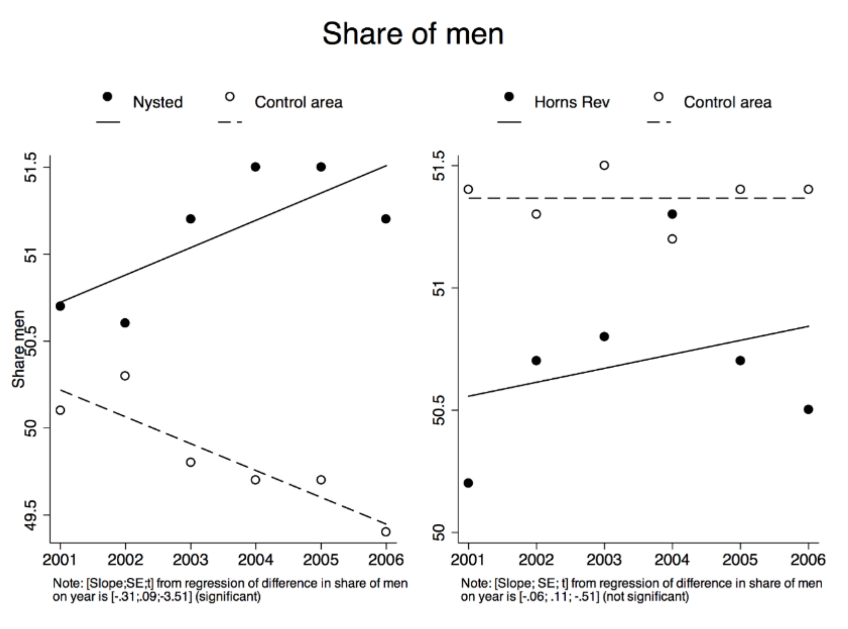
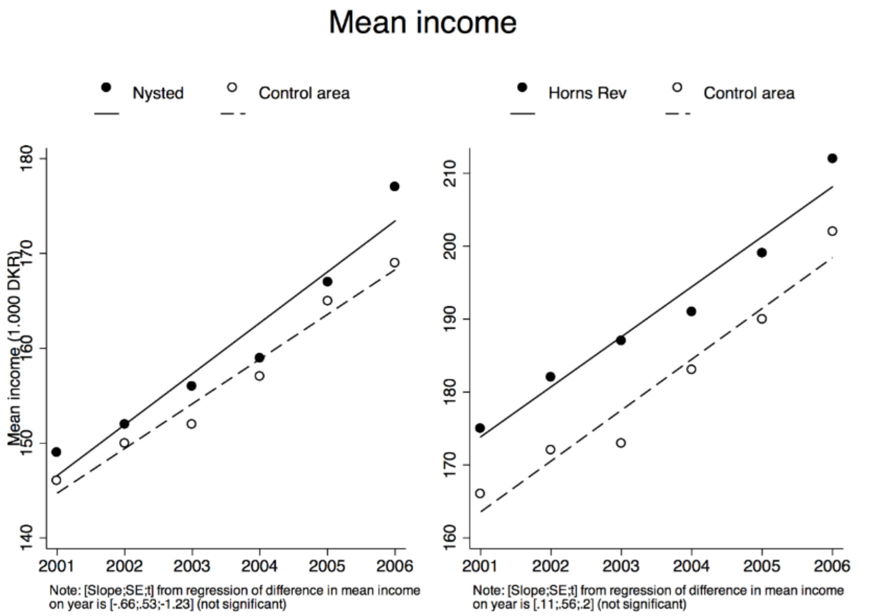


Figure 7: Comparison of trend in average income in Nysted and Horns Rev sample compared to control areas.



Except for the share of male respondents in the Nysted area relative to the control areas, the assumption of parallel trends is not rejected. In the case of male respondents it should be noted, that the change/difference is only app. 2 % point in 2006, compared to 0,5 % points in 2001. Furthermore, a national survey carried out in the same research study did not reveal any differences in preferences between genders Ladenburg & Dubgaard (2007) or differences in attitude towards offshore wind farms (Ladenburg 2008). Accordingly, we might suspect that the differences in trend in the NY sample and the control areas are of less significance. However, as a robustness check all estimated models have been carried out on gender level and do not change the conclusion of the paper[6]. Accordingly, the grounds for interpreting differences in preferences between the respondents in the Nysted and Horns Rev samples do not seem to be violated by specific groups moving away from the area as a response to the choice of location an offshore wind farm at Nysted or Horns Rev.

The next step in assessing the data in relation to analysing causal effects is to look at effective samples characteristics. Recall that the income level is higher in Horns Rev area, people in the Horns Rev area have a higher education and are younger. In Table 2 below the statistics of the sociodemographic variables and variable related to the recreational use of the coastal area, having a view to onshore and offshore wind farms from the residence and the representation of the CE choice set design (Choice set blocks) are presented. Differences in samples are estimated using a logit model.

[6] The results are available upon request

Table 2: Comparison of samples

	Joined Sample		HR sample		HR sample weighted		NY sample		NY sample Weighted	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Female[a]	0.46	0.50	0.47	0.50	0.43	0.50	0.46	0.50	0.47	0.50
Age[b]										
Age: 20-37 years	0.24	0.43	0.32	0.47	0.24	0.43	0.18	0.39	0.21	0.41
Age: 38_48 years	0.24	0.43	0.20	0.40	0.21	0.41	0.27	0.45	0.26	0.44
Age: 49_56 years	0.21	0.41	0.20	0.40	0.21	0.41	0.23	0.42	0.21	0.41
Age: 57_66 years	0.26	0.44	0.24	0.43	0.31	0.46	0.27	0.44	0.28	0.45
Education[c]										
Vocational	0.36	0.48	0.32	0.47	0.34	0.48	0.40	0.49	0.36	0.48
Short term	0.14	0.35	0.15	0.36	0.14	0.35	0.13	0.34	0.15	0.36
Medium term	0.21	0.41	0.25	0.43	0.24	0.43	0.18	0.39	0.21	0.41
Bachelor or Master	0.06	0.23	0.08	0.27	0.05	0.23	0.04	0.20	0.05	0.22
(HIL)										
HIL >66.666€	0.36	0.48	0.45^{***}	0.50	0.39	0.49	0.29^{***}	0.45	0.35	0.48
HIL >39.999€&<66.667€	0.38	0.49	0.36	0.48	0.38	0.49	0.39	0.49	0.37	0.49
Weekly beach visits[e]										
Summer[e]	0.51	0.50	0.38^{*}	0.49	0.51	0.50	0.61^{*}	0.49	0.51	0.50
Winter[e]	0.26	0.44	0.14^{+}	0.34	0.27	0.45	0.35^{+}	0.48	0.27	0.45
Recreational group										
Angler[f]	0.27	0.44	0.23	0.42	0.24	0.43	0.30	0.46	0.27	0.45
Boater[g]	0.22	0.42	0.22	0.42	0.21	0.41	0.23	0.42	0.23	0.42
View turbines from permanent or summer residence[h]										
View offshore	0.16	0.37	0.11	0.31	0.15	0.36	0.21	0.41	0.17	0.38
View onshore	0.47	0.50	0.26^{***}	0.44	0.49	0.50	0.64^{***}	0.48	0.51	0.50
Choice set blocks[i]										
Block 1	0.19	0.39	0.18	0.39	0.20	0.40	0.19	0.39	0.20	0.40
Block 2	0.16	0.36	0.14	0.35	0.17	0.38	0.17	0.37	0.16	0.37
Block 3	0.16	0.37	0.14	0.35	0.14	0.34	0.17	0.38	0.17	0.37
Block 4	0.16	0.37	0.17	0.38	0.16	0.37	0.15	0.36	0.17	0.37
Block 5	0.16	0.37	0.12^{**}	0.33	0.14	0.35	0.20^{**}	0.40	0.17	0.37
N	300		132		132		168		168	

Notes: Differences in the socio-demographics and the choice set blocks are estimated using a logit models. In the logit models, the dependent variable has the value 1 if the respondent is from the HR sample and 0 if the respondent is from the NY sample. Reference categories in the logit models for differences between the samples: a)Male respondents, b) Age >67, c) Elementary school or High school, d)Household income <40.000 €, e) do not visit the beach weekly, f) Not angler, g) Not boater, h) No view to turbines and i) Choice set block 6. $^{+}$ $p < 0.10$, * $p < 0.05$, *** $p < 0.001$

The logit estimates for the non-weighted and weighted data are in Appendix A. In Table 2's column 2 and 4 the raw statistics for the Horns Rev and Nysted samples are presented. In these two columns, the above mentioned differences are apparent, though not significant in all cases. In the Horns Rev sample the share of respondents in the age category 20-37 years is almost twice as high (32% vs 18%) and the shares in the other age categories are lower. Likewise, there are larger shares of respondents in the Horns Rev sample (25% vs 18%) having a medium term education (x years) and (8% vs 4%) having a master or Ph.D. (15 and 18 years). The differences are though not significant. However the household income levels are significantly different between the respondents in the two samples. In the Horns Rev sample, 45% of the respondents have a household income level above 66.666 €/year, whilst 29% in the Nysted sample. Likewise, on 19% have a household income lower than 40.000€/year, compared to 32% in the Nysted sample. If we move on to the recreational and viewshed demographics, fewer respondents in the HR sample have a view to an onshore wind turbine/wind farm from the permanent or summer residence (0.26% vs.0.64%) and visit the beach weekly (during winter and summer) significantly less compared to the respondents in the NY sample (0.38 vs 0.61 and 0.14 vs. 0.35). The difference in the samples is though only significant on a 0.10 level in the case of winter visits. Finally, the respondents in the HR sample have made choices is choice set block 5 significantly fewer times compared to the respondents in the NY sample (0.12 vs. 0.20).

These potential differences might influence our interpretation of potential effects from experiences on preferences. For example age and income is found in Ladenburg and Dubgaard (2007) to influence WTP in the general population based on the same survey setup. We have therefore weighted the data (column 3 and 5) relative to the joined characteristics of the two samples (column 1). The weighting of the data removes all significant differences and generally makes the weighted samples more align. Or stated differently, with the weighted data, we minimise confounding between difference in socio, recreational and viewshed demographics and the potential relation between preferences for offshore wind farm location and experience with visual disamenities from existing offshore wind farms in the two case areas. This improves our identification of potential experience effects.

In the following analysis of the effect from differences in the prior experience with the distance location of offshore wind farms we will therefore either use the socio-demographic variables and the choice set block variables as controls or use the weighted data for the NY sample. The weighted data will be used in the preferences elicitation models Mixed Logit and Conditional Logit models. Models and test results from weighted and non-weighted data will be presented. The control variable approach will be used in binary and multinomial logit model and OLS regression models. The choice set block variables will only be used in models that are related to preferences or certainty in choice, see later.

In the following section, we will analyse how preferences and WTP might be affected by differences in the experience with offshore wind farms. However, such potential effects can potentially by confounded with difference in perception of global warming and the acceptance of that more wind power should be used to reduce $C0_2$ emission. For example, Duan et al. (2014) find a positive correlation between climate change awareness and WTP for CO_2 reductions. In another study, Carlsson et al. (2012) find positive relations between positive perceptions of humans influencing global temperature increases, own country CO_2 mitigation responsibility and WTP for CO2 mitigation across samples of respondents from Sweden, the US and China. In Table 3, we report the results from an analysis of the perceptions and potential differences between the two samples. The full models with controls are in Appendix B.

As suggested by the results, the attitude towards global warming, CO2 reductions and using wind power to reduce CO2 reductions are not significantly different between the two samples. Accordingly, potential differences in preferences for offshore wind turbine locations should not be driven by differences in the above mentioned perceptions.

Econometric model of preferences

We model the respondents' choices between wind turbines scenarios in a random utility framework (Manski, 1977), where the utility associated with a particular alternative can be represented by a systematic component, and an error component that accounts for the unobserved utility of the particular alternative.

$$U_{ia} = V_{ia} + \epsilon_{ia} \qquad (1)$$

where U_{ia} is the total utility that the respondent i associates with alternative a, V_{ia} represents the systematic component of this utility, and ϵ_{ia} is the error term.

In a binary choice set, with alternatives a and b, respondent i will choose alternative a if and only if the respondents finds that the utility associated with this alternative is higher than the utility associated to alternative b. Based on this, we can express the probability of respondent i choosing alternative a over alternative b as:

$$P_{ia} = P(\epsilon_{ib} - \epsilon_{ia} < V_{ia} - V_{ib}) \qquad (5)$$

By assuming that the error terms are i.i.d with a Gumbel distribution (also known as extreme value type I) the probability defined in Eq. 5 becomes:

$$P_{ia} = \frac{e^{\lambda V_{ia}}}{e^{\lambda V_{ia}} + e^{\lambda V_{ib}}} \qquad (6)$$

This probability defines the Binary Logit Model, based on respondents choosing between two different alternatives, where λ represents the scale parameter, inversely proportional to the variance of the model. It is important to note that for both the Binary Logit Model, as well as for the MNL, the model is normalized so the scale parameter λ equals 1, without loss of information nor distorting the relation between the parameters (Ben-Akiva & Lerman, 1985).

In the present study, we are interested in exploring the respondents' preferences based on the attributes of the alternatives. Due to this, we assume that:

$$V_{ia} = \mathrm{B} \cdot X_{ia} \qquad (9)$$

where B is a vector of parameters representing the preferences for each of the k attributes, and X_{ia} represents a vector of

Table 3: Comparison of attitudes towards global warming, CO_2 reductions and the use of wind power to a great extent to reduce CO_2 emissions.

	Global warming is a significant problem Marginal Estimate	Denmark should implement significant CO_2 reductions Marginal Estimate	Wind energy should be used to a great extent to reduce CO_2 emissions Marginal estimate
Horns Rev	0.0377	-0.0314	0.0164
	[0.0341]	[0.0455]	[0.0455]
Controls	*Yes*	*Yes*	*Yes*
N	300	300	300
LL(0)	-76.09	-131.9	-128.5
LL(β)	-62.16	-110.2	-109.0
McFadden R^2	0.183	0.165	0.152

Notes: Standard errors in brackets.

attributes of the alternative. This formulation is referred to as Conditional Logit.

Mixed Logit

The formulation of the conditional logit shown before, while simple, assumes that the observed preferences do not vary across individuals; with all deviations and the influence of unobserved preferences being captured by the error term ϵ. By assuming that ϵ is i.i.d., we assume that the unobserved preferences are homogeneous across the population and that there is no taste variation between respondents.

