



Dynamic properties of the preferences for renewable energy sources – A wind power experience-based approach



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ABSTRACT

Based on a Danish survey including respondents with on-shore viewshed experience and varying degrees of off-shore viewshed experience, it is estimated how the different types of wind power experience influence the preferences for wind power, biomass energy and solar energy development in Denmark. The preference relations indicate that on-shore viewshed experience reduces preferences for wind power by 6% and increases preferences for biomass and solar energy solutions relative to wind power by nearly 5%. In contrast, off-shore viewshed experience increases preferences for wind power relative to biomass energy by 24%. However, the effect is dependent on the type of off-shore wind farm experience. Thus, experience of near-shore wind farms can reduce the preferences for wind power. The results also suggest that wind turbines in the viewshed influence the relative preferences between solar energy and biomass energy.

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1. Introduction

The transition to a low carbon economy is dependent on the mix of RES (Renewable Energy Sources) chosen and the flexibility of the existing energy network in terms of coping with the challenges of the higher variability of energy generation from RES [1–3]. The cost of transition is an important factor when choosing among different low carbon paths and RES mixes. Such costs typically include investments, generations, grid costs etc. [3–5]. However, from a welfare economic point of view, the external (social) costs of RES, such as disamenities, pollution, loss of biodiversity, etc., should be included in the analysis [3,5,6]. An example of this can be seen in Garcia et al. [7], in which the dynamic cost of Hybrid Energy Solutions is estimated. The external cost is modelled in a relatively simple manner (as also stated by the authors) and is limited to take into account the cost of CO₂ emissions associated with conventional brown energy. A similar approach has been applied in Cosentino et al. [4]. However, as stated in the preferences literature, the external costs of RES depend on the type of RES and can hardly be

explained by a unit price for CO₂. This is illustrated in Hong et al. [8], who include the external cost of nuclear energy from radiation.

Preferences for RES and the mitigation of their external costs have received considerable attention in the literature on energy economics. Generally, the literature indicates that people have the strongest preferences for solar energy and wind power [9–13]. Interestingly, a new study by Ribeiro et al. [13] finds that acceptance of solar energy, wind power, biomass power and hydropower is dependent on the experience people have with the different RES. These results are in line with the finding that preferences for RES are influenced (both positively and negatively) by people's knowledge of RES [11,14,15]. However, a limitation of Ribeiro et al. [13] is that they do not test the effects of living in an area with the *j*th RES on the acceptance of other RES ($\neq j$ th). The effects from experience of RES on the preferences for other RES have only been explored in a few studies, and so far no significant effect has been identified. This is despite the important implications an experience-driven feedback mechanism on relative preferences would have for an efficient deployment of RES and the associated costs paths. If preferences for different RES vary according to people's experience and/or their spatial interrelation with RES, the RES-specific preferences – and particularly the relative preferences – among different RES would be dynamic in experience and spatial dimensions, as commonly found in, for instance, environmental economics studies [16–19]. Based on the two papers [20,21] published in Energy, I will try to exemplify my arguments. Cohen et al.

Abbreviations: RES, renewable energy sources; CVM, contingent valuation method; CE, choice experiments; WTP, willingness to pay.

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Nomenclature	
<p>Preference: measure of the extent to which a renewable energy source should be used</p> <p>Relative preference: measure of the extent to which one type of renewable energy source should be used relative to another type of renewable energy source</p> <p>Viewshed: all locations visible from a view source, for my purposes a residence</p> <p>On-shore wind turbine/farm: wind turbine/farm located on shore/on land</p> <p>Off-shore wind farm: wind farm located at sea</p> <p>Near-shore wind farm: off-shore wind farm located relatively close to the coast</p> <p>Far-shore wind farm: off-shore wind farm located relatively far from the coast</p> <p>Preference_{ij}: respondent <i>i</i>'s preference for the <i>j</i>th RES</p> <p>Preference_{ijk}: respondent <i>i</i>'s relative preference for the <i>j</i>th and <i>k</i>th RES</p> <p><i>X</i>: vector of socio-demographic characteristics of respondent <i>i</i></p> <p>Nysted: dummy variable controlling for whether respondent <i>i</i> is in the Nysted sample or not</p> <p>Horns Rev: dummy variable controlling for whether respondent <i>i</i> is in the Horns Rev sample or not</p> <p>Viewshed Onshore: dummy variable controlling for if respondent <i>i</i> has an onshore wind farm in the viewshed or not</p> <p>Viewshed Offshore: dummy variable controlling for if respondent <i>i</i> has an offshore wind farm in the viewshed or not</p> <p>Viewshed Offshore_NY: dummy variable controlling for if respondent <i>i</i> in the Nysted sample has</p>	<p>an offshore wind farm in the viewshed or not</p> <p>Viewshed Offshore_HR: dummy variable controlling for if respondent <i>i</i> in the Horns Rev sample has an offshore wind farm in the viewshed or not</p> <p>β: the estimated impact from the socio-demographic variables of respondent <i>i</i> on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>γ: the estimated impact from respondent <i>i</i> in the Nysted sample on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>μ: the estimated impact from respondent <i>i</i> in the Horns Rev sample on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>δ: the estimated impact from respondent <i>i</i> having an onshore wind farms in the viewshed on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>θ: the estimated impact from respondent <i>i</i> having an offshore wind farms in the viewshed on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>ν: the estimated impact from respondent <i>i</i> in the Nysted sample having an offshore wind farms in the viewshed on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>τ: the estimated impact from respondent <i>i</i> in the Horns Rev sample and having an offshore wind farms in the viewshed on preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p> <p>ϵ: the idiosyncratic error term related to respondent <i>i</i>'s estimated preferences for the <i>j</i>th RES or the relative preferences for the <i>j</i>th and the <i>k</i>th RES</p>

[20] discuss the acceptance literature associated with wind power, pylons and pump hydro-storage. In their paper, acceptance for the three landscape infrastructures mentioned above is assumed to be independent of the existing level of the infrastructures in the landscape. As found by Ribeiro et al. [13], it seems a fair assumption that the acceptance of additional hydro-storage capacity is conditional on the existing capacity. What about the relative acceptance, though? People living in areas with hydro-storage facilities might have a higher/lower level of acceptance for an additional hydro-storage facility relative to additional wind turbines. In the other example, Ladenburg et al. [21], the acceptance of wind power, relative to the number of wind turbines in the area people live in, is estimated and a significant negative relation is found. If the lower level of acceptance among people who see numerous wind turbines daily increases their acceptance for other RES, the relation between existing RES facilities and acceptance of new ones cannot be analysed separately for each RES, but must be analysed jointly.

