3D Modelling of offshore wind farms for the west coast of Scotland

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Summary: Marine renewables are identified as having a significant contribution to reducing greenhouse gas emission, and Scottish Government targets for the generation of energy from renewable sources. Public policy emphasises the importance of using an ecosystem approach, and the role of public engagement in decisions about future uses of land and sea. A prototype 3D model was developed to present alternative designs of a hypothetical windfarm offshore of the island of Tiree, on the west coast of Scotland. The model was used to identify issues associated with the development of offshore windfarms, including alternative options for the heights of wind turbines, and factors such as sea state and atmospheric visibility. A virtual reality environment (Virtual Landscape Theatre) was used as the medium with invited groups from schools and youth groups, university students, natural heritage managers, planners, and the general public, enabling fly-throughs, exploring specific views, and switching between windfarms with alternative designs of turbine height. Factors identified for detailed testing included the significance of lighting conditions on the east and west coast, sea state on perceptions of seascape and wind energy generation, and people's activities at different times of the day.

KEYWORDS: 3D Model, GIS, Offshore Wind Farm, Public Engagement, Tiree

1. Introduction

Coastal Scotland is the interface between land and marine environments, generally with discrete management, designations and ownership. Yet, uses of land, lochs and coastal waters can be interdependent for tourism, recreation, economic activity and potential environmental impacts. Forty five percent of Scotland's population live within 5km of the coastline, an area which also makes significant contributions to the rural economy from aquaculture and shellfish valued at £600m[2]; sailing £101m[3]; wildlife tourism £100m; and, sea angling £141m. Scotland's coastal environment also provides natural resources for the provision of renewable energy by means of tidal, wave and offshore wind. This paper describes development of a 3D model the purpose of which was to identify opportunities and limitations to renewable energy use with different types of stakeholders.

2. Background

The 2020 Renewable Routemap for Scotland – Update (Scottish Government, 2012) sets out ambitious targets of the equivalent of 100% of Scottish demand for electricity and 11% of heat capacity to be generated from renewable sources by the end of 2020. This is to be achieved in the context of international agreements for reductions in greenhouse gas emissions alongside those relating to environmental, economic and social considerations.

Planning Scotland's Seas (Consultation; Scottish Government, 2013) notes the importance of considering the onshore implications of offshore developments, and recognises that renewable energy developments offshore have associated infrastructure onshore. In particular, Planning Scotland's Seas identifies links between the marine and terrestrial planning systems, and the requirement for inputs from local stakeholders and knowledge in the development of spatially more detailed Marine Region Plans. It proposes the use of the Ecosystem Approach to better integrate management of seas and coastal areas, the same approach as advocated in the Scottish Land Use Strategy (Scottish Government, 2011). In highlighting the involvement of people, the outline also echoes objectives of the Land Use Strategy and the objectives of responsible stewardship of Scotland's natural resources, and the Principal I which encourages people having 'opportunities to contribute to debates about land use and management decisions which affect their lives and future'.

In this study visualisation tools were used to present topographic contexts of land and sea use and the introduction of potentially new features such as renewable energy. This takes advantage of the ongoing development of software tools for use in representing 3D environments, such as Maya, 3D Max, Vega Prime, Octaga or specialized landscape visualisation tools such as Visual Nature Studio. These provide a high degree of visual realism for landscape and seascape, enabling the rendering of images or animations (Ball et al., 2007; Wang et al., 2012; Wang et al., 2013).

The tool used was PC-based, enabling the incorporation of interactive functionality for manipulating features in 3D models such as wind farms. The code is written in VRML and implemented in a viewer (Octaga). The medium for representing alternative futures was the Virtual Landscape Theatre (VLT; Ball et al., 2007). This paper describes the development and use of such a model in a virtual environment for engagement with stakeholders.

3. Methodology

3.1 Study Area

The study area was the area around the island of Tiree on Scotland's west coast, which is approximately 12 miles long by 3 miles wide with a population of about 750.

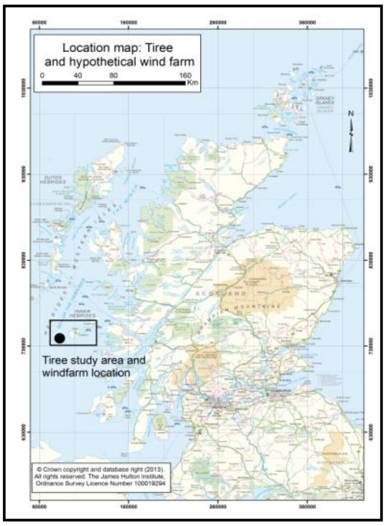

Figure 1. Location of study area and hypothetical windfarm.