In our data, each respondents are presented with three consecutive choice sets. We thus have panel data, which most likely means that the error terms are not i.i.d., since there is a likely correlation on the error terms of all the choice sets answered by the same respondent (D. A. Hensher, 2001). The mixed logit model (MXL) is an expanded formulation that aims to overcome the deficiencies of the MNL model shown previously. The setup presented here follows (D. A. Hensher, 2001; Train, 2009). For the MXL, we define the utility of alternative a for respondent i as:

$$U_{ia} = \mathrm{B}_i X_{ia} + \epsilon_{ia} \tag{10}$$

where B_i is a vector of length k that contains the parameters related to preferences for each attribute of the choice alternatives associated to respondent i, and X_{ia} is a vector of length k representing the attributes of alternative a. The MXL allows for taste variation across respondents by assuming that B_i is distributed $f(\mathrm{B}|\theta)$, with θ being parameters that characterise the distribution. The error term ϵ_{ij} is assumed i.i.d. with a Gumbel distribution, as in the MNL.

The terms B_i and ϵ_{ia} are known by respondent i but cannot be observed by the researcher. Therefore, the probability of respondent i choosing alternative a under the MXL now also depends on B_i and its distribution. Thus, we have to integrate the standard logit probability shown in Eq. 7 over the distribution of B_i:

$$P_{ia} = \int_{\mathrm{B}} \frac{e^{\mathrm{B_i} X_{ia}}}{\sum_j e^{\mathrm{B_i} X_{ij}}} \qquad (11)$$

Heteroscedastic conditional logit model

As presented before, the MNL assumes that the scale parameter is constant across individuals. In particular, the MNL assumes that λ is inversely proportional to the error variance σ_ϵ^2, leading to $\lambda = \pi/6\sigma_\epsilon^2$. The assumption of scale invariance across respondents might not always be fulfilled, and it is of interest to account for it and in our case model how prior experience influence the scale relatively. The logit scaling approach to test for scaling differences between samples takes its point of origin in the models introduced by (DeShazo & Fermo, 2002): the heteroscedastic logit model and the parametrized heteroscedastic multinomial logit as defined by (D. Hensher, Louviere, & Swait, 1998). This model is an alternative to the conditional logit model, by allowing for unequal variances across individuals:

$$P_{ia} = \frac{e^{\lambda_\mathrm{i} \mathrm{B_i} X_a}}{\sum_j e^{\lambda_i \mathrm{B_i} X_j}} \qquad (12)$$

where λ is no longer assumed to be equally inversely related with the error variance σ_ϵ^2 for all respondents in the model, as in the MNL. Instead, it is assumed a function of individual characteristics. The relation between characteristics and the error variance is parametrized as $e^{Z_i \gamma}$ where Z_i is a vector of individual characteristics and γ is a vector of parameters reflecting the influence of those characteristics on the error variance. The model is estimated in STATA using the code by HOLE

Results

The effect from differences in experience with offshore wind farms is analysed in several steps, including non-parametric analysis, analysis of preferences using mixlogit and conditional logit models and analysis of differences in scale. In the first part of the results we will focus on the overall preferences, WTP differences caused by prior experience and scale. In the second part will elaborate on out findings and estimated sub model that allows to explore heterogeneity in the impact of prior experience on the preference and scale relations.

Non-parametric analysis

In the figures below, the weighted propensity to choose an offshore wind farm as a function of the price vector (cost per household/year), distance from the coast (km) and the number of wind turbines per wind farm/number of wind farms are presented for the HR-sample and NY-sample.

Clearly, the choices of alternatives appear to be different with regards to the price vector between the two samples. The respondents in the NY-sample have chosen alternative with 0 cost less frequently (52% of the times an alternative had 0 € in costs) compared to the respondents in the HR-sample (73% of the times an alternative had 0 € in costs). On the other hand, the respondents in the Nysted sample have chosen an alternative a cost of 173 €/household/ year 35% of the times an alternative had 173 in cost, compared to 15% in the HR-sample. This strongly suggests that the sensitivity towards changes in the cost per household is less in the NY-sample relative to the HR-sample, suggesting a higher WTP. That said the differences only appear to be with regard to those two specific costs levels (0 and 173 €). Particularly the latter suggests that the willingness to pay for having the preferences fulfilled is larger in the NY-sample compared to the HR-sample and that substantial higher share of the respondents are willing to pay minimum 173 € for locating the wind farms at the preferred distance from the shore and for the preferred combination of number of wind turbines per wind farm/number of wind farms. This is supported by a Chi^2 test. The test value is 17.43, with five degrees of freedom, which is significant on a 0.004 level. The corresponding test value for the non-weighted models are 22.23, equal to a test probability >0.001[7]. This suggests that the respondents in the NY-sample are more willing to pay 1.300 €/year for having their preferences fulfilled, when compared to the respondents in the HR-sample and on the other hand opt in for the 0 cost alternatives less frequently.

The choice of distance and wind farm size do not seem to be different between the two samples, though the respondents in the HR sample seem to choose wind farms at 18 km (62%) more frequently compared to the respondents in the NY sample (57%). A chi-test (test value 2.79, DF=3) does not reject that the choice distributions in the two samples origins from the same distribution. The same goes for the choice of wind farm size/number of wind farms.

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[7] As found in the comparison of the two samples, there are significant fewer choice sets from in Block 5 in the HR sample and significant more choice sets from block 6. A robustness analysis is therefore carried out without the two blocks. The choice patterns are the same. The X^2-test value is 12.9, which has a test probability of 0.024.

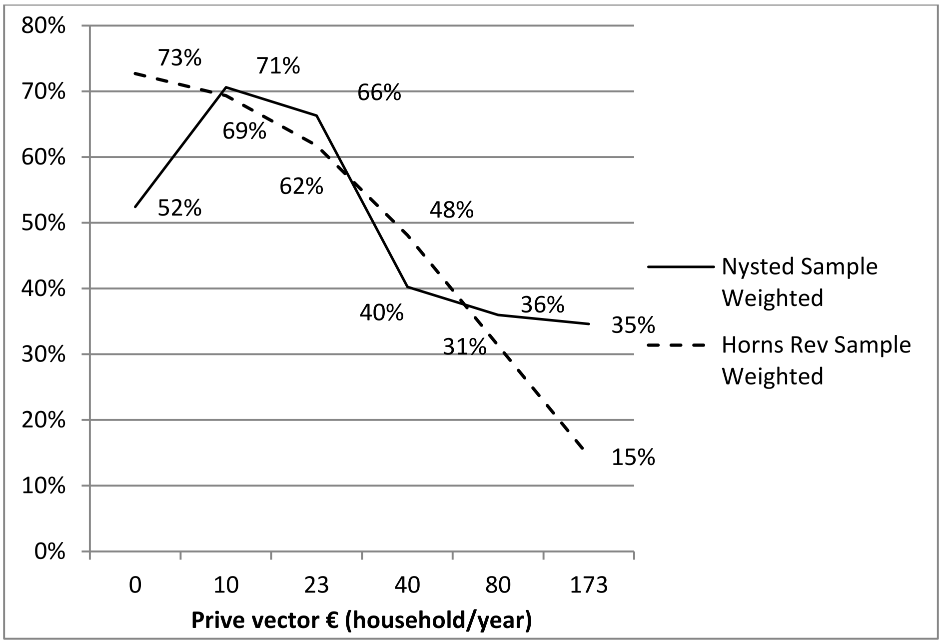

Figure 8. Choices and the price vector (weighted data)

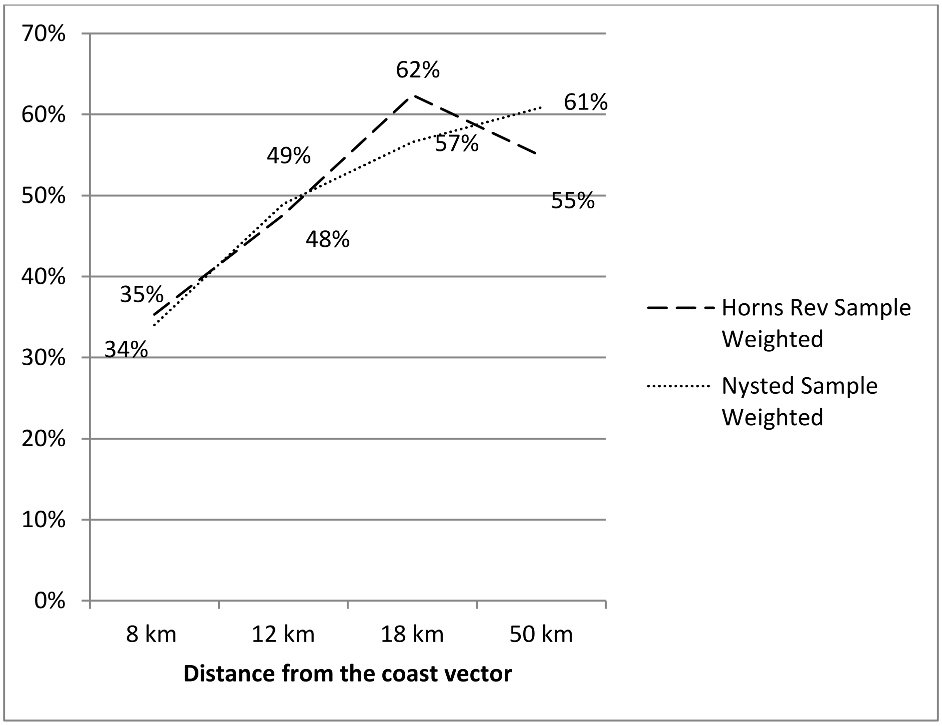

Figure 9. Choice and distance to the coast

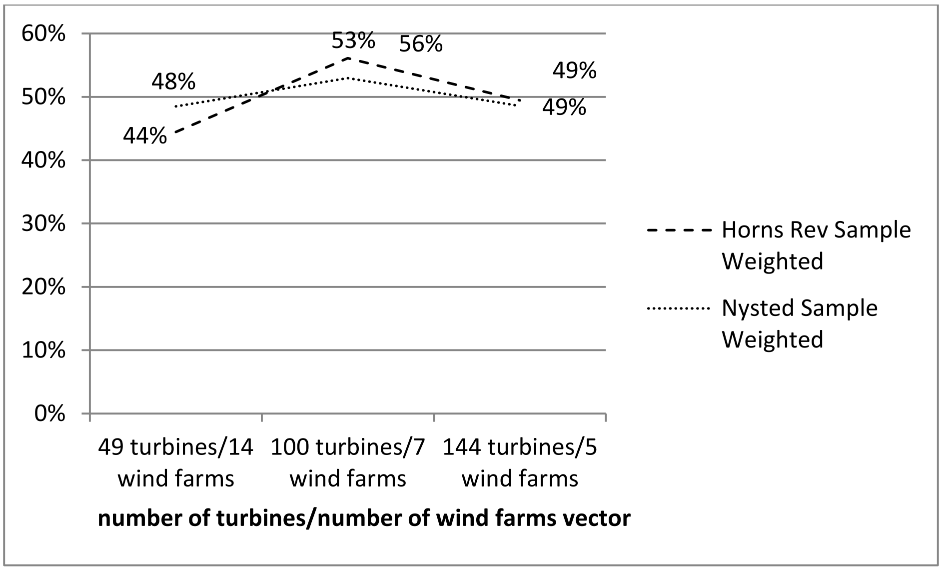

Figure 10. Choice and number of turbines per wind farm/number of wind farms

As a robustness check we have estimated the probability of choosing an alternative with each of the attribute levels (price, distance from the coast and number of wind turbines/number of wind farms). The model is estimated using a binary logit model taking the value 1 if the respondent has chosen an alternative with the attribute level in focus and 0 if the alternative chosen has another cost. In the models, we only include choice observation based on choice sets where one of the two alternatives has the costs level on focus. In the models, the variables used in the weighting model are used as control variables, while including a dummy variable for the HR sample. The models are estimated with individual cluster robust standard errors. The results can be found in the appendix C, D and E and overall confirm the observed difference in choices penned out in Figure 8-10. The logit models are though more nuanced and suggest that the respondent in the HR sample choose the 40€ and 18 km alternatives more frequently.

Parametric models

Main Effect and Interacted Random parameter model

Several models have been tested. in the case of the Nysted sample, only estimated standard deviation for the Distance 50 km was significant. In case of the Horns Rev sample the estimated standard deviation 100 wind turbines/7 wind farms variable and Distance 50 km were significant. In the model, the correlation between the estimated standard deviations was also tested but found to be insignificant. Three models are presented for each sample. A main effect model, a full interaction model and adjusted interaction model. In the full interaction model all possible combinations between the distance and size of wind farms/number of wind farm attributes are included. In the adjusted interaction model, only significant (90% level of confidence) interaction variables are included.

The weighted estimated Mixlogit models are presented below in Table 4. All equivalent non-weighted models are in Appendix F.

In all models, the respondents prefer wind turbines to be located at 12, 18 and 50 km relative to the reference distance at 8 km. Furthermore, the preferences seems to increase with the distance $\beta_{Distance\ 12\ km} < \beta_{Distance\ 18\ km} < \beta_{Distance\ 50\ km}$. In the HR sample, a Wald test confirms that both $\beta_{Distance\ 18}$ km and $\beta_{Distance\ 50\ km}$ are significantly different from $\beta_{Distance\ 12\ km}$ (prob=0.002 and prob=0.0192), respectively. However, it cannot be rejected that $\beta_{Distance\ 18\ km} = \beta_{Distance\ 50\ km}$ (prob=0.911) If we move on to the NY sample the preferences seem to have a different structure. More specifically in the weighted NY sample, test rejects that the respondents are indifferent between having wind farms at 12 or 18 km (prob =0.162). Despite the relative high variance of the $\beta_{Distance\ 50\ km}$ estimate, we reject on a 90% level of confidence that $\beta_{Distance\ 12\ km} = \beta_{Distance\ 50\ km}$ (prob=0.062).

Looking at the estimated Standard Deviations, the also appear to be some differences. In the HR sample, the estimated standard deviation for a wind farm with 100 turbines and location wind turbines at 50 km are significant. Based on estimated mean and standard deviation, 15.6% and 20.5% of the respondents in the HR sample hold negative preferences for locating the offshore wind farms at 50 km relative to 8 km and for five 144 turbines wind farms relative to 14 49 turbines wind farms. In NY sample 28.2% hold negative preferences for locating the offshore wind farms at 50 km relative to 8 km.

In the HR full interaction model, none of the estimated interaction parameters are significant. Furthermore, in the interaction model the main effects variables are insignificant, except costs. This suggest that the inclusion of the interaction variables do not improve the model, which is supported by a LR-test comparing the restricted main effect model with the less restricted interaction model (Chi=3.38, DF(6), prob=0.76). The adjusted HR interaction model, which only includes significant interaction variables is also identical to the main effect model (no interaction variables are significant).