In the present article, two novel measures of experience of wind turbines are used to test the potential effect that wind power experience can have on the preferences for wind power and, most importantly, the preferences for solar energy and biomass energy. First of all, I use information on whether or not people have on-shore or off-shore wind turbines in their viewshed. So far, the literature has only tested on-shore viewshed effects. Secondly, two samples, in which the respondents have significantly different experiences with the visual impacts from large off-shore wind farms, are included in the analysis of preferences for wind power, solar energy and biomass energy. This unique design feature makes it

possible to test whether systematic variations in the visual disamenities from off-shore wind farms influence preferences for wind power and particularly other RES.

The paper is structured as follows. First, the relevant studies are reviewed, in order to define the analytical framework of the study. This is followed by a description of the study, the sample and the results. Finally, a discussion and a conclusion are provided.

2. Review of the literature and analytical setup

Preference studies for RES have employed different types of data, frameworks and econometric analyses. Some of the literature analyses the preferences for a single type of RES, such as biomass [22,23], biomass ethanol [24], on-shore wind power [25] and off-shore wind power [26]. Preferences for green electricity in general [27–29] and for an increase in the renewable share of the energy mix [15,30–32] have also been estimated. Generally, the studies find significant positive preferences for RES and a price premium/willingness to pay for a greater share of RES.

Most policies focus on a mix of different sources of renewable energy with different current and expected future generation costs profiles [33]. In order to be able to take into account the differences in these costs profiles, and in order to identify efficient RES deployment schemes, the relevant economic question is what the relative preferences are for the various types of renewable energy sources. In the subsequent section, a brief review of the existing literature will be given. The review is divided into three parts, presenting the studies that elaborate on the relation between

preferences and socio-demographics of the respondents, knowledge of RES and experience of RES, respectively.

2.1. Heterogeneity in preferences and the socio-demographics of the respondents

Apart from estimating the average preferences for RES, see Refs. [34,35] for example, preferences for j th type of RES are typically regressed on the socio-demographic characteristics of respondents, such as gender, age, education and income. An example of such a study is Komarek et al. [12]. Using CE (Choice Experiments) [36–38], the preferences for coal (baseline in the study), natural gas, biomass, wind power, solar energy and nuclear energy are elicited among the students, faculty and staff at Michigan State University. Komarek et al. [12] find that the respondents across students, faculty and staff have the strongest preferences for wind power and solar energy, and that the relative preferences among the three groups show some variation. In Borchers et al. [9], the preferences for solar energy, wind power, farm methane energy and biomass energy using CE are estimated. The results of the study indicate that solar energy is preferred to wind power, followed by farm methane and biomass energy. The results also suggest that respondents between 30 and 50 years of age and low-income households have stronger preferences for renewable energy. Recently, also based on a CE study, Cicia et al. [10] estimate the relative preferences among wind power, solar energy, farm biomass energy and nuclear power using a latent class model [39]. Generally, nuclear power is the least preferred energy source across the three latent classes estimated. Solar energy and wind power are preferred, whilst the relative preferences for farm biomass and the other energy sources vary considerably. The latent class model indicates that heterogeneity in preference is related to age and the education level of the respondents, among other variables.

2.2. Heterogeneity in preferences and knowledge of RES

A common feature of the mentioned studies is that they do not control for the level of respondents' knowledge of RES. Applying estimated preferences for RES when deciding how to develop RES efficiently would thus rest on the assumption that preferences are independent of knowledge – also in a longer perspective. This assumption is questionable, however. Significant knowledge effects for single types of RES have been found in the literature on stated preferences for energy. The effects range from positive [40,41] over neutral [42] to negative [15]. Similarly, experience of energy sources also seems to influence preferences [26]. Following this logic, the relative preferences between different RES could be a function of people's knowledge of specific RES.

Knowledge of RES is a broad concept, which can range from having heard of RES to having in-depth knowledge of RES characteristics, such as production efficiency, technology, direct and external impacts, etc. So far, the effect of knowledge on preferences has been tested using relatively common/simple scales, but not all of the RES characteristics mentioned above been accounted for. Such an approach is used in a Korean study by Kim et al. [11], in which the preferences for wind power, PV (photovoltaic) power and hydropower are estimated in a so-called RPS (Renewable Portfolio Standard) framework. In the study, two knowledge variables are tested. The first knowledge variable is whether or not the respondents have heard of renewable energy, and the second knowledge variable is related to whether the respondents have heard of RPS. The study does not find an effect from general knowledge on preferences for the specific types of RES. This suggests that the preferences are inelastic with regard to whether or

not the respondents have heard of renewable energy. However, in the case of hydropower a positive effect of having knowledge of RPS is found. Fimereli et al. [43] elicit preferences for low-carbon technologies, i.e. wind, biomass and nuclear energy, relative to the present energy mix using CE. Interestingly, the authors find that respondents with no knowledge of any of the three types of technology have significantly weaker preferences for all three types of technology. Finally, in a CVM (Contingent Valuation Study) [44,45]. Kontogianni et al. [46] find that respondents with knowledge of photovoltaic power being a RES have weaker preferences for on-shore wind power. In a longer perspective, the results thus indicate that as people become more informed about photovoltaic power, the demand for on-shore wind power development can be expected to decrease.

