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# Valuation of ecological and amenity impacts of an offshore windfarm as a factor in marine planning

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ABSTRACT

Integrated marine planning, which must take into consideration environmental and social impacts, is being introduced widely in Europe, the USA, Australia and elsewhere. Installation of offshore windfarms creates impacts both on local marine ecosystems and the view of the seascape and is one of multiple activities in the marine area that must be addressed by marine planning. The impacts on people's values (and hence welfare) of changes in ecology and amenity that could arise from the installation of a windfarm in the Irish Sea were assessed using a discrete choice experiment administered through an online survey. The ecological changes investigated were: increased species diversity resulting from artificial reef effects, and the effect of electromagnetic fields from subsea cables on marine life; whilst the amenity change was the visibility of offshore turbines from land. Respondents expressed preferences for ecological improvements but had less clear preferences regarding the height and visibility of the turbines. In particular distance decay effects were observed with respondents further away from the coast being less concerned about visual impact created by offshore turbines. Understanding ecological and amenity impacts and how they are valued by people can support the decisions made within marine planning and licensing.



## 1. Introduction

In recent years European Union and United Kingdom energy policies for implementation of renewable energy to fulfil carbon emission reduction targets have become one of the main drivers for the development of offshore wind energy. For example, the UK has ambitious plans for the installation of up to 31 GW of offshore wind power (Toke, 2011). Offshore windfarms (OWFs) will mitigate the global environmental effects of climate change through the generation of carbon-free energy, but there are a range of potential local ecological impacts on the marine environment, including the effects of noise, altered sediment distribution and electromagnetic fields, which may disturb or injure marine life (Bailey et al., 2010; Brandt et al., 2011; Fisher and Slater, 2010; Gill et al., 2005; Guillemette and Larsen, 2002; Rothery et al., 2009; Wilson et al., 2010). On the positive side some of the ecological impacts of OWFs can be beneficial. The underwater foundations of turbines (metal or concrete pilings and associated scour protection) have been shown to provide habitat for new species to settle in the OWF site (e.g. Kerckhof et al., 2010). These so-called artificial reef effects increase local biodiversity and, by providing an additional source of food and shelter, can support fish stocks (Reubens et al., 2014) and populations of commercially important brown crab (Hooper and Austen, 2014). However, increases in the abundance or biomass of fish and benthic species are not universal across all sites and species (Ashley et al., 2014), and this introduction of new habitat is not always viewed as positive (Russell et al., 2014). To the best of our knowledge, there have been no attempts so far to assess the level of public concern about and the value of these ecological impacts.

However, the extent to which the sight of the wind turbines on the horizon impairs the view of the seascape has been discussed. The depth limitations on wind turbine installation suggest that in most cases they will be visible from land and thus alter the seascape. It is also possible that substantial amounts of noise could be generated, which might be audible from the shore. These potential amenity impacts have been studied by means of a range of methods including economic valuation and in particular discrete choice experiments (DCE) (e.g. Krueger et al., 2011; Ladenburg and Dubgaard, 2007; Westerberg et al., 2013) and contingent valuation (McCartney, 2006; Müürsepp and Ehrlich, 2012). Most studies find a positive willingness to pay (WTP) of respondents to decrease the

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visual impact of OWFs by moving them further offshore. This indicates that respondents expect a loss of welfare resulting from visible turbines.

Thus, while there are several studies assessing the visual disamenities of offshore turbines there is a lack of studies that value ecological and visual impacts of such installations at the same time. The present study aims to fill this gap by employing a DCE to assess values for local ecological improvements in OWFs and the mitigation of visual disamenities created by the installation of such turbines. Contrary to most previous visual impact studies, which typically use distance from the shore as proxy for visibility, the present study took a different approach by developing the DCE survey around a real future OWF site and varying the potential height of the turbines, whereas the location of the windfarm was already fixed.

The relative importance that the general public attached to each of these effects was studied in a case study in UK waters in the Irish Sea. The assessment of welfare effects resulting from changes in the marine environment can feed into integrated marine planning, which is being widely introduced in Europe through the recent Marine Planning Directive, the USA, Australia and elsewhere. In the UK, marine planning was introduced as a requirement under the Marine and Coastal Access Act (2009) and the Marine Scotland Act (2010) and must take into account a wide range of policies and regulation. The same acts also control licensing consents for offshore infrastructure. Installation of marine energy exploitation devices, including OWFs, is considered as one of multiple activities in the marine area which must be considered within marine planning and for which licensing consents are required. Both marine planning and licensing must take into consideration environmental and social impacts including the wider welfare effects.