Moving on to the NY sample, the main effects remain significant and the wind farm size variables become significant. The Distance 12 km interactions parameters are both significant and with a negative sign, suggesting that the utility gain of moving wind farms from 8 to 12 km is less if there are fewer but larger wind farms. A LR-test comparing the restricted main effect model with the less restricted full interaction model is significant (Chi=33.66, DF(6), prob<0.001). The adjusted interaction model including only significant interaction variables also has a significant better fit compared to the main effect model (Chi=31.23, DF(2), prob<0.001) and is not worse than the full interaction model (Chi=2.43, DF(4), prob=0.66). Overall, this denotes that inclusion of the two Distance 12 km interactions variables influence preferences significantly.

One final observation is the apparent difference in the model fits. The estimated McFadden R^2 are 0.306 in the HR sample and 0.124 in the main effect model and 0.168 in the adjusted interaction model in the NY sample. This strongly point towards that the stated preferences in the HR sample has smaller variance in the choices compared to the respondents in the NY sample. Particularly due to the variance difference it is not possible to compare the magnitude of the estimated preferences in the three models. To explore the potential differences in preference strength,

Table 4: Estimated main effect and interaction Mixlogit models (standard errors in brackets)

	Main effect Model		Full interaction Model		Adjusted interaction Model	
	Horn Rev	Nysted	Horn Rev	Nysted	Horn Rev	Nysted
Mean						
Distance 12 km	1.040**	0.684***	1.866	3.216***	1.040**	2.873***
	[0.375]	[0.204]	[1.759]	[0.750]	[0.375]	[0.594]
Distance 18 km	2.041***	0.978***	2.641	1.615*	2.041***	1.254***
	[0.484]	[0.264]	[1.792]	[0.735]	[0.484]	[0.314]
Distance 50 km	1.991**	1.340**	3.746	2.566**	1.991**	1.695**
	[0.614]	[0.409]	[2.357]	[0.987]	[0.614]	[0.524]
7*100 turbines/wind farm	1.034*	0.306	2.296	1.960*	1.034*	1.520**
	[0.413]	[0.234]	[2.260]	[0.917]	[0.413]	[0.524]
5*144 turbines/wind farm	0.907*	0.161	1.561	1.305^{+}	0.907*	0.856**
	[0.387]	[0.201]	[1.714]	[0.701]	[0.387]	[0.308]
Costs (€)	-0.0242***	-0.0098***	-0.0299**	-0.0095*	-0.0242***	-0.0086***
	[0.0050]	[0.0021]	[0.0098]	[0.0034]	[0.0050]	[0.0021]
Interaction						
Distance 12 km X 7*100 turbines/ wind farm			-1.538	-3.896***		-3.361***
			[2.415]	[1.137]		[0.925]
Distance 18 km X 7*100 turbines/ wind farm			-0.0952	-0.376		
			[1.892]	[0.944]		
Distance 50 km X 7*100 turbines/wind farm			-2.394	-1.210		
			[2.614]	[1.666]		
Distance 12 km X 5*144 turbines/wind farm			0.284	-2.595*		-2.398***
			[1.746]	[1.057]		[0.566]
Distance 18 km X 5*144 turbines/wind farm			0.113	-0.407		
			[2.176]	[1.142]		
Distance 50 km X 5*144 turbines/wind farm			-1.840	-1.401		
			[2.583]	[1.089]		
Standard deviation						
Distance 50 km	1.969**	2.326***	2.555	2.934**	1.969**	3.051**
	[0.757]	[0.682]	[1.570]	[0.892]	[0.757]	[0.935]
7*100 turbines/wind farm	1.103*		1.575		1.103*	
	[0.521]		[1.097]		[0.521]	
N_resp	132	168	132	168	132	168
N_choices	264	504	264	504	264	504
LL(0)	-274.5	-349.4	-274.5	-349.4	-274.5	-349.4
LL(β)	-192.2	-306.2	-190.5	-289.4	-192.2	-290.6
McFadden R^2	0.300	0.124	0.306	0.172	0.300	0.168

preferences are compared in WTP terms in the Table 5 and 6 for different wind farm locations and configurations.

Generally, the estimated WTPs for the different wind farm configurations are higher in NY-sample (except $WTP_{144\ turbines|8km}$, $WTP_{100\ turbines|8km}$ and $WTP_{100\ turbines|50km}$) and the differences (%) are in the higher range for many of the wind farm configurations (+40%). However, none of the estimated WTP differences are significant on conventional levels. These results are confirmed in the non-weighted models, though the WTP for 144 turbine wind farms at 18 km is significantly higher in the NY sample on a 0.05 level of confidence, see Appendix G. The observed differences in the choice of alternatives with a cost of 173 and 0 €/household/year and the choice of distance 18 km are thus not strong enough to translate into overall differences in WTP.

The lack of significant difference in the WTPs is also reflected in a Louiviere & Swait (1993) LR test for equality of parameters between the estimated preferences in the two samples, which we only rejected on a 90% level when comparing models with on the Distance 50 km specified as a random parameter. If both the Distance 50 km and 7*100 turbines/wind farm are specific as random parameter, we cannot reject equality and preferences. The differences in preferences, though borderline, indicate that the differences in prior experience influence scale, preferences or both significantly. Accordingly, the results from the weighted model point towards that experience with nearer shore wind farms might increase the preference strength for location of offshore wind farms but also increase the variance of choice.

In the interaction WTP comparison in Table 6 the differences are more pronounce and higher for all types of wind farm configurations in the NY sample. More specifically, the estimated differences in WTP suggest that the respondents in the NY sample have significantly higher WTP at a 95 % level of confidence for 49 turbines wind farms located at 12 km (relative to 8 km), 100 turbines located at 8 km and 144 turbine wind farms located at 18 km compared to the respondents in the HR sample. The results also suggest that the respondents hold significantly higher WTP on a 90% level of confidence for 100 turbine wind farms located at 18 km and 144 turbine wind farms located at 50 km (again the reference is 49 turbine wind farms located at 8 km). These results are strongly supported by the LR-test of preferences equality. In the tests, equality of preferences in rejected on a 99.9% level of confidence. These results are supported by the non-weighted models in appendix H.

Scale and certainty in choice

Both the differences in the model fits (higher in the HR sample) and the potentially differences in scales (2.3-2.4 and 1.8-1.9 in the main effect and interaction models, respectively) makes is interesting to test the final hypothesis– do differences in experience influence certainty in choice? We estimate four models. In the first models, we only include the Horns Rev dummy the scale function for a main effect and adjusted interaction model. In the last models we include the all the controlled variables in the scale component, to test the robustness of the potentially effect from differences in prior experience. However, these two models are not based on a weighted dataset, as these could not converge. We only present the HR- scale variables. The models are presented in Table 7 and the full models are in the appendix I

Table 5: Main effect WTP comparisons (€/household/year)

Horns Rev	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm	-	43.0^{**}	84.4^{***}	82.4^{***}
		[15.7]	[18.8]	[24.7]
7*100 turbines wind farm	42.8^{**}	85.8^{**}	127.2^{***}	125.1^{***}
	[15.6]	[26.5]	[27.0]	[34.7]
5*144 turbines/wind farm	37.5^{**}	80.6^{**}	122.0^{***}	119.9^{***}
	[12.6]	[24.8]	[25.7]	[31.9]
Nysted	**Distance 8 km**	**Distance 12 km**	**Distance 18 km**	**Distance 50 km**
14*49 turbines/wind farm	-	70.1^{***}	100.1^{***}	137.2^{***}
		[155.1]	[29.2]	[39.7]
7*100 turbines wind farm	31.4	101.4^{***}	131.5^{***}	168.5^{***}
	[21.6]	[30.5]	[37.2]	[44.9]
5*144 turbines/wind farm	16.5	86.6^{**}	116.6^{**}	153.7^{***}
	[20.0]	[31.7]	[38.6]	[46.59]
Difference in WTP	**Distance 8 km**	**Distance 12 km**	**Distance 18 km**	**Distance 50 km**
14*49 turbines/wind farm	0.0	27.0	15.7	54.8
		[25.8]	[34.7]	[46.8]
7*100 turbines wind farm	-11.4	15.6	4.3	43.4
	[26.7]	[40.4]	[46.0]	[56.8]
5*144 turbines/wind farm	-21.0	6.0	-5.4	33.8
	[23.7]	[40.3]	[46.4]	[56.5]
LR-test			$14.98(8)^{a, c+}$	
			$10.80(9)^{b, cNS}$	

Notes: a) Models with one random parameter (Distance 50 km), b) Models with two random parameters (Distance 50 km and100 turbines/farm), c) The scale is estimated to be 2.4 in both models for the HR sample relative to the NY sample. Standard errors in brackets, $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6: Interaction model WTP comparisons (€/household/year)

	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm	-	43.0**	84.4***	82.4***
		[15.5]	[18.8]	[24.7]
7*100 turbines wind farm	42.8**	85.8**	127.2***	125.1***
	[15.6]	[26.5]	[27.0]	[34.8]
5*144 turbines/wind farm	37.5**	80.6**	122.0***	119.9***
	[12.6]	[24.8]	[25.7]	[31.9]
Nysted	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm	-	332.9***	145.3***	196.4**
		[98.7]	[41.1]	[63.1]
7*100 turbines wind farm	176.1**	119.6**	321.4***	372.5***
	[65.4]	[41.0]	[97.4]	[111.3]
5*144 turbines/wind farm	99.2**	154.3*	244.5***	295.6***
	[36.8]	[75.7]	[70.5]	[85.9]
Difference in WTP	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm	-	289.9**	60.9	114.0
		[99.9]	[45.2]	[67.8]
7*100 turbines wind farm	132.3*	33.8	194.2^{+}	247.4
	[67.2]	[48.8]	[101.0]	[116.6]*
5*144 turbines/wind farm	61.7	73.7	122.5	175.7^{+}
	38.9	[79.7]	[75.1]	[91.6]
LR-test			38.1(10) $^{a\ ***}$	
			39.6(11)^{b***}	

Notes: a) Models with one random parameter (Distance 50 km), b) Models with two random parameters (Distance 50 km and100 turbines/farm), c) The scale is estimated to be 1.8 in the model with only one random parameter and 1.9 in the model for two random parameters for the HR sample relative to the NY sample. The scales are significantly different from 1. Standard errors in brackets, $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7: Heteroscedastic conditional logit models

	Weighted		Non-weighted sociodemographic variables in the scale function	
	Main effect model	Adjusted interaction model	Main effect model	Adjusted interaction model
Scale	0.916^{***}	0.738^{**}	0.502^{*}	0.393^{+}
	[0.232]	[0.265]	[0.228]	[0.231]
Controls in the scale function	No	No	Yes	Yes
N_resp			300	
N_choices			900	
LL(0)			-623.8	
LL(β)	-512.5	-510.2	-487.8	-485.4
McFadden R^2	0.178	0.182	0.218	0.222

As expected from the higher McFadden R2 in the HR models, we see that the respondents in the HR sample have significantly higher scales i.e. lower variance. The results are robust to the choice of models, though the estimate becomes borderline significant in the adjusted interaction model with controls. In our case, the results point towards the respondents with the far shore offshore wind farm experience have the largest scale and therefore also the smallest variance in their choice within each sample.

These models are supported by ordinary regression model and multinomial logit regression model where we model the stated level of certainty in choice are presented. The stated level of certainty is done on a 0-10 scale with 0 representing Very Uncertain and 10 "Very Certain" and was asked after the final choice set. The multinomial model is included to test for non-linearity in the effect from experience on certainty and to control for a relatively low number of very uncertain (0-4 on the scale) respondents. In the multinomial logit model, we have therefore defined three new variables: "Uncertain" (stated certainty 0-5), "Certain" (stated certainty 6-8) and "Very Certain" (stated certain 9-10). The results are in Table 8. The full models are in Appendix J.

The OLS regressions results point towards that the respondents in the HR sample are more certain compared to the respondents in the NY sample. The estimated effect is app. 0.7 certainty units. The results are supported by the Multinomial Logit model, where the respondents in the HR sample have a significant higher probability to be in the "Certain" or "Very certain" group of respondents. Jointly, the results suggest that, the experience with a far shore, relative to near shore, wind farm have made the respondents more certain in their choices.

Table 8: Effect of experience on certainty in choice, OLS and Multinomial Logit Models.

	OLS	Multinomial logit[a]	
		"Certain"	"Very Certain"
	Parameter Estimate	Parameter Estimate	Parameter Estimate
Horns Rev	0.704*	0.994**	0.889*
	[0.306]	[0.363]	[0.419]
Controls:	Yes	Yes	
N	300	300	
SST/LL(0)	1713.79	-304.7	
SSE/LL(β)	160.70	-273.0	
R2/McFadden R2	0.094	0.104	

Notes: a) "Uncertain" is the reference category, Standard errors in brackets, * $p < 0.05$ and ** $p < 0.01$

Conclusion

Offshore wind power is one of the major drivers in the change to a fossil free energy production. Compared to onshore wind farms, offshore is expected to on one side alleviate some of the external cost of wind energy but on the other hand increase production costs. This makes is highly attractive to locate offshore wind farms close to shore as the cost thereby is minimised. Using a natural experiment, the present paper test if near shore locations relative to far shore location influence the perceptions of the sea scape amenity degradation caused by offshore wind farms. If such effects are present, this will give rise to dynamic effect in the external costs of wind power. Our findings are clear. Living in an area with a nearer shore wind farm significantly increase the preferences for reductions in the

The results of the analysis clearly demonstrate that the respondents living in an area with a nearshore wind farm choose the 0 price alternatives and 173€ alternatives, significantly fewer and more times, respectively. In terms of preferences and WTP this translates into significantly different preferences and higher levels of WTP for locating the offshore wind farms further from the shore. The results also point towards that the preferences and WTP differences specifically is related to choice sets with a 0 or/and 173 € price alternative. When confronted with choice sets with prices in the intermediate range (0<price<173), neither preferences nor WTP differences can be found. Interestingly, the difference in prior experience also influences the error variance of the model. Respondents from the nearshore area, has substantially lower McFadden R^2 compared to the respondents in the sample with a far shore wind farm. Again these differences can solely be found in the choice sets with 0 and 163 € alternatives and not in the intermediate priced choice sets. Jointly, the results point towards that location of offshore wind farms close to shore can form the perception of the sea scape quality degradation caused by offshore wind farms and subsequently introduce dynamics in the preferences formation and external cost of wind power.

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Appendix 1: Preamble

The next question concern your preferences for different attributes of offshore wind farms. In the questions it is assumed that approximately 1/3 of the Danish electricity generation will be covered by offshore wind energy in 2030.