2.3. Heterogeneity in preferences and experience of RES

As RES generation capacity reaches higher levels, people will start gaining experience of RES. The influence of experience of wind energy has been analysed in several papers focussing on the acceptance of wind power, see Ladenburg and Möller [47] and Ladenburg et al. [21] for reviews. However, in the field of energy economics there are only a few studies that extend the knowledge framework by including variables related to the experience people have with the different RES and conventional “brown” energy production facilities. One study is Ribeiro et al. [13], which analyse the acceptance of new renewable energy projects (biomass energy, hydropower, wind energy and solar energy) and test whether acceptance of RES is influenced by the experience of living in an area with the different types of RES. Ribeiro et al. [13] find varying effects, ranging from positive (wind power) to negative effects (hydropower), but also find that the experience effects are conditional on the sociodemographics of the respondents and the geographical location of the renewable energy projects. A limitation of Ribeiro et al. [13], though, is that they do not test the effect of living in an area with a specific type of RES on the acceptance of other types of RES. This is done in Fimereli et al. [43], but an effect from experience of wind power, biomass or nuclear energy on the preferences for the various energy sources is not found. Accordingly, respondents having seen or lived near, for example, a wind turbine, and thus having first-hand experience of the potential disamenities such as noise, flickering and general visual impacts has seemingly not shaped these respondents' preferences, as compared to those of respondents who do not have these experiences. However, they find that respondents who have seen a gas or coal power station have significantly stronger preferences for all of the low-carbon technologies relative to respondents who have not seen a gas or coal power station.

2.4. The contribution of the present article

In the present article, the relation between experiences and the preferences for wind power, biomass energy and solar energy is explored by extending the analytical framework used in Ribeiro et al. [13] and Fimereli et al. [43]. First of all, off-shore wind farm development is often found to be preferred to on-shore wind farm development [48–53], though differences persist [46,54]. In this perspective, prior experience of off-shore wind power could influence preferences for wind power and substitute RES differently compared to experience of on-shore wind power. This expectation is backed up by Ladenburg et al. [21], who find evidence of that on-shore viewshed effects are negative in relation to the support of further on-shore wind power development, whilst off-shore viewshed effects are insignificant in relation to supporting more off-shore development [47,51]. In the analysis, experience of on-

Table 1
Socio-demographics of the respondents.

Variable	National sample	Horns Rev sample	Nysted sample	Coding
Female	52.8%	46.3%	45.0%	=1 if female, else = 0
Age				
Between 20 and 34 years	24.6%	30.6%	15.4%	Continuous
Between 35 and 49 years	36.9%	32.1%	38.3%	
Above 49 years	34.8%	37.3%	45.6%	
Age_Missing ^a	3.7%	0.0%	0.7%	=1 if age not reported, else = 0
Household income				
0–299,999 DKK/Year ^b	25.8%	20.9%	26.8%	Continuous (1, 2 and 3)
300–499,999 DKK/Year	30.8%	34.3%	41.6%	
>499,999 DKK/Year	41.8%	44.8%	30.9%	
Household Income_Missing ^c	1.5%	0.0%	0.7%	=1 if not reported, else = 0
Education				
Bachelor	6.5%	3.7%	1.3%	=1 if the highest level education is a bachelor degree, else = 0
Master	14.5%	3.0%	2.7%	
Children	40.0%	47.0%	36.2%	=1 if the respondent has children, else = 0
Organisation				
Mem. Nature	12.0%	9.7%	10.7%	=1 if member of a nature organisation such as WWF, else = 0
Mem. Recreation	8.3%	8.2%	13.4%	=1 if member of a recreational organisation such as The Danish Hunter Association, else = 0
Viewshed Onshore	25.2%	23.9%	64.4%	=1 if view from residence or summer house, else = 0
Viewshed Offshore	4.6%	11.2%	21.5%	=1 if view from residence or summer house, else = 0
Viewshed Offshore_Missing ^d	0.6%	3.0%	2.7%	=1 if not reported, else = 0
Number of respondents	318	134	149	

^a Missing values are coded as zero in age variable.

^b 1 euro = 7.45 DKK (Danish Kroner) at the time the survey was carried out.

^c Missing values are coded as zero in the household income variable.

^d Missing values are coded as zero in the viewshed offshore variable.

shore and off-shore wind turbines is captured by using information on whether the respondents have an on-shore (Viewshed On-shore) or an off-shore (Viewshed Off-shore) wind turbine in the viewshed of their permanent or summer residence.

In addition, the types of seascape quality reduction caused by off-shore wind farms and the effects on preferences are tested. As found in Ladenburg [55], near-shore location of wind farms might influence the perception of off-shore wind farms negatively, compared to location of wind farms further from the shore. Following this argument, the preferences for wind power and the relative preferences for substitute RES may be sensitive to the variation in people's experience of off-shore wind power. To control for this, the data used in Ladenburg [55] are included in the analysis. In Ladenburg [55], the data include preferences for RES in two distinct populations living in the areas next to Nysted Offshore Wind Farm and Horns Rev Offshore Wind Farm. The unique features of the two samples are that the two wind farms were built at approximately at the same time, but the otherwise highly similar wind farms (72–80 tall turbines; a height of 110 m) were located at different distances from the coast. The Nysted off-shore wind farm is located approximately 6–10 km from the coast, whereas the Horns Rev wind farm is located 14–17 km from the coast (pseudo-natural experiment). Consequently, the two off-shore wind farms have distinctively different impacts on the seascape quality. So, using these two data sets it is possible to test whether differences in the experience of off-shore wind farms influence the preferences for wind energy and for substitute RES, in our case solar energy and biomass energy. The influence of experience is estimated by including two dummy variables, which are equal to 1 if the respondents are from the Nysted or Horns Rev samples and otherwise equal to 0. As demonstrated in Ladenburg [55], respondents

with an off-shore wind farm in their viewshed and who live near the Nysted off-shore wind farm are particularly opposed to off-shore wind farms compared to their counterparts living close to the Horns Rev off-shore wind farm. Accordingly, it is also tested whether respondents who have one of the off-shore wind farms Nysted (Viewshed Off-shore_NY) and Horns Rev (Viewshed Off-shore_HR) in their viewshed have significantly different preferences from respondents with an off-shore wind farm in their viewshed in a National sample.