When social welfare is affected by the provision of goods or services which are not traded in markets, such as environmental and amenity goods, no market prices can be used for welfare analysis. Therefore, non-market valuation techniques are required to value those ecological and amenity effects of an OWF in support of marine planning and licensing decision-making. The survey-based discrete choice experiment (DCE) approach (e.g. Hanley et al., 1998; Louviere et al., 2000) is one way to asses use and non-use values of non-market environmental and amenity goods. Respondents are required to choose between typically two policy options, each of which will lead to a change in some environmental and/or amenity quality attributes at a cost to the respondent, and a status-quo option which comes at zero cost. In these choice tasks, the policy options are described in terms of a set of choice attributes, which specify the effects of hypothetical management measures. From respondents' stated choices, the value they attach to the different choice attributes can be inferred and expressed as their WTP. WTP can be estimated for each choice attribute. It is an indicator of the change in well-being that respondents expect from a change in the provision of that particular choice attribute.

There are a large number of DCE studies that value the visual disamenities created by an OWF (e.g. Dimitropoulos and Kontoleon, 2009; Krueger et al., 2011; Ladenburg and Dubgaard, 2007; Strazzera et al., 2012; Vecchiato, 2012; Westerberg et al., 2013).[1] In one of the first such studies, Ladenburg and Dubgaard (2007) found significant positive willingness to pay (WTP) of Danish respondents for moving turbines further offshore and reducing noise levels. The set of attributes used in this study did not include any ecological components but focused entirely on technical specifications of the windfarm, such as distance from the shore and number of turbines. Krueger et al. (2011) conducted a similar DCE survey valuing visual disamenity of a windfarm in Delaware, USA. Results showed that while there was significant WTP for moving wind turbines further offshore, the inclusion of certain programmes to fund beach nourishment and development of green energy did not affect choices of respondents living at or close to the coast. It appears that in the presence of visual impacts, respondents were indifferent towards the latter (somewhat more environmental) issues. Westerberg et al. (2013) conducted a choice experiment with tourists in the South of France to investigate whether visual disamenities could be compensated with recreational values created by turbine foundations as artificial reefs (thus providing opportunities for scuba diving, snorkelling and sea-angling). Survey responses indicated that some of the disutility from the visual impact could be compensated by a coherent environmental policy around the windfarm fostering the development of artificial reefs. However, the assessment of this type of ecological impact in this study was only geared towards recreational use of the sea by tourists. Also, respondents to this survey were tourists rather than local residents and interviews were conducted on beaches, which makes selection bias likely. The present DCE study sampled from the whole resident population of a region potentially impacted by OWF development. In a review of some of the above studies Ladenburg and Lutzeyer (2012) found that (1) age, (2) gender, (3) level of education, (4) frequency of visits to the coast, (5) experience with offshore windfarms and (6) location of residence frequently affect the valuation of visual impact in most of the studies. The present study tested the effects of these respondent-specific variables on preference for both amenity and ecological windfarm attributes.

## 2. Methodology

### *2.1. Development of valuation scenario and choice attributes; questionnaire design*

As a first step in the preparation of the main survey, 60 semi-structured interviews regarding the knowledge of and attitude towards offshore wind energy developments in the UK were conducted with members of the general public in locations near the Irish Sea coast (Liverpool, Cumbria, Lancashire and North Wales). In a second step, four focus group meetings were conducted in Anglesey, Liverpool and Rhyl (Fig. 1). These meetings served to explore which detrimental and beneficial environmental impacts of the installation of OWFs were perceived by people, and to help formulate the valuation scenario and the selection, and description, of the choice attributes. The preliminary questionnaire was then tested in an online pilot survey ($N = 90$) and modified further based on the findings.[2]

In the final valuation scenario, respondents were informed that a windfarm will be installed in the Irish Sea between Anglesey and the Isle of Man (Fig. 1). During the focus groups it had become clear that energy generation, distribution and pricing was a very sensitive topic and so, in order to pre-empt protest responses it was stressed repeatedly that both the decision to build the OWF and the anticipated power output (and thus the supplier's potential profit) were fixed.

The study employed three non-monetary and one monetary choice attributes (Table 1). The first attribute – enhanced biodiversity – was measured in numbers of additional species that are expected to settle in and around the windfarm once it is installed. This attribute conveyed the idea of artificial reef effects

[1] Beyond the literature on visual impact of offshore wind turbines, there is a range of studies on such installations on land (e.g. Alvarez-Farizo and Hanley, 2002; Bergmann et al., 2006, 2008; Meyerhoff et al., 2010), which will not be reviewed here.

[2] Respondents in the pilot survey were drawn from the same panel as the sample for the main survey to ensure that insights gained in the pilot were applicable to the population in the survey area.