It is renowned for its beaches and seascapes, attracting visitors to international wind surfing competitions and sailing. Interest has also been attracted for the development of marine renewables, with exploration of the potential for offshore windfarms to the west of the island.

3.2 Creation of 3D Model

A 3D model was created of the sea surface and area surrounding Tiree as follows:

(i) Ordnance Survey (10m resolution) Digital Terrain Model extracted for the land area.
(ii) Visual Natural Studio (VNS) used to render a 3D model combining the sea and terrestrial areas (10m resolution).
(iii) High-resolution aerial imagery used for background landscape textures.
(iv) Extruded buildings were derived from Ordnance Survey MasterMap.

Further elements added to the model were:

(i) Features associated with coastal environments, developed in Autodesk Maya, including a light house, surfers and a community-owned wind turbine.
(ii) Three designs of a windfarm, comprising 15 wind turbines.
(iii) Embedding of video imagery.
(iv) Different sea states (WMO, 2008).

A 3D geo-referenced model was created of the island and surrounding sea, with representation of alternative layouts and designs of offshore wind turbines. The spatial data were compiled in ArcGIS, in a single coordinate reference system. The software tools used for the 3D models were Google Sketch-up, VNS and Maya.

The spatial data were converted for use in the Octaga virtual reality software in the Virtual Landscape Theatre (www.hutton.ac.uk/learning/exhibits/vlt). The theatre is a mobile curved screen projection facility in which people can be 'immersed' in computer models of their environment to explore landscapes/seascapes. Figure 2 shows an extract from the model with a view across the island of Tiree, including the existing community-owned wind turbine.

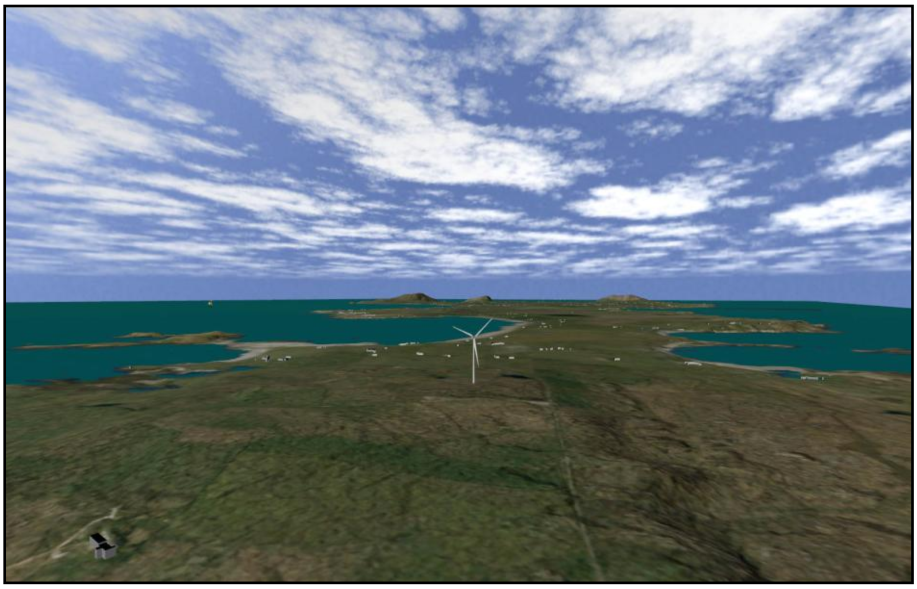

Figure 2. View across Tiree looking towards the west, showing the existing community-owned wind turbine.

The hypothetical offshore windfarm was located approximately 5km to the west of the island, in an area identified in the relevant spatial marine plan as a candidate for wind turbine development. The model of the windfarm comprises 15 turbines, approximately 1 km apart, with three different heights of wind turbine: 110m, 150m and 185m.

The model includes three different representations of sea state (based on the World Meteorological Organization sea state code; WMO, 2008), each with a unique texture and tide height. Wind speed and wind direction have also been considered and corresponding parameters have been added into the 3D Tiree model, with a dominant wave direction applied to the sea surface, each of which can be switched between. The modelling of illumination conditions is used to enable the inclusion of shadows from the wind turbines in appropriate sunlit conditions and reflections off the sea surface.

The software tools used for visualisations can also accommodate the embedding of video imagery, including the functionality of 'clicking' on individual features and the display of images of a location, of a pre-recorded video or of an animation. Figure 3 shows a view of the hypothetical wind farm, with turbine heights of 185m to the tip of blade.