3. The survey

The preferences for wind power, solar energy and biomass energy are elicited based on the responses to a wind energy survey [56] that was carried out as a part of the Danish monitoring programme related to the construction of Horns Rev I and Nysted II under the Danish Energy Authority [57]. In 2004, 1400 respondents were drawn from the DCRS (Danish Civil Registration System).¹ 700 respondents were drawn randomly from the entire population (National sample), while 350 were drawn randomly from each of the populations living close to one of the off-shore wind farms Nysted (Nysted sample) and Horns Rev (Horns Rev sample). Each respondent was mailed an eleven-page questionnaire. The questionnaire

¹ The DCRS was established in 1968, at which time all persons alive and living in Denmark were registered. Among many other variables, it includes socio-economic information on an individual level 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 Pedersen et al. [58].

was developed based on focus group interviews, expert consultation and the results of a pre-test of the questionnaire. The effective responses were 318, 134 and 149 respondents in the National, Horns Rev and Nysted samples, respectively. This gives response rates of 45.2%, 38.3% and 42.3%, respectively. The demographics of the respondents in the three samples are presented in Table 1. The table also includes information on how the socio-demographics variables enter the subsequent analysis (Coding).

The distributions of the demographics of the respondents in the three samples are different with regard to several characteristics. First of all, there are more female respondents in the National sample than in the Horns Rev and Nysted samples. The respondents in the Nysted sample are older than in the two other samples. Similarly, there are fewer respondents from higher income households in the Nysted sample. The respondents in the National sample also have a higher level of education. Respondents in the Horns Rev sample have the highest frequency of having children. The respondents in the National sample have the highest propensity to be a member of a nature organisation, and the respondents in the Nysted sample have the highest number of recreational organisation memberships.

Moving on to experience of wind turbines and the focus of this paper, 64.4% have an on-shore wind turbine in the viewshed of their permanent or summer residence in the Nysted sample.² The corresponding percentages are 25.2% and 23.9% in the National and Horns Rev samples, respectively. The Nysted sample has the highest frequency (21.5%), followed by the Horns Rev sample (11.2%) and the National sample (4.6%) for having an off-shore wind farm in the viewshed. In addition, the Nysted wind farm and Horns Rev off-shore wind farm have a substantially higher number of wind turbines compared to the other wind farms in operation at the time of the surveys. In addition, Nysted is located relatively close to the shore, considering the size of the individual wind turbines and of the wind farm as a whole. So, effects associated with having experience of Nysted off-shore wind farm are a combination of having a large near-shore wind farm, as opposed to a large far-shore, small near-shore or small far-shore wind farm, in the viewshed. The effects of having Horns Rev off-shore wind farm in the viewshed are a combination of having a large far-shore wind farm, as opposed to a large near-shore, small near-shore or small far-shore wind farm, in the viewshed.

4. Economic model

Preferences for RES were elicited by asking respondents to what extent they would prefer Denmark to use wind power, biomass and solar energy, respectively, in order to reduce CO₂ emissions. The preferences were stated on a discrete scale with three levels: “Not at all”, “To a moderate extent” and “To a high extent”. This preference scale is admittedly simple, but it is comparable to scales used in other stated preference studies, see for example Refs. [10,35,43,46,59]. In Table 2, the levels of the stated preferences are presented.

Most respondents prefer the three RES to be used to a “To a high extent” or a “To a moderate extent”. Few respondents selected “Not at all”. The frequencies of “Not at all” preferences are particularly low in the case of wind power and solar energy. It has not been possible to estimate models by applying the full preferences scale, in the endeavour to estimate the influence of on-shore and off-shore wind power experience on the preferences for the three RES. The stated preferences are therefore converted into a binary

Table 2
Distribution of the extent for the preferences (number of respondents).

Preferences	Wind energy	Biomass	Solar energy
<i>To a high extent (total)</i>	522	269	515
National sample	275	121	278
Nysted sample	125	97	128
Horns Rev sample	121	51	109
<i>To a moderate extent (total)</i>	72	309	79
National sample	40	183	35
Nysted sample	21	50	21
Horns Rev sample	11	76	23
<i>Not at all (total)</i>	7	23	7
National sample	3	14	5
Nysted sample	3	2	0
Horns Rev sample	1	7	2
<i>Total</i>	601		
National sample	318		
Nysted sample	149		
Horns Rev sample	134		

variable for each of the three RES. The new preference variables take the value 1, if the respondents prefer the use of wind power, biomass or solar energy, respectively, to a “high extent”. If the respondents prefer the use of wind power, biomass or solar energy to a “moderate extent” or “Not at all”, the new preference variables take the value 0, respectively.

Based on these three preference variables, the analysis of preferences will be carried out with the aim of estimating the preferences for the each of the three RES (wind power, biomass and solar energy) and the relative preferences among the three RES. The setup of the analyses is described below.

4.1. Model 1: preferences for RES

In the first model, respondent i 's preferences for each (j th) of the three types of RES are regressed using a binary probit model [60], see equation (1)

$$\begin{aligned} \text{Preferences RES}_{ij} = & \beta X_{ij} + \gamma \text{Nysted}_{ij} + \mu \text{Horns Rev}_{ij} \\ & + \delta \text{Viewshed Onshore}_{ij} \\ & + \theta \text{Viewshed Offshore}_{ij} \\ & + \vartheta \text{Viewshed Offshore_NY}_{ij} \\ & + \tau \text{Viewshed Offshore_HR}_{ij} + \varepsilon_{ij} \end{aligned} \quad (1)$$

where Preferences RES_{ij} is the binary variable coding for whether or not respondent i has preferences for using the j th RES to a “high extent”. X_{ij} is a vector representing the socio-demographics of the respondents. Nysted_{ij} and Horns Rev_{ij} are dummy variables controlling for whether or not respondent i is from the Nysted or Horns Rev samples. Viewshed Onshore_{ij} and Viewshed Offshore_{ij} are dummy variables controlling for whether respondent i has an on-shore or off-shore wind farm in the viewshed. Viewshed Offshore_NY_{ij} and Viewshed Offshore_HR_{ij} are dummy variables coding for whether Nysted or Horns Rev Offshore wind farms are in the viewshed. ε_{ij} is the individual specific error term, which is assumed to have a normal distribution with a zero mean and a variance of σ^2 .