This can be done by erecting 100 m (to the tower) high wind turbines with a wing span of 120 m. With this size, 720 turbines must be erected along the Danish coasts. The offshore turbines will be put up at different locations and minimizing the impact on landscape, wild life and protected areas will be accounted for in the planning process.

The purpose of the following questions is to identify your preferences for how the expansion of the offshore wind power capacity shall be done.

In the following you will be asked to choose between different typoes of offshore wind frams, which will have different features. The features are listed below.

Size of the offshore wind farms:

a) 49 turbines per wind farm, equivalent with etablishin 14 offshore wind farms in Denmark
b) 100 turbines per wind farm, equivalent with etablishin 7 offshore wind farms in Denmark
c) 144 turbines per wind farm, equivalent with etablishin 5 offshore wind farms in Denmark

Distance from the coast – placement of the offshore wind farms:

a) 8 km from the coastline
b) 12 km from the coastline
c) 18 km from the coastline
d) 50 km from the coastline

In this study we assume that the cost of extending the capacity of the offshore wind farms must be paid by the Danish energy consumers via a fixed yearly contribution to renewable energy. The contribution must be paid by all households as part of the electricity bill. Prices for electricity (DKK/kwh) are assumed to be unchanged.

On the following pages you will find 3 sets of questions, each containing two alternatives, which you must choose between. We would like to point out that all alternatives are hypothetical and none of the reflect actual projects.

For each alternative you are requested to examine the pictures thoroughly. The pictures are visualisations and reflect real size and distance properties. We would like to point out that the pictures might deviate from real life as the visibility of a wind farm will be affected by light and weather. The pictures must be placed app. 25 cm from your eyes.

After examining the pictures you must closely study de attributes of the two alternatives. After a carefully consideration of the pros and cons between the two alternatives you are requested to choose the alternative, which you prefer. This is done by marking it with a X.

Be aware that the stated payment for renewable energy is the amount that your household must pay in case that the alternative is realized. Research on peoples' willingness to pay has shown that people have a tendency to overestimate their willingness to pay. With this in mind please consider the annual payment in relation to your budget, so you are absolutely sure that you are prepared to pay the amount listed in the chosen alternatives.

Appendix A: logit models for unweighted and weighted data

	Non-weighted		Weighted	
	Logit Estimate	Marginal Estimate	Logit Estimate	Marginal Estimate
Female[a]	0.0835	0.0146	-0.194	-0.0467
	[0.302]	[0.0529]	[0.317]	[0.0761]
Age[b]				
	0.680	0.119	0.256	0.0617
Age: 20-37 years	[0.779]	[0.136]	[0.721]	[0.174]
	-0.157	-0.0274	-0.198	-0.0478
Age: 38-48 years	[0.792]	[0.139]	[0.733]	[0.176]
	-0.214	-0.0374	-0.0662	-0.0160
Age: 49-56 years	[0.800]	[0.140]	[0.743]	[0.179]
	0.431	0.0754	0.165	0.0397
Age: 57-66 years	[0.784]	[0.137]	[0.720]	[0.173]
Education[c]				
	-0.138	-0.0242	-0.0418	-0.0101
Vocational	[0.388]	[0.0680]	[0.381]	[0.0918]
	0.273	0.0479	0.0389	0.00937
Short term	[0.482]	[0.0843]	[0.495]	[0.119]
	0.572	0.100	0.272	0.0655
Medium term	[0.432]	[0.0750]	[0.423]	[0.102]
Bachelor or	-0.0341	-0.00597	-0.0743	-0.0179
Master	[0.660]	[0.116]	[0.640]	[0.154]
Household income level (HIL)[d]				
	1.406***	0.246***	0.372	0.0896
HIL >66.666€	[0.392]	[0.0635]	[0.384]	[0.0921]
HIL	0.438	0.0767	0.284	0.0685
>39.999€&<66.667€	[0.377]	[0.0655]	[0.390]	[0.0937]
Weekly beach visits[e]				
	-0.706*	-0.124*	0.0646	0.0156
Summer[e]	[0.343]	[0.0586]	[0.343]	[0.0826]
	-0.817+	-0.143+	-0.0309	-0.00746
Winter[e]	[0.436]	[0.0747]	[0.427]	[0.103]
Recreational group				
	-0.410	-0.0718	-0.174	-0.0420
Angler[f]	[0.384]	[0.0669]	[0.392]	[0.0945]
	0.627	0.110	-0.0951	-0.0229
Boater[g]	[0.404]	[0.0698]	[0.416]	[0.100]

View turbines from permanent or summer residence[h]				
	0.120	0.0210	-0.108	-0.0259
View offshore	[0.440]	[0.0770]	[0.430]	[0.104]
	-1.802***	-0.316***	-0.0767	-0.0185
View onshore	[0.321]	[0.0449]	[0.323]	[0.0777]
Choice set blocks[i]				
	-0.592	-0.104	-0.244	-0.0588
Block 1	[0.464]	[0.0805]	[0.477]	[0.115]
	-0.697	-0.122	-0.236	-0.0570
Block 2	[0.501]	[0.0868]	[0.518]	[0.125]
	-0.548	-0.0959	-0.474	-0.114
Block 3	[0.487]	[0.0846]	[0.499]	[0.119]
	-0.224	-0.0393	-0.400	-0.0963
Block 4	[0.501]	[0.0876]	[0.534]	[0.128]
	-1.240*	-0.217**	-0.544	-0.131
Block 5	[0.489]	[0.0824]	[0.498]	[0.119]
Constant	0.541		-0.0906	
	[0.856]		[0.847]	
N	300		300	
			300	
LL(0)	-205.8		-205.8	
LL(β)	-157.3		-202.4	
Mcfadden R2	0.150		0.017	

Notes: Reference categories: [a)]Male respondents, [b)] Age >67, [c)] High school, [d)]Household income <40.000 €, [e)] do not visit the beach weekly, [f)] Not angler, [g)] Not boater, [h)] No view to turbines and [i)] Choice set block 6, except for Cost=80€, where block 1 is the reference, Standard errors in brackets, $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix B: Comparison of attitudes towards global warming, CO_2 reductions and the use of wind power to a great extent to reduce CO_2 emissions, models with controls

	Global warming is a significant problem		Denmark should implement significant CO2 reductions		Wind energy should be used to a great extent to reduce CO2 emissions	
	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate
Horns Rev	0.671	0.0382	-0.272	-0.0310	0.131	0.0146
	[0.594]	[0.0340]	[0.400]	[0.0456]	[0.409]	[0.0455]
Female[a]	0.943	0.0537	1.692***	0.193***	0.367	0.0408
	[0.593]	[0.0341]	[0.433]	[0.0470]	[0.383]	[0.0425]
Age[b]						
Age: 20-37	1.386	0.0789	0.0409	0.00467	1.473^{+}	0.164^{+}
years	[1.017]	[0.0581]	[0.808]	[0.0924]	[0.797]	[0.0876]
Age: 38-48	1.332	0.0759	0.312	0.0357	2.553**	0.284**
years	[1.037]	[0.0594]	[0.820]	[0.0937]	[0.926]	[0.101]
Age: 49-56	1.549	0.0882	0.944	0.108	0.386	0.0429
years	[1.075]	[0.0617]	[0.879]	[0.100]	[0.764]	[0.0849]
Age: 57-66	0.0359	0.00205	-0.410	-0.0468	0.765	0.0851
years	[0.949]	[0.0541]	[0.793]	[0.0905]	[0.755]	[0.0836]
Education[c]						
	-0.503	-0.0286	0.627	0.0716	-0.0705	-0.00785
Vocational	[0.663]	[0.0378]	[0.441]	[0.0499]	[0.492]	[0.0548]
	-0.168	-0.00956	0.889	0.102	-0.717	-0.0797
Short term	[0.966]	[0.0550]	[0.668]	[0.0759]	[0.577]	[0.0638]
	0.795	0.0453	0.957^{+}	0.109^{+}	0.443	0.0492
Medium term	[0.958]	[0.0548]	[0.557]	[0.0630]	[0.587]	[0.0651]
Bachelor or	-1.308	-0.0745	-0.0295	-0.00337	-1.544*	-0.172*
Master	[0.955]	[0.0543]	[0.750]	[0.0856]	[0.724]	[0.0790]
Household income level [d]						
(HIL)	-1.372^{+}	-0.0782^{+}	-1.031*	-0.118*	-0.176	-0.0196
HIL >66.666€	[0.765]	[0.0441]	[0.501]	[0.0564]	[0.498]	[0.0554]
HIL	-0.695	-0.0396	-0.468	-0.0535	-0.179	-0.0199
>39.999€&<66.667€	[0.764]	[0.0437]	[0.499]	[0.0569]	[0.484]	[0.0538]
Weekly beach visits[e]						
	0.0158	0.000899	0.136	0.0155	-0.0795	-0.00885
Summer[e]	[0.646]	[0.0368]	[0.466]	[0.0532]	[0.456]	[0.0507]
	1.789*	0.102*	0.296	0.0338	0.115	0.0128
Winter[e]	[0.855]	[0.0493]	[0.530]	[0.0605]	[0.491]	[0.0545]
Recreational group						
	-0.648	-0.0369	0.149	0.0171	-0.607	-0.0675
Angler[f]	[0.620]	[0.0354]	[0.446]	[0.0509]	[0.428]	[0.0472]

	0.919	0.0524	0.309	0.0353	-0.556	-0.0619
Boater[g]	[0.799]	[0.0460]	[0.501]	[0.0571]	[0.456]	[0.0504]
View turbines from permanent or summer residence[h]						
	-1.541*	-0.0878*	-0.522	-0.0597	0.0499	0.00555
View offshore	[0.662]	[0.0384]	[0.461]	[0.0523]	[0.506]	[0.0563]
	0.232	0.0132	-1.089**	-0.124**	-0.447	-0.0497
View onshore	[0.598]	[0.0341]	[0.406]	[0.0451]	[0.411]	[0.0455]
Constant	2.036+		1.608+		1.350	
	[1.167]		[0.906]		[0.869]	
N	300		300		300	
LL(0)	-76.09		-131.9		-128.5	
LL(β)	-62.2		-110.3		-109.2	
Mcfadden R^2	0.183		0.165		0.152	

Notes: Reference categories: a)Male respondents, b) Age >67, c) High school, d)Household income <40.000 €, e) do not visit the beach weekly, f) Not angler, g) Not boater and h) No view to turbines, Standard errors in brackets,+ $p < 0.10$, * $p < 0.05$, *** $p < 0.001$

Appendix C: Estimated logit model of choosing an alternative with specific costs, models with controls

	Cost=173€		Cost=80€		Cost=40€		Cost=23€		Cost=10€		Cost=0€	
	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate
Horns Rev	-1.367***	-0.201***	-0.129	-0.0221	0.652*	0.119*	-0.359	-0.0720	-0.458	-0.0765	1.203***	0.206***
	[0.413]	[0.0573]	[0.362]	[0.0617]	[0.322]	[0.0575]	[0.307]	[0.0613]	[0.335]	[0.0554]	[0.327]	[0.0533]
Female[a]	-0.445	-0.0654	0.508	0.0866	0.480	0.0877	0.131	0.0263	0.179	0.0299	-0.304	-0.0522
	[0.351]	[0.0511]	[0.339]	[0.0570]	[0.299]	[0.0538]	[0.284]	[0.0570]	[0.315]	[0.0525]	[0.286]	[0.0486]
Age[b]												
Age: 20-37	-1.240+	-0.182+	-0.530	-0.0904	0.962	0.176	-1.640	-0.329	1.531*	0.256*	0.0893	0.0153
years	[0.698]	[0.101]	[0.829]	[0.141]	[0.815]	[0.148]	[1.117]	[0.222]	[0.745]	[0.122]	[0.714]	[0.123]
Age: 38-48	-1.187+	-0.174+	0.328	0.0559	1.534+	0.280+	-1.946+	-0.391+	1.008	0.168	-0.431	-0.0741
years	[0.700]	[0.101]	[0.826]	[0.141]	[0.823]	[0.147]	[1.124]	[0.223]	[0.725]	[0.120]	[0.698]	[0.120]
Age: 49-56	-1.493*	-0.219*	0.143	0.0244	1.592+	0.291+	-1.729	-0.347	1.125	0.188	-0.200	-0.0344
years	[0.714]	[0.102]	[0.825]	[0.141]	[0.834]	[0.149]	[1.123]	[0.223]	[0.750]	[0.124]	[0.712]	[0.122]
Age: 57-66	-1.490*	-0.219*	0.642	0.109	0.749	0.137	-1.097	-0.220	1.142	0.191	-0.734	-0.126
years	[0.681]	[0.0973]	[0.820]	[0.139]	[0.822]	[0.149]	[1.144]	[0.229]	[0.731]	[0.120]	[0.675]	[0.116]
Education[c]												
	0.227	0.0333	0.641	0.109	0.406	0.0741	-0.829*	-0.167*	-0.695+	-0.116+	0.296	0.0508
Vocational	[0.410]	[0.0601]	[0.444]	[0.0744]	[0.374]	[0.0679]	[0.373]	[0.0729]	[0.398]	[0.0654]	[0.358]	[0.0616]
	0.918+	0.135+	0.934+	0.159+	-0.106	-0.0194	-0.967*	-0.194*	-0.162	-0.0270	-0.160	-0.0275
Short term	[0.526]	[0.0761]	[0.540]	[0.0896]	[0.489]	[0.0892]	[0.464]	[0.0911]	[0.524]	[0.0874]	[0.454]	[0.0778]
	-0.453	-0.0666	0.534	0.0911	0.0827	0.0151	-0.289	-0.0580	-0.0595	-0.00994	0.0501	0.00860
Medium term	[0.498]	[0.0729]	[0.482]	[0.0809]	[0.431]	[0.0787]	[0.447]	[0.0896]	[0.475]	[0.0793]	[0.402]	[0.0691]
Bachelor or	0.156	0.0230	-0.502	-0.0856	0.609	0.111	-0.441	-0.0885	-0.572	-0.0955	1.039	0.178
Master	[0.797]	[0.117]	[0.797]	[0.136]	[0.656]	[0.119]	[0.609]	[0.122]	[0.649]	[0.108]	[0.779]	[0.133]
Household income level (HIL)[d]												
	-0.252	-0.0370	0.121	0.0206	-0.119	-0.0218	0.336	0.0676	0.726+	0.121+	-0.628	-0.108+
HIL >66.666€	[0.423]	[0.0619]	[0.485]	[0.0826]	[0.370]	[0.0675]	[0.363]	[0.0726]	[0.395]	[0.0648]	[0.386]	[0.0649]
HIL	-1.117**	-0.164**	0.282	0.0481	-0.135	-0.0246	0.329	0.0662	0.397	0.0662	0.414	0.0710
>39.999€&<6 6.667€	[0.425]	[0.0600]	[0.486]	[0.0824]	[0.365]	[0.0666]	[0.346]	[0.0691]	[0.381]	[0.0632]	[0.327]	[0.0559]
Weekly beach visits[e]												
	0.271	0.0398	-0.408	-0.0695	-0.133	-0.0243	-0.0254	-0.00509	0.109	0.0182	-0.197	-0.0338
Summer[e]	[0.406]	[0.0594]	[0.367]	[0.0625]	[0.338]	[0.0617]	[0.306]	[0.0615]	[0.364]	[0.0608]	[0.325]	[0.0556]

