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Climate sensitivity of marine energy

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Abstract

Marine energy has a significant role to play in lowering carbon emissions within the energy sector. Paradoxically, it may be susceptible to changes in climate that will result from rising carbon emissions. Wind patterns are expected to change and this will alter wave regimes. Despite a lack of definite proof of a link to global warming, wind and wave conditions have been changing over the past few decades. Changes in the wind and wave climate will affect offshore wind and wave energy conversion: where the resource is constrained, production and economic performance may suffer; alternatively, stormier climates may create survival issues. Here, a relatively simple sensitivity study is used to quantify how changes in mean wind speed—as a proxy for wider climate change—influence wind and wave energy production and economics.

Keywords: Marine energy; Wave energy; Wind energy; Wind climate; Wave climate; Climate change

1. Introduction

Marine energy has a key role to play in meeting long-term renewable energy targets as part of the drive to a low carbon economy. This is particularly true in the United Kingdom, which possesses significant marine energy resources with the most favourable sites tending to be located off the Scottish north and west coasts. With mean wave power in excess of 50 kW/m of wave front, Scotland's offshore wave power potential is estimated at 14 GW and could provide some 45 TWh/year. Similarly, offshore wind potential is some 25 GW (82 TWh/year) and tidal stream around 7.5 GW (33.5 TWh/year) [1].

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While marine energy is being developed in order to limit or avoid climate change, its reliance on the natural environment means that it may be vulnerable to changes in climate that result from rising carbon emissions. Marine technologies share this risk with other renewable sources including hydropower [2] and wind [3]. With evidence of a changing marine climate over recent decades and the suggestion of a link to global warming [4], closer examination is justified.

2. Changing offshore climate

From the late 1980s, the trend of increasing wave height in the north east Atlantic has been reported [5,6]. Suggested increases in mean wave height of some 2% per year have been backed up by other sources that indicate changes of 30–50% over 30 years. While the early studies (e.g. [6]) were unable to identify local wind speed trends to explain the greater wave heights, there was recognition that local wave conditions are a complex blend of local and distant wind activity [7]. Investigations turned to broader climate conditions for explanations and found connections between wave heights and the north–south atmospheric pressure gradient in the north Atlantic [7]. Recent analysis of European offshore wind speeds [8] has identified changes over the past 40 years such as UK winter wind speeds rising by 15–20% over that period.

As much of this work was based on in situ data from buoys and weather ships, identification of underlying changes in weather patterns from this data is difficult given poor spatial data coverage, few long-term series and observational practice changes [9]. Several approaches have been used to avoid such difficulties. The first is ‘hindcasting’ in which wave models are driven by historic weather data in order to develop a wave climate history, e.g. [10,11]. In [10], the wave model was then used to project changes in wave climate by driving it with data from a steady-state (CO_2 doubling) climate change experiment, although the result was not conclusive. The second approach has been to use atmospheric proxies for wave heights for which regressions between significant wave height and sea level pressure [12] and the North Atlantic Oscillation (NAO) [9] have been employed; again, these have been used to project future wave conditions.

To date, however, there has been no investigation of the impacts of changes in wind and wave climate on marine energy.

3. Marine energy impacts

Alteration of wind patterns is a widely expected anticipated outcome of climate change albeit an uncertain one given the inconsistency between general circulation models (GCMs) and their physical representations [13]. On an annual basis, relatively minor changes are forecast UK-wide [13], although there are regional and seasonal trends: southern and central UK winter wind speeds are forecast to rise by up to 10% while changes in windier Scotland appear minimal. Elsewhere in the world, the United States may see wind speed reduce by between 3 [3] and 20% [14] over the next 50 years. Offshore winds will also change and given the cubic relationship between wind speed and wind energy and the capability of wind