4.2. Model 2: relative preferences for RES

In the second model, relative preferences among wind power, biomass and solar energy are estimated. The aim of this analysis is to elaborate on the substitution patterns in the preferences for the three RES. The relative preferences are estimated by coding the stated preferences for the three RES with respect to whether the

² The large percentage of respondents with an on-shore wind turbine in their viewshed in the NY-sample corresponds with the generally high densities of on-shore wind turbines in that area, combined with a relatively flat landscape.

respondents have stronger preferences for wind power relative to biomass or solar energy, and the relative preferences between biomass and solar energy.

To allow estimation of the relative preferences for wind power, solar energy and biomass energy, twelve new relative preference variables are defined. To illustrate the coding of the relative preference variables, the relative preference variables constructed between wind power and biomass are presented below.

- The first relative preference variable (Preference_{Biomass>Wind Power}) is coded as 1, if the respondent prefers biomass to be used to a higher extent than wind power (preferences biomass > preferences wind power). If this is not the case, Preference_{Biomass>Wind Power} is coded as 0.
- The second relative preference variable (Preference_{Biomass<Wind Power}) is coded as 1, if the respondent prefers biomass to be used to a lesser extent than wind power (preferences biomass < preferences wind power). If this is not the case, Preference_{Biomass<Wind Power} is coded as 0.

The third and the fourth relative preference variables represent cases where respondent *i* has indifferent preference between wind power and biomass:

- The third variable relates to a respondent preferring both wind power and biomass to be used to a high extent. If this is the case, the relative preferences variable Preference_{Biomass=Wind Power|High} is coded as 1. If not, Preference_{Biomass=Wind Power|High} is coded as 0.
- Similarly, if the respondent prefers both wind power and biomass to be used to a moderate extent or not at all, the fourth relative preference variable, Preference_{Biomass=Wind Power|Moderate_Not at all}, is coded as 1. If this is not the case, Preference_{Biomass=Wind Power|Moderate_Not at all} is coded as 0.

Similar variables are constructed for the relative preferences between wind power and solar energy, and between solar energy

and biomass. The relative preferences between the *j*th and *k*th RES are estimated using binary probit models, see equation (2)

$$\begin{aligned} \text{Relative preferences RES}_{ijk} = & \beta X_{ijk} + \gamma \text{Nysted}_{ijk} \\ & + \mu \text{Horns Rev}_{ijk} \\ & + \delta \text{Viewshed Onshore}_{ijk} \\ & + \theta \text{Viewshed Offshore}_{ijk} \\ & + \vartheta \text{Viewshed Offshore_NY}_{ijk} \\ & + \tau \text{Viewshed Offshore_HR}_{ijk} + \varepsilon_{ij} \end{aligned} \quad (2)$$

where Preferences RES_{ijk} is the binary variable coding for whether or not respondent *i* has preferences for using the *j*th RES relative to the *k*th RES. *X*_{ijk} is a vector representing the socio-demographics of the respondents. Nysted_{ijk} and Horns Rev_{ijk} are dummy variables controlling for whether or not respondent *i* is from the Nysted or Horns Rev samples. Viewshed Onshore_{ijk} and Viewshed Offshore_{ijk} are dummy variables controlling for if respondent *i* has an on-shore or off-shore wind farm in the viewshed. Viewshed Offshore_NY_{ijk} and Viewshed Offshore_HR_{ijk} are dummy variables coding for whether or not the viewshed is to Nysted or Horns Rev Offshore wind farms. ε_{ijk} is the individual specific error term, which is assumed to have a normal distribution with a zero mean and a variance of σ^2 .

5. Results

In the subsequent sections, the results from the analyses of preferences and relative preferences for wind power, biomass and solar energy are presented. The presentation will focus on the effects from the wind power experience variables. The result related to heterogeneity in preferences due to differences in the socio-demographic variables of the respondents will be presented briefly. Unless otherwise stated, the presented results are significant on a confidence level of 95% or higher.

Table 3
Preferences for wind power, biomass and solar energy.

	Wind energy		Solar energy		Biomass energy	
	Parameter estimate	Marginal effect	Parameter estimate	Marginal effect	Parameter estimate	Marginal effect
Female	0.171 [0.146]	0.0326 [0.0278]	0.589*** [0.146]	0.119*** [0.0291]	-0.109 [0.111]	-0.0401 [0.0408]
Age ^a	-0.0222*** [0.00672]	-0.00422*** [0.00127]	-0.0101+ [0.00590]	-0.00206+ [0.00119]	-0.000605 [0.00473]	-0.000224 [0.00175]
Household Income ^b	-0.142+ [0.0776]	-0.0271+ [0.0147]	-0.0986 [0.0738]	-0.0200 [0.0149]	-0.0428 [0.0580]	-0.0158 [0.0214]
Bachelor	-0.344 [0.333]	-0.0654 [0.0633]	0.0234 [0.350]	0.00475 [0.0708]	-0.327 [0.267]	-0.121 [0.0984]
Master	-0.447+ [0.231]	-0.0851+ [0.0438]	-0.441+ [0.224]	-0.0894+ [0.0452]	-0.291 [0.197]	-0.107 [0.0723]
Children	0.201 [0.162]	0.0383 [0.0307]	0.342+ [0.155]	0.0694* [0.0311]	0.194 [0.118]	0.0718+ [0.0433]
Mem. Nature	0.565+ [0.266]	0.108* [0.0504]	0.257 [0.235]	0.0521 [0.0475]	0.0919 [0.169]	0.0340 [0.0626]
Mem. Recreation	-0.230 [0.216]	-0.0437 [0.0410]	-0.0857 [0.213]	-0.0174 [0.0432]	0.205 [0.187]	0.0759 [0.0687]
Viewshed Onshore	-0.333* [0.156]	-0.0635* [0.0295]	-0.298+ [0.157]	-0.0604+ [0.0316]	0.151 [0.124]	0.0557 [0.0457]
Viewshed Offshore	0.947 ^c [0.594]	0.180 [0.113]	0.851 [0.566]	0.173 [0.115]	-0.535 [0.392]	-0.198 [0.144]
Horns Rev (HR)	0.191 [0.200]	0.0363 [0.0380]	-0.325+ [0.176]	-0.0658+ [0.0355]	-0.0168 [0.142]	-0.00622 [0.0525]
Nysted (NY)	0.159 [0.190]	0.0302 [0.0360]	0.166 [0.197]	0.0336 [0.0399]	0.591*** [0.148]	0.218*** [0.0525]
Viewshed Offshore_HR	-0.639 [0.820]	-0.122 [0.156]	-0.636 [0.729]	-0.129 [0.148]	-0.101 [0.551]	-0.0372 [0.203]
Viewshed Offshore_NY	-1.374+ [0.660]	-0.262+ [0.125]	-1.049 [0.643]	-0.213 [0.130]	0.367 [0.468]	0.136 [0.173]
Age_Miss	-1.548* [0.635]	-0.295* [0.120]	-0.272 [0.672]	-0.0551 [0.136]	-0.0799 [0.529]	-0.0295 [0.195]
Household Income_Miss	-0.609 [0.697]	-0.116 [0.133]	-0.970 [0.646]	-0.197 [0.130]	-0.285 [0.556]	-0.105 [0.205]
Viewshed Offshore_Miss	0.538 [0.655]	0.102 [0.125]	0.629 [0.635]	0.128 [0.129]	0.223 [0.436]	0.0823 [0.161]
Constant	2.581*** [0.420]		1.660*** [0.356]		-0.148 [0.275]	
N	601		601		601	
LL(0)	-233.9		-246.7		-413.3	
LL(β)	-209.0		-221.5		-388.2	
χ ²	49.77		50.43		50.21	