	-0.634	-0.0931	-0.944^{+}	-0.161*	1.029*	0.188**	0.708^{+}	0.142^{+}	0.469	0.0782	-0.166	-0.0285
Winter[e]	[0.452]	[0.0655]	[0.489]	[0.0802]	[0.413]	[0.0728]	[0.415]	[0.0820]	[0.444]	[0.0736]	[0.405]	[0.0693]
Recreational group												
	0.866*	0.127*	0.917*	0.156*	0.227	0.0415	-0.837*	-0.168**	-0.593	-0.0990	-0.454	-0.0780
Angler[f]	[0.436]	[0.0626]	[0.378]	[0.0619]	[0.366]	[0.0666]	[0.336]	[0.0650]	[0.377]	[0.0620]	[0.382]	[0.0651]
	-0.378	-0.0556	-0.523	-0.0891	-0.663^{+}	-0.121^{+}	0.528	0.106	0.281	0.0469	0.967*	0.166*
Boater[g]	[0.479]	[0.0702]	[0.428]	[0.0718]	[0.389]	[0.0698]	[0.371]	[0.0737]	[0.400]	[0.0666]	[0.397]	[0.0655]
View turbines from permanent or summer residence[h]												
	0.673	0.0988	0.174	0.0297	-0.243	-0.0445	-0.218	-0.0437	-0.230	-0.0384	-0.591	-0.101
View offshore	[0.432]	[0.0625]	[0.526]	[0.0896]	[0.418]	[0.0761]	[0.386]	[0.0774]	[0.436]	[0.0726]	[0.362]	[0.0619]
	0.0219	0.00322	-0.0741	-0.0126	0.296	0.0541	-0.432	-0.0869	0.103	0.0171	0.162	0.0278
View onshore	[0.363]	[0.0533]	[0.371]	[0.0631]	[0.322]	[0.0585]	[0.313]	[0.0621]	[0.344]	[0.0574]	[0.329]	[0.0564]
Choice set blocks[i]												
			-1.202**	-0.205**	0.908*	0.166*	-0.493	-0.0990	-0.647	-0.108		
Block 1			[0.442]	[0.0708]	[0.433]	[0.0768]	[0.319]	[0.0631]	[0.446]	[0.0734]		
	-0.373	-0.0548	-3.580***	-0.610***	-0.263	-0.0480			0.704	0.118	2.767***	0.475***
Block 2	[0.538]	[0.0788]	[0.725]	[0.106]	[0.491]	[0.0894]			[0.458]	[0.0757]	[0.528]	[0.0759]
	-0.917	-0.135	-2.794***	-0.476***	2.289***	0.418***	0.334	0.0670			1.824***	0.313***
Block 3	[0.576]	[0.0835]	[0.601]	[0.0881]	[0.513]	[0.0819]	[0.433]	[0.0867]			[0.435]	[0.0672]
	-1.837**	-0.270**	-0.788^{+}	-0.134^{+}	1.235**	0.226**	-0.326	-0.0655	-1.933***	-0.323***	4.106***	0.705***
Block 4	[0.653]	[0.0921]	[0.479]	[0.0803]	[0.465]	[0.0811]	[0.428]	[0.0857]	[0.491]	[0.0736]	[0.644]	[0.0873]
	0.0169	0.00248			-0.960^{+}	-0.175^{+}			0.699	0.117	2.436***	0.418***
Block 5	[0.454]	[0.0667]			[0.530]	[0.0953]			[0.543]	[0.0900]	[0.515]	[0.0758]
Constant	1.302		0.0184		-2.794**		3.038**		-0.112		-1.504^{+}	
	[0.823]		[0.901]		[0.915]		[1.163]		[0.844]		[0.790]	
N	293		304		300		312		299		292	
LL(0)	-164.5		-196.6		-206.0		-203.1		-184.6		-194.4	
LL(β)	-132.7		-154.6		-163.1		-182.9		-151.7		-149.9	
McFadden R^2	0.193		0.214		0.208		0.099		0.178		0.229	

Notes: Reference categories: a)Male respondents, b) Age >67, c) High school, d)Household income <40.000 €, e) do not visit the beach weekly, f) Not angler, g) Not boater, h) No view to turbines and i) Choice set block 6, except for Cost=80€, where block 1 is the reference, Standard errors in brackets, $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

D: Estimated logit model of choosing an alternative with a specific distance from the coast, models with controls

	Distance 8 km		Distance 12 km		Distance 18 km		Distance 50 km	
	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate
Horns Rev	-0.150	-0.0269	-0.287	-0.0554	0.501*	0.109*	-0.0734	-0.0140
	[0.275]	[0.0492]	[0.217]	[0.0419]	[0.218]	[0.0473]	[0.270]	[0.0514]
Female[a]	0.0630	0.0113	-0.239	-0.0463	0.177	0.0385	0.0227	0.00434
	[0.270]	[0.0482]	[0.194]	[0.0374]	[0.207]	[0.0449]	[0.262]	[0.0501]
Age[b]								
Age: 20-37 years	0.591	0.106	0.153	0.0296	-0.294	-0.0641	-0.229	-0.0438
	[0.776]	[0.138]	[0.609]	[0.118]	[0.489]	[0.106]	[0.509]	[0.0972]
Age: 38-48 years	0.121	0.0216	0.543	0.105	0.230	0.0501	-0.870+	-0.166+
	[0.803]	[0.143]	[0.600]	[0.115]	[0.478]	[0.104]	[0.498]	[0.0948]
Age: 49-56 years	0.104	0.0186	0.328	0.0633	0.282	0.0616	-0.472	-0.0901
	[0.803]	[0.143]	[0.599]	[0.115]	[0.510]	[0.111]	[0.498]	[0.0946]
Age: 57-66 years	0.0726	0.0130	0.632	0.122	0.182	0.0398	-0.700	-0.134
	[0.779]	[0.139]	[0.599]	[0.115]	[0.473]	[0.103]	[0.460]	[0.0877]
Education[c]								
Vocational	-0.240	-0.0430	0.0629	0.0122	-0.302	-0.0660	0.535+	0.102+
	[0.339]	[0.0605]	[0.251]	[0.0485]	[0.261]	[0.0566]	[0.309]	[0.0581]
Short term	-0.526	-0.0939	0.0376	0.00727	-0.157	-0.0342	0.549	0.105
	[0.412]	[0.0732]	[0.334]	[0.0644]	[0.336]	[0.0733]	[0.374]	[0.0711]
Medium term	-0.530	-0.0947	-0.260	-0.0502	0.0564	0.0123	0.731*	0.140*
	[0.375]	[0.0669]	[0.276]	[0.0533]	[0.311]	[0.0679]	[0.319]	[0.0606]
Bachelor or Master	-0.277	-0.0494	0.101	0.0196	-0.184	-0.0402	0.193	0.0368
	[0.504]	[0.0900]	[0.381]	[0.0737]	[0.329]	[0.0717]	[0.470]	[0.0898]
Household income level (HIL) [d]								
HIL >66.666€	0.291	0.0520	-0.294	-0.0568	-0.275	-0.0600	0.497	0.0950
	[0.347]	[0.0620]	[0.262]	[0.0505]	[0.268]	[0.0582]	[0.337]	[0.0641]
HIL >39.999€&<66.667€	0.513	0.0916	0.139	0.0269	-0.634*	-0.138*	0.254	0.0485
	[0.318]	[0.0566]	[0.246]	[0.0475]	[0.257]	[0.0547]	[0.305]	[0.0586]
Weekly beach visits[e]								
Summer[e]	0.146	0.0260	-0.412+	-0.0795+	-0.425+	-0.0926+	0.865**	0.165**
	[0.284]	[0.0508]	[0.229]	[0.0438]	[0.233]	[0.0500]	[0.293]	[0.0542]

	0.455	0.0812	0.159	0.0307	0.0485	0.0106	-0.831*	-0.159*
Winter[e]	[0.371]	[0.0659]	[0.266]	[0.0513]	[0.284]	[0.0619]	[0.349]	[0.0645]
Recreational group								
	-0.750*	-0.134*	-0.0885	-0.0171	0.328	0.0716	0.493	0.0942
Angler[f]	[0.314]	[0.0546]	[0.256]	[0.0494]	[0.274]	[0.0593]	[0.343]	[0.0644]
	0.392	0.0700	-0.140	-0.0270	-0.170	-0.0371	-0.210	-0.0401
Boater[g]	[0.304]	[0.0538]	[0.273]	[0.0527]	[0.268]	[0.0583]	[0.358]	[0.0684]
View turbines from permanent or summer residence[h]								
	-0.245	-0.0438	0.00399	0.000772	-0.112	-0.0245	0.332	0.0635
View offshore	[0.382]	[0.0682]	[0.275]	[0.0532]	[0.287]	[0.0625]	[0.370]	[0.0702]
	-0.200	-0.0358	0.0313	0.00605	-0.108	-0.0235	0.351	0.0671
View onshore	[0.273]	[0.0487]	[0.219]	[0.0424]	[0.235]	[0.0512]	[0.241]	[0.0457]
Choice set blocks[i]								
	1.215**	0.217**	-1.001***	-0.193***	0.435	0.0949	0.0817	0.0156
Block 1	[0.393]	[0.0674]	[0.247]	[0.0446]	[0.324]	[0.0702]	[0.434]	[0.0829]
	2.104***	0.376***	-2.859***	-0.552***	0.623**	0.136**	1.971***	0.377***
Block 2	[0.468]	[0.0775]	[0.348]	[0.0518]	[0.222]	[0.0476]	[0.463]	[0.0832]
	-0.539	-0.0964	-2.463***	-0.476***	2.326***	0.507***	1.913***	0.365***
Block 3	[0.437]	[0.0775]	[0.425]	[0.0713]	[0.490]	[0.0981]	[0.434]	[0.0741]
	-0.331	-0.0591	-0.448	-0.0865	0.403	0.0878	2.834***	0.541***
Block 4	[0.441]	[0.0783]	[0.372]	[0.0716]	[0.307]	[0.0666]	[0.587]	[0.103]
	-0.910	-0.163+	-0.315	-0.0608	0.876*	0.191**	0.718*	0.137*
Block 5	[0.557]	[0.0982]	[0.372]	[0.0717]	[0.341]	[0.0729]	[0.364]	[0.0682]
Constant	-1.138		1.110+		0.0504		-1.290*	
	[0.835]		[0.637]		[0.535]		[0.619]	
N	452		455		447		446	
LL(0)	-290.6		-314.9		-304.2		-299.6	
LL(β)	-242.4		-259.0		-278.8		-250.7	
McFadden R^2	0.166		0.178		0.083		0.163	

Notes: Reference categories: a)Male respondents, b) Age >67, c) High school, d)Household income <40.000 €, e) do not visit the beach weekly, f) Not angler, g) Not boater, h) No view to turbines and i) Choice set block 6, Standard errors in brackets, $^{+} p < 0.10$, $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$

Appendix E: Estimated logit model of choosing an alternative with specific number of turbines/number of wind farms, models with controls

	49 turbines/15 wind farms		100 turbines/7 wind farms		144 turbines/5 wind farms	
	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate	Logit estimate	Marginal estimate
Horns Rev	-0.137	-0.0280	0.0469	0.00955	0.0638	0.0134
	[0.209]	[0.0426]	[0.199]	[0.0405]	[0.180]	[0.0379]
Female[a]	0.212	0.0433	-0.171	-0.0348	-0.0780	-0.0164
	[0.191]	[0.0390]	[0.178]	[0.0362]	[0.167]	[0.0351]
Age[b]						
Age: 20-37	-0.360	-0.0736	0.289	0.0589	0.207	0.0436
years	[0.497]	[0.101]	[0.513]	[0.104]	[0.447]	[0.0941]
Age: 38-48	-0.649	-0.133	0.327	0.0666	0.347	0.0729
years	[0.489]	[0.0991]	[0.526]	[0.107]	[0.466]	[0.0980]
Age: 49-56	-0.326	-0.0666	0.384	0.0781	-0.0374	-0.00788
years	[0.490]	[0.0998]	[0.521]	[0.106]	[0.464]	[0.0976]
Age: 57-66	-0.444	-0.0907	0.508	0.103	0.0453	0.00954
years	[0.485]	[0.0986]	[0.530]	[0.108]	[0.447]	[0.0940]
Education[c]						
	0.330	0.0673	-0.435^{+}	-0.0886^{+}	0.0620	0.0130
Vocational	[0.242]	[0.0493]	[0.229]	[0.0461]	[0.217]	[0.0456]
	0.381	0.0779	-0.359	-0.0730	-0.0319	-0.00671
Short term	[0.290]	[0.0589]	[0.268]	[0.0542]	[0.295]	[0.0621]
	0.133	0.0271	-0.231	-0.0470	-0.00456	-0.000959
Medium term	[0.259]	[0.0529]	[0.252]	[0.0512]	[0.219]	[0.0460]
Bachelor or	0.154	0.0314	0.535	0.109	-0.606^{+}	-0.127^{+}
Master	[0.349]	[0.0713]	[0.378]	[0.0770]	[0.333]	[0.0698]
Household income level (HIL) [d]						
	0.0992	0.0203	-0.0848	-0.0173	0.0274	0.00576
HIL >66.666€	[0.250]	[0.0510]	[0.225]	[0.0458]	[0.206]	[0.0434]
HIL	-0.209	-0.0428	0.00540	0.00110	0.225	0.0473
>39.999€&<66.667€	[0.244]	[0.0499]	[0.232]	[0.0471]	[0.191]	[0.0401]
Weekly beach visits[e]						
	0.0438	0.00894	-0.163	-0.0331	0.134	0.0282
Summer[e]	[0.226]	[0.0461]	[0.210]	[0.0427]	[0.182]	[0.0383]
	-0.892***	-0.182***	0.456^{+}	0.0929^{+}	0.413^{+}	0.0869^{+}
Winter[e]	[0.268]	[0.0536]	[0.251]	[0.0506]	[0.240]	[0.0504]
Recreational group						
	0.431^{+}	0.0881^{+}	-0.562**	-0.114**	0.147	0.0308
Angler[f]	[0.246]	[0.0497]	[0.212]	[0.0422]	[0.199]	[0.0417]
Boater[g]	0.0138	0.00282	0.333	0.0677	-0.319^{+}	-0.0672^{+}