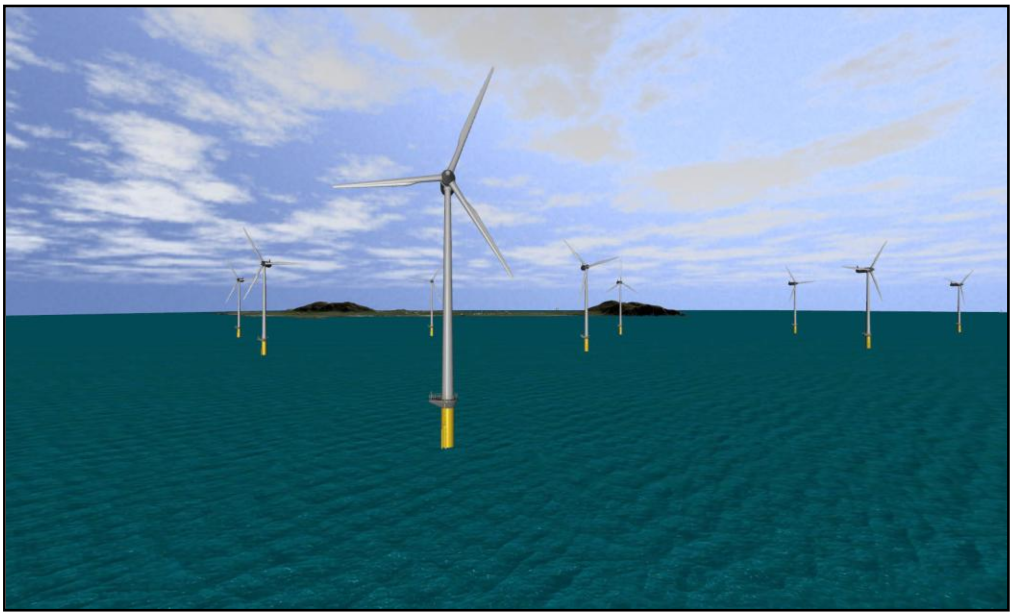

Figure 3. View of the hypothetical windfarm, with wind turbines 185m to the tip of the blade, looking east towards the island.

3.3 Eliciting audience opinions

A prototype of the virtual reality model was tested with a range of different audience types at events in Oban, on the west coast of Scotland, and Aberdeen on the east coast. The Virtual Landscape Theatre was used as the medium with invited groups drawn from schools and youth groups, universities, natural heritage managers, planners, and the general public.

A regional model was used to introduce the events, providing a context for discussion of issues around the development of offshore windfarms. The Tiree model was then used to elicit opinions on the issues associated with developing a windfarm in this area of the west coast of Scotland. A preset flythrough route was used to introduce the island, its geography, and the uses of the land and surrounding seas. This was followed by views of the different options for wind farms from specific view points, including at the coast, from specific properties, and from the tops of two of the island's prominent hills. Audience opinions regarding the views were recorded using electronic handsets.

4. Results

Audience feedback suggested that the virtual environment was very effective in providing an impression of the different layouts and characteristics of the offshore wind farm, and enabled comparisons to be made of the differences in the visual impacts of the alternative heights of wind turbines.

Comparing the feedback on presentations in venues on the west and east coast of Scotland, with models of windfarms on each coast, the issues arising included the different impacts in the morning and evenings of developments on the east and west coast relating to lighting conditions and the patterns of people's daily activities. In particular, differences were identified between visual impacts at sunrise and sunset in an east and west coast environment, and the effects of horizontal views (i.e. with sky backdrops) compared to those downwards towards the development (i.e. with sea backdrops).

Findings from use of the prototype are being used to develop tests to consider the potential significance of sea state with respect to view characteristics, and the significance of different lighting conditions and turbine layouts on people's landscape preferences (Bishop and Miller, 2007).

Figure 4. Audience discussion over the different options for windfarms offshore of Tiree.

5. Discussion and Conclusions

Exploring and interpreting the offshore environment was reported by teachers, and professionals, as providing a better understanding of the potential impacts of a proposed windfarm. Some of the issues raised were identified as being of specific relevance to the school curriculum for follow-up discussions in class. Feedback from professionals in natural heritage management and planning reported the value of being able to see representations of different options in heights and siting of turbines, and from locations selected by members of the audience.

Engaging with stakeholders and the public has enabled discussion, explanations and opinions to be exchanged, and feedback on renewable energy use, now and in the future. The results are being used to inform improvements in the design of tools for eliciting public responses to prospective changes in offshore wind farms interpretation, and demonstration of one aspect of an ecosystem approach to the planning of change at sea.

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Biography

Chen Wang is a Landscape and Visualisation Scientist at the James Hutton Institute. He received his BEng at Soochow University, and a PhD at University of Bradford. His research interests include 3D modelling of landscapes; urban environment modelling and reconstruction; character and traffic animation; 3D real time flood simulation.