Standard errors in brackets. +*p* < 0.10, **p* < 0.05, ***p* < 0.01, ****p* < 0.001.

^a Log(age) and age² specifications has also been tested, but the loglikelihood at model convergence is numerically higher, compared to the linear specification.

^b Log(Household Income) and Household Income² specifications has also been tested, but the loglikelihood at model convergence is numerically higher, compared to the linear specification.

^c Jointly significant on a 90% level of confidence with Viewshed Offshore_NY.

5.1. Preferences for RES

Starting with the preferences for the specific RES, the results from the probit regressions and the estimated marginal effects are presented in Table 3. In the following, the terms “stronger preferences” and “weaker preferences” will be used, to refer to groups (defined by the variables in the models) of respondents having higher or lower probability of having preferences for the j th RES being used to a high extent (Preferences $RES_{ij} = 1$) relative to a moderate extent or not at all (Preferences $RES_{ij} = 0$).

5.1.1. Socio-demographic variables

The socio-demographics of the respondents influence the preferences for the three types of RES. Female respondents have 12 percentage points stronger preferences for solar energy ($\beta_{Female|Solar\ Energy} > 0$). Older respondents expressed significantly weaker preferences for wind power and solar energy compared to younger respondents ($\beta_{Age|Wind\ Power} < 0$ and $\beta_{Age|Solar\ Energy} < 0$). However, in the case of solar energy the age effect is only significant on a confidence level of 90%. For each year of difference in age, the preferences are weakened by approximately 0.4 and 0.2 percentage points, respectively. These results are in line with Bigerna and Polinori [14] and Krueger et al. [26], who find that the preferences for RES (generally and off-shore wind, respectively) are stronger among younger respondents. The age results are also in line with the wind power acceptance literature, which, with the exception of a few papers, finds that younger generations are more in favour of wind power compared to older generations, see Ladenburg and Lutzeyer [61] for a discussion. The results also suggest that higher household income levels weaken the preferences for wind power ($\beta_{Household\ Income|Wind\ Power} < 0$), though only on a confidence level of 90%. The marginal effect on preferences is a reduction of 2.7 percentage points per increase in income category (0–299,999, 300,000–599,999 and >600,000 DKK (Danish Kroner)/household/year). Holding a master's degree weakens the preferences for wind power and solar energy by between 8.5 and 8.9 percentage points ($\beta_{Master|Wind\ Power} < 0$ and $\beta_{Master|Solar\ Energy} < 0$). Respondents who have children in the household have approximately 7 percentage points stronger preferences ($\beta_{Children|Solar\ Energy} > 0$ and $\beta_{Children|Biomass} > 0$) for solar and biomass energy, relative to respondents with no children in the household. Respondents who are members of a nature organisation have stronger preferences (11 percentage points) for wind power ($\beta_{Mem.\ Nature|Wind\ Power} > 0$).

5.1.2. Preference effects from having on-shore and off-shore wind turbines in the viewshed

There seems to be some evidence that having a wind turbine in the viewshed influences the preferences for wind power. Respondents who have an on-shore wind turbine in the viewshed of their permanent or summer residence have weaker preferences (6 percentage points) for wind power ($\beta_{Viewshed\ On-shore|Wind\ Power} < 0$), compared to respondents who do not have an on-shore turbine in their viewshed. In contrast, if an off-shore wind farm is in the viewshed, the effect on wind power preferences is positive ($\beta_{Viewshed\ Offshore|Wind\ Power} > 0$). The estimate is borderline significant on a confidence level of 90%, but is jointly significant on a 90% level with the Viewshed Off-shore_NY variable.³ Accordingly, respondents who have an off-shore wind farm in their viewshed have 18.0 percentage points stronger preferences for wind power, relative to

respondents who do not have an off-shore wind farm in the viewshed. Perhaps even more interestingly, controlling for the respondents who have a large near-shore wind farm, with negative visual effects on the seascape, (Nysted off-shore wind farm) in their viewshed, the positive off-shore wind farm effect is completely absent ($\beta_{Viewshed\ Offshore_NY|Wind\ Power} < 0$). The effect is a reduction in preferences of 26.2 percentage points. Controlling for the respondents who have the Horns Rev wind farm in their viewshed does not give any significant effects. As suggested by the results, some of the viewshed effects seem to carry over to the preferences for solar energy. Respondents who have an on-shore wind turbine in their viewshed have 6 percentage points weaker preferences for solar energy, though this is only significant on confidence level of 90%.