	[0.272]	[0.0556]	[0.227]	[0.0461]	[0.193]	[0.0405]
View turbines from permanent or summer residence[h]						
	0.370	0.0756	-0.589*	-0.120*	0.169	0.0356
View offshore	[0.256]	[0.0520]	[0.242]	[0.0481]	[0.205]	[0.0431]
	-0.0477	-0.00974	0.149	0.0303	-0.103	-0.0217
View onshore	[0.214]	[0.0437]	[0.192]	[0.0391]	[0.185]	[0.0389]
Choice set blocks[i]						
	-0.392	-0.0800	0.672*	0.137*	0.623^{+}	0.131^{+}
Block 1	[0.321]	[0.0654]	[0.301]	[0.0600]	[0.345]	[0.0717]
	0.733**	0.150**	-1.598***	-0.325***	1.345***	0.283***
Block 2	[0.284]	[0.0569]	[0.324]	[0.0615]	[0.341]	[0.0687]
	-1.794***	-0.366***	0.151	0.0307	2.366***	0.498***
Block 3	[0.318]	[0.0587]	[0.191]	[0.0388]	[0.405]	[0.0768]
	-0.274	-0.0560	1.349***	0.275***	-0.406	-0.0853
Block 4	[0.299]	[0.0610]	[0.284]	[0.0544]	[0.414]	[0.0867]
	-1.650***	-0.337***	1.263***	0.257***	1.024**	0.215**
Block 5	[0.273]	[0.0503]	[0.268]	[0.0514]	[0.330]	[0.0675]
Constant	0.719		-0.190		-1.246*	
	[0.543]		[0.573]		[0.559]	
N	596		600		604	
LL(0)	-412.8		-414.8		-418.4	
LL(β)	-354.8		-355.5		-367.4	
McFadden R^2	0.141		0.143		0.122	

Notes: Reference categories: [a)]Male respondents, [b)] Age >67, [c)] High school, [d)]Household income <40.000 €, [e)] do not visit the beach weekly, [f)] Not angler, [g)] Not boater, [h)] No view to turbines and [i)] Choice set block 6, Standard errors in brackets, $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix F: Non-weighted WTP estimates Main effect

Horns Rev	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm		236.0**	611.8***	610.4***
		[88.04]	[101.4]	[128.1]
7*100 turbines wind farm	153.4	389.4*	765.2***	763.8***
	[98.94]	[153.0]	[160.3]	[191.7]
5*144 turbines/wind farm	114.0	350.0*	725.8***	724.4***
	[86.08]	[150.0]	[157.6]	[178.0]
Nysted	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm		490.9***	623.3***	1043.3***
		[140.4]	[155.7]	[237.0]
7*100 turbines wind farm	225.7	716.6***	849.0***	1269.0***
	[138.0]	[197.5]	[229.7]	[296.1]
5*144 turbines/wind farm	161.5	652.4***	784.8***	1204.8***
	[126.4]	[195.7]	[223.9]	[284.9]
Difference in WTP	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm		254.8	11.4	432.9
		[165.7]	[185.8]	[269.4]
7*100 turbines wind farm	72.4	327.2	83.8	21.0
	[169.8]	[249.9]	[280.1]	[352.7]
5*144 turbines/wind farm	47.5	302.4	543.2*	480.4
	[152.9]	[246.5]	[273.8]	[335.9]
LR-test				

Appendix G: Non-weighted WTP estimates Interaction effect

Horns Rev	Distance 8 km	Distance 12 km	Distance 18 km	Distance 50 km
14*49 turbines/wind farm	-	262.9**	667.9***	651.7***
		[88.31]	[100.9]	[134.6]
7*100 turbines wind farm	170.1+	432.9**	838.0***	821.8***
	[99.14]	[152.7]	[163.0]	[199.2]
5*144 turbines/wind farm	125.9	388.7**	793.8***	777.6***
	[89.18]	[148.4]	[158.8]	[182.8]
Nysted	**Distance 8 km**	**Distance 12 km**	**Distance 18 km**	**Distance 50 km**
14*49 turbines/wind farm	-	1935.7***	840.8***	1896.8***
		[453.4]	[183.7]	[450.3]
7*100 turbines wind farm	1056.9**	864.1***	1897.7***	1955.3***
	[327.9]	[225.5]	[443.3]	[483.6]
5*144 turbines/wind farm	742.8***	1183.7**	1583.6***	1641.2***
	[210.2]	[420.9]	[347.3]	[378.8]
Difference in WTP	**Distance 8 km**	**Distance 12 km**	**Distance 18 km**	**Distance 50 km**
14*49 turbines/wind farm	-	1672.9***	172.9	1245.1**
		[461.9]	[209.6]	[470.0]
7*100 turbines wind farm	886.8**	431.2	1059.7*	761.8
	[342.6]	[272.3]	[472.3]	[523.0]
5*144 turbines/wind farm	617.0**	794.9+	1161.5**	863.6*
	[228.3]	[446.3]	[381.8]	[381.8]
LR-test				

Appendix H: Full heteroscedastic models

	Weighted		Socio demographics in scaling model		Non-weighted	
	Main effect model	Adjusted interaction model	Main effect model	Adjusted interaction model	Main effect model	Adjusted interaction model
Mean						
Distance 12 km	0.308** [0.117]	0.631* [0.297]	0.519+ [0.278]	0.469+ [0.267]	0.272** [0.0889]	0.494* [0.209]
Distance 18 km	0.605*** [0.168]	0.714*** [0.190]	0.662 [0.438]	0.412 [0.389]	0.618*** [0.130]	0.666*** [0.144]
Distance 50 km	0.638*** [0.191]	0.725*** [0.217]	0.608 [0.493]	0.391 [0.387]	0.682*** [0.164]	0.732*** [0.180]
7*100 turbines/ windfarm	0.170* [0.0772]	0.277* [0.120]	0.0426 [0.118]	0.0880 [0.109]	0.0723 [0.0627]	0.141 [0.0896]
5*144 turbines/ wind farm	0.201* [0.0917]	0.267+ [0.150]	0.234 [0.202]	0.192 [0.147]	0.0998 [0.0745]	0.164 [0.104]
Costs	-0.0676*** [0.0130]	-0.0074*** [0.0196]	-0.0055 [0.0034]	-0.0042 [0.0034]	-0.0071*** [0.0012]	-0.0074*** [0.0013]
Distance 12 km X 7*100 turbines/ wind farm		-0.296 [0.327]		-0.0533 [0.345]		-0.256 [0.216]
Distance 12 km X 5*144 turbines/wind farm		-0.519 [0.380]		-0.514 [0.337]		-0.333 [0.286]
Heteroscedastic function						
Horns Rev	0.916*** [0.232]	0.738** [0.265]	0.502* [0.228]	0.393+ [0.231]	0.881*** [0.195]	0.771*** [0.215]
Female[a]			-0.0529 [0.210]	-0.0371 [0.197]		
Age[b]						
Age: 20-37 years			0.412 [0.414]	0.616 [0.498]		
Age: 38-48 years			0.281 [0.472]	0.423 [0.526]		
Age: 49-56 years			0.437 [0.418]	0.548 [0.491]		
Age: 57-66 years			0.321 [0.432]	0.465 [0.496]		
Education[c]						
Vocational			-0.475+ [0.285]	-0.505+ [0.299]		
Short term			-0.419 [0.394]	-0.492 [0.394]		
Medium term			0.303 [0.241]	0.243 [0.268]		

Bachelor or Master		0.0923	0.184		
		[0.441]	[0.415]		
Household income level (HIL)[d]					
HIL >66.666€		0.177	0.216		
		[0.253]	[0.245]		
HIL >39.999€&<66.667€		0.248	0.286		
		[0.260]	[0.257]		
Weekly beach visits[e]					
Summer[e]		-0.141	-0.103		
		[0.255]	[0.266]		
Winter[e]		0.256	0.411		
		[0.377]	[0.371]		
Recreational group					
Angler[f]		-0.763^{+}	-0.884*		
		[0.457]	[0.440]		
Boater[g]		0.371	0.506		
		[0.313]	[0.350]		
View turbines from permanent or summer residence[h]					
View offshore		-0.551^{+}	-0.549^{+}		
		[0.328]	[0.291]		
View onshore		0.0978	0.0171		
		[0.255]	[0.259]		
Choice set blocks[i]					
Block 1		-1.304	-0.501		
		[1.036]	[0.860]		
Block 2		1.754	2.227^{+}		
		[1.168]	[1.290]		
Block 3		0.394	0.640		
		[0.747]	[0.924]		
Block 4		-0.244	-0.0957		
		[0.505]	[0.606]		
Block 5		-0.319	0.0803		
		[0.436]	[0.529]		
N_resp	300				
N_choices	900				
LL(0)	-623.8				
LL(β)	-512.5	-487.8	-485.4	-508.9	-507.8
McFadden R^2	0.178	0.218	0.222	0.184	0.186
chi2	27.30	68.43	62.04	26.15	17.37

Appendix I: Certainty in choice, full models

	OLS	Multinomial logit[j]	
	Parameter Estimate	"Certain" Parameter Estimate	"Very Certain" Parameter Estimate
Horns Rev	0.704*	0.994**	0.889*
	[0.324]	[0.382]	[0.443]
Female[a]	0.124	0.259	0.393
	[0.300]	[0.343]	[0.399]
Age[b]			
Age: 20-37 years	-0.855	0.240	-1.782^{+}
	[0.742]	[0.832]	[0.983]
Age: 38-48 years	-0.135	0.331	-0.0801
	[0.747]	[0.850]	[0.929]
Age: 49-56 years	-0.304	-0.349	-0.604
	[0.758]	[0.855]	[0.933]
Age: 57-66 years	-0.328	-0.233	-0.332
	[0.739]	[0.832]	[0.909]
Education[c]			
Vocational	0.320	0.458	0.456
	[0.377]	[0.413]	[0.473]
Short term	-0.200	0.392	-0.191
	[0.479]	[0.524]	[0.633]
Medium term	0.559	0.862^{+}	0.393
	[0.430]	[0.495]	[0.572]
Bachelor or Master	0.355	1.133	0.774
	[0.665]	[0.857]	[1.043]
Household income level (HIL)[d]			
HIL >66.666€	0.337	0.413	0.615
	[0.377]	[0.429]	[0.500]
HIL >39.999€&<66.667€	0.0370	0.314	0.264
	[0.365]	[0.396]	[0.476]
Weekly beach visits[e]			
Summer[e]	0.220	-0.0794	0.541
	[0.344]	[0.380]	[0.447]
Winter[e]	0.344	1.028*	0.522
	[0.410]	[0.502]	[0.549]
Recreational group			
Angler[f]	0.253	0.605	0.709
	[0.371]	[0.468]	[0.522]
Boater[g]	0.661^{+}	0.397	0.566

	[0.390]	[0.500]	[0.551]
View turbines from permanent or summer residence[h]			
	0.0767	-0.0967	0.222
View offshore	[0.409]	[0.488]	[0.540]
	0.459	0.219	0.606
View onshore	[0.323]	[0.366]	[0.422]
Choice set blocks[i]			
	0.347	0.807	0.882
Block 1	[0.471]	[0.547]	[0.632]
	-0.199	0.352	0.142
Block 2	[0.498]	[0.535]	[0.651]
	0.584	0.341	0.833
Block 3	[0.495]	[0.550]	[0.641]
	-0.0937	0.137	0.110
Block 4	[0.497]	[0.544]	[0.645]
	0.161	0.510	0.627
Block 5	[0.485]	[0.535]	[0.629]
Constant	5.904***	-1.163	-1.828^{+}
	[0.846]	[0.945]	[1.067]
N	300	300	
SST/LL(0)	1713.79	-304.7	
SSE/LL(β)	170,11	-273.2	
R2/McFadden R2	0.099	0.104	

Notes: Reference categories: [a)]Male respondents, [b)] Age >67, [c)] High school, [d)]Household income <40.000 €, [e)] do not visit the beach weekly, [f)] Not angler, [g)] Not boater, [h)] No view to turbines, [i)] Choice set block 6 and [j)] "Uncertain", Standard errors in brackets, $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix G

Survey utilised in Stated Preference Studies

Intro

Velkommen!

Dette spørgeskema handler om vindmøller. Det handler også om placeringen af fremtidige vindmøller i dit nærområde.

Gender

Hvad er dit køn?

◯	Kvinde
◯	Mand

BirthYear

Hvilket år er du født?

Region

Hvilken region er du bosat i?

◯	Region Hovedstaden
◯	Region Sjælland
◯	Region Syddanmark
◯	Region Midtjylland
◯	Region Nordjylland
◯	Udlandet
◯	Ved ikke

Go to question SCREENING_1 if Region == [6,7] .

Q1_global_opvarmning

Er global opvarmning et problem, som skal tages seriøst?

◯	Ja
◯	Nej
◯	Ved ikke

Q2_handling_nedsaette_CO2

I hvor høj grad synes du, Danmark som samfund bør gøre følgende for at reducere udslippet af CO2?

	I meget høj grad	I høj grad	Hverken eller	I ringe grad	I meget ringe grad
Investere i og bygge atomkraftværker	◯	◯	◯	◯	◯
Investere i og øge antallet af vindmøller på landjorden	◯	◯	◯	◯	◯
Investere i og øge antallet af vindmøller på havet	◯	◯	◯	◯	◯
Investere i og øge antallet af vandkraftværker	◯	◯	◯	◯	◯
Investere i og bygge bølge- og tidevandskraftværker	◯	◯	◯	◯	◯
Investere i energibesparende teknologier	◯	◯	◯	◯	◯
Bruge skatter og afgifter til at reducere borgernes CO2-udledninger.	◯	◯	◯	◯	◯
Bruge skatter og afgifter til at reducere virksomhedernes CO2-udledninger.	◯	◯	◯	◯	◯

Q3_holdning_vindmoeller_land

Show question if dummy_til_valg_startsted == [1-3] .

Hvad er din generelle holdning til vindmøller på land?