5.1.3. Preference effects of living in an area with large near-shore (Nysted) and far-shore (Horns Rev) wind farms

Controlling for the off-shore viewshed effects in the Nysted and Horns Rev samples, the respondents in the Horns Rev sample have weaker preferences for solar energy, compared to the national and the Nysted samples (6.6 and 9.9 percentage points, respectively). Similarly, compared to the Nysted sample the respondents in the national and Horns Rev samples also have weaker preference for biomass energy (21.8 and 21.2 percentage points, respectively). Interestingly, then, after controlling for off-shore viewshed effects the preferences for wind energy may in fact be the same across the three samples.

5.2. Relative preferences for RES

In the present section, the effect on the relative preferences among the different energy sources will be elaborated upon. As previously explained, four categories of relative preferences are defined for the relative preferences between wind power and solar energy, wind power and biomass energy and solar energy and biomass energy, respectively. The stated relative preferences are presented in Table 4.

Relatively few respondents have stated moderate preferences for all three types of RES, just as relatively few respondents have stated preferences for using solar and biomass energy to a higher extent than wind power. In Table 5, the probit results related to the influence of wind power experience are presented as marginal effects. The results (parameter estimates and marginal effects) from the other variables and the log-likelihood estimates are shown in Appendix A. Note that some of the parameters are not estimated, due to few observations or too little variation in the independent variables' effect on the dependent variables.

5.2.1. Relative preference effects from having on-shore and off-shore wind turbines in the viewshed

Experience of on-shore and off-shore wind turbines seems to influence the relative preferences for wind power, solar energy and biomass energy. Having an on-shore wind turbine in the viewshed increases preferences for solar and biomass energy relative to wind power ($\beta_{Viewshed\ On-shore_Solar\ Energy>Wind\ Power}$ and $\beta_{Viewshed\ On-shore_Biomass>Wind\ Energy} > 0$) with 4.7–4.8 percentage points. Accordingly, the on-shore viewshed effect seems to cause a shift in respondents' preferences from wind power to an alternative RES.

In the case of relative preferences for solar energy and wind energy, the on-shore effects are heterogeneous. Having an on-shore wind farm in the viewshed thus also strengthens the preferences for wind power relative to solar energy by 5.0 percentage points ($\beta_{Viewshed\ On-shore_Wind>Solar\ Energy} > 0$) and weakens the preferences for the joint use of wind power and solar energy to a high extent with 11.1 percentage points ($\beta_{Viewshed\ On-shore\ Solar\ Energy=Wind}$

³ Excluding the Viewshed Off-shore variable from the model renders Viewshed Off-shore_NY insignificant. A model with both variables excluded has a log-likelihood of -208.982. Testing the joint significance of the variables gives a Chi-test value of 5.383, which with 2 degrees of freedom gives a test statistic of 0.068.

Table 4
Frequencies of relative preferences.

Preferences	Solar > Wind	Solar = Wind High	Solar = Wind Moderate	Solar < Wind	Total
No. of respondents	41	474	38	48	601
National sample	24	254	19	21	318
Nysted sample	11	117	13	8	149
Horns Rev sample	6	103	6	19	134
Preferences	Biomass > Wind	Biomass = Wind High	Biomass = Wind Moderate	Biomass < Wind	Total
No. of respondents	32	237	47	285	601
National sample	14	107	29	168	318
Nysted sample	15	48	9	74	149
Horns Rev sample	3	82	9	43	134
Preferences	Biomass > Solar	Biomass = Solar High	Biomass = Solar Moderate	Biomass < Solar	Total
No. of respondents	29	240	57	275	601
National sample	9	112	31	166	318
Nysted sample	14	83	7	45	149
Horns Rev sample	6	45	19	64	134

Power|High < 0). Accordingly, the viewshed effects seem to either cause respondents to prefer wind power to solar energy or vice versa.

On-shore wind farms in the viewshed also have a negative influence on the relative preferences between biomass and solar energy. First of all, having an on-shore wind farm in the viewshed weakens the preferences for biomass relative to solar energy by nearly 11 percentage points ($\beta_{Viewshed\ On-shore|Biomass>Solar} < 0$). Secondly, on-shore viewshed effects also increase the preferences for joint use of biomass and solar energy to a moderate extent with approximately 5 percentage points ($\beta_{Viewshed\ On-shore|Biomass=Solar|Moderate_Not\ at\ all} > 0$), though this is only significant on a confidence level of 90%.

Having an off-shore wind farm in the viewshed strengthens the preferences for wind power relative to the use of biomass ($\beta_{Viewshed\ Off-shore|Biomass<Wind} > 0$) by 23.5 percentage points and strengthens the joint preferences for using both solar energy and wind power to a high extent ($\beta_{Viewshed\ Off-shore|Biomass=Wind|High} > 0$) by 32.1 percentage points. Respondents who have the Nysted off-shore wind farm in their viewshed have 39.9 percentage points weaker preferences for the joint use of solar energy and wind power to a high extent.

5.2.2. Relative preference effects of living in an area with large near-shore (Nysted) and far-shore (Horns Rev) wind farms

After controlling for the off-shore viewshed effects in the Nysted and Horns Rev samples, there seems to be some effects from living in an area with a large near-shore wind farm. Compared to the national sample, the respondents in the Nysted sample have 18.6 percentage points weaker preferences for wind power relative to

biomass ($\beta_{Nysted\ sample|Biomass<Wind} < 0$), but also stronger preferences for the joint use of both technologies to a high extent ($\beta_{Nysted\ sample|Biomass=Wind|High} > 0$). The respondents in the Nysted sample have 7.9 percentage points stronger preferences for the joined use of wind power and solar energy to a high extent ($\beta_{Nysted\ sample|Solar=Wind|High} > 0$). The respondents in the Nysted sample also have 15.4 percentage points weaker preferences for biomass energy relative to solar energy ($\beta_{Nysted\ sample|Biomass>Solar} < 0$) but also have 17.3 percentage points stronger preferences for the use of the two RES to a high extent ($\beta_{Nysted\ sample|Biomass=Solar|High} > 0$).