	Meget positiv		Neutral		Meget negativ	Ved ikke
Hvad er din generelle holdning til vindmøller på landjorden?	◯	◯	◯	◯	◯	◯
Hvilken påvirkning har vindmøller på landskabets udseende?	◯	◯	◯	◯	◯	◯
Hvad er din holdning til at opstille flere vindmøller på land?	◯	◯	◯	◯	◯	◯
Hvad er din holdning til at erstatte mange små vindmøller med færre, men store vindmøller?	◯	◯	◯	◯	◯	◯
Hvilken påvirkning har vindmøller på landjorden og din brug af naturen/ rekreative områder?	◯	◯	◯	◯	◯	◯

Q4_holdning_vindmoeller_til_havs

Show question if dummy_til_valg_startsted == [1-3] .

Hvad er din generelle holdning til vindmøller til havs, dvs. ud for kysten?

	Meget positiv		Neutral		Meget negativ	Ved ikke
Hvad er din generelle holdning til havvindmøller?	○	○	○	○	○	○
Hvilken indflydelse har havvindmøller på landskabets udseende?	○	○	○	○	○	○
Hvilken påvirkning har havvindmøller på livet i havet, så som fisk, planter, bunddyr og havpattedyr?	○	○	○	○	○	○
Hvad er din holdning til at opstille flere vindmøller til havs?	○	○	○	○	○	○
Hvilken påvirkning har vindmøller på havet og din brug af kysten / rekreative områder?	○	○	○	○	○	○

Q5_introtekst

I de næste par spørgsmål vil vi også spørge dig om, hvor du bor. Dine adresseoplysninger vil være anonyme. Vi skal kun bruge oplysningerne til en geografisk analyse af, hvor vindmøllerne er placeret i dit område.

Q6_postnummer

Hvilket postnummer bor du i?

Q7_adresse

Hvad er din adresse?

(skriv venligst vejnavn)

Q8_hvor_laenge_boet_nuvaerende_bopael

Hvor længe har du boet på din nuværende bopæl?

◯	Under 5 år
◯	5-9 år
◯	10-14 år
◯	15-19 år
◯	20 år eller derover
◯	Ved ikke

Q9_ser_antal_vindmoeller_pr_dag

Hvor mange vindmøller ser du i løbet af en almindelig dag?

◯	Ingen
◯	1-5
◯	6-10
◯	11-15
◯	16-20
◯	21 eller derover

Q10_udsigt_vindmoeller_bopael

Har du direkte udsigt til vindmøller fra din bopæl/sommerhus?

◯	Ja
◯	Nej

◯	Ved ikke

Q11_antal_vindmoeller_se_fra_hus

Show question if Q10_udsigt_vindmoeller_bopael == [1] .

Hvor mange vindmøller kan du se fra din bopæl/sommerhus?

Hvis du kan se vindmøller fra både din bopæl og dit sommerhus, skal du svare ud fra det sted, hvor du kan se flest vindmøller.

◯	1
◯	2-3
◯	4-5
◯	6-10
◯	11 eller derover

Q12_udsigt_havmoeller_hus

Har du direkte udsigt til havvindmøller fra din bopæl/sommerhus?

◯	Ja
◯	Nej
◯	Ved ikke

Q13_hyppighed_besoeg_havmoelleparker

Hvor mange gange har du inden for de seneste 5 år set/besøgt følgende havvindmølleparker?

	Aldrig	1 gang	2-5 gange	6-10 gange	11-20 gange	21 gange eller derover
Middelgrunden (Københavns havn)	◯	◯	◯	◯	◯	◯
Nysted I og II (syd/vest for Lolland)	◯	◯	◯	◯	◯	◯
Horns Rev I og II (vest for Esbjerg/Blåvands Huk)	◯	◯	◯	◯	◯	◯
Tunø Knob (mellem Jylland og Samsø)	◯	◯	◯	◯	◯	◯
Samsø (mellem Samsø og Fyn)	◯	◯	◯	◯	◯	◯
Vindeby (vest for Lolland)	◯	◯	◯	◯	◯	◯
Sprogø (nord for Sprogø/Storebæltsbroen)	◯	◯	◯	◯	◯	◯
Rønland (ved Nissum)	◯	◯	◯	◯	◯	◯
Frederikshavn (ud fra havnen)	◯	◯	◯	◯	◯	◯
Avedøre Holme (syd for København)	◯	◯	◯	◯	◯	◯

Q14_introtekst

Vindmøller på land

På land er det et energipolitisk mål at finde omkring 150 områder, hvor der kan sættes nye vindmøller op. På havet er der udpeget 5 større områder, hvor de nye havvindmøller skal placeres. Der vil være en del tekst og billeder, som vi vil bede dig om at læse og se grundigt på.

Q15_planer_om_nye_moeller

Er der planer om at opstille nye landmøller i din egen eller nabokommune?

◯	Ja
◯	Nej
◯	Ved ikke

Q16_udsigt_til_nye_moeller

Show question if Q15_planer_om_nye_moeller == [1] .

Vil du kunne se de nye vindmøller fra dit hjem?

◯	Ja
◯	Nej
◯	Ved ikke

Infoside_1

Først vil vi bede dig om at foretage dit foretrukne valg vedr. placeringen af vindmøller til lands.

På land kan man forestille sig at udbygge med 3 MW, 1,5 MW eller 750 KW vindmøller. 3 MW møller er de største vindmøller og den billigste måde at producere strømmen på. Mindre møller er relativt dyrere og knap så effektive. Du skal forestille dig, at dækning af de evt. øgede udgifter skal dækkes af den enkelte husstand gennem et fast årligt tillæg til elregningen.

Infoside_2

Show question if dummy_til_valg_startsted_1 == [1] .

Placeringerne af vindmøllerne vil variere med hensyn til:

- Størrelsen af vindmøllen: 3 MW mølle, to 1,5 MW møller eller fire 750 kW møller.
- Afstand til nærmeste bebyggelse: 500 m eller 1.000 m.
- Antal beboere, som bor i nærheden af den nærmeste bebyggelse: 1-10, 11-100 eller over 100 beboere.
- De årlige omkostninger for din husstand: 0, 50, 100, 300, 600 eller 1.200 kr./husstand/år.

Infoside_3

Du skal i de kommende 4 spørgsmål vælge imellem to alternative vindmøllestørrelser og -placeringer. Der vil være et billede af hvert vindmøllealternativ.

Der vil ikke være støj fra møllerne, uanset størrelse og afstand til nærmeste bebyggelse.

Vi anbefaler, at du klikker på hvert billede, inden du foretager et valg, så du kan se billederne af vindmøllerne på en fuld skærm. På grund af billederne kan det tage lidt tid, inden spørgsmålet vises på skærmen.

I de alternativer du bliver vist, skal du forestille dig, at det område som vi viser billeder af, er et sted i *din egen kommune* eller i *en nabokommune*. De resterende 149 områder er i *andre kommuner*. Men det er vigtigt, at du forholder dig til, at dine valg er gældende for placeringen af vindmøller på *alle* de 150 steder.

Vi vil bede dig om at betragte situationerne, som var de virkelige. Det gælder ikke mindst den øgede elektricitetsregning, da lignende undersøgelser har vist, at folk har en tendens til at overvurdere, hvor meget de rent faktisk er villige til at betale. Det er derfor vigtigt i forbindelse med dine valg, at du er helt sikker på, at du er villig til at betale de ekstra beløb, som du vælger.

Blok1_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok1_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 1-10 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok1_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok1_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	**Alternativ B**
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere:>100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 500 m Beboere:1-10 Betaling 0 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere:11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 11-100 Betaling:1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok3_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 600 kr./år

○	Alternativ A
○	Alternativ B

Blok3_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Betaling: 4*750 kW Afstand:1.000 m Beboere:1-10 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok3_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	**Alternativ B**
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: >100 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Blok3_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: >100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere >100 Betaling: 300 kr./år

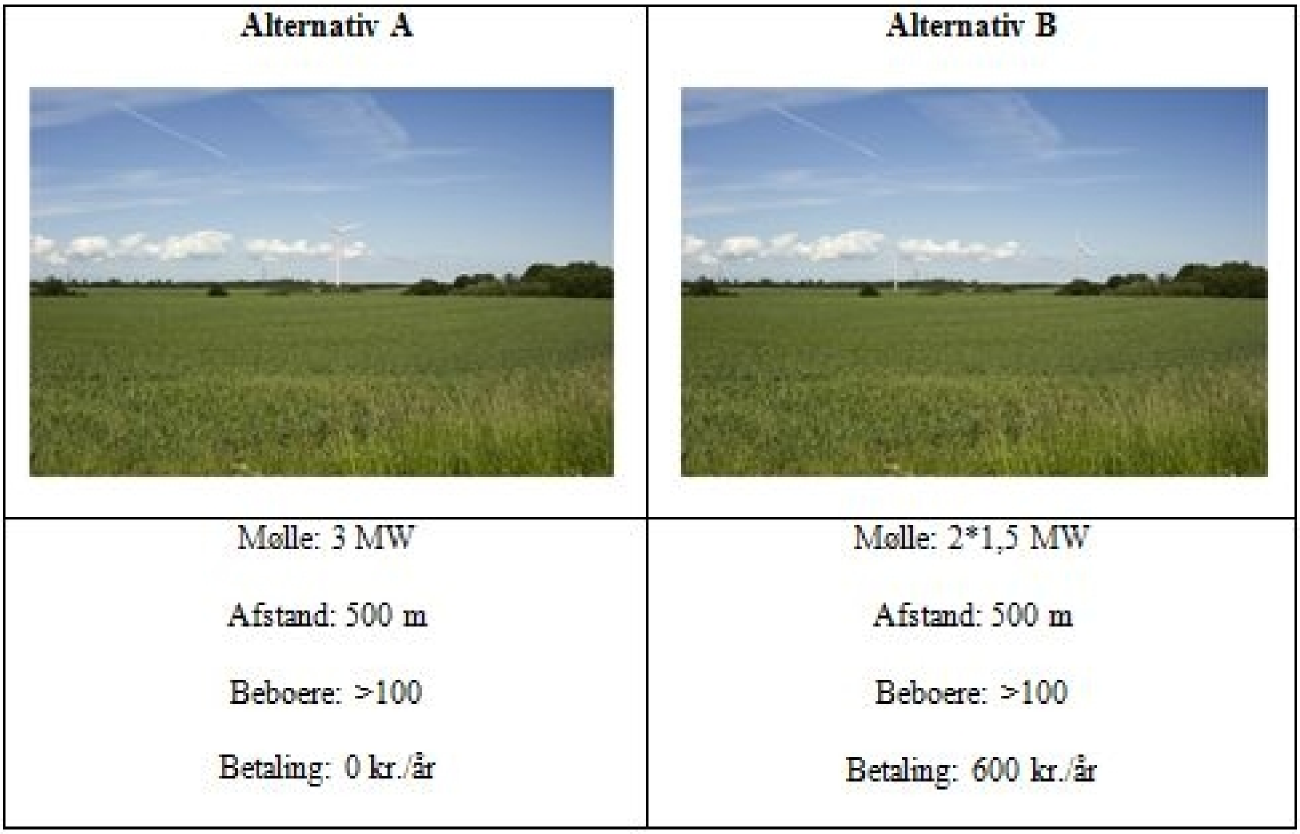
◯	Alternativ A
◯	Alternativ B

Blok5_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.



Alternativ A	Alternativ B
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: >100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok6_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 500 m Beboere:11-100 Betaling: 0 kr

◯	Alternativ A
◯	Alternativ B

Blok6_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: >100 Betaling:1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok6_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok6_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 1-10 Betaling: 0 kr./år

○	Alternativ A
○	Alternativ B

Blok7_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 300 kr./år

○	Alternativ A
○	Alternativ B

Blok7_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: 1-10 Betaling: 0 kr./år

◯	Alternativ A
◯	Alternativ B

Blok7_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: 11-100 Betaling: 100 kr./år

○	Alternativ A
○	Alternativ B

Blok7_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: >100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: >100 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: 1-10 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	**Alternativ B**
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 1-10 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: >100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_valg1

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_valg2

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_valg3

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: >100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_valg4

Hvilken placering af vindmølle(r) foretrækker du?

Billedet viser møllernes afstand til den nærmeste bebyggelse. Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Mølle: 3 MW Afstand: 500 m Beboere: >100 Betaling: 0 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Q17_sikkerhed_i_valg

Hvor sikker var du i dine foregående fire valg?

◯	Meget sikker
◯	
◯	Hverken eller
◯	
◯	Meget usikker

Q18_hvorfor_altid_A

Show question if Blok1_valg1 == [1] && Blok1_valg2 == [1] && Blok1_valg3 == [1] && Blok1_valg4 == [1] || Blok2_valg1 == [1] && Blok2_valg2 == [1] && Blok2_valg3 == [1] && Blok2_valg4 == [1] || Blok3_valg1 == [1] && Blok3_valg2 == [1] && Blok3_valg3 == [1] && Blok3_valg4 == [1] || Blok4_valg1 == [1] && Blok4_valg2 == [1] && Blok4_valg3 == [1] && Blok4_valg4 == [1] || Blok5_valg1 == [1] && Blok5_valg2 == [1] && Blok5_valg3 == [1] && Blok5_valg4 == [1] ||Blok6_valg1 == [1] && Blok6_valg2 == [1] && Blok6_valg3 == [1] && Blok6_valg4 == [1] || Blok7_valg1 == [1] && Blok7_valg2 == [1] && Blok7_valg3 == [1] && Blok7_valg4 == [1] || Blok8_valg1 == [1] && Blok8_valg2 == [1] && Blok8_valg3 == [1] && Blok8_valg4 == [1] || Blok9_valg1 == [1] && Blok9_valg2 == [1] && Blok9_valg3 == [1] && Blok9_valg4 == [1].

I de valgsituationer, du har svaret på, valgte du altid alternativ A. Hvad var den primære årsag dertil?

◯	Jeg har ikke råd til højere betaling
◯	Jeg synes ikke, at forbedringerne ved at ændre møllernes placering var omkostningerne værd.

◯	Det har en værdi for mig at reducere generne fra landvindmøller, men jeg vil ikke betale mere.
◯	Jeg kan ikke forholde mig til at skulle betale mere
◯	Jeg viste ikke, hvad jeg skulle vælge
◯	Andet – beskriv venligst

Q19_hvorfor_altid_B

Show question if Blok1_valg1 == [2] && Blok1_valg2 == [2] && Blok1_valg3 == [2] && Blok1_valg4 == [2] || Blok2_valg1 == [2] && Blok2_valg2 == [2] && Blok2_valg3 == [2] && Blok2_valg4 == [2] || Blok3_valg1 == [2] && Blok3_valg2 == [2] && Blok3_valg3 == [2] && Blok3_valg4 == [2] || Blok4_valg1 == [2] && Blok4_valg2 == [2] && Blok4_valg3 == [2] && Blok4_valg4 == [2] || Blok5_valg1 == [2] && Blok5_valg2 == [2] && Blok5_valg3 == [2] && Blok5_valg4 == [2] ||Blok6_valg1 == [2] && Blok6_valg2 == [2] && Blok6_valg3 == [2] && Blok6_valg4 == [2] || Blok7_valg1 == [2] && Blok7_valg2 == [2] && Blok7_valg3 == [2] && Blok7_valg4 == [2] || Blok8_valg1 == [2] && Blok8_valg2 == [2] && Blok8_valg3 == [2] && Blok8_valg4 == [2] || Blok9_valg1 == [2] && Blok9_valg2 == [2] && Blok9_valg3 == [2] && Blok9_valg4 == [2].

I de valgsituationer, du har svaret på, valgte du altid alternativ B. Hvad var den primære årsag dertil?

◯	Jeg har slet ikke taget højde for betalingen
◯	Jeg synes, at forbedringerne ved at ændre møllernes placering var omkostningerne værd.
◯	Det har en værdi for mig at reducere generne fra landvindmøller, og jeg vil gerne betale for det.
◯	Det er jo ikke rigtige penge, så jeg har ikke kigget på betalingen
◯	Jeg viste ikke, hvad jeg skulle vælge
◯	Andet – beskriv venligst

Q20_intro_havvindmoeller

Havvindmøller

Som et alternativ til at placere nye vindmøller i 150 områder på landjorden, kan man samle vindmøllerne og i stedet placere dem i havet i en enkelt havvindmøllepark. På kortet nedenfor vises de 5 områder, som de danske myndigheder har udpeget til nye havvindmøller. Disse er markeret med GULT. De andre områder er steder, hvor der allerede er havvindmølleparker af forskellig størrelse.

Q21_kendskab_nye_havmoelleparker

Er du bekendt med, at nogle af disse områder er udpeget til at placere nye havvindmølleparker?

◯	Ja
◯	Nej

Infoside_vandmoeller_1

Alt afhængig af vind- og dybdeforhold og afstanden til kysten vil havvindmøller producere billigere eller dyrere strøm i forhold til de nye landmøller.

Nedenfor vil vi gerne have dig til at vælge imellem de landmølleplaceringer, som du foretrak, og forskellige placeringer i havet.

Infoside_vandmoeller_2

Show question if dummy_til_valg_startsted_2 == [1] .

Placeringerne i havet vil variere med hensyn til:

- Hvilket område havvindmølleparken placeres i.
- Afstand til kysten: 8, 12, 18 eller 50 km.
- De årlige omkostninger for din husstand: 0, 50, 100, 300, 600 1.200 kr./husstand/år.

info_vandmoeller_3

Du skal i de kommende 4 spørgsmål forestille dig, at man i stedet for at placere vindmøllerne på land kan sætte dem i havet i en enkelt havvindmøllepark.

I hvert spørgsmål vil du blive bedt om at vælge imellem en af de tidligere landmølleplaceringer og en alternativ placering på havet.

Igen er der for hvert valg et billede af hvert vindmøllealternativ. Vi anbefaler, at du klikker på hvert billede, inden du foretager et valg, så du kan se billederne af vindmøllerne på en fuld skærm.

Ligesom i spørgsmålene om dine præferencer for landmøller, er det vigtigt, at du nøje ser på alternativerne og deres egenskaber, derunder ikke mindst omkostningerne.

Blok1_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 12 km fra kysten Betaling: 100 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok1_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 50 km fra kysten Betaling: 50 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 1-10 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok1_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Jammerbugt Afstand: 18 km fra kysten Betaling: 600 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok1_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 8 km fra kysten Betaling: 300 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: >100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Vesterhavet Afstand: 12 km fra kysten Betaling: 100 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 1-10 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Blok2_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 12 km fra kysten Betaling: 300 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 12 km fra kysten Betaling: 600 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok2_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Jammerbugt Afstand: 18 km fra kysten Betaling: 50 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 11-100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok3_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 18 km fra kysten Betaling: 0 kr.	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok3_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Vesterhavet Afstand: 50 km fra kysten Betaling: 300 kr./år	Betaling: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok3_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Jammerbugt Afstand: 12 km fra kysten Betaling: 1.200 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: >100 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Blok3_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 8 km fra kysten Betaling: 300 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 50 km fra kysten Betaling: 600 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 18 km fra kysten Betaling: 0 kr.	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Vesterhavet Afstand: 8 km fra kysten Betaling: 100 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: >100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok4_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 12 km fra kysten Betaling: 1.200 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 8 km fra kysten Betaling: 600 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: >100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Jammerbugt Afstand: 50 km fra kysten Betaling: 1.200 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: >100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 50 km fra kysten Betaling: 50 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok5_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 8 km fra kysten Betaling: 50 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok6_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 18 km fra kysten Betaling: 50 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 11-100 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Blok6_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Vesterhavet Afstand: 8 km fra kysten Betaling: 300 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: >100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok6_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 12 km fra kysten Betaling: 1.200 kr./år	Mølle: 4*750 kW Afstand: 1.000 m Beboere: 1-10 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok6_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 50 km fra kysten Betaling: 100 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 1-10 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Blok7_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Jammerbugt Afstand: 8 km fra kysten Betaling: 1.200 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 11-100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok7_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Vesterhavet Afstand: 12 km fra kysten Betaling: 0 kr.	Mølle: 4*750 kW Afstand: 500 m Beboere: 1-10 Betaling: 0 kr.

◯	Alternativ A
◯	Alternativ B

Blok7_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 18 km fra kysten Betaling: 0 kr.	Mølle: 4*750 kW Afstand: 500 m Beboere: 11-100 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok7_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Bornholm Afstand: 12 km fra kysten Betaling: 600 kr./år	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: >100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Syd for Anholt Afstand: 18 km fra kysten Betaling: 0 kr.	Mølle: 2*1,5 MW Afstand: 1.000 m Beboere: >100 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 8 km fra kysten Betaling: 100 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: 1-10 Betaling: 50 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 12 km fra kysten Betaling: 1.200 kr./år	Mølle: 3 MW Afstand: 500 m Beboere: 1-10 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok8_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Jammerbugt Afstand: 50 km fra kysten Betaling: 100 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: >100 Betaling: 600 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_2valg1

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	**Alternativ B**
	
Placering: Syd for Bornholm Afstand: 18 km fra kysten Betaling: 50 kr./år	Mølle: 3 MW Afstand: 1.000 m Beboere: 1-10 Betaling: 100 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_2valg2

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Øst for Møn Afstand: 50 km fra kysten Betaling: 600 kr./år	Mølle: 2*1,5 MW Afstand: 500 m Beboere: 11-100 Betaling: 1.200 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_2valg3

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

Alternativ A	Alternativ B
	
Placering: Vesterhavet Afstand: 8 km fra kysten Betaling: 300 kr./år	Mølle: 4*750 kW Afstand: 500 m Beboere: >100 Betaling: 300 kr./år

◯	Alternativ A
◯	Alternativ B

Blok9_2valg4

Hvilken placering af vindmølle(r) foretrækker du?

Vindmøllernes størrelse på billedet svarer til det visuelle udtryk, man vil få, hvis man stod ved den nærmeste bebyggelse eller på stranden og så ud mod vindmøllerne.

Hvis du klikker på ét af billederne, kan du se dem i en større størrelse.

<table>
<tr><th>Alternativ A</th><th>Alternativ B</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Placering: Syd for Anholt
Afstand: 8 km fra kysten
Betaling: 0 kr.</td><td>Mølle: 2*1,5 MW
Afstand: 1.000 m
Beboere: 11-100
Betaling: 0 kr.</td></tr>
</table>

◯	Alternativ A
◯	Alternativ B

Q22_sikkerhed_i_valg

Hvor sikker var du i dine foregående fire valg?

◯	Meget sikker
◯	
◯	Hverken eller
◯	
◯	Meget usikker

Q23_hvofor_aldrig_landmoeller

Show question if Blok1_2valg1 == [1] && Blok1_2valg2 == [1] && Blok1_2valg3 == [1] && Blok1_2valg4 == [1] || Blok2_2valg1 == [1] && Blok2_2valg2 == [1] && Blok2_2valg3 == [1] && Blok2_2valg4 == [1] || Blok3_2valg1 == [1] && Blok3_2valg2 == [1] && Blok3_2valg3 == [1] && Blok3_2valg4 == [1] || Blok4_2valg1 == [1] && Blok4_2valg2 == [1] && Blok4_2valg3 == [1] && Blok4_2valg4 == [1] || Blok5_2valg1 == [1] && Blok5_2valg2 == [1] && Blok5_2valg3 == [1] && Blok5_2valg4 == [1] || Blok6_2valg1 == [1] && Blok6_2valg2 == [1] && Blok6_2valg3 == [1] && Blok6_2valg4 == [1] || Blok7_2valg1 == [1] && Blok7_2valg2 == [1] && Blok7_2valg3 == [1] && Blok7_2valg4 == [1] || Blok8_2valg1 == [1] && Blok8_2valg2 == [1] && Blok8_2valg3 == [1] && Blok8_2valg4 == [1] || Blok9_2valg1 == [1] && Blok9_2valg2 == [1] && Blok9_2valg3 == [1] && Blok9_2valg4 == [1] .

I de valgsituationer, du lige har svaret på, valgte du aldrig en placering på land. Hvad var den primære årsag dertil?

	Jeg synes, at forbedringerne ved at flytte vindmøllerne ud på havet var større end omkostningerne.

◯	
◯	Betalingen havde slet ingen betydning for mit valg
◯	Det er jo ikke rigtige penge, så jeg har slet ikke forholdt mig til betalingen
◯	Jeg synes, det er vigtigt at reducere generne fra landvindmøller, og jeg gerne betale for det
◯	Jeg viste ikke, hvad jeg skulle vælge
◯	Andet – beskriv venligst

Q3_holdning_vindmoeller_land_2

Show question if dummy_til_valg_startsted == [4] .

Hvad er din generelle holdning til vindmøller på land?

	Meget positiv		Neutral		Meget negativ	Ved ikke
Hvad er din generelle holdning til vindmøller på landjorden?	◯	◯	◯	◯	◯	◯
Hvilken påvirkning har vindmøller på landskabets udseende?	◯	◯	◯	◯	◯	◯
Hvad er din holdning til at opstille flere vindmøller på land?	◯	◯	◯	◯	◯	◯
Hvad er din holdning til at erstatte mange små vindmøller med færre, men store vindmøller?	◯	◯	◯	◯	◯	◯
Hvilken påvirkning har vindmøller på landjorden og din brug af naturen/ rekreative områder?	◯	◯	◯	◯	◯	◯

Q4_holdning_vindmoeller_til_havs_2

Show question if dummy_til_valg_startsted == [4] .

Hvad er din generelle holdning til vindmøller til havs, dvs. ud for kysten?

	Meget positiv		Neutral		Meget negativ	Ved ikke
Hvad er din generelle holdning til havvindmøller?	◯	◯	◯	◯	◯	◯
Hvilken indflydelse har havvindmøller på landskabets udseende?	◯	◯	◯	◯	◯	◯
Hvilken påvirkning har havvindmøller på livet i havet, så som fisk, planter, bunddyr og havpattedyr?	◯	◯	◯	◯	◯	◯
Hvad er din holdning til at	◯	◯	◯	◯	◯	◯

opstille flere vindmøller til havs?						
Hvilken påvirkning har vindmøller på havet og din brug af kysten / rekreative områder?	◯	◯	◯	◯	◯	◯

Q24_antal_UN_undersoegelser

Inden for det sidste halve år, hvor mange spørgeskemaundersøgelser fra Userneeds har du cirka deltaget i?

◯	Dette er den første
◯	1
◯	2-4
◯	5-7
◯	8-9
◯	10 eller flere
◯	Ved ikke

Q25_sidste_undersoegelse

Show question if Q24_antal_UN_undersoegelser == [2-7] .

Hvornår har du sidst deltaget i en undersøgelse fra Userneeds?

◯	I går
◯	I denne uge
◯	Inden for 14 dage
◯	I denne måned
◯	2 måneder siden
◯	Længere tid siden
◯	Ved ikke

Q26_antal_andre_undersoegelser

Hvor mange andre spørgeskemaundersøgelser har du ellers deltaget i (på internettet, over telefonen mv.) inden for det sidste halve år?

◯	Ingen
◯	1
◯	2-4
◯	5-7
◯	8-9
◯	10 eller flere
◯	Ved ikke

Q27_emne_andre_undersoegelser

Handlede nogle af disse undersøgelser ligesom denne om, hvor meget du vil betale for forskellige varer/ydelser?

◯	Ja
◯	Nej
◯	Ved ikke

Q28_hvilke_emner

Show question if Q27_emne_andre_undersoegelser == [1] .

Hvilke varer/ydelser handlede undersøgelsen(erne) om?

(Angiv gerne flere svar)

☐	Madvarer
☐	Sundhed
☐	Miljø
☐	Offentlige ydelser (daginstitutioner, skoler, ældrepleje mv.)
☐	Transport
☐	Energi
☐	Andre

Q29_hoejeste_fuldfoerte_udd

Hvad er din højeste *fuldførte* uddannelse?

◯	Grundskole (folkeskole)
◯	Erhvervsuddannelse (f.eks. kontorassistent, håndværksuddannelse)
◯	Gymnasiet, HF, HTX og lign.
◯	Kort videregående uddannelse
◯	Mellemlang videregående uddannelse
◯	Lang videregående uddannelse
◯	Ph.d. eller anden forskeruddannelse
◯	Andet

Q30_tilknytning_arbejdsmarked

Hvordan er din tilknytning til arbejdsmarkedet?

◯	Offentlig ansat
	Privat ansat

◯	
◯	Selvstændig
◯	Studerende, elev eller lærling
◯	Arbejdsløs
◯	Efterlønsmodtager eller pensionist
◯	Førtidspensionist
◯	Revalidering
◯	Hjemmegående (selvforsørgende eller på orlov)
◯	Andet

Q31_samlet_husstandsindkomst

Hvad er den samlede indkomst i din husstand før skat (husstandsindkomst)?

◯	Under 100.000
◯	100.000-199.999
◯	200.000-299.999
◯	300.000-399.999
◯	400.000-499.999
◯	500.000-599.999
◯	600.000-699.999
◯	Over 700.000

Q32_vindmoeller_tydelige_paa_billeder

På billederne af vindmøller på land, som du har set, har du da altid kunne se vindmøllerne?

◯	Ja
◯	Nej
◯	Ved ikke

Q33_skaerm_stoerrelse

Hvor stor er din computerskærm?

◯	Større end en A4-side
◯	Ca. sammen størrelse som en A4-side
◯	Mindre end en A4-side
◯	Ved ikke