6. Discussion

One noticeable result is wind power viewshed effects on preferences for wind power, solar energy and biomass energy. Having an on-shore wind turbine in the viewshed not only seems to reduce the preferences for using wind power, but simultaneously strengthens the preferences for using biomass and solar energy. In cases where on-shore wind power generation costs are lower than the costs for biomass and solar energy, the energy planning authority might be strongly motivated to push forward on-shore wind power development. However, the results suggest that – due to the negative on-shore wind power viewshed effects on the preferences for wind power and the substitute positive effect on the preferences for particularly biomass energy and to some extent solar energy – developing on-shore in areas with many households could shift the preferences towards solar energy and biomass. Interestingly, the case is different if vast and relatively cheap off-shore wind

Table 5
Relative preferences models, selected results.

	Viewshed onshore	Viewshed offshore	Viewshed Offshore_HR	Viewshed Offshore_NY
Biomass > Wind Power	0.0466* [0.0204]	-0.00245 [0.0273]	^a	^a
Biomass = Wind Power High	0.0127 [0.0454]	-0.136 [0.144]	-0.0612 [0.202]	-0.00451 [0.171]
Biomass = Wind Power Moderate	0.0221 [0.0243]	-0.0901 [0.0815]	0.0895 [0.111]	0.128 [0.0957]
Biomass < Wind Power	-0.0724 [0.0462]	0.239+ [0.134]	-0.00979 [0.193]	-0.206 [0.168]
Wind > Solar	0.0503* [0.0224]	0.000813 [0.0340]	^a	^a
Wind = Solar High	-0.111** [0.0357]	0.318* [0.149]	-0.280 [0.185]	-0.397* [0.164]
Wind = Solar Moderate	0.0172 [0.0219]	-0.00360 [0.0298]	^a	^a
Wind < Solar	0.0478* [0.0245]	-0.0266 [0.0392]	^a	^a
Biomass > Solar	-0.106* [0.0459]	0.257+ [0.133]	-0.0346 [0.189]	-0.178 [0.166]
Biomass = Solar High	0.0476 [0.0453]	-0.153 [0.144]	-0.0439 [0.203]	0.0301 [0.172]
Biomass = Solar Moderate	0.0485+ [0.0260]	-0.101 [0.0866]	0.0976 [0.112]	0.100 [0.107]
Biomass < Solar	-0.00987 [0.0199]	-0.000950 [0.0265]	^b	^a

Standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$.

^a The estimate has questionable standard errors.

^b The variable predicts a zero outcome in the dependent variable perfectly.

resources are available. As the results suggest, off-shore viewshed effects do not weaken the preferences for wind power. On the contrary, there are some indications that viewshed effects from off-shore wind farms have a positive effect on wind power preferences. These circumstances provide energy planners with a tool to increase the wind power capacity by developing offshore, thereby at least keeping the preferences for wind power steady and potentially even increasing them.

The results, however, also indicate that the energy planner must be cognisant. The consequences in terms of the cost of opting for off-shore development instead of on-shore development are generally higher generation costs offshore, particularly at large distances from the coast [62]. So, in order to minimise generation costs it would be tempting to develop off-shore wind power at near-shore locations. The review by Ladenburg and Lutzeyer [61] argues that a choice of developing nearshore should take into account the external costs from higher visual disamenities. Whilst nearer shore locations have lower generation costs, the external costs are higher compared to more far-shore locations. In the present application, near-shore off-shore location in combination with a large wind farm relative to more distant locations and/or wind farms with fewer turbines affects preferences for wind power negatively in those respondents who can see the off-shore wind turbines from their residence. Accordingly, there is a trade-off between the preferences for wind power and the location of off-shore wind farms in terms of both distance from the shore and the number of houses that will have the wind farm in their viewshed. That said, the optimum location of off-shore wind farms is a function of both the preferences presented in this paper and the cost of generation. Accordingly, near-shore locations may be the best solution, if far off-shore locations are too costly to develop or/and relatively few households will have the wind farm in their viewshed. On the other hand, if a large number of properties will have the wind farm in their viewshed, the apparent negative effect on preferences could make more distant locations optimum.

Unfortunately, the present study did not include measures of experience of biomass and solar energy, which are included in Fimereli et al. [43]. If such experience effects could be found, the preference models would become even more complex. The preferences for the different RES could be a joint matrix of experience-driven preferences parameters. This calls for further research.

7. Conclusion

Jointly, the results strongly indicate that preferences for renewable energy sources may be influenced by the experience people have with the individual types of Renewable Energy Source (RES) – exemplified here by wind power.

The costs of transitioning to a low carbon economy are dependent on the choice of how to combine RES. From a welfare economic point of view, the costs of RES also include external costs, such as disamenities, pollution and loss of biodiversity. To estimate the relative importance of these external costs, the preferences for different types of RES have been assessed in a large number of studies. A common feature of the vast majority of the published papers is that the preferences are assessed without taking into account the potential influence that experience with the specific types of RES can have on the preferences. Accordingly, an implicit assumption when using results to guide an economic or/and policy recommendation as to how many resources should be invested in a specific type of RES is that preferences are invariant to, for example, respondents living close to the renewable energy production facilities. Such assumptions may be too general, however, as highlighted in a large number of surveys in the attitude literature regarding wind power. In the present paper, a novel test of this

assumption is performed based on stated preferences for biomass, wind power and solar energy among three samples of Danish respondents. The respondents in one of the samples have experience of a large nearshore wind farm, whilst the respondents in another sample have experience of a large far shore wind farm. The third sample is a sample representing the Danish population with mixed experiences. The stated preferences indicate that on-shore viewshed experience reduces preferences for wind power by 6%. Simultaneously, the results suggest that the decrease in the preference for wind power caused by the viewshed experience is associated with an increase of nearly 5% in preferences for biomass and solar energy solutions relative to wind power. Interestingly, off-shore viewshed experience increases preferences for wind power by 18% and increases the preferences by 24% for wind power relative to biomass energy. However, the positive off-shore viewshed effect is dependent on the type of off-shore wind farm experience. Thus, experience of large near-shore wind farms can reduce the preferences for wind power. The results also suggest that some of the viewshed effects from wind turbines carry over to the relative preferences between solar energy and biomass energy, and in fact that on-shore viewshed effects can both increase and decrease the relative preferences between wind power and solar energy.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.energy.2014.08.050